Diplomarbeit

Titel der Arbeit

The winner takes it all:

Feedback processing of gains and losses in a competitive situation: An EEG study

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Abstract (in English)

Many studies have been conducted to investigate different event-related potential (ERP) components, which occur during the neuronal feedback processing. The feedback-related negativity (FRN) and the P300 are often the focus of interest.

Although many studies took the personality or a competitive situation into account, few of them combined those two factors to investigate the neuronal processing. This will be done in the actual study.

In this study, 21 pairs of gender-matched participants had to compete against each other in the administered gambling task. The main focus of that study was to gain insight into the neuronal differences in feedback processing of winners and losers. The gambling task was externally manipulated and thereby the allocation of the participants to be the winner or the loser was accomplished. Two conditions were included: playing against a computer and against a human opponent. Before the measurement, online questionnaires assessing personality and behaviour had to be completed.

The results revealed that winners showed larger FRN amplitudes for losses than for gains in the PC vs. human condition than the losers; in contrast the losers' FRN amplitudes in the human vs. human condition were larger for losses than for gains compared to the winner. Further, winners showed larger P300 amplitudes for losses and losers for gains in general.

Emotionality and motivation showed great impact on the ERP amplitude variation as well as the unexpectedness of an event. The results are in line with the reinforcement learning theory (RL-theory), but further investigations would be necessary to support that finding.

No significant results concerning the gender were found, which leads to the assumption that males and females did not show differences in amplitude sizes for both components.

Results concerning the influence of personality on ERP components have to be interpreted with caution as they are only partly consistent with previous findings and therefore, additional research is needed to make clear and valid conclusions.

<u>Key words</u>: BIS/BAS, competition, emotionality, extraversion, FRN, motivation, NEO-FFI, neuroticism, P300, personality, unexpectedness

Abstract (in German)

Eine Vielzahl von Studien wurde durchgeführt, um unterschiedliche ereigniskorrelierte Potentiale (EKP-Komponenten) der neuronalen Feedbackverarbeitung zu erforschen. Dabei wurde der Fokus auf die feedback-related negativity (FRN) und die P300 gelegt.

Obwohl es einige Studien gibt, die entweder die Persönlichkeit in die Analyse mit einschließen oder eine Wettbewerbssituation erzeugen, ist es erst selten geschehen, dass beide Faktoren in einer Studie integriert wurden, um so die zugrundeliegende neuronale Verarbeitung zu erforschen. Dies wird in der aktuellen Studie versucht.

In der vorliegenden Studie wurden 21 Paare an Versuchspersonen mit gleichem Geschlecht gebildet und ein Glücksspiel musste absolviert werden. Das Hauptziel der Studie war es, Unterschiede in den ERP-Komponenten von Gewinnern und Verlierern zu untersuchen. Deshalb unterlag dieses Glücksspiel einer externen Manipulation. Vor dem Spiel wurde durch Münzwurf entschieden, wer der beiden Spieler der Gewinner und wer der Verlierer sein würde. Dieses Spiel musste einmal gegen einen Computer und einmal gegen den menschlichen Gegenspieler gespielt werden. Vor der Untersuchung im Labor wurden online Fragebögen bezüglich Persönlichkeit und Verhalten bearbeitet.

Den Resultaten zufolge waren von den Gewinnern in der PC vs. Mensch Bedingung größere FRN Amplituden bei Verlusten als bei Gewinnen zu beobachten als von den Verlieren. Betrachtet man die Mensch vs. Mensch Bedingung, konnte ein gegensätzliches Ergebnis gesehen werden. Weiters zeigten Gewinner im Allgemeinen größere Amplituden der P300 für Verluste und Verlierer für Gewinne.

Es konnte gezeigt werden, dass Emotionen, die Motivation und weiters das unerwartete Eintreten eines Ergebnisses, große Einflussfaktoren auf die Amplitudengröße darstellen. Die Ergebnisse stimmen mit der reinforcement learning (RL) Theorie überein. Um diese Vermutung bestätigen zu können sind weitere Untersuchungen notwendig.

Bezüglich des Geschlechts konnten keine signifikanten Ergebnisse erzielt werden, was zu der Vermutung führt, dass zwischen Männern und Frauen keine Unterschiede in der Amplitudengröße der beiden untersuchten Komponenten vorhanden sind.

Die Resultate bezüglich des Einflusses der Persönlichkeit müssen mit Vorsicht interpretiert werden, da diese nur teilweise konsistent mit bisherigen Ergebnissen sind. Zusätzliche Forschungsprojekte werden benötigt um klare und gültige Aussagen treffen zu können.

1. Introduction

Competition exists since the early beginnings of humanity. Back then, our ancestors were facing a lot of different struggles in the environment as well as in their tribes. Competition is defined as the situation when people are devoted to a specific goal, but deny that in front of others (Bernstein, 2008). If someone has the feeling that another person or any other circumstance hinders the achievement of that particular goal, a conflict arises. This conflict can be handled in different ways: One would be cooperating which means to work together with others towards the same goal. This option brings along some compromises and in the worst case an outcome worse than expected. This might arise, for example, when a specific outcome has to be shared. If this is the case and someone doesn't want to take this opportunity, competing with others will be the chosen strategy. So the person is acting without making compromises (Bernstein, 2008).

Playing against each other ends up in winning or losing for the participants most of the time. The decision whether to compete or to cooperate is driven by intrinsic motivation (Tauer, & Harackiewicz, 1999). Performance feedback gives information whether a gain or a loss occurred. This is especially important in competition to enable the comparison with the opponent. Being highly motivated to win is associated with more positive feelings in a competitive situation. It was shown that winners state more positive feelings in a competitive situation than in a non-competitive one (Tauer, & Harackiewicz, 1999). Losing brings along more negative feelings than winning and moreover, if negative feedback is presented, the experienced competence is rated more negative (Tauer, & Harackiewicz, 1999).

Performance feedback is also reflected by electrophysiological reactions. The electroencephalogram (EEG) reveals differences in scalp potentials after the feedback presentation depending on whether the outcome was a gain or a loss. Several components were identified to play a role during feedback processing.

2. Different components involved in feedback processing

2.1. The error-related negativity - ERN

A component found to be important in feedback processing is the error-related negativity (ERN; e.g. Gehring, Goss, Coles, Meyer, & Donchin, 1993). This component was observed for the first time by conducting an Erikson Flanker Task (Erikson, & Erikson, 1974). The Erikson Flanker task requires focused attention to a particular stimulus. Participants have to concentrate only to react to the instructed stimulus and withhold the response in the case of an incongruent stimulus. Whenever this is not possible and an error has been committed, the ERN is elicited (Erikson, & Erikson, 1974).

The component can be observed as soon as the error is committed and it is peaking about 100 milliseconds after the erroneous response (Gehring, Coles, Meyer, & Donchin, 1995). It is larger at midline central and frontal electrodes, like the Cz, than at more posterior electrode locations (Gehring et al., 1993). The ERN can only be observed for incorrect trials, but not for correct ones (Gehring et al., 1995). Besides the error detection, it is also elicited when trying to compensate an incorrect response. The approach to correct an error when it is detected elicits large ERN amplitudes than when not doing so (Gehring et al., 1995). Larger ERN amplitudes are also elicited, in cases where more precision is raised to complete the different trials (Gehring et al., 1993). It could also be detected that larger ERN amplitudes indicate a more accurate processing of the following trial (Gehring et al., 1993).

2.2. The feedback-related negativity - FRN

Another negative deflection is the feedback-related negativity (FRN; Miltner, Braun, & Coles, 1997), also often referred to as medial-frontal negativity (MFN; e.g. Gehring, & Willoughby, 2002a). Other than the ERN component, which is a response-locked ERP component, the FRN component is elicited in response to the feedback stimulus itself. FRN amplitudes are reported to be larger in cases where the feedback is negative, for example, indicating a loss or an outcome worse than expected. The FRN or

MFN component is also elicited during gambling tasks (e.g. Gehring, & Willoughby, 2002a). In gambling tasks, gains, losses, and breaking even are the possible outcomes for the participants. In order to win, different tasks such as responding to a stimulus as fast as possible have to be carried out. Whenever losses are indicated by external feedback, an FRN component can be observed (Gehring, & Willoughby, 2002a).

2.2.1. The FRN component and its characteristics

Miltner and colleagues (1997) reported the FRN component to be a negative deflection for incorrect feedback with a peak between 230 and 330 milliseconds after feedback onset. The time window in which the FRN amplitude's peak was found, ranges from 200 to 400 milliseconds (Yeung, & Sanfey, 2004; Wu, & Zhou, 2009; Rigoni, Polezzi, Rumiati, Guarino, & Sartori, 2010). Yu and Zhou (2006) stated an average peak latency of 278 milliseconds (Yu, & Zhou, 2006).

Miltner and colleagues (1997) observed a larger negative deflection on midline electrodes compared to lateral ones. The FRN's amplitude is most pronounced on different fronto-central electrodes, like Fz (Yu, & Zhou, 2006; Li, Jia, Feng, Lui, Suo, & Li, 2010; Rigoni et al., 2010; van Meel, & van Heijningen, 2010), FCz (Nieuwenhuis, Slagter, Altling von Geusau, Heslenfeld, & Holroyd, 2005b; Yu, & Zhou, 2006; Wu, & Zhou, 2009; Pfabigan, Alexopoulos, Bauer & Sailer, 2010), or Cz (van Meel, & van Heijningen, 2010).

2.2.2. The sensitivity of the FRN's amplitude to feedback valence

The FRN component is elicited in situations, which require evaluation. Such situations are losses and unfavourable outcomes (Hajcak, Moser, Holroyd, & Simons, 2006). FRN amplitude variation is larger for negative compared to positive feedback, or in other words, for losses than for gains (Yeung, & Sanfey, 2004; Yu, & Zhou, 2006; Rigoni et al., 2010; van Meel, & van Heijningen, 2010) with no distinction between small and large losses (Yeung, & Sanfey, 2004). So the FRN amplitude does not seem to be sensitive to the magnitude, but to the valence of the outcome or feedback (Yeung, & Sanfey, 2004). The feedback valence is considered the subjective classification of the presented feedback on a good vs. bad dichotomy where the FRN's amplitude is larger for bad than for good outcome (Hajcak et al., 2006).

This could be found, for example, in an experiment done by Hajcak and fellows (2006). In a gambling task, the FRN amplitude was generally found to be larger for losses than for gains. A third outcome possibility was to break even, which indicated a neutral feedback with no gain or no loss at all. Participants showed similar large FRN amplitudes for losses and breaking even but not for gains. According to the good vs. bad dichotomy losses and breaking even are rated as a bad outcome. Gains, on the other hand, showed smaller FRN amplitudes, which were rated as good outcome (Hajcak et al., 2006).

However, not only negative, but also positive feedback elicits the FRN component. As an FRN component is said to be generated for error detection, this can be explained by the so-called prediction error: Whenever the situation is worse than expected, named negative prediction error, larger FRN amplitudes are elicited (Holroyd, & Coles, 2002; Bellebaum, & Daum, 2008). This is presumably due to changes in mesencephalic dopamine release, which is conveyed to the anterior cingulate cortex (ACC). A negative prediction error is associated with decrease of mesencephalic dopamine release. The other possibility is that the situation is better than expected, which is known as the positive prediction error, leading to smaller FRN amplitudes caused by enhanced dopamine levels (Holroyd, & Coles, 2002; Nieuwenhuis, Holroyd, Mol, & Coles, 2004a).

This dopamine theory is known as the reinforcement learning theory (RL-theory). The axons of the mesocorticolimbic dopaminergic system form synapses in the basal ganglia and the cortex. Along those paths, event-related potentials, such as the component FRN, are elicited (Holroyd, & Coles, 2002). According to the reinforcement-learning theory, the FRN component mirrors the down regulated dopamine release to the ACC (Hajcak, et al., 2006): Less dopamine elicits larger and conversely, more dopamine elicits smaller FRN amplitudes. Holroyd, Nieuwenhuis, Yeung, Nystrom, Mars, Coles, and Cohen (2004a) focused on the dorsal ACC (dACC) in their research and came up with the result that the released amount of dopamine influences the ACC's activity. Unexpected feedback and error responses enhance the activity of the ACC compared to expected feedback and correct responses (Nieuwenhuis et al., 2004a).

2.2.3. Unexpectedness influences the FRN's amplitude size

Inferring from the prediction error and different study results, FRN amplitudes are not only sensitive to the feedback valence. The FRN amplitude is also sensitive to the expectancy about a particular event or outcome. An FRN component is generated for negative and unexpected feedback in a gambling task with the chance of a monetary gain (Pfabigan et al., 2010). Further, Bellebaum and Daum (2008) found more negative FRN amplitudes for negative unexpected feedback compared to positive unexpected feedback. This indicates that an FRN component is also elicited by positive feedback but is smaller than for negative feedback.

The unexpectedness indicates that there is a discrepancy between the external and internal representation, which means the FRN amplitude variation mirrors the deviation of the real outcome from the expected one (Pfabigan et al., 2010). Therefore, the component FRN plays a role in learning from mistakes and new situations (Bellebaum, & Daum 2008). One possible explanation for this finding might be again the RL-theory. The RL-theory serves as an identifier regarding the success of an outcome. Should that outcome be worse than expected, a decrease of dopamine neurons activation to the ACC is occurring. This is theoretically described in terms of a temporal difference error or a negative prediction error. This error leads to the enhanced FRN amplitudes in situations with negative outcome (Holroyd, & Coles, 2002).

Nieuwenhuis and his team (2004a) described the relation of learning and the FRN component. Shortly after the beginning of the process of learning a task, the FRN's amplitude is larger than it is during later stages in the learning process. This means that the increasing predictability, or in other words expectancy, of an outcome decreases the FRN amplitudes. But whenever this predictability is broken, the FRN component can be observed as a large negative deflection again (Nieuwenhuis et al., 2004a; Bellebaum, & Daum, 2008).

Several other studies showed that FRN amplitude size is dependent on the comparison between expected and actual outcome (Holroyd, Nieuwenhuis, Yeung, & Cohen, 2003; Holroyd, Larsen, & Cohen, 2004b). The experiment done by Holroyd and colleagues (2004b) comprised a winning and a losing condition. Both conditions included "0" as a possible outcome. When scoring "0" in the winning condition, where "0" was the worst possible outcome, a clear FRN component could be observed for scoring "0", whereas in the losing condition, where "0" was the best possible outcome, this effect was not visible. Whenever there is the chance of a gain and the expectancy to win is violated, the amplitude of the observed ERP-component is more negative (Holroyd et al., 2004b).

Another expectancy violation represents the validity of feedback. Valid feedback is defined as informative feedback, which means positive feedback in the case of correct response and negative feedback when an error has been made. Invalid feedback corresponds to positive feedback in the case of an error and negative feedback when no error has been made (van Meel, & van Heijningen, 2010). When giving invalid feedback, the FRN's amplitude is larger than when giving valid feedback: More specifically, FRN amplitude size is larger after making an error and receiving incorrect positive feedback than when receiving incorrect negative feedback when no error was made. Interestingly, those findings could only be observed in a competitive situation against a human person, but not when playing against a computer generated opponent (van Meel, & van Heijningen, 2010).

2.2.4. The impact of responsibility, motivation, and emotions on the FRN's amplitude

In a competitive situation, the responsibility felt for the attainment of a gain or loss has an influence on the FRN's size (Li et al., 2010). Li and colleagues (2010) conducted a simulated dice-game, in which three participants were involved. The participants didn't know each other and had to take part in two different conditions: the self-executing one, in which they had to throw three dice and therefore, were wholly responsible for their luck and the cooperation condition, in which everyone threw one dice and in this case, the responsibility was spilt between the participants. FRN amplitudes were more negative for the self-execution condition, showing the so-called "diffusion of responsibility effect" (Li et al., 2010). Feeling less responsible for the outcome decreased the negative emotions when e.g. a loss occurred. This finding is also supported by questions asked during the experiment regarding interest, emotion, and responsibility: Participants stated to feel more responsibility in the self-execution task than in the cooperation task. Further, interest and attention did not change during the experiment. The stable feelings across both conditions indicate no emotional influence on the enhanced component's size (Li et al., 2010).

Emotions were found to have an impact on the FRN's amplitude size (Rigoni et al., 2010; van Meel, & van Heijningen, 2010). It could be shown that the actual negative affective state is correlated to more negative FRN amplitudes (Rigoni et al., 2010; Santesso et al., 2011).

The stronger feelings of personal motivation when winning and losing in a social context might be an influencing factor on the FRN's amplitude size (Rigoni et al., 2010). The more a person is motivated to win in a game, the more the person is probably willing to take risky choices and therefore, the expectancy to win increases (Gehring, & Willoughby, 2002b; Yeung, & Sanfey, 2004). So the FRN's amplitude is thought to be sensitive to the degree of motivation to take riskier choices and not to the error made itself (Gehring, & Willoughby, 2002b). The influence of personal motivation could also be shown in a gambling-task experiment, including three different conditions. The first condition was called solo condition, in which everyone was playing against a computer-generated opponent. The second one, a comparison condition, allowed participants to compare their own outcome with the opponent's. Last, in the competition condition, participants played against each other for a fixed amount of money (Rigoni et al., 2010). The participants had to complete a task fully dependent on their luck by choosing between two different covert cards with specified amounts of gains or losses on it. Both alternatives were presented to the participants after the choice. So participants could see their actual outcome, the obtained one, and the possible other, the non-obtained, outcome. Some evidence could be found for an enhanced amplitude when comparing the non-obtained with the obtained outcome. A possible explanation is that the obtained outcome, which is the outcome the participant really gets, is more motivating and so the dopamine release to the ACC is increased, which elicits a smaller FRN amplitude (Rigoni et el., 2010). Again, this finding speaks for the validity of the RL-theory in relation with the FRN component.

2.2.5. The FRN component's possible generator site – The anterior cingulate cortex (ACC)

Despite all the findings, it is still unclear where the FRN component is exactly generated, but it is thought to occur in the medial prefrontal cortex (MPFC, Hajcak et al., 2006), more specifically said in the ACC and supplementary motor areas (Miltner et al., 1997; Nieuwenhuis et al., 2004a). Bush and colleagues (2000) write that the ACC functions as an error monitoring and error correction system. The ACC is active during both, making and correcting the error (Bush, Luu, & Posner, 2000).

The ACC is ranked amongst the limbic system (Bush et al., 2000). It is located superior to the brain stem and is deeply buried in the cortex. The limbic system is said to have great influence on emotions, error detection and correction, regulating, and integrating cognitive information.

It is interesting to see that cognitive and emotional information are processed independently. Those two systems mutually suppress each other. Emotional information is processed in the rostral-ventral ACC, whereas cognitive information is processed in the dorsal ACC (dACC). While performing a task, which requires cognitive resources, the rostral-ventral ACC is deactivated, but if a task requires emotions and affect, the cognitive part in the dorsal ACC (dACC) is suppressed (Bush et al., 2000). The function of the dACC involves, but is not limited to guiding attention in the competitive situation, motivation, novelty, error detection, and working memory (Bush et al., 2000). On the other hand, the rostral-ventral part of the ACC shows relations to the amygdala, nucleus accumbens (NAcc), periaqueductal grey, the hypothalamus, hippocampus, the orbitofrontal cortex, and the anterior insula. Its function is to rate the emotional and motivational input and later modulating the emotional response to that input (Bush et al., 2000).

Taking more recent results into account, Vogt (2005) introduced a new subdivision of the cingulate cortex. The former ACC is now labelled as anterior midcingulate cortex (aMCC), which is assumed to be the generator site of the FRN and the ERN (Vogt, 2005).

2.3. The P300 component

2.3.1. The P300 component and its characteristics

A positive deflection was observed in all feedback modalities with longer latencies for correct than incorrect feedback at parietal electrode sites (Miltner et al., 1997). This so-called P300 component is the third positive deflection in the ERP occurring between 250 and 600 milliseconds after feedback presentation (Wu & Zhou, 2009). There are two peaks in that time range, which have different names: the frontal P3a and the parietal P3b. The P3a component is registering the novelty of a stimulus (Bledowski, Prvulovic, Hoechstetter, Scherg, Wibral, Goebel, & Linden, 2004; Debener, Makeig, Delorme, & Engel, 2005; Nieuwenhuis, Aston-Jones, & Cohen, 2005a; Polich, & Criado, 2006) with a peak between 60 and 80 milliseconds before the P3b component (Nieuwenhuis et al., 2005a). Whenever the component P300 is mentioned in the current thesis, the P3b component is addressed.

The P300 amplitude's maximum is most pronounced on electrodes such as CPz (Yeung, & Sanfey, 2004; Wu, & Zhou, 2009; Li et al., 2010; Rigoni et al., 2010; van Meel, & van Heijningen, 2010) or Pz (Hruby, & Marsalek, 2003; Yeung, & Sanfey, 2004; Hajcak, Moser, Holroyd, & Simons, 2007; Boksem et al, 2010; van Meel, & van Heijningen, 2010; Santesso et al., 2011) and additionally, in competition studies on Cz (Hajcak et al., 2007; Boksem, Kostermans, & de Cremer, 2010; Li et al., 2010; van Meel, & van Heijningen, 2010;) with less activity on frontal and lateral electrodes (Yeung, & Sanfey, 2004). The activity increases going from frontal to posterior electrodes and it is also higher on the midline (Katayama, & Polich, 1999).

2.3.2. The P300's amplitude and its sensitivity to valence and magnitude of an outcome

Generally, the amplitude of the P300 is larger if a reward is a possible outcome than when no reward is possible (Bellebaum, & Daum, 2008). The P300 component is sensitive to the magnitude of the feedback, which means that there is a difference in the amplitude's size for the size of the gain or the loss: A more positive deflection could be detected for large compared to small gains or losses (Yeung, & Sanfey, 2004; Wu, & Zhou, 2009; Rigoni et al., 2010; Santesso et al., 2011).

There are controversial findings regarding the P300 amplitude's sensitivity to valence: some authors could detect that difference (Hajcak, Moser, Holroyd, & Simons, 2007; Wu, & Zhou, 2009; Rigoni et al., 2010) but others did not (Yeung, & Sanfey, 2004). If the sensitivity is confirmed, the amplitude was found to be more positive after gains than after losses (Hajcak et al., 2007; Boksem et al., 2010; Li et al., 2010; Rigoni et al., 2010), in other words it is larger for positive than for negative feedback (Li et al., 2010). On the contrary, the P300's amplitude was also found to be larger for negative compared to positive emotional stimuli (Ito, Larsen, Smith, & Cacioppo, 1998). Further, it is larger for obtained compared to non-obtained outcome (Rigoni et al., 2010).

Ito and colleagues (1998) found larger P300 amplitudes for negative compared to positive feedback, but no differences in P300 amplitude sizes were obvious for emotionally neutral stimuli. This might be due to the so-called negativity bias, which suggests that people's behaviour and values are more affected by negative than positive input from the environment (Cacioppo, & Berntson, 1994).

Yeung and Sanfey (2004) observed the sensitivity of the P300 amplitude to valence only in relation with non-obtained outcome. When presenting this feedback type, the P300 amplitude is larger for gains than for losses, most notable for large outcomes. The P300 amplitude's sensitivity might be related to the actual affective state, e.g. motivation after a gain or a loss, which arises when picking between two possible outcomes (Yeung, & Sanfey, 2004). Large outcomes are more motivating, no matter whether it's a gain or a loss. An additional emotional coding of the outcome is necessary to enhance the P300's amplitude. Reward orientation alone is not sufficient to do so (Yeung, & Sanfey, 2004). This finding could only be found for the non-obtained outcome, but not for the obtained one. A possible explanation might be that there was no variation in feedback presentation. The obtained outcome was presented first all the time and therefore, no comparison, if the best choice was made, could be made (Yeung, & Sanfey, 2004).

2.3.3. Unexpectedness and the P300's amplitude

The P300 component seems to be sensitive to the expectancy about the feedback or the outcome. The P300's amplitude is higher for positive and negative unexpected feedback compared to expected one (Hajcak et al., 2007; Bellebaum, & Daum, 2008; Wu, & Zhou, 2009; Boksem et al., 2010; Pfabigan et al., 2010).

The amplitude of the P300 increases for infrequent stimuli (Donchin, & Coles, 1988; Yeung, & Sanfey, 2004; Bellebaum, & Daum, 2008; Pfabigan et al., 2010). Such infrequent stimuli can be induced, e.g. by using invalid or unexpected feedback (Pfabigan et al., 2010; van Meel, & van Heijningen, 2010). One prominent theory holds that larger P300 amplitudes reflect an update the working memory contents in cases where the actual and the anticipated outcome differ. The appearance of unexpected feedback needs to be integrated in the memory and update the previous representation (Donchin, & Coles, 1988).

Contrasting results, regarding the validity of feedback, could be found by van Meel and van Heijningen (2010). In the valid feedback condition, the amplitude was more positive for negative compared to positive feedback (van Meel, & van Heijningen, 2010). The possible reason for that finding may be the arousal level. When a situation creates a higher degree of arousal linked with increased motivation, larger P300 amplitudes could be detected than when the arousal level and motivation are low (Briggs, & Martin, 2009).

The P300's amplitude is more positive for invalid positive feedback, which means positive feedback when an error was made, than for invalid negative feedback, false negative feedback when no error was made (van Meel, & van Heijningen, 2010). Again, this can be explained by the infrequent stimulus presentation. The authors reasoned that invalid negative feedback was presented less often than invalid positive feedback. Another explanation is the increased attention paid to the task. Whenever an error was made, the attention was increased to following feedback (van Meel, & van Heijningen, 2010), which militates for the working memory updating (Donchin, & Coles, 1988).

2.3.4. Responsibility, motivation, and emotions influence the P300's amplitude

When taking the subjective personal responsibility into account, the P300's amplitude is enhanced when being highly responsible for an outcome compared to when one's own influence is reduced (Li et al., 2010). This, for example, would be the case in a cooperative setting, which requires people playing together to achieve a common goal. Additionally, an interesting finding is that the P300's amplitude is more positive when evaluating one's own outcome compared to the evaluation of the outcome achieved by others (Rigoni et al., 2010). This study result provides evidence for higher motivational involvement when feeling responsible for the outcome (Li et al, 2010) and that personal outcome might be more important and motivating than the opponent's.

The impact of emotions on the P300's amplitude was shown very early by Johnston, Miller and Burleson (1986). The authors presented pictures with positive, negative, and neutral connotations to their participants. It was shown that positive and negative pictures influenced P300 amplitude variation, with higher amplitudes sizes for emotional relevant stimuli, whereas there was no change in amplitude's size when presenting the neutral pictures (Johnston et al., 1986).

The possible influence on the outcome of a task leads to increased attention and motivation (Rigoni et al., 2010). Experiencing an error or unexpected feedback in such situations leads to a higher amplitude of the P300. This can be explained by the positive prediction error. If people expect a particular outcome they are surprised when the opposite happens. Furthermore, increased attention is paid to the following to integrate new information from the environment (Donchin, & Coles, 1988; van Meel, & van Heijningen, 2010).

As stated earlier, motivation has an impact on the P300's amplitude (Yeung, & Sanfey, 2004). Enhanced motivation is also influenced by the performed task and its required attention. No matter which stimulus is presented, if no attention is paid to it, no P300 component can be registered (Duncan-Johnson, & Donchin, 1977).

2.3.5. The presumed generator sites of the P300 component

The origin of the P300 component is still unclear but there are speculations about the origin in the temporo-parietal junction (Hruby, & Marsalek, 2003; Nieuwenhuis et al., 2005a). It was reported that this is a possible common generator site of the P3a and P3b component (Nieuwenhuis et al., 2005a). For the P3b component, bilaterally the inferior parietal lobe, the inferior temporal cortex, and the posterior parietal cortex are more active after feedback reception in an oddball task, which intends the participant to react whenever an infrequent stimulus appears on the screen. As this task requires a huge amount of attention, the parietal activation was not surprising, because this region is concerned with paying directional attention (Bledowski et al., 2004). Further, this area is important for the integration of visuomotor information. Additionally, the enhanced inferior temporal cortex activity mirrors the categorisation process of the brain (Bledowski et al., 2004).

Halgren, Marinkovic, and Chauvel (1998) showed that the higher activation of the inferior parietal lobe and the prefrontal cortex were related with the occurrence of unlikely events and the posterior prefrontal cortex showed more activity as the importance of the task increased (Halgren et al., 1998).

The neuronal origin is non-specific for the presented feedback modality. It could only be shown that the component P300 is more easily elicited by auditory feedback than by visual one (Halgren et al., 1998).

3. The influence of personality on people's behaviour

An additional factor, which influences people's behaviour, is their personality. The research field investigating personality and its underlying neuronal processes is called personality neuroscience (DeYoung, & Gray, 2009).

There are several different methods to gain information about this correlation. First, personality is measured by using self- or others-rated questionnaires, which can then be used in combination with the different neuronal techniques. Those neuronal techniques include "[…] neuroimaging […] molecular genetics […] electrophysiological techniques […] assays of endogenous psychoactive substances or their byproducts […] psychopharmacological manipulation […]" (DeYoung, & Gray, 2009, p.5).

3.1. The existence of different personality theories

Eysenck and Eysenck (1985) defined three personality factors, which are Extraversion, Neuroticism and Psychoticism. Two of those three factors can exactly be found in model of Costa and McCrae (1992), which is represented by personality questionnaire NEO Personality Inventory. Based on the theory of the Big Five personality, traits are said to be stable and can be classified within five categories named Neuroticism, Extraversion, Agreeableness, Conscientiousness and Openness/Intellect (Costa, & McRae, 1992).

Gray (1970) came up with another theory, which anticipates two different motivation systems activated by different affective states. The behavioural approach system (BAS) is sensitive to rewards and the behavioural inhibition system (BIS) to potentially dangerous stimuli. Additionally, there is the Fight-Flight-Freezing System (FFFS), which is activated if there is a threatening stimulus (Gray & Mc Naughton, 2000). This theory is known as the Reinforcement Sensitivity Theory.

Relating those two theories has been tried by many different scientists.

The trait Neuroticism is measured on a continuum ranging from emotionally stable on the one side to neurotic on the other one. The trait is characterised with words like tension, anxiety, or the appropriate reaction to stress (Borkenau, & Ostendorf, 1993).

The trait Neuroticism is linked to the experience of negative emotions (Eysenck, & Eysenck, 1985; Larsen, & Ketellar, 1991; Jorm, Christensen, Henderson, Jacomb, Korten, & Rodgers, 1999; DeYoung, & Gray, 2009; Costa, & McCrae, 1992) including danger and punishment (Depue, & Collins, 1999). People scoring high in the Neuroticism scale are said to be more vulnerable to experience negative emotions than the one scoring low. The FFFS was proven to be activated by feelings such as fear, panic, and anger (Gray, & McNaughton, 2000) and links to the trait Neuroticism could be detected (Costa, & McCrae, 1992).

The scores reached in the Neuroticism scale shows a positive correlation with the BIS scores of the BIS/BAS questionnaire (Gray, 1970; Jorm et al., 1999; Smits, & Boeck, 2006; Boksem, Tops, Wester, Meijman, & Lorist, 2006), but is negatively correlated with two subscales of the BAS scale, the drive seeking scale (BASD) and the fun seeking scale (BASF). With the third BAS subscale, the reward responsiveness scale (BASR), no correlation could be found (Smits, & Boeck, 2006). Another study (Carver, & White, 1994) did not come up with these BAS scales correlations. This might be due to the fact that the correlation between Neuroticism scores and the BAS scale is still not investigated very well.

In imaging studies, an enhanced activation of brain areas correlated with negative affect and detection of errors was found, which included the dACC and the mid cingulate cortex (Eisenberger, Lieberman, & Satpute, 2005; DeYoung, Hirsh, Shane, Papademetris, Rajeevan, & Gray, 2010).

The dimension Extraversion is also measured on a dichotomous scale. Scoring low equals introversion whereas scoring high means extraversion. Again there are traits, which are measured. Those are e.g. cheerfulness, optimism or sociability (Borkenau, & Ostendorf, 1993).

Extraversion scores are negatively correlated with Neuroticism scores (Eisenberger et al., 2005) and can therefore, be linked with positive affect (Eysenck, & Eysenck, 1985; Larsen, & Ketelaar, 1991; Costa, & McCrae, 1992). Further, Extraversion scores showed a negative correlation with the Conscientiousness scores, whereas Neuroticism scores were strongly positively correlated with Conscientiousness scores

(Eisenberger et al., 2005).

Extraverts and introverts show differences in sensitivity to positive, but not to negative affect. Focusing on the positive emotions, extraverts are more activated by positive emotions than introverts. For the dimension Neuroticism, the reverse pattern could be found: emotionally unstable persons were more sensitive to negative affect than stable ones and showed no differences regarding the positive affect (Larsen, & Ketelaar, 1991). The relation between the Extraversion scores and positive affect can also be explained by Gray's Reinforcement Sensitivity Theory, which proposes a linkage between Extraversion scores and the BAS scale (Gray, 1970; Carver, & White, 1994; Depue, & Collins, 1999; Smillie, Jackson, & Dalgleish, 2006; Smits, & Boeck, 2006). Smits and Boeck (2006) found a positive correlation between all the BAS scales and the achieved Extraversion score and further, a negative correlation with the BIS scale was observed.

Differences in extraverts and introverts manifest in the cortical arousal level (Eysenck, 1967). The reason for that difference lies in the activation for the ascending reticular activating system (ARAS), which stimulates the cerebral cortex. Introverts are more easily aroused than extraverts. Therefore, extraverts need more stimulating activities to reach the higher activation level and to be as activated as introverts (Eysenck, 1967).

Participants scoring high in the trait Extraversion showed high activation in reward-related brain areas, such as the medial orbitofrontal cortex (DeYoung et al., 2010) or the NAcc (Depue, & Collins, 1999; Canli, Zhao, Desmond, Kang, Gross, & Gabrieli, 2001).

Besides those two well-investigated personality scales, the scales Agreeableness, Conscientiousness and Openness/Intellect need further research.

The dimension Agreeableness can be seen as a trait on a dichotomy scale ranging from antisocial to prosocial behaviour. High scores can be described with words like cooperation, altruism, empathy, or confidence (Borkenau, & Ostendorf, 1993). Linking this scale to the Reinforcement Sensitivity Theory, a positive correlation between the BIS scale was observed and further, a negative correlation with the BASD and BASF scales (Smits, & Boeck, 2006)

The personality trait Conscientiousness on the other hand does not represent social traits but motivational ones (DeYoung, & Gray, 2009). This inner factor is needed to sustain a specific level of personal motivation. Conscientiousness scores can be linked to Extraversion scores, as both factors have an impact on the trait impulsivity. Impulsivity is characterized by a high Extraversion score in correlation with a low Conscientiousness score (Depue, & Collins, 1999). In line with those findings is the negative correlation of the Conscientiousness scale and the BASF scale. The BASF scale is related to impulsivity and for that reason, a low score of Conscientiousness would suggest a high BASF score. The reached Conscientiousness scores show a positive correlation with the BASD and BIS scale (Smits, & Boeck, 2006).

The dimension Openness can be described as the urge to experience something new in life and further, a variety in life and not sticking to the old one. People scoring high in the Openness scale tend to have a great interest in e.g. foreign cultures and have great creativity (Borkenau, & Ostendorf, 1993). Smits and Boeck (2006) could reveal a positive correlation between the Openness scale and the BASF scale.

Regarding the BIS/BAS questionnaire, the following internal correlations could be found. BIS scores were negatively correlated with the BASD scores and BASF scores, but a positive correlation was found between the BIS scale and the BASR scale. Moreover, the BAS scales were positively correlated among each other (Smits, & Boeck, 2006).

The ACC was often linked with personality in several studies (e.g. Eisenberger et al., 2005). The Neuroticism trait showed a positive correlation with the dorsal part of the ACC and a negative one with the rostral part (rACC), which is more active in emotionally unstable participants. An indirect correlation between rACC activity and negative emotion was observed by Santesso and colleagues (2011). A higher activation in the rostral part of the ACC was associated with more negative FRN amplitudes. The rostral-ventral area of the ACC was found to be involved in processing emotions (Bush et al., 2000) and larger activation may be caused by higher emotionality in high Neuroticism scoring participants (Hirsh, & Inzlicht, 2008). Further, a negative correlation for Neuroticism scores was found with the left prefrontal cortex (LPFC) and the left posterior parietal cortex (LPPC).

Conversely, high Extraversion scores showed a positive correlation with activation in the LPFC, the LPPC and the rACC. Moreover, a negative correlation with the activation in the dACC was found (Eisenberger et al., 2005). These findings give rise to the assumption that a negative correlation between the two traits Extraversion and Neuroticism is present.

3.2. The relation of the FRN and P300 component with the different personality dimensions

Only few studies are available relating the component FRN with the different personality dimensions. The findings regarding the characteristics of the FRN component are consistent with previous results, which did not include the factor personality: The FRN's amplitude was found to be maximal over the electrode Fz with a larger negativity for negative than for positive feedback (Hirsh, & Inzlicht, 2008; De Pascalis, Varriale, & D'Antuono, 2010; Santesso et al., 2011). This negativity was again largest 250 milliseconds after feedback presentation (Hirsh, & Inzlicht, 2008) on midline electrodes compared to any other electrode site (De Pascalis et al., 2010).

Generally, positive and negative affect is linked to specific personality dimensions. The most-investigated ones are the traits Neuroticism and Extraversion. Canli and colleagues (2001) showed pictures to their participants, which had a positive or negative emotional association and found a positive relationship between Extraversion scores and positive, and Neuroticism scores and negative pictures, but not conversely. This means Extraversion scores showed no correlation with negative associated pictures and Neuroticism scores showed no relationship with positive pictures. Transferring Canli and colleague's (2001) findings to Eysenck's model (1967), which links Extraversion scores with the arousal level and Neuroticism scores with emotions, it can be seen that in this study both of the personality dimensions can be linked to emotion, Extraversion scores to positive and Neuroticism scores to negative affect (Canli et al., 2001).

FRN amplitude's and high Neuroticism scores were found to be correlated for uncertain feedback, but not for negative feedback (Hirsh, & Inzlicht, 2008). This relation is highest at fronto-central electrodes. Further, splitting the Neuroticism groups, low Neuroticism scores showed the other way round. A larger FRN amplitude was detected for negative compared to uncertain feedback. The middle scoring group showed no significant difference, but that the FRN amplitude is of similar size for uncertain and negative feedback. These findings indicate that neurotic subjects are more easily aroused by the unknown (Hirsh, & Inzlicht, 2008).

Only one study investigated the personality dimension Extraversion and the FRN's amplitude. Smillie, Cooper, and Pickering (2011) conducted the first study, in which the Extraversion score and the FRN's amplitude were linked. They found that the FRN's amplitude is more negative after unexpected negative feedback (non-reward) than after unexpected positive feedback (reward) for extraverts compared to introverts. The size of the FRN's amplitude was two times higher in high Extraversion scoring participants (Smillie et al., 2011). An FRN component was also found for unexpected reward, but the negativity was the smallest of all amplitudes. No significant difference of the FRN's amplitude could be found for the expected outcome condition (Smillie et al., 2011). Regarding the unexpectedness of an event, it is in line with previous findings, that unexpected events elicit larger FRN amplitude sizes than expected events (e.g. Pfabigan et al., 2010).

The RL-theory is supported by another congruent result. Scores on the Extraversion scale are assumed to be dopamine-dependent (Depue, & Collins, 1999; Smillie, Cooper, Proitsi, Powell, & Pickering, 2010; Smillie et al., 2011). As stated earlier, the temporal difference error characterizes a decrease in dopamine release to the ACC if an outcome is worse than expected, which enhances the negativity of the FRN's amplitude (Holroyd & Coles, 2002). This decrease can be found in the larger FRN amplitudes after unexpected negative feedback compared to unexpected positive feedback, which indicates an increase of dopamine. This finding can be related to the personality dimension in that way that the FRN was larger for extraverts in comparison to introverts (Smillie et al., 2011).

As well as for the personality dimensions of the NEO-FFI, there are only few results for the BIS/BAS questionnaire. Generally, the FRN amplitude was found to be more pronounced for high BIS scores compared to low ones (De Pascalis et al., 2010). High BIS scores were correlated with an enhanced amplitude of the FRN when losing and a high BAS score was correlated with a small FRN amplitude (De Pascalis et al., 2010). Further, the latency was longer for participants scoring high compared to normal or low on the BIS scale. This could only be found for losses, but not for gains (De Pacalis et al., 2010).

As in previous studies, the P300's amplitude was most pronounced on the electrode Pz with larger amplitudes for infrequent stimuli (Russo, De Pascalis, Varriale, & Barrett, 2008). Positive feelings were related with small P300 amplitudes in general and shorter reaction times to losses (De Pascalis et al., 2008). Positive feedback or gains prolonged the P300 component, which was due to the fact that processing positive feedback or gains take more time than processing negative feedback or losses (De Pascalis et al. 2010). A rather seldom finding is that the P300 amplitude was larger for losses than for gains. In De Pascalis and colleagues' study (2010) losses were presented less often than gains and therefore, the unexpectedness might be a possible explanation for that outcome. If there is a discrepancy between the actual and anticipated outcome, the BIS system is responsible for increased attention to gather new information why that has happened (McNaughton, & Corr, 2004). Again, this is in line with the actualisation theory of Donchin and Coles (1988).

As stated before, a low score in the Conscientiousness scale and a high score in the Extraversion scale represent the trait impulsivity (Depue, & Collins, 1999). It could be shown that large P300 amplitudes are related with high impulsivity scores (Russo et al., 2008). Impulsivity is seen as having a negative effect on task performance, which is characterised by a lack of concentration and focused attention (Zeidner, & Matthews, 2000).

P300 amplitudes are smaller for people with a high responsiveness to reward. The latency of the P300 is prolonged in high reward-responsive persons compared to low reward-responsive persons, which indicate a longer time to process the available information (De Pascalis et al., 2010).

4. Rationale/Research Question/Hypotheses

The main aim of this study was to investigate whether there are differences in feedback-related brain responses for winners and losers in a competitive gambling task.

To induce the feeling of being a winner or a loser in the game, a manipulation was implemented. Before starting the game in the lab, the two players were allocated to be player 1 and player 2 by a coin flip. Allocation to be player 1 means being the winner and being player 2 equals being the loser. Both players were assigned a colour to identify their feedback on the screen later in the game. This was blue for player 1 and green for player 2.

The winning probability for player 1 was meant to be 60 % whereas the one for player 2 should have been 40 % in both conditions. Due to malfunction of the program, player 2 lost more than 60 % of the trials in the human vs. human condition.

Implicit and explicit types of manipulation were used for that study. Player 2 was losing more trials than player 1 in the test trials and PC vs. human trials. Furthermore, player 2's implicit realisation to be the loser in that condition was used. After the PC vs. human condition a bar chart was presented to both of the players in the according feedback colours. This bar chart showed the performance of each player against the PC in the preceding trials. This chart was also manipulated by showing better performance for player 1 than player 2 all the time. The blue bar for player 1 was 2/3 times bigger than the green bar for player 2. This was done to confirm the impression that player 1 acted better than player 2, which is the explicit manipulation.

The manipulation made it necessary to use invalid feedback. Especially player 2 was affected by that feedback. This was due to the fact that player 2 should lose more trials compared to player 1 and therefore, negative feedback was presented to player 2 even if he/she made the correct response in some of the trials.

Several studies have been done focusing on competition or personality and their linkage to neuronal activity. Hardly any literature can be found including both factors and investigating the impact on neural correlates of feedback processing. So additionally, the variables gender and personality were taken into account. The most-investigated components concerning feedback processing are the FRN and the P300 components, which will be the components of interest in this study as well. Based on the theoretical background, three different sets of hypotheses separated for the two components and the personality questionnaires have been formulated. Theoretical support of the hypotheses formulation should be given in the following sections.

4.1. The hypotheses concerning the FRN's amplitude

The component FRN was also found for expected, positive, or valid feedback (Holroyd, & Coles, 2002; Pfabigan et al., 2010; van Meel, & van Heijningen, 2010), but with smaller amplitudes than unexpected, negative, or invalid feedback. These findings led to the hypotheses that there are differences in the amplitude variation for the feedback valence. The hypotheses were formulated in a non directional way:

The FRN's amplitude size is different for losers and winners for gains. (H1)

The FRN's amplitude size is different for losers and winners for losses. (H2)

Further, no gender differences were expected (e.g. van Meel, & van Heijningen, 2010):

The FRN's amplitude size is not different for males and females. (H3)

Invalid feedback was found to elicit larger FRN amplitudes than valid feedback when competing against another human opponent (van Meel, & van Heijningen, 2010). Rigoni and colleagues (2010) take the actual state of emotionality into account and say that more negative emotions elicit larger FRN amplitudes.

These two findings might be true for player 2 in our study because he/she is getting more negative invalid feedback and losing more trials than player 1. Since there is no explicit finding present for this particular situation of invalid feedback in a PC vs. human condition, a non directional hypotheses has been formulated:

The FRN's amplitude is more negative for losers than for winners in the human vs. human condition. (H4)

The FRN's amplitude size is different for losers and winners in the PC vs. human condition. (H5)

4.2. The hypotheses concerning the P300's amplitude

Higher amplitudes of the P300 can be observed in participants who are highly motivated during the task (Yeung, & Sanfey, 2004; Nieuwenhuis et al., 2005a).

Moreover, unexpected feedback elicits larger P300 amplitudes than expected one (van Meel, & van Heijningen, 2010). For the reason that the task is manipulated in the way that player 1 is winning more trials than player 2, the expectancy for player 1 to win and for player 2 to loose is assumed to be introduced. Thus, losing for player 1 and winning for player 2 indicate unexpected situations. The gains and losses might additionally influence the motivational component. Therefore, the hypotheses have been formulated in a directional way:

The P300's amplitude is more positive for winners than for losers when losing. (H6)

The P300's amplitude is more positive for losers than for winners when winning. (H7)

As well as for the FRN, no gender differences were expected to occur:

The P300's amplitude is not different for males and females. (H8)

No particular predefined assumptions were available concerning the differences in the two conditions and therefore, the hypotheses were formulated in a non-directional way:

The P300s amplitude size is different for losers and winners in the human vs. human condition. (H9)

The P300's amplitude size is different for losers and winners in the PC vs. human condition. (H10)

4.3. The hypotheses concerning personality

A third set of hypotheses has been formulated to compare the different questionnaires among themselves and to calculate correlations with the components. The focus here was laid on the personality dimensions Neuroticism and Extraversion, as these are the most investigated scales of the NEO-FFI.

In previous studies, a negative correlation between the dimension Neuroticism and Extraversion was found (Eisenberger et al., 2005) and further, that the personality dimension Neuroticism can be explained by the BIS scale (Gray, 1970; Jorm et al., 1999; Smits, & Boeck, 2006; Boksem, et al., 2006).

There is not much evidence to underpin previous findings regarding the relation between the FRN and P300 components and personality. Thus non directional hypotheses have been formulated.

There is a correlation between the achieved score in the personality questionnaires and *the FRN's amplitude. (H11)*

There is a correlation between the achieved score in the personality questionnaires and the P300's amplitude. (H12)

5. Material and Methods

5.1. Participants

The sample consisted of 60 participants with an age range between 19 and 35 years. Participants were randomly assigned to the different time slots. Another criterion was that the pairs were gender-matched, which means that only females were allowed to play against females and males were allowed to play against males. All of the participants' education level was at least the matriculation. In addition, the participants had normal or corrected vision.

The first pair, two female participants, served as a test measurement to be sure that the task manipulation and the technical equipment worked out. Moreover, the first six participants, four males and two females, were also excluded from data analysis because the task manipulation was too obvious and had to be reprogrammed.

Now the sample was reduced to 52 participants. Two male participants (pair 22 and 23, both player 1) did not show up for the arranged appointment. Another female one (pair 14, player 2) fainted while applying the cap and therefore, the procedure was stopped. In those three cases, gender-matching lab assistants were asked to play against the remaining participant. No data was collected from them because they were informed about the aim of the study. Nevertheless, this was done to create a competitive situation and furthermore, to ensure the data collection in the competition situation.

Moreover, no data was acquired of one pair (pair 13), which was not gender-matched. After pre-processing, data of pair 7, 15 and the remaining dataset of pair 22 were excluded due to high level of noise in the EEG signal.

Finally, the data of 42 participants between 19 and 35 years old (M = 25.66, SD = 4.175), 22 male and 20 female participants, were used for the analysis. According to the data, the split of the sample in winners and losers revealed that there were 10 male and 11 female winners and 12 male and 9 female losers.

5.2. Procedure and experimental task

At an earlier date, several questionnaires were filled out online (https://www.soscisurvey.de/questionnaires/) by the participants to gain relevant information for the purpose of this study. Participants had to complete the German version of all questionnaires. In the following part, those questionnaires are explained in more detail.

5.2.1. Questionnaires

The first one was the German short-version of the "NEO-Personality Inventory (NEO-PI)", which was first published in 1985 (Costa, & McCrae, 2008). In 1992, the NEO-PI was revised (NEO-PI-R) and now it comprises 240 items. The short version, called "NEO-Five-Factor-Inventory", or in German "NEO-Fünf-Faktoren-Inventar" (NEO-FFI, Borkenau, & Ostendorf, 1993), includes 60 items of the NEO-PI-R. Those items are the ones, which loaded highest in each scale (Costa, & McCrae, 2008). This self-evaluative questionnaire measures personality on five different dimensions: Extraversion, Neuroticism, Openness/Intellect, Agreeableness and Conscientiousness. To do so, 60 statements have to be answered on a five-point-scale ranging from "1 - strong refusal (starke Ablehnung)" to "strong agreement (starke Zustimmung)" (Gerlitz, & Schupp, 2005).

Second, the "Behavioural Inhibition System/Behavioural Approach System" questionnaire, BIS/BAS (Carver, & White, 1994), was presented. This questionnaire is built up on Gray's theory (1970) about the two motivational systems. The first one is the BIS, which is activated when penalty or new stimuli arise. The BIS scale is also said to be activated when experiencing negative feelings (Carver, & White, 1994).

The second one is called BAS scale and comes into action in the case of reward and the escape from penalty. It is also said that the system is active when feeling positive emotions (Carver, & White, 1994).

Four subscales, one for BIS and three for BAS are measured. The three subscales are named drive, fun seeking and reward responsiveness (Smits, & Boeck, 2006). The BASD scale represents the desire to achieve a particular goal, the BASF the request for new stimuli and the last one, the BASR characterises the sensitivity to positive rewards (Smits, & Boeck, 2006)

In general, the sensitivity to each of the two systems is tried to be evaluated (Carver, & White, 1994). This is done by answering 24 items on a four-point scale ranging from "1 – does not apply at all" to "4 – totally applies". The German translation is as follows: "1 – trifft für mich gar nicht zu", to "4 – trifft für mich genau zu".

The "Barrett Impulsivity Scale - 11th version" (BIS-11, Patton, Stanford, & Barratt, 1995) is a self-evaluative questionnaire including 30 items on how a person controls his/her behaviour. Participants have to answer the items on a four-point scale ranging from "1-never (nie)" to "4-always (immer)". The whole scale is divided into three sub-dimensions, which are named attentional-, motor-, and non-planning impulsiveness. High scores stand for high impulsivity (Patton et al., 1995).

The "Saarbrückener Persönlichkeitsfragebogen" (SPF, Paulus, 2009) is the German version of the "Interpersonal Reactivity Index" (IRI) and is used for the measurement of empathy.

"The Aggression Questionnaire" (TAQ, Buss, & Perry, 1992) was developed to find something out about a person's aggression. Therefore, the TAQ divides into four sub-scales: anger, hostility, physical-, and verbal aggression (Buss, & Perry, 1992).

5.2.2. Before the experiment

After the participants arrived at the lab, the allocation to be player 1 and player 2 was done by a coin flip. As said before, it was done to assign a feedback colour to the participants, which was blue for player 1 and green for player 2, and secondly, the outcome of the game was manipulated. Player 1 was determined to be the winner and player 2 the loser. Participants did not know about the manipulation.

Before the measurement, participants were asked to read and sign a written informed consent. This informed consent was provided by the Faculty of Psychology of the University of Vienna, which was formulated according to the Declaration of Helsinki (1983).

Additionally, the instruction to the gambling game was handed out to familiarise the participants with the task. This instruction can be found in the appendix.

Together with the written informed consent and the instruction to the game, the Edinburgh Handedness Inventory (Oldfield, 1971) and the "Positive and Negative Affective Schedule" (PANAS, Watson, & Clark, 1988) were presented.

The PANAS (Watson, & Clark, 1988) measures the actual affective state of participants before and after the EEG-recording. Therefore, 20 items have to be rated on a five-point scale ranging from "1 - very slightly (sehr wenig)" to "5 – extremely (extrem)". Those items are taken together to two scales, the positive activation and the negative activation (Harmon-Jones, Harmon-Jones, Abramson, & Peterson, 2009).

5.2.3. The experiment

After the paperwork was completed and the electrodes were positioned, participants were guided into a sound-attenuated room and comfortably seated in front of a 19-inch cathode ray tube (CRT) monitor with about 70 cm distance.

Participants had to undergo two different conditions: The first one was a PC vs. human condition, in which the participant played against a computer. In the second condition, the two opponents were told to play against the human opponent but in fact, they both played against the PC at the same time. Therefore, the condition was called human vs. human condition. To induce a competitive situation, participants were instructed that they have to win as many points as possible. Those points were transferred into money at the end of the experiment.

The measurement started with two sessions against the PC per participant, followed by four sessions against the PC at the same time as the other player. Each session lasted 50 trials. This means in total, 100 trials in the PC vs. human condition and 200 trials in the human vs. human condition had to be completed.

The task performed by the participants was to press a particular key as fast as possible whenever the black coloured square appeared on the screen. Player 1 used the left and player 2 used the right arrow key.

To familiarise the participants with the main task, we asked them to perform a training session with 20 trials. All the test trials and the competition trials against the

PC and the human opponent were manipulated.

The order in which participant started to play against the PC depended on the number of the pair. If the pair number was odd, like 15, player 2 was starting or if the pair number was even, like 22, player 1 was starting.

While one participant was playing, the opponent's monitor was switched off and he/she had to fill out two questionnaires, the Beck's Depression Inventar – II (Herzberg, & Goldschmidt, 2008) and the State and Trait Anxiety Inventory (Laux, Glanzmann, Schaffner, & Spielberger, 1981).

The “Beck Depression Inventory – II” (BDI-II, Herzberg, & Goldschmidt, 2008) is used to find out if a depression is prevalent and if so, the severity of it. This should be done by answering 21 items on a four-point scale “0 – not at all (überhaupt nicht)” to “3 – exactly (sehr)” (Herzberg & Goldschmidt, 2008). The higher the score the higher the severity of the depression.

The State-Trait-Angstinventar (Laux et al., 1981) is an inventory to measure anxiety. It comprises 40 items. 20 of those items build up the state-scale, which marks the anxiety as a temporal condition. The other 20 items are asked to find out about how much the anxiety is part of the personality, the so-called trait-scale. All the items are answered on a four-point scale with the lowest end at “1 – not at all (überhaupt nicht)” and the highest at “4 – very much (sehr)” (Laux et al., 1981).

After both participants finished their PC sessions and the questionnaires, the earlier mentioned plot was presented.

To reduce any distraction, the participants had to put in earplugs for the human vs. human competition condition and further the ventilation was turned on.

In between each single session, four questions regarding happiness, satisfaction, anticipation to win, and motivation had to be answered. Additionally, after each condition, one for the PC and one for the human condition, several questions concerning the game, actual feelings, and the opponent were answered. All questions were answered on a seven-point scale. The exact formulated questions can be found in the appendix.

The gambling task comprised different outcome possibilities: In both conditions winning, losing, and breaking even was possible. As the feedback was presented for player 1 and player 2 to both players, the feedback order varied. This means that, for example, in the human vs. human condition in the first and third session, player 1 got feedback first and in the second and fourth session player 2.

5.2.4. The experimental task

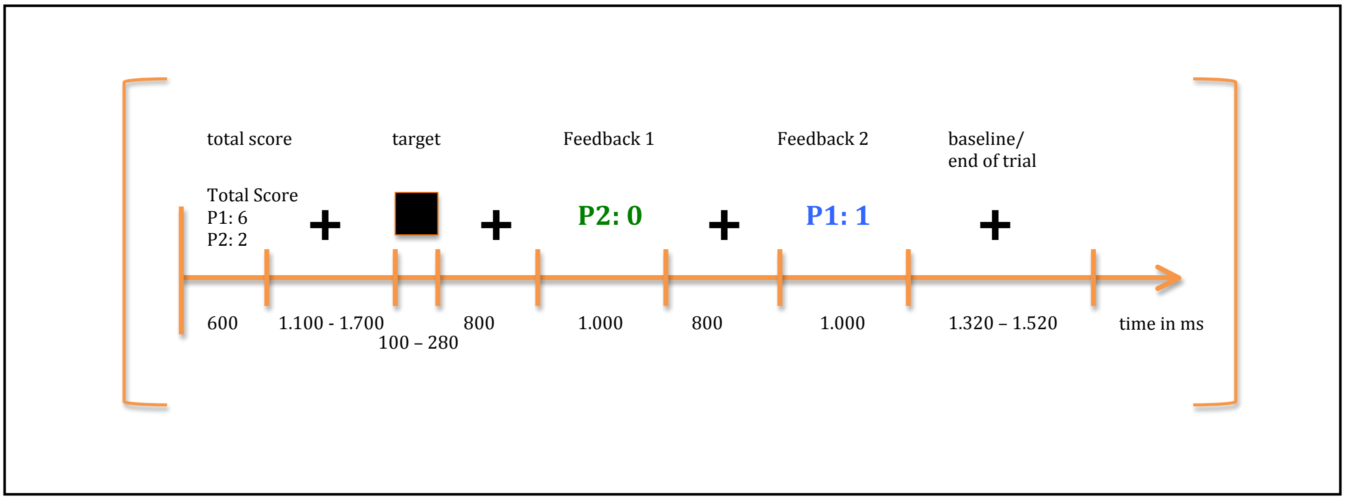

Figure 1: timeline of a human vs. human trial in the gambling task

Figure 1 represents a timeline of the human vs. human condition. Each trial started with the total score reached so far, which was presented in the middle of the screen for 600 milliseconds. This presentation included the own and the opponent's total score. After the total score, the fixation cross, which illustrated the anticipation period for the target, appeared with a variable duration between 1.100 and 1.700 milliseconds. As well as the total score, the fixation cross always appeared in the middle of the screen. The anticipation period varied because this should prevent the participants to learn or to predict when the target will appear. Following that fixation cross, the target, a black coloured square, showed up on the screen between 100 and 280 milliseconds. This time window indicated the button press for the participants. If participants missed to press the button after target presentation, the words "too late" in German, "zu spät" appeared on the screen in red colour.

The following period was identified as the feedback anticipation period. The first feedback appeared after 800 milliseconds and remained on the screen for 1.000 milliseconds. After the first feedback, another 800 milliseconds had to be waited until the second feedback appeared on the screen for 1.000 milliseconds. The feedback presentation consisted of the number of the player, P1 or P2, and the reached outcome, 0 for loss and 1 for gain, in the according feedback colour. The presentation of the last fixation cross varied between 1.320 and 1.520 milliseconds. This fixation cross indicated the end of the trial and served as a baseline until the end. The variation in the length of each trial was due to the variable stages, the anticipation period and the target presentation, during one trial.

Each single trial lasted between 7.000 and 7.500 milliseconds. Each participant had to complete 20 test trial and 100 trials against the PC and further, 200 trials playing against the PC at the same time had to be absolved. Therefore, a total processing time of the task between 51 and 55 minutes was calculated for each measurement.

5.2.5. After the experiment

The participants were asked to fill out the PANAS again after the experiment was finished. This was done to assess how the actual mood influenced the behaviour during the task and how it changed while playing.

The participants were released from the cap and guided to the bathroom to wash their hair. Last, they filled out the fee note and collected € 30,- for participation.

5.3. Electrophysiological recoding

For the experiment, 61 silver/silverchloride (Ag/AgCl) ring electrodes on a cap (EASYCAP GmbH, model M10; Herrsching, Germany) were used. Additionally, a ground electrode was positioned on the participant's forehead between the eyebrows. The electro-oculogram (EOG), vertically and horizontally, was recorded with two additional electrodes positioned approximately one centimetre below and above the left eye and one electrode on the temple of each eye, which were embedded in the EEG cap. This was done to assess eye movements more precisely. The right mastoid electrode was used as the online-reference electrode. The electrodes were positioned according to the International 10/10 system (American Electroencephalographic Society, 1994).

After disinfecting the forehead with a 70-%-ethyl-alcohol, the cap was placed on the participant's head. Next step was to remove the hair with a cropped cotton bud to ensure the contact to the scalp. Now, all electrodes were disinfected with alcohol using the top of the cotton bud. With a sterile single use needle, the scalp, where the electrodes were placed, was slightly scratched to remove dandruff to ensure better impedances. After that, the electrodes were filled with degassed electrode gel (Electro-Gel, Electrode-Cap International, Inc.; Eaton, OH). To make sure that all the electrodes worked, they were checked with an impedance meter (Ing. Kurt Zickler, GmbH, model: 32-Kanal-Elektroden-Impedanzmessgerät; Pfaffstätten, Österreich). All the impedances were kept below 2 kΩ. Further, the conductivity was steadily observed during the measurement to ensure a proper recording.

After applying the cap, the participants were guided to a Faraday cage, a soundproof room. All electronical devices were taken from the participants beforehand. The participants were sitting on non-moveable chairs in 140 cm distance face-to-face with two 19-inches-CRT monitors between them. On the table, flexible rubber boards were placed for response submission. Those keyboards were used to minimize the noise of the button press.

Participants were given a short general EEG instruction, which included instructions not to move, nor to talk or laugh during the measurement. Further, they were told not to blink too much because this would cause artefacts to the data.

The electrodes were connected with a 64-EEG-channel-amplifier (neuroConn GmbH; Ilmenau, Deutschland). The measurement was done using a sample rate of 1.000 Hz. EEG data were sampled from DC to 500 Hz. Stimulus presentation occurred by connecting the computer outside of the Faraday cage with the monitors on the inside. The task was programmed in Matlab 7.5.0 (The MathWorks, Inc.; Natick, USA) and presented by Cogent 2000 (Laboratory of Neurobiology; London, UK).

5.4. Data analysis

The data were analysed using EEGLAB version 6.0.3b (Delorme, & Makeig, 2004), which was implemented in Matlab 7.5.0 (The MathWorks, Inc.; Natick, USA).

5.4.1. Pre-processing

First, data were processed by using a 30 Hz low pass and a 0.1 Hz high pass filter and further, the data were downsampled to 250 Hz. Offline, the filtered data were re-referenced to a mean of the left and the right mastoid electrode. These data were screened for artefacts. Obviously noisy data were rejected before independent component analysis (ICA, Makeig, Bell, Jung, & Sejnowski, 1996) was run. ICA was performed to remove artefacts caused by eye movement.

After these steps, the trigger indicating the feedback valence, positive or negative, were loaded to the data. This was done via the log files. Moreover, the data were epoched for the time window starting with 200 milliseconds before the feedback presentation to 1.000 milliseconds after the feedback presentation. The first 200 milliseconds served as baseline interval.

The data were merged together, which made four different conditions available for further data processing: positive and negative feedback for oneself and positive and negative feedback for the opponent. The breaking even trials were also added, as feedback order was not important for the current research question. Those data were available for the PC vs. human and the human vs. human condition. As for the present study, only the own feedback was of interest, four different outcomes were possible: winning and losing in the PC vs. human and in the human vs. human condition.

5.4.2. Artefact correction

A semi automatic approach was chosen for the artefact correction of the data. Extreme values and abnormal trends were identified as values, which the potential of the amplitude by +/- 75 μV. Another criterion was that no drift over 50 μV was allowed. Values, which did not meet these criteria were marked and suggested for rejection by EEGLAB (Delorme, & Makeig, 2004). Data were again visually inspected and rejection was accomplished. After artefact correction, grand averages of the data were calculated.

5.4.3. ERP-quantification

The amplitude's peaks were assessed by using the BRL peak finder 0.1b plug-in, which is implemented in Matlab (The MathWorks, Inc.; Natick, USA). To calculate the component FRN, a peak-to-peak-to-peak method was used (Yeung, & Sanfey, 2004). The electrodes of interest were Fz (Yu, & Zhou, 2006; Li et al., 2010; Rigoni et al., 2010; van Meel, & van Heijningen, 2010) and FCz (Nieuwenhuis et al., 2005b; Yu, & Zhou, 2006; Wu, & Zhou, 2009; Pfabigan, et al., 2010). Using these electrodes, the FRN component was assessed in the time window ranging from 150 to 350 milliseconds after feedback presentation. Further to do the peak-to-peak-to-peak calculation, the component P200 was important. This is the positive peak in the time window between 120 and 200 milliseconds after feedback presentation prior to the FRN peak. Another important peak for this calculation was the P300 component in the time window 250 to 500 milliseconds after feedback presentation following the FRN peak.

The formula for calculating the FRN's amplitude was the following:

$$\text{FRN-amplitude} = (\text{P200}+\text{P300})/2 - \text{FRN}$$

For assessing the component P300, a peak-to-peak method was used. Beside the P300 component, which was anticipated in the time window 200 to 500 milliseconds after feedback presentation, the component N2, a negativity peaking between 150 and 250 milliseconds after feedback presentation prior to the P300 peak, was important.

The formula for the P300's amplitude calculation was the following:

$$\text{P300-amplitude} = \text{P300} - \text{N2}$$

The peak-to-peak-to-peak and the peak-to-peak methods were used because they are more robust than using a normal base-to-peak method. Variations caused to the components of preceding and following components can be taken into account (Yeung, & Sanfey, 2004).

5.4.4. Statistical analysis

For the statistical analysis the program SPSS Statistics 20 (IBM; New York, USA) was used. Missing data or outliers, which exceeded > 2 standard deviations were replaced by the according mean of the variable to reduce bias of the data. Values, how often this happened, can be extracted from Table 1 below.

component	electrode	condition	number of cases
FRN amplitude	Fz	PC vs. human	2
FRN amplitude	FCz	PC vs. human	3
FRN amplitude	Fz	human vs. human	1
FRN amplitude	FCz	human vs. human	2
P300 amplitude	Pz	PC vs. human	5
P300 amplitude	Pz	human vs. human	2
FRN latency	Fz	PC vs. human	1
FRN latency	FCz	PC vs. human	1
FRN latency	Fz	human vs. human	0
FRN latency	FCz	human vs. human	1
P300 latency	Pz	PC vs. human	1
P300 latency	Pz	human vs. human	0

Table 1: number of missing data and outliers replaced by the mean of the according variable

The significance level was set to $p < 0.05$ for all the analysis. Only for the assumptions regarding normality and homogeneity of variances, the significance level was lowered to $\alpha = 0.001$. This was done because the used statistical methods are very robust against assumption violations.

The calculated effect sizes are indicated in terms of Cohen's d (Cohen, 1988) for the correlations and t-tests, and η_p^2 for the calculated ANOVAs. According to Cohen (1988) reaching d =0.2 characterises a low, d = 0.5 a medium, and d = 0.8 a high effect. Regarding the η_p^2, a low effect is expressed by $\eta_p^2 = 0.01$, a medium one by $\eta_p^2 = 0.06$ and high effect by $\eta_p^2 = 0.14$ (Kirk, 1996).

The PANAS scores were analysed by applying a 2x2x2 repeated measure ANOVA with the within-subject factors affect (positive and negative) and time (before and after). The factor player (winner and loser) served as a between-subject factor. This was done to gain insight into the feelings stated by the participants before and after the experiment. So, emotional changes during the experiment could be disclosed.

To investigate significant results in detail, Tukey post-hoc tests were carried out for significant interactions.

Further, t-tests were performed concerning the questions between each session and after each condition. A paired-samples t-test was used when all the assumptions were met. If any violation of assumptions was present, the non-parametric Wilcoxon test was used for the analysis. Regarding the questions after each condition, two measurements, one after the PC vs. human and on after the human vs. human condition were available to compare. Two measurements for the questions between each single session were available in the PC vs. human condition, which were used for further comparison. But regarding the questions between each session in the human vs. human condition, four measurements were obtained in the course of the game. In this case, the first and the last presentation of the questions were used to compare. The aim of doing these comparisons was to investigate the possible changing of emotions, the actual affective state and motivation while performing the task.

To investigate the FRN's amplitude, two 2x2x2x2x2 repeated-measure ANOVAs were conducted. The amplitude and the latency of the FRN component served as the dependent variables in the ANOVAs. Three within factors were added: electrode (Fz and FCz), valence (win and loss) and condition (PC vs. human and human vs. human). Further, the player (winner and loser) and gender (male and female) were added as between factors.

As the component P300 was only measured on the electrode Pz (Hruby, & Marsalek, 2003; Yeung, & Sanfey, 2004; Hajcak et al., 2007; Boksem et al., 2010; van Meel, & van Heijningen, 2010; Santesso et al., 2011), the within factor electrode was not included in this analysis. Therefore, two 2x2x2x2 repeated measure ANOVAs to investigate the amplitude and the latency of the P300 component were conducted, including the within factors valence (win and loss) and condition (PC vs. human and human vs. human). Again, the player (winner and loser) and gender (male and female) were added as between factors.

Correlations were used to explore the relation between the personality dimensions of the NEO-FFI and BIS/BAS questionnaires and moreover, to investigate the correlations between the questionnaires with the ERP components. Depending on the violation of normality and variance homogeneity of the data, a two-tailed Pearson or Spearman correlation was used.

Besides the statistical analysis, sLORETA calculations (Pascual-Marqui, 2002) were conducted. Those results are not included in this thesis.

6. Results

6.1. Behavioural results

6.1.1. PANAS results

The main factor *affect* ($F_{[1,39]}$ = 326.952, p < 0.001, ηp^2 = 0.893) was significant with generally more positive than negative affect during the experiment.

The second main factor *time* did not reach significance ($F_{[1,39]}$ = 0.161, p = 0.690, ηp^2 = 0.004), as well as the between-subject factor *player* ($F_{[1,39]}$ = 2.252, p = 0.142, ηp^2 = 0.055).

The interaction *player * affect* was significant ($F_{[1,39]}$ = 5.345, p = 0.026, ηp^2 = 0.121). Descriptively, the winner showed more positive affect than the loser and regarding the negative feelings, the winner showed slightly less. Both players showed more positive than negative affect.

Taking a look at the *time * affect* interaction ($F_{[1,39]}$ = 8.946, p = 0.005, ηp^2 = 0.187) displayed that the positive affect before the experiment was more pronounced than the negative affect and further, that the positive affect after the experiment were less than at the beginning on a descriptive level. Negative emotions rose from before the experiment to after the experiment. After the experiment, the positive emotions were still higher than the negative ones.

Conducting post-hoc tests regarding the three-way interaction *player * affect * time* ($F_{[1,39]}$ = 15.607, p < 0.001, ηp^2 = 0.286) revealed that the loser's positive affect after the experiment significantly differed from all the other results in the post-hoc test (p < 0.001; winner positive before: p = 0.028; winner positive after: p = 0.028). Before the experiment, the loser showed more positive affect than afterwards, but compared to the negative affect at the end of the experiment, the positive ones were still higher. The winner's positive affect before the experiment was higher than the negative affect (p < 0.001). Moreover, the winner's positive affect after the experiment was still higher than the negative affect (p < 0.001). Regarding the loser, the positive affect before the experiment was higher than the negative affect before the experiment (p < 0.001).

Figure 2 illustrates the findings of the interaction player * affect * time.

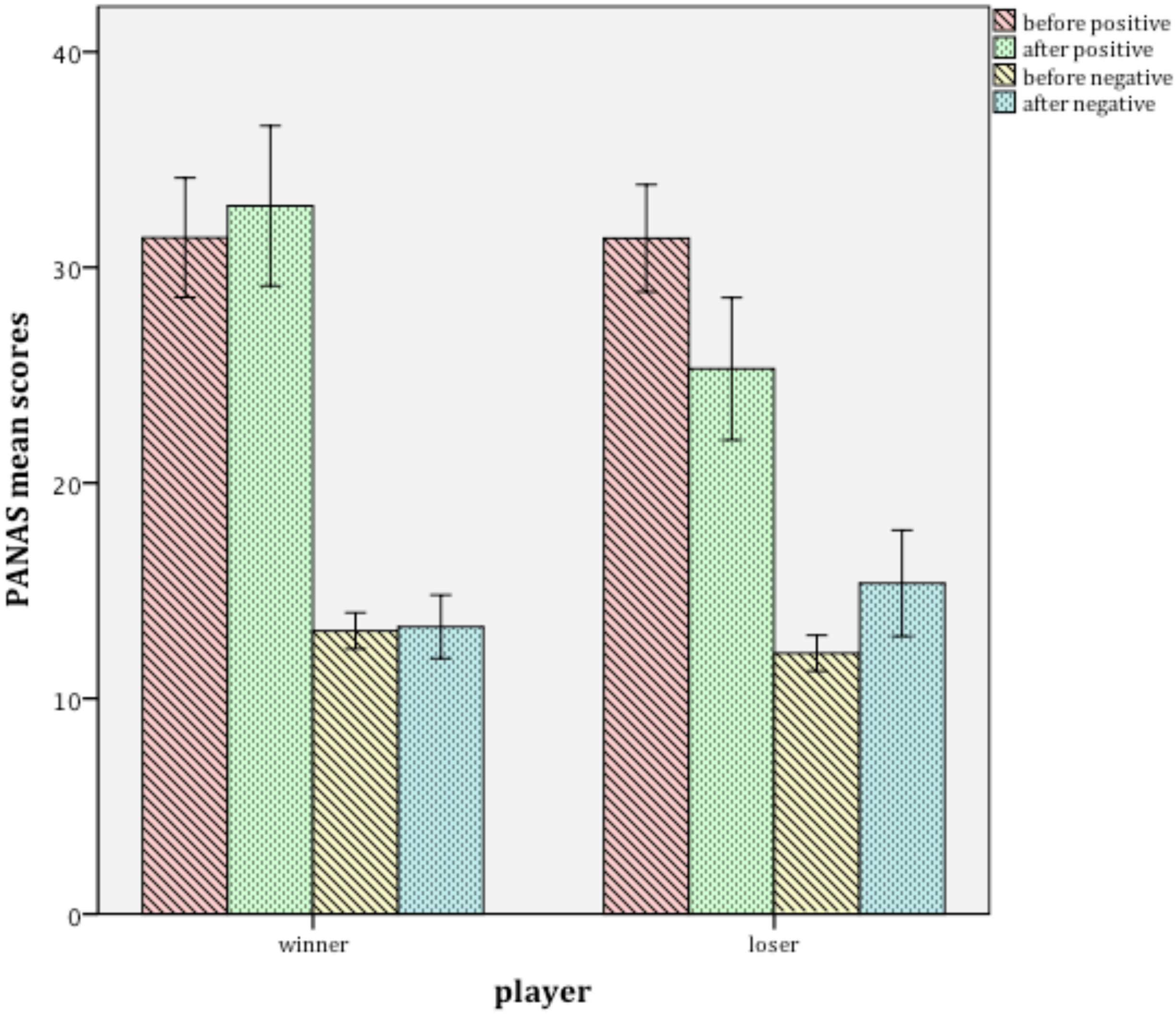

Figure 2: PANAS results winners and the losers: Positive and negative affect before the experiment were similar for both players. After the experiment, winners showed more positive affect than losers and losers more negative affect compared to winners. Error bars indicate two standard errors.

6.1.2. Questions between each condition

Generally, the participants' *sadness after a loss* decreased in the course of the game (t(41) = 2.460, p = 0.018, d = 0.380).

Splitting that result for the two players, it became significant for the winner (t(20) = 2.335, p = 0.030, d = 0.510). For the loser, the significance level was not exceeded (t(20) = 1.142, p = 0.267, d = 0.249).

For the winner, the *attention to the own feedback* was higher in the human vs. human condition than in the PC vs. human condition (Z = -2.673, p = 0.008, d = 0.553).

For the loser, the question regarding the *interest in the game* became significant (t(20) = 2.227, p = 0.038, d = 0.486) with more interest in the PC vs. human than in the human vs. human condition. Further, the loser started to doubt the own *competence* (Z = -2.721, p = 0.007, d = 0.735): The personal feeling about the competence was higher in the PC vs. human condition than in the human vs. human condition.

6.1.3. Questions between each session

Only few results reached the significance level. Generally, the *happiness* decreased in the PC vs. human condition (t(41) = 2.297, p = 0.027, d = 0.354).

This could also be found for the *motivation* in the PC vs. human condition (t(41) = 2.735, p = 0.009, d = 0.422). Higher motivation after the first session in the PC vs. human condition was present than after the last session.

The *motivation* continued to decrease in the human vs. human condition (Z = -4.996, p < 0.001, d = 1.046).

Those results were split for the winner and loser for additional analysis. For the *loser*, the *happiness* in the PC vs. human condition decreased from the beginning compared to the end (t(20) = 2.911, p = 0.009, d = 0.634).

The *motivation* for the *winner* started to decrease in the human vs. human condition (Z = -0.3666, p < 0.001, d = 1.125).

As well as for the winner, the *loser's motivation* decreased. For the loser it has already started in the PC vs. human condition (t(20) = 3.408, p = 0.003, d = 0.743).

This *motivational* decrease for the loser continued in the human vs. human condition (Z = -3.455, p = 0.001, d = 0.971).

Figure 3 shows the motivational decrease of the winner and the loser in the course of the experiment.

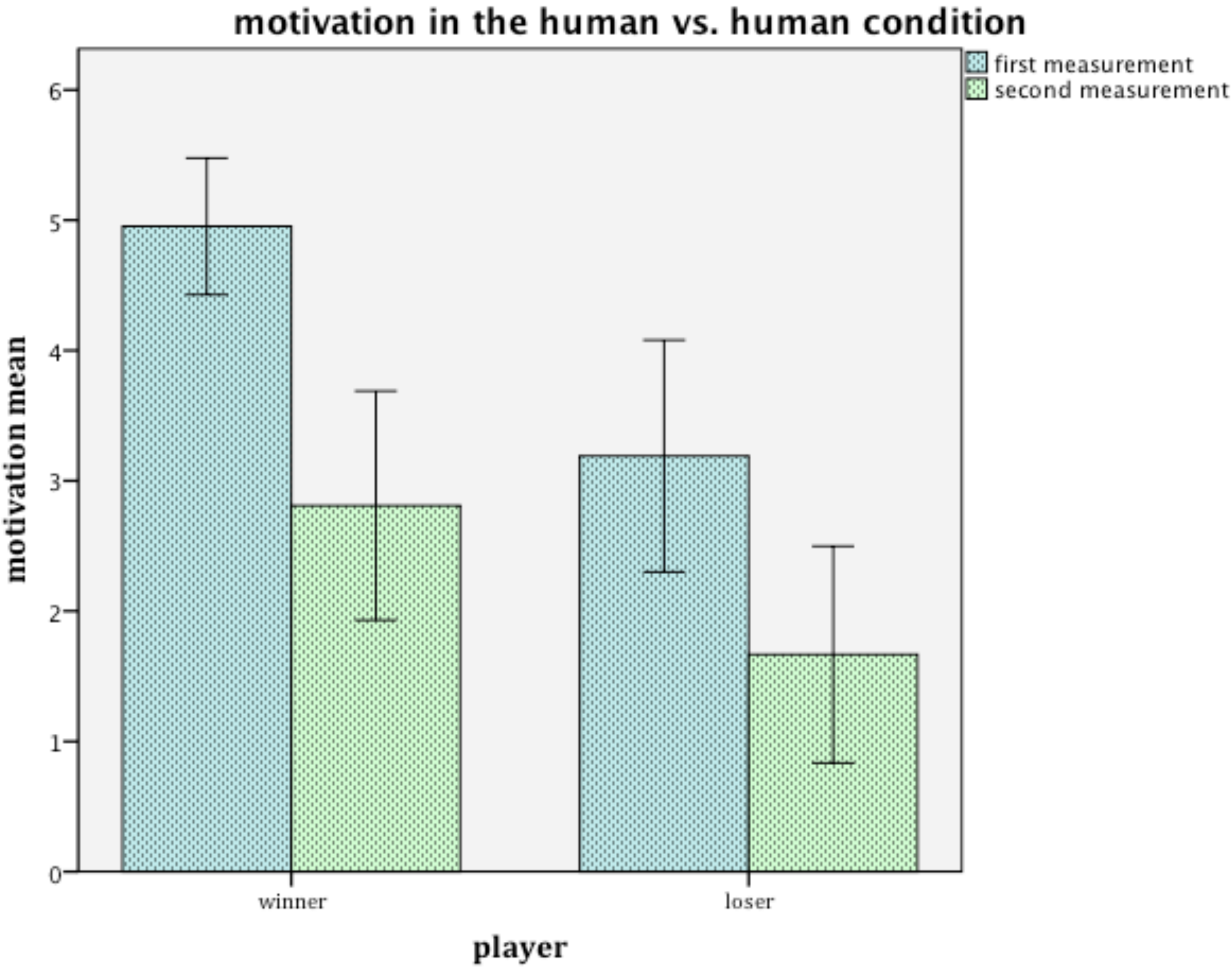

Figure 3: means of the factor motivation for the winner and the loser in the human vs. human condition: During the experiment, the motivation decreased for the winner and for the loser. The winner was still more motivated than the loser at the end of the experiment. Error bars indicate two standard errors.

The *anticipation to win* did not reach significance (Z = -1.894, p = 0.058, d = 0.369), but the tendency for the *winner* is interesting to see: It increased in the course of the human vs. human condition.

Again, the *anticipation to win* did not reach the significance level for the *loser* (Z = -1.943, p = 0.052, d = 0.331). The tendency for the loser is an early decrease in the PC vs. human condition.

6.2. The FRN's amplitude

Investigating the 2x2x2x2x2 repeated measure ANOVA with the FRN's amplitude as the dependent variable revealed that the main factor *electrode* was significant ($F_{[1,38]} = 30.792$, $p < 0.001$, $\eta_p^2 = 0.448$) with larger FRN amplitudes on Fz than on the FCz.

It could also be found that the FRN's amplitude was different for the main factor *valence* ($F_{[1,38]} = 203.158$, $p < 0.001$, $\eta_p^2 = 0.842$): Gains elicited smaller FRN amplitudes compared to losses.

Neither the between factor *gender* ($F_{[1,38]} = 0.237$, $p = 0.629$, $\eta_p^2 = 0.006$) nor *player* ($F_{[1,38]} = 1.092$, $p = 0.303$, $\eta_p^2 = 0.028$) reached significance.

When taking a look at the interaction effects, it became clear that the interaction *electrode * valence* ($F_{[1,38]} = 9.942$, $p = 0.003$, $\eta_p^2 = 0.207$) was significant with larger FRN amplitudes on the electrode Fz when winning and losing than on the electrode FCz. So, the amplitudes were more pronounced on the electrode Fz than on FCz.

The interaction *player * valence* showed a significant result ($F_{[1,38]} = 70.366$, $p < 0.001$, $\eta_p^2 = 0.649$) with largest FRN amplitudes for the winner when losing. In general, the amplitude's size for losses for both players, the winner and the loser, were more negative compared to gains. The winner showed larger FRN amplitudes in the case of a gain compared to the loser, but when winning the loser showed more negative FRN amplitudes than the winner.

Figure 4 illustrates the findings of the player * valence interaction effect in the PC vs. human condition. In this condition, the winner's FRN amplitude was larger than the one for the loser when winning, but the opposite result is apparent from Figure 5, which displays the human vs. human condition. This is due to the fact that the interaction player * valence does not include the factor condition and therefore, an overall result over both condition was calculated.

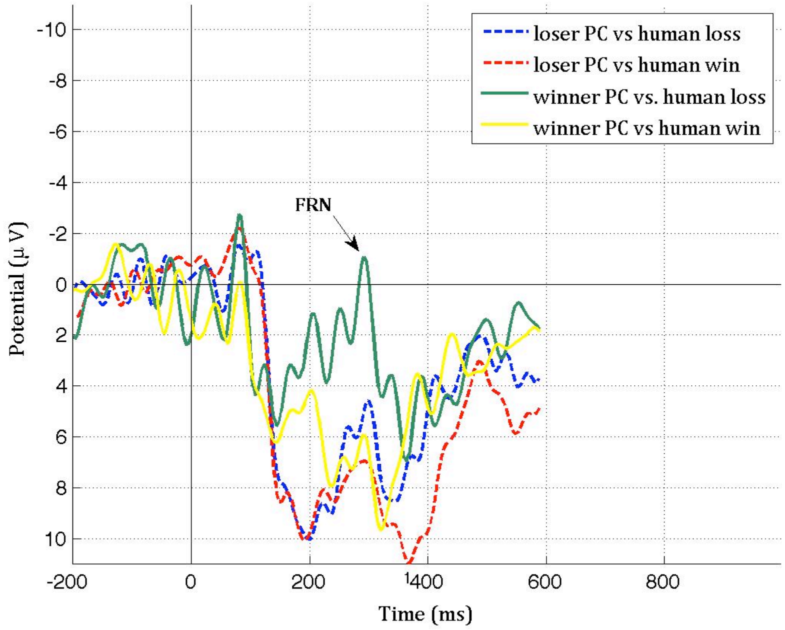

Figure 4: FRN amplitudes for winners and losers according to the feedback valence on the electrode Fz in the PC vs. human condition: Winners showed largest FRN amplitudes when losing in the PC vs. human condition. Generally, losses elicited larger FRN amplitudes than gains for both players.

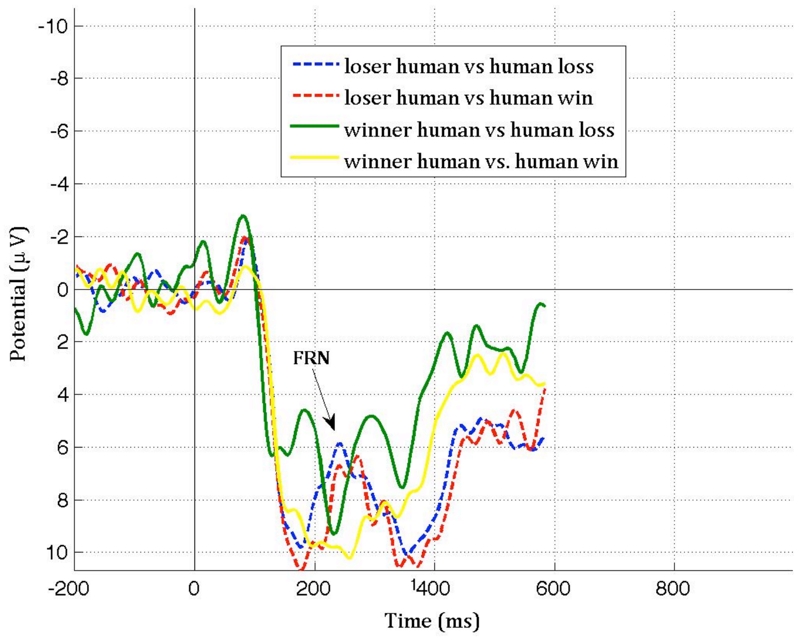

Figure 5: FRN amplitudes for winners and losers according to the feedback valence on the electrode Fz in the human vs. human condition: Again, winners losing in the human vs. human condition showed largest FRN amplitudes. Losses for the winner and the loser elicited larger FRN amplitudes than gains.

Moreover, the three-way interaction *player * electrode * valence* was significant ($F_{[1,38]}$ = 5.994, p = 0.019, η_p^2 = 0.136) with largest FRN amplitudes for the winner when losing on the electrode Fz. Winner showed more negative FRN amplitudes on both electrodes for losses compared to the loser. But the loser showed larger FRN amplitudes for gains than for losses compared to the winner. This was again found on both electrodes, Fz and FCz.

6.3.Comparing the FRN's amplitude in the different conditions

The last main factor *condition* was significant ($F_{[1,38]}$ = 107.025, p < 0.001, η_p^2 = 0.738) with more negative FRN amplitudes in the PC vs. human condition compared to the human vs. human condition.

An interaction including the electrode, which reached significance, was the *electrode * condition* interaction ($F_{[1,38]}$ = 63.812, p < 0.001, η_p^2 = 0.627). It showed that larger FRN amplitudes were found on the electrode Fz in the PC vs. human condition compared to the electrode FCz and that the human vs. human condition elicited larger FRN amplitudes than the PC vs. human condition on the electrode site FCz.

The *player * condition* interaction ($F_{[1,38]}$ = 4.183, p = 0.048, η_p^2 = 0.099) showed that the winner's FRN amplitudes were more negative in the PC vs. human condition than for the loser. In the human vs. human condition, the loser showed more negative FRN amplitudes than the winner.

Figure 6 illustrates the results found for the interaction effect for gains. The finding that losses elicited more negative FRN amplitudes than gains cannot be found in that figure because the feedback valence loss is not included and the figure displays an overall result over the feedback valence gain. When taking a look at Figure 7, the result can be seen when losing for the winner and the loser.

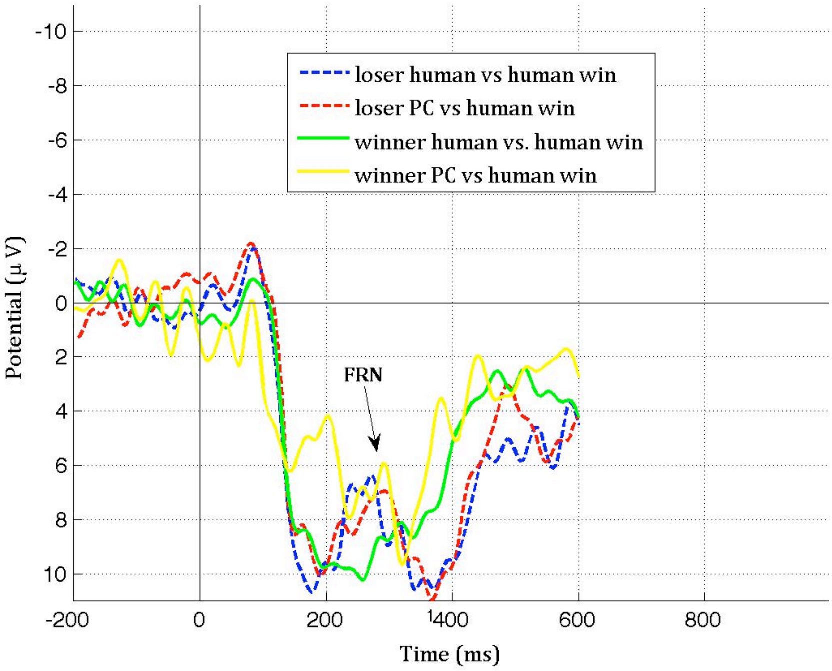

Figure 6: FRN amplitudes for winners and losers when winning on the electrode Fz in the PC vs. human condition and human vs. human condition: Largest FRN amplitudes were found for the winner in the PC vs. human condition when receiving a gain. When playing against a human opponent, the loser showed larger FRN amplitudes compared to the winner, and when playing against a computer, the winner displayed larger FRN amplitudes than the loser.

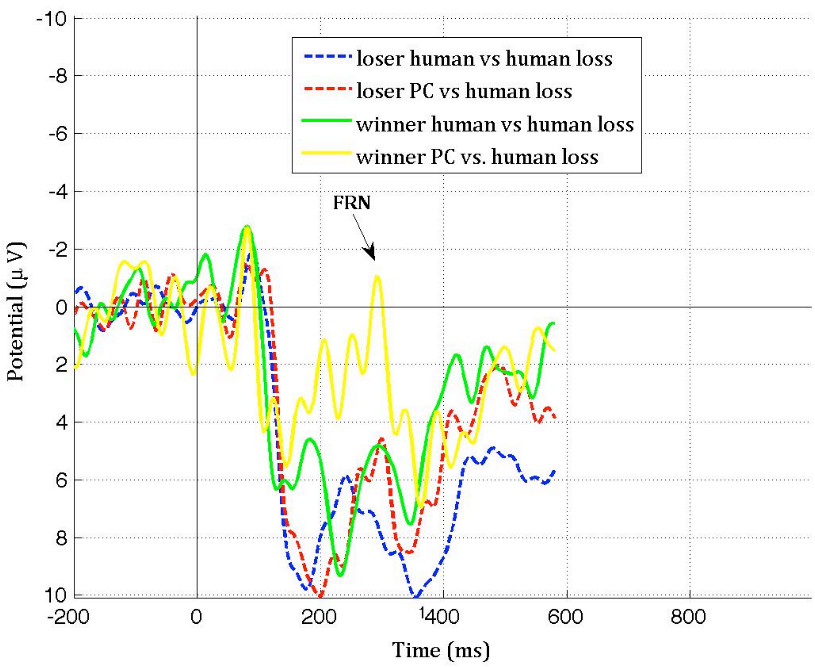

Figure 7: FRN amplitudes for winners and losers when losing on the electrode Fz in the PC vs. human condition and human vs. human condition: Largest FRN amplitudes were displayed by the winner when losing in the PC vs. human condition. Generally, losing in the PC vs. human condition elicited larger FRN amplitudes than losing in the human vs. human condition.

Additionally, the interaction *valence * condition* ($F_{[1,38]}$ = 27.770, p < 0.001, ηp^2 = 0.422) reached significance. Losing in the PC condition elicited largest FRN amplitudes. Besides, the amplitude's size for losses was larger than for gains in the PC vs. human condition and in the human vs. human condition.

The three-way interaction *player * electrode * condition* ($F_{[1,38]}$ = 11.976, p = 0.001, ηp^2 = 0.240) revealed that winners showed largest FRN amplitudes on the electrode Fz in the PC vs. human condition followed by the loser's on the same electrode in the same condition. Now, when taking the between factor player into account, it can be seen that generally the PC vs. human condition elicited larger FRN amplitudes compared to the human vs. human condition on both electrodes for winner and loser. The winner showed larger FRN amplitudes on the electrode Fz in both conditions and on the electrode FCz in the PC vs. human condition than the loser, but not in the human vs. human condition: There, the loser displayed more negative FRN amplitudes than the winner.

The three-way interaction *valence * condition * player* yielded another significant result ($F_{[1,38]}$ = 16.116, p < 0.001, ηp^2 = 0.298). Tukey post-hoc tests revealed that losing of the winner in the PC vs. human condition elicited largest FRN amplitudes and that it was different from all the other groups (p <0.001). Further, when the winner was losing against another human opponent, the FRN's amplitude was significantly different from winning in the PC vs. human condition for the winner (p < 0.001). More negative FRN amplitudes were found in the PC vs. human condition. Taking a look at the results for the loser, it can be seen that the FRN's amplitude was larger for losing in the PC vs. human condition than in the human vs. human condition (p < 0.001). Another significant difference was found for gains in the PC vs. human and the human vs. human condition: Losers showed larger FRN amplitudes in the PC vs. human condition than in the human vs. human condition (p = 0.025) for gains.

As well as the three-way interaction, the four-way interaction *electrode * valence * player * condition* ($F_{[1,38]}$ = 4.614, p = 0.038, ηp^2 = 0.108) became significant. Winners showed largest FRN amplitudes on the electrode Fz when losing in the PC vs. human condition. Again, all the FRN amplitudes were larger on Fz compared to FCz with one exception in the human vs. human condition for the loser. Further, the PC vs. human condition elicited larger FRN amplitudes than the human vs. human condition for the winner and the loser. Gains elicited smaller FRN amplitudes compared to losses on both electrodes for the winner and on the electrode Fz for the loser. The electrode FCz showed larger FRN amplitudes for the loser's gains than for losses in the human vs. human condition, but not in the PC vs. human condition.

6.4. The FRN's latency

Comparing the neuronal responses on the different *electrodes* ($F_{[1,38]}$ = 11.635, p = 0.002, η_p^2 = 0.234) showed that the latency of the FRN component is slightly prolonged on Fz than on FCz.

A significant result was found for the main factor *valence* ($F_{[1,38]}$ = 32.861, p < 0.001, η_p^2 = 0.464) with later FRN peaks for losses than for gains.

The between-subject factor *player* was significant ($F_{[1,38]}$ = 57.477, p < 0.001, η_p^2 = 0.602) with later FRN components for the winner than for the loser.

The second between-subject factor *gender* did not reach the significance level ($F_{[1,38]}$ = 0.033, p = 0.856, η_p^2 = 0.001).

The interaction *player * valence* ($F_{[1,38]}$ = 5.070, p = 0.030, η_p^2 = 0.118) revealed later FRN latencies of winners for both feedback valences, gains and losses, compared to the loser.

Although the between-subject factor *gender* did not reach significance, the interaction *gender * electrode * player* did ($F_{[1,38]}$ = 4.550, p = 0.039, η_p^2 = 0.107). Generally, later FRN components were found on the electrode Fz compared to FCz. Male winners showed faster FRN latencies on electrode Fz compared to female winners and further, male losers displayed earlier FRN components on FCz than female losers. When taking a look at the female winners, they showed earlier FRN components on FCz than male winner and female losers showed earlier FRN components on the electrode Fz than male losers.

6.5. Comparing the FRN's latency in the different conditions

The main factor *condition* was significant ($F_{[1,38]} = 65.603$, $p < 0.001$, $\eta_p^2 = 0.633$) with later FRN components in the PC vs. human condition than in the human vs. human condition.

When investigating the *player * condition* interaction ($F_{[1,38]} = 10.253$, $p = 0.003$, $\eta_p^2 = 0.212$) it was found that the winner showed later FRN components compared to the loser in both conditions and further, that the PC vs. human condition elicited later FRN components for winners and losers than in the human vs. human condition.

The interaction *condition * valence* became significant as well ($F_{[1,38]} = 7.408$, $p = 0.010$, $\eta_p^2 = 0.163$). Losses elicited later FRN components compared to gains in both conditions and moreover, that the PC vs. human condition showed later FRN components than the human vs. human condition. Latest FRN components were present in the PC vs. human condition when losing.

The interaction *player * electrode * condition* reached significance ($F_{[1,38]} = 9.800$, $p = 0.003$, $\eta_p^2 = 0.205$) with later FRN latencies in the PC vs. human compared to the human vs. human condition for winners and losers. Additionally, those FRN latencies were later on the electrode Fz for the winner than on FCz in both conditions and for the loser only in the PC vs. human condition, but not in the human vs. human condition. Further, the winner showed later FRN latencies compared to the loser in both conditions and on both electrodes.

Another interaction, *electrode * valence * condition*, showed a significant result ($F_{[1,38]} = 4.147$, $p = 0.049$, $\eta_p^2 = 0.098$). This interaction revealed that gains and losses displayed later FRN components on the electrode Fz in the PC vs. human than on FCz. For the human vs. human condition, it was found that gains on the Fz elicited earlier FRN components than on the FCz, but the FRN components for losses peaked later on the Fz than on the FCz. The earliest FRN components were elicited on the electrode Fz for gains in the human vs. human condition and the temporally latest for losing in the PC vs. human condition on Fz.

The three-way interaction *player * valence * condition* ($F_{[1,38]} = 41.192$, $p < 0.001$, $\eta p^2 = 0.520$) was further investigated with a post-hoc test and showed that loser losing in the human vs. human condition were different from all other groups ($p < 0.001$; for loser gain PC vs. human: $p = 0.0147$): Those were the earliest FRN components. The winner losing in the human vs. human condition was different from winning with later FRN latencies for losing than winning ($p < 0.001$) For gains, the winner showed later FRN components in the PC vs. human condition than in the human vs. human condition ($p = 0.007$). Comparing the winner and the loser revealed that when the winner was losing in the human vs. human condition, later FRN components were elicited than for the loser ($p < 0.001$). Moreover, when the winner was yielding a gain in the PC vs. human condition FRN components were shown later than when the loser was winning in the PC vs. human condition ($p < 0.001$). For the loser it was valid, when losing in the PC vs. human condition the FRN component was elicited later than when winning in the PC vs. human condition ($p < 0.001$).

6.6. The P300's amplitude

The main factor *valence* reached significance ($F_{[1,38]} = 31.870$, $p < 0.001$, $\eta p^2 = 0.456$) with more positive P300 amplitudes for losses than for gains.

There are differences in the between-subject factor *player* ($F_{[1,38]} = 42.875$, $p < 0.001$, $\eta p^2 = 0.530$). Winners showed more positive P300 amplitudes than losers.

Again, no *gender* differences could be found ($F_{[1,38]} = 0.706$, $p = 0.406$, $\eta p^2 = 0.018$).

The interaction *player * valence* ($F_{[1,38]} = 65.499$, $p < 0.001$, $\eta p^2 = 0.633$) disclosed that the winner losing showed largest P300 amplitudes. Conducting post-hoc tests came up with the result that this group was significantly different from all the others (p < 0.001). When losing, the winner yielded larger P300 amplitudes than the loser. Further, the winner's P300 amplitudes were larger for a loss than for a gain.

Figure 8 depicts the findings of the interaction effect player * valence in the PC vs. human condition. Additionally, Figure 9 shows equally the same, but for the human vs. human condition. The factor condition is not taken into account and therefore, it is not possible to show the result that the P300 amplitude is larger for losses than for gains in figure 8.

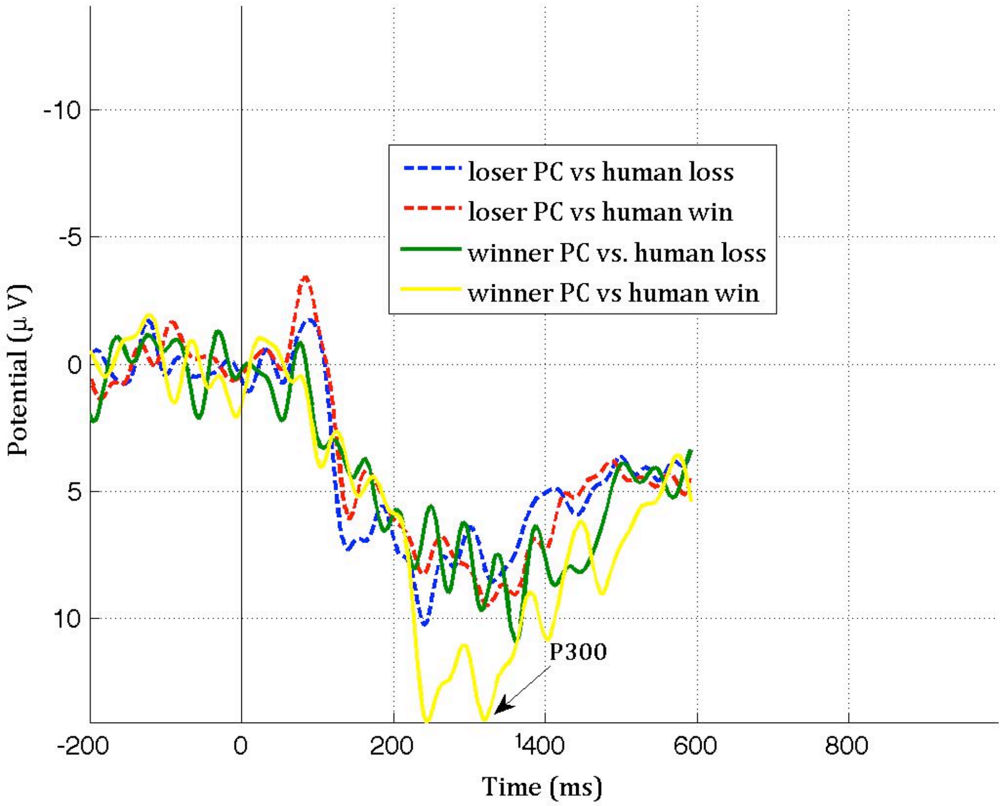

Figure 8: P300s amplitude for the winner and the loser according to the feedback valence on the electrode Pz in the PC vs. human condition: Most positive P300 amplitudes could be found when winning in the winner in the PC vs. human condition. The winner showed more positive P300 amplitudes than the loser when losing.

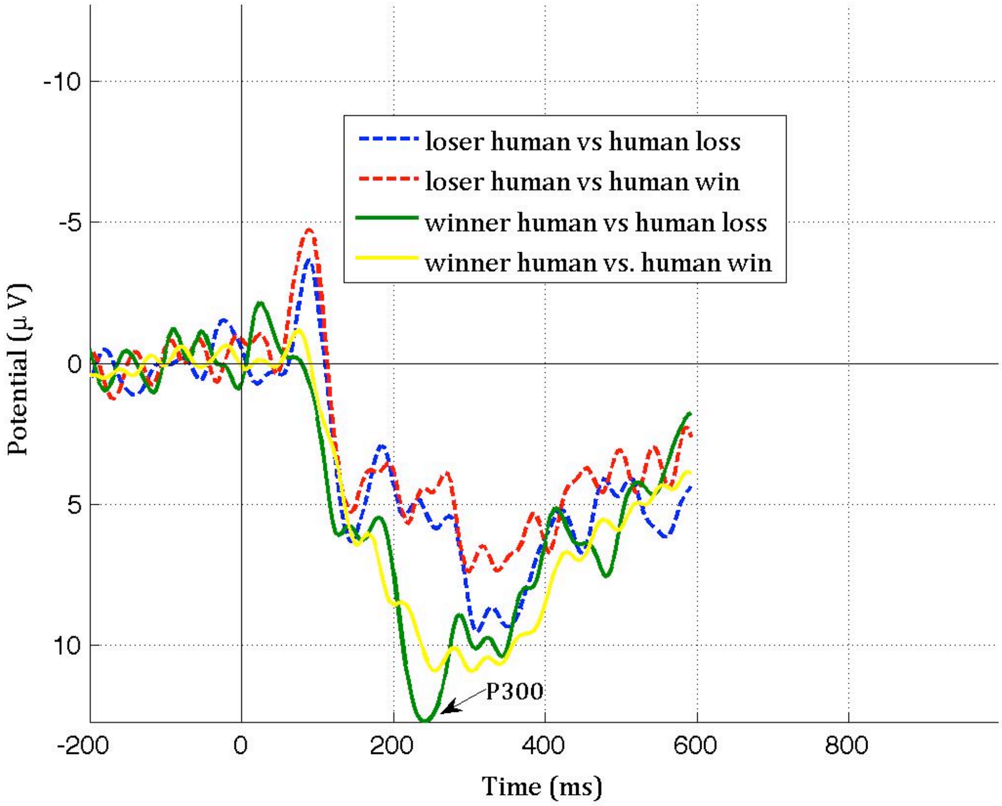

Figure 9: P300s amplitude for the winner and the loser according to the feedback valence on the electrode Pz in the human vs. human condition: In the human vs. human condition, largest P300 amplitudes were found in the winner when losing. Further, gains elicited smaller P300 amplitudes than losses for the winner. Comparing the loser's P300 amplitude with the winner, the winner showed larger ones for losses than the loser.

6.7. Comparing the P300's amplitude in the different conditions

Additionally, the main factor *condition* ($F_{[1,38]} = 37.828$, $p < 0.001$, $\eta p^2 = 0.499$) showed larger P300 amplitudes in the human vs. human condition than in the PC vs. human condition.

Investigating the *condition * valence* interaction ($F_{[1,38]} = 33.637$, $p < 0.001$, $\eta p^2 = 0.470$) with post-hoc tests yielded the result that losing in the human vs. human condition was different from all the other groups ($p < 0.001$). It can be seen that losing in the human vs. human condition elicited more positive P300 amplitudes than losing in the PC vs. human condition. Further, the P300 amplitudes were more positive for losses than for gains in the human vs. human condition.

Figure 10 illustrates the findings regarding the P300s amplitude of losses for winners and losers in both conditions. It cannot be seen from that diagram that gains elicited smaller P300 amplitudes than losses in the human vs. human condition because only losses are displayed in that diagram.

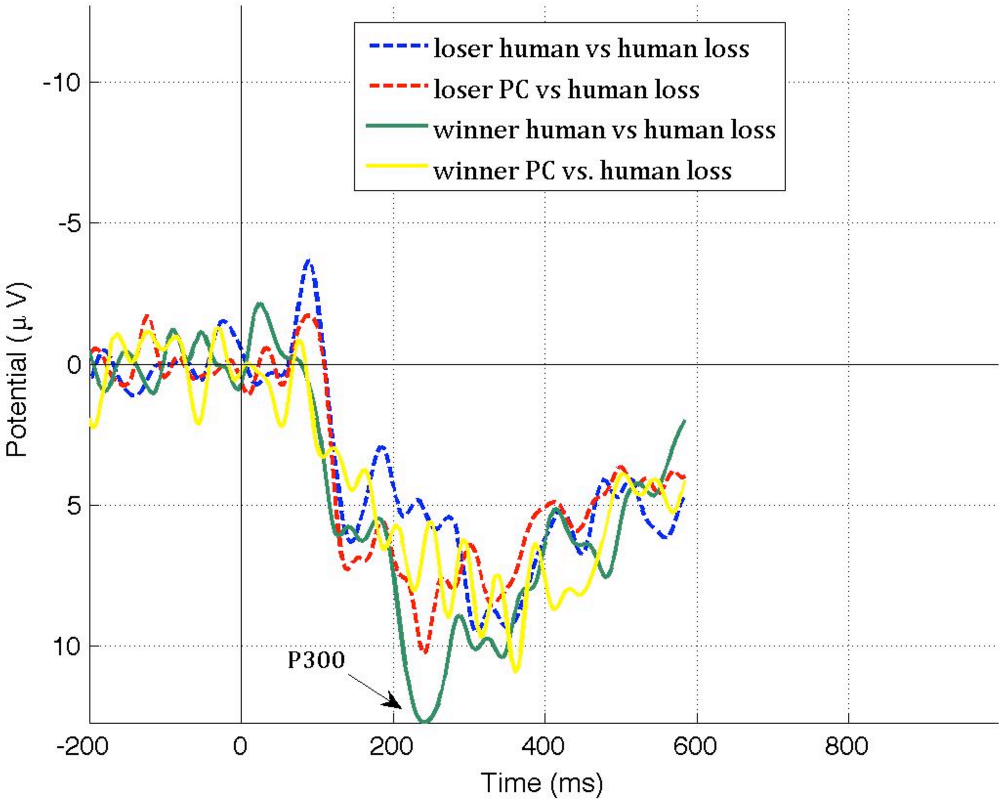

Figure 10: P300 amplitudes for the winner and the loser when losing on the electrode Pz in both conditions: Largest P300 amplitudes were found for the winner when losing in the human vs. human condition. Losses yielded in the human vs. human condition elicited larger P300 amplitudes than the ones in the PC vs. human condition.

6.8. The P300's latency

Examining the factor *player* ($F_{[1,38]} = 58.037$, $p < 0.001$, $\eta_p^2 = 0.604$) made clear that the winner showed earlier P300 components than the loser.

The factor *gender* did not reach significance: $F_{[1,38]} = 1.390$, $p = 0.246$, $\eta_p^2 = 0.035$.

6.9. Comparing the P300's latency in the different conditions

The main factor *condition* was significant ($F_{[1,38]}$ = 370.690, p < 0.001, η_p^2 = 0.907). Later P300 latencies were found in the PC vs. human condition than in the human vs. human condition.

The analysis of the interaction *player * condition* ($F_{[1,38]}$ = 89.716, p < 0.001, η_p^2 = 0.702) indicated that winners showed later P300 latencies than the loser when playing against a computer and that losers showed later latencies than winners in the human vs. human condition. Further, the PC vs. human condition elicited later P300 components than the human vs. human condition for the winner and for the loser.

Another significant result produced the *condition * valence* interaction ($F_{[1,38]}$ = 51.716, p < 0.001, η_p^2 = 0.576). Losing in the PC vs. human condition elicited latest P300 components. In general, the PC vs. human condition elicited later P300 components than the human vs. human condition. When playing against a PC, winning showed earlier P300 components than losing and the opposite was valid for the human vs. human condition: Winning showed later P300 components than losing.

The three-way interaction *player * valence * condition* reached the significance level ($F_{[1,38]}$ = 90.556, p < 0.001, η_p^2 = 0.704). Via Tukey post-hoc tests it could be shown that the winner losing in the PC vs. human condition was significantly different from all the other groups (p < 0.001). This group showed latest P300 components. The P300 latencies were later in the PC vs. human condition when the winner was losing and moreover, later for losses than for gains in the PC vs. human condition for the winner. Comparing the response to losing in the PC vs. human condition, winners showed later P300 components than losers.

Winning in the PC vs. human condition for the winner was also different from all the other groups (p < 0.001; for loser loss PC vs. human: p = 0.008; for loser gain PC vs. human: p = 0.010). Gains elicited earlier P300 components than losses for the winner in the PC vs. human condition. Yielding a gain showed later P300 components in the human vs. human condition than in the PC vs. human condition for the winner. Moreover, the winner showed earlier P300 components than the loser in the PC vs.

human condition when winning.

The loser winning in the human vs. human condition was another group, which differed from all the others (p < 0.001; for winner gain human vs. human: p = 0.002). In the human vs. human condition, it could be found that gains showed earlier P300 components than losses for the loser and further, that the human vs. human condition elicited earlier P300 components than the PC vs. human condition for gains. For gains in the human vs. human condition, the winner showed earlier P300 components than the loser.

Comparing the PC vs. human and the human vs. human condition for the loser, earlier P300 components could be seen when losing in the human vs. human condition than the PC vs. human condition (p <0.001).

6.10. EEG and personality results

personality trait 1	**personality trait 2**	**r/rs**	**n**	**p**
Neuroticism	Extraversion	-0.337	42	0.015
Neuroticism	BIS	-0.776	42	< 0.001
Neuroticism	BASR	-0.266	42	0.045
Extraversion	Conscientiousness	0.397	42	0.005
Extraversion	BIS	0.375	42	< 0.001
Extraversion	BASF	-0.356	42	0.010
Conscientiousness	BASF	-0.273	42	0.040
Conscientiousness	BASD	-0.555	42	< 0.001
Openness/Intellect	Agreeableness	0.346	42	0.013

Table 2: correlations of the NEO-FFI with the BIS/BAS questionnaire

The different scales of the questionnaires NEO-FFI and BIS/BAS were correlated with each other. The reached Neuroticism scores showed a significant negative correlation with the Extraversion scores (r = -0.337, n = 42, p = 0.015). When correlating Neuroticism scores with the BIS/BAS questionnaire, a negative correlation with the BIS scale (r = -0.776, n = 42, p < 0.001) and with the BASR scale was present (rs = -0.266, n = 42, p = 0.045).

The Extraversion scores were positively correlated to the Conscientiousness scores (r = 0.397, n = 42, p = 0.005), the BIS scale (r = 0.375, n = 42, p < 0.001), and negatively to the BASF scale (r = -0.356, n = 42, p = 0.010).

The Conscientiousness scale of the NEO-FFI was also related to two of the BAS scales, namely the BASF (r = -0.273, n = 42, p = 0.040) and the BASD (r = -0.555, n = 42, p < 0.001).

The Openness/Intellect scale of the NEO-FFI showed a positive correlation with the Agreeableness scores (r = 0.346, n = 42, p = 0.013; see Table 2).

personality trait 1	**personality trait 2**	**r/rs**	**n**	**p**
BIS	BASR	0.348	42	0.012
BASR	BASF	0.334	42	0.015
BASR	BASD	0.421	42	0.003

Table 3: internal correlations of the BIS/BAS questionnaire

When investigating the internal correlations of the BIS/BAS questionnaire, the BIS scores showed a positive correlation with the BASR scores (rs = 0.348, n = 42, p = 0.012) and further, the BASR scores were positively correlated with the BASF scores (rs = 0.334, n = 42, p = 0.015) and the BASD scores (rs = 0.421, n = 42, p = 0.003; see Table 3).

personality trait	**component**	**r/rs**	**n**	**p**
BASR	P300 gain PC	0.314	42	0.043
BASD	FRN gain human Fz	0.344	42	0.026
Conscientiousness	FRN gain human Fz	-0.504	42	0.001
Conscientiousness	FRN gain human FCz	-0.366	42	0.017

Table 4: correlations between the personality traits and the components

Regarding the components, it could be found that the BASR scores were positively correlated with the P300 amplitude for gains in the PC vs. human condition (rs = 0.314, n = 42, p = 0.043). The BASD scale of the BIS/BAS questionnaire showed a positive correlation to the FRN's amplitude on the electrode Fz for gains in the human vs. human condition (rs = 0.344, n = 42, p = 0.026).

The Conscientiousness scale displayed a negative relation to the FRN amplitude for gains in the human vs. human condition on both electrodes (Fz: rs = -0.504, n = 42, p = 0.001; FCz: rs = -0.366, n = 42, p = 0.017; see Table 4).

personality trait 1	**component**	**r/rs**	**n**	**p**
winner				
Conscientiousness	FRN gain human Fz	-0.658	21	0.001
Conscientiousness	FRN gain human FCz	-0.554	21	0.009
loser				
BASR	P300 gain PC	0.438	21	0.047

Table 5: correlations between the personality traits and the components for winners and losers

Investigating these findings for the winner and the loser separately, a negative correlation was shown for the winner's Conscientiousness scores and the FRN amplitude for gains in the human vs. human condition on both electrodes (Fz: rs = -0.658, n = 21, p = 0.001; FCz: rs = -0.554, n = 21, p = 0.009). For the loser, the BASR scores and P300 amplitude correlation for gains in the PC vs. human condition reached significance (rs = 0.438, n = 21, p = 0.047; see Table 5).

personality trait 1	**component**	**r/rs**	**n**	**p**
N > 30.31				
Neuroticism	FRN gain PC Fz	0.477	19	0.039
Neuroticism	FRN gain PC FCz	0.513	19	0.025
C > 38				
Conscientiousness	FRN loss human Fz	-0.372	37	0.023
Conscientiousness	FRN gain human Fz	-0.355	37	0.031

Table 6: correlations between high scores in the dimensions Neuroticism and Conscientiousness and the components

Further analyses were conducted for the participants yielding high scores in the Neuroticism scale (N > 30.31) and in the Conscientiousness scale (C > 38, Borkenau, & Ostendorf, 1993). It was found that a high Neuroticism score was positively correlated with the FRN amplitudes for gains in the PC vs. human condition on the electrode Fz ($r = 0.477$, $n = 19$, $p = 0.039$). A high Neuroticism score was also found to be positively correlated with the FRN's amplitude for gains in the PC vs. human condition on the electrode FCz ($r = 0.513$, $n = 19$, $p = 0.025$). No significant result was found for normal scoring participants, which were the remaining 23 participants of that study.

For high Conscientiousness scoring participants, it could be detected that a negative correlation with the FRN's amplitude for losses ($r = -0.372$, $n = 37$, $p = 0.023$) and for gains ($r_s = -0.355$, $n = 37$, $p = 0.031$) in the human vs. human condition on the electrode Fz was present (see Table 6).

No significant results were found for the remaining scales of the personality questionnaires and the FRN and P300 component (all p-values > 0.056).

7. Discussion

7.1. Answer to the research question

Generally, the FRN amplitude was larger for losses compared to gains in both conditions separately, which is in line with a large body of literature (e.g. Yeung, & Sanfey, 2004; Yu, & Zhou, 2006; Rigoni et al., 2010; van Meel, & van Heijningen, 2010).

Further, the P300's amplitude was more positive for losses than for gains in both conditions. Additionally, winners showed larger P300 amplitudes for losses than for gains compared to losers.

Bearing in mind the factor condition, more negative FRN amplitudes could be found in the PC vs. human condition for losses than for gains. In this condition, winners showed larger FRN amplitudes for losses than for gains compared to the loser. Taking a look at the human vs. human condition, it can be seen that losers elicited more negative FRN amplitudes for losses than for gains when comparing with winners. For the P300's amplitude it can be said that losses showed larger amplitudes in the human vs. human condition compared to the PC vs. human condition.

Taking the gender into account, no significant ERP differences could be found. The analysis regarding the ratings of affective and emotional states revealed that winners were more motivated and showed a higher anticipation to win during the game than losers did. In addition, the increased attention to one's own feedback of the winner and the declining interest in the game and dropping competence feeling of the loser are factors contributing to the alteration in the feedback processing components.

Influencing factors are represented by emotionality and motivation. Moreover, unexpectedness of an event can be referred to as an influential factor on ERP differences because a high anticipation to win and competence feeling might have increased the attention to the feedback of following trials if a mistake was made.

The speculation that those factors might be linked to the RL-theory exists, but further analysis is needed to confirm this assumption.

Besides the emotional state, personality traits have been involved. The results are varying in consistence with previous findings and furthermore, additional analysis is needed to make clear and valid conclusions.

7.2. The FRN's amplitude

In the current study, results found concerning the electrode sites of the FRN component were consistent with previous findings. The FCz (Nieuwenhuis et al., 2005b; Yu, & Zhou, 2006; Wu, & Zhou, 2009; Pfabigan et al., 2010) and the Fz (Yu, & Zhou, 2006; Li et al., 2010; Rigoni et al., 2010; van Meel, & van Heijningen, 2010) were often the electrodes of interest. Especially in studies focusing on personality, the FRN component was found to be most pronounced on the electrode site Fz (Hirsh, & Inzlicht, 2008; Santesso et al, 2011).

Other authors observed larger FRN amplitudes for losses than for gains (Yeung, & Sanfey, 2004; Hajcak et al., 2006; Yu, & Zhou, 2006; Rigoni et al., 2010; van Meel, & van Heijningen, 2010). This is consistent with the findings in this experiment, that the FRN's amplitude is more negative for losses compared to gains.

Larger FRN amplitudes were elicited for negative, unexpected, or invalid feedback than for positive, expected, or valid one. When taking the factor player into account, both, the winner and the loser, showed larger FRN amplitudes for losses than for gains. For losses, the winner showed more negative FRN amplitudes than the loser.

A possible explanation for the winner's enhanced FRN amplitudes for losses might be the RL-theory. In this theory, the unexpectedness of an event plays a major role. Player 1 was assigned to be the winner before the human vs. human condition started and therefore, won more trials than player 2. The anticipation to win for the winner and the loser did not reach the significance level in the statistical analysis. But the tendency discloses that in the course of the game the winner's anticipation to win rose and the loser's decreased. A reason for this might be the two different types of manipulation. First, the impression for player 2 of being worse than the opponent was induced by the subjective feeling of player 2 himself during the test trials and during the PC vs. human condition and second, the plot, which was presented after the PC vs. human condition, confirmed this subjective feeling of being worse than player 1. As this plot indicated that player 1 won more often against the PC than player 2 did, player 1 could have felt more confident than player 2. This can be strengthened by the finding that after both conditions, the loser doubted the own competence in that game.

This is in line with the finding that losing and negative emotions lower the competence feeling (Tauer, & Harackiewicz, 1999), which was observed for player 2 in this study. Further, in the human vs. human condition, at the beginning of each single trial, the total score was presented to both players and additionally, both feedbacks for the current trial appeared on the screen and so direct comparison with the opponent was possible. As most of the time the feedback for player 2 was worse than the one for player 1, losing might be unexpected for player 1. This unexpectedness can be referred to as negative prediction error: Predicting a gain but yielding a loss decreased the dopamine release to the ACC, which winds up in larger FRN amplitudes (Holyroyd, & Coles, Nieuwenhuis et al., 2004a).

As the between-subject factor gender and further, any interaction including the factor gender did not become significant, it can be assumed that there were no differences in amplitude sizes for male and female participants.

7.3. Comparing the FRN's amplitude in the different conditions

The between-subject factor player did not reach significance, but when taking a look at the different interactions, it becomes apparent that the amplitude sizes for winners and losers are distinct when comparing the two different conditions. In case the participants were playing against the PC, the winner showed more negative FRN amplitudes than the loser, but when playing against another human it was reversed. The loser showed larger FRN amplitudes than the winner. Van Meel and van Heijningen (2010) showed that invalid feedback elicits more negative FRN components than valid feedback. The authors could only verify that finding for participants playing against another person. Rigoni and his colleagues (2010) took the actual emotionality into account and showed that experiencing more negative feelings elicited larger FRN amplitudes than when feeling happy. A possible explanation for the loser's larger FRN amplitude in the human vs. human condition might be the fact that this player was getting more negative feedback than the opponent. The feedback manipulation of the experiment was designed to be more positive for player 1 than for player 2.

Generally, the FRN component was found to be more pronounced in the PC vs. human condition than in the human vs. human condition. As stated earlier, the RL-theory is associated with the generation of the FRN component. According to this theory, dopamine release to the basal ganglia and cortex is decreased if a situation is unexpected or worse than expected and therefore, larger FRN amplitudes are elicited (Nieuwenhuis et al., 2004a). Rigoni and colleagues (2010) compared obtained with non-obtained outcomes and found larger FRN amplitudes for non-obtained outcomes than obtained ones. They explained their results in that way that the obtained outcome is more motivating and therefore, increases the dopamine release to the ACC, which produces smaller FRN amplitudes. Summed up, it might be that competing against a PC was not that motivating than playing against another human and therefore, less dopamine was released. This assumption might explain the larger FRN amplitudes for the winner in the PC vs. human condition than for the loser. More generally, it might be a reason for larger FRN amplitudes in the PC vs. human than in the human vs. human condition. Additionally supporting this assumption are the significant results of the behavioural data, which give information about the motivational state of the participants. The motivation for the loser started to decrease while playing against the PC and continued to decrease further in the human vs. human condition. This might be due to the fact that the loser lost more often against the PC and the human opponent and because of that reason he/she showed less motivation than the opponent during the game. There is evidence from the questions after each session that the loser's happiness has already started to decrease during the PC vs. human condition. Looking at the PANAS results, it becomes clear that the winner's positive affect was higher before than after the game. For the winner, there was also a motivational decrease, but this decrease started not until the human vs. human condition. Someone might think that this could be because of the steady game design with no variations. As it was a monotonous task for the participants to perform, the motivation to do so could have decreased. But still, the winner showed higher motivation at the end of the experiment compared to the loser.

7.4. The FRN's latency

No specific hypotheses concerning the latency of the FRN component were formulated before the study. Literature available on the FRN component's latency is hardly available.

The FRN component was found to peak between 230 and 300 milliseconds after feedback presentation in previous studies (e.g. Miltner et al., 1997). In the actual study, it was found to be later for winners (M = 286.484, SD = 1.766) than for losers (M = 267.458, SD = 1.783) and further, to be later for losses (M = 283.353, SD = 0.857) than for gains (M = 270.589, SD = 2.212). Referring to findings about the appearance of the FRN component, a consistent result was observed.

7.5. Comparing the FRN's latency in the different conditions

The PC vs. human condition showed later FRN components than the human vs. human condition did.

The temporally most delayed FRN component was found for the loser losing in the PC vs. human condition and the earliest for the loser losing in the human vs. human condition. Compared to the latency of the P300 component, these results are completely contrary, which might be an indicator that the two components are completely independent in the course of feedback processing.

7.6. The P300's amplitude

Despite most of the literature, in this study, larger P300 for losses than for gains have been found. Rigoni and his colleagues (2010) could detect larger P300 amplitudes for gains and for non-obtained outcomes than for losses or obtained outcomes. Participants had to choose between two covert cards. First, the non-obtained outcome was revealed and the obtained one afterwards. This study, like several other studies using a gambling task design, possibly came up with these results because they used a game of pure chance. It means that participants could hardly intervene and had just to rely on their luck. In the present study, this was not the case. Participants had to press a button in a particular time window. Therefore, the motivation to win and to be better than the opponent might have been more developed. This explanation is underpinned by a theory, which says that the P300 component is related to the motivational system. Higher motivation elicits more positive P300 components (Yeung, & Sanfey, 2004; Nieuwenhuis et al., 2005a). In the case of the present study, it would mean that the motivation was higher after a loss than after a gain.

Affective states were also detected to have an influence on the P300 component. In previous studies, more positive P300 amplitudes were found for negative compared to positive feedback (Cacioppo, & Berntson, 1994; Ito et al., 1998), which is known as the negativity bias. Negative feedback influences the people's behaviour more than positive one does. This assumption would fit to the findings of the actual study, that losses elicited larger P300 amplitudes than gains did.

The assumption about the unexpectedness was also related with the P300 amplitude's size. It can be said that the unexpectedness of an event increases the size of the P300's amplitude. This theory is used in the investigation of two hypotheses concerning the P300's amplitude in the case of an unexpected event for the two players.

When taking a look at the anticipation to win, the tendency for the winner's anticipation to win was rising while the one for the loser was decreasing. This finding is in line with the theory about the unexpectedness of the event, which would be losing for the winner in that case. Most positive P300 amplitudes were found when the winner was losing.

In general, infrequent stimuli were found to enhance the P300's amplitude (Donchin, & Coles, 1988; Yeung, & Sanfey, 2004; Pfabigan et al., 2010; van Meel , & van Heijningen, 2010).

Again, neither the between-subject factor gender nor any interactions including the factor gender did reach significance, which indicated no gender difference in the P300 amplitude's size.

7.7. Comparing the P300's amplitude in the different conditions

Winners showed more positive P300 amplitudes than losers, which gives rise to the assumption that the winner was more motivated to win. To investigate the factor motivation, an insight into the behavioural data was taken: As noted before, during the PC vs. human condition, the loser's happiness and motivation decreased and the motivation continued to decrease in the course of the human vs. human condition. Although the motivation of the winner decreased in the human vs. human condition, it was still higher than that of the loser. The winner also reported more attention to the own feedback in the human vs. human condition than when playing against the PC, which points to more motivation during the game. Another indicator is that the loser stated less interest in the game in the human vs. human condition than in the PC vs. human condition.

The results of the post-hoc test according the valence * condition interaction showed no significant results in the PC vs. human condition for gains and losses. But in the human vs. human condition, it was found that losses elicited larger P300 amplitudes compared to gains. Li and colleagues (2010) found that feeling responsible for an outcome enlarges the P300 component. This might be a possible explanation for more positive P300 amplitude for losses than gains. Comparing with Rigoni and colleagues' (2010) study, in the present one, participants did not have to depend on the luck but were able to intervene via the button press. This task gave participants the possibility to decide whenever they wanted to press the button and therefore, feeling responsible for their own decision. So, participants were not dependent on the decisions made by others or their luck in the current study. This generates more responsibility for the outcome than just luck. The generally larger P300 amplitudes in the human vs. human than PC vs. human condition might be explained by the fact that playing against a real person is more motivating than playing against a computer and therefore, more attention is paid to the game. Concerning the P300 component, a high amount of motivation was found to elicit larger amplitudes (Yeung, & Sanfey, 2004; Nieuwenhuis et al., 2005a).

7.8. The P300's latency

As well as for the FRN, no particular hypotheses have been formulated for the latency of the P300 component because of the lack of available literature.

The actual result is consistent with the finding that the P300 component occurs between 250 and 600 milliseconds after feedback presentation (e.g. Wu, & Zhou, 2009). The mean latency for the winner (M = 304.664, SD = 2.061) is earlier than for the loser (M = 326.972, SD = 2.080).

In this study, the winner showed earlier P300 components than the loser. It was shown that generally, the positive affect before the experiment exceeded the positive affect at the end. Moreover, more positive and less negative affects were displayed by the winner than by the loser, which is in line with the findings that positive emotions are related with shorter reaction times (De Pascalis et al., 2010).

One might think that the feedback order is additionally a possible influencing factor. Getting feedback first or last could influence the time, which is needed to properly process the own feedback. It is not likely that the difference in the results is due to feedback order variations in this study because feedback variation was balanced for both players.

7.9. Comparing the P300's latency in the different conditions

The earliest P300 component was found for the winner in the human vs. human condition when winning and the latest also for the winner but in the PC vs. human condition when losing. Generally, the P300 component was later in the PC vs. human condition than in the human vs. human condition.

In earlier studies, it was observed that personality and positive emotions have an influence on the latency of that component (e.g. Hirsh, & Inzlicht, 2008; De Pascalis et al., 2010). The P300 component was found to reach its peak earlier when experiencing more positive feelings and moreover, delayed P300 components are supposed to take more time to process positive feedback (De Pascalis et al. 2010). This would indicate that participants needed more time to process the positive feedback in the PC vs. human condition. This might be due to the learning effect, which was stronger in the PC vs. human condition than in the human vs. human condition because the PC vs. human condition was temporally before the human vs. human condition. The loser's interest in the game, the happiness and the subjective feeling of being competent were higher in the PC vs. human condition than in the human vs. human condition. These are facts, which confirm that the finding is in line with the theory regarding the positive affect (De Pascalis et al., 2010).

Further studies are needed to gain insight into the meaning of the P300's latency.

7.10. EEG and personality results

Correlations among the different personality scales of the two presented questionnaires yielded some significant results, which are valid to the current sample. Some results are consistent with the available literature and others are not. This might be due to different influencing factors such as the circumstance of an online assessment.

The Neuroticism scale of the NEO-FFI showed a negative correlation to the Extraversion scale of the same questionnaire. This finding represents the fact that those two dimensions are contrary (Eisenberger et al., 2005). An example was already given in the theoretical background, that Extraversion scores are correlated to positive and Neuroticism scores to negative affect (Eysenck, & Eysenck, 1985; Larsen, & Ketellar, 1991; Costa, & McCrae, 1992; Eisenberger et al., 2005; DeYoung, & Gray, 2009).

Neuroticism scores were also found to be negatively correlated with the BIS and the BASR scale. This is contrary to previous studies (Gray, 1970; Carver, & White, 1994; Smits, & Boeck, 2006). Earlier, it was found that Neuroticism scores and BIS scores are positively correlated. This result was reasonable because BIS can be induced by positive and negative external circumstances, which influence emotional unstable persons more than emotionally stable persons (Smits, & Boeck, 2006). As the BIS is highly sensitive especially to threatening stimuli (Gray, & McNaughton, 2000), a negative correlation to the Neuroticism scale is not a reliable finding.

The negative correlation to the BASR scale was not found so far. This indicates that high Neuroticism scores are associated with a low sensitivity to reward.

Taking a look at the Extraversion scores, a positive relation to the Conscientiousness scale and BIS scale and further, a negative one to the BASF scale could be found. In previous studies (e.g. Eisenberger et al., 2005) a negative correlation between Extraversion and Conscientiousness scores, but a positive between Neuroticism and Conscientiousness scores was observed.

The positive correlation between Extraversion scores and BIS is not a logical result. Smits and Boeck (2006) also found a correlation to the BASF scale but this was a positive one, and not a negative, like in the actual study. Normally, extraverted people tend to search for fun and adventurous activities. Further, impulsivity is related to a low Conscientiousness score and a high Extraversion score (Smits, & Boeck, 2006). As in this study those two dimensions are positively correlated, the previous finding could not be replicated.

The Conscientiousness scale was negatively correlated to the BASF scale, which was also found in a previous study (Smits, & Boeck, 2006). This correlation might be due to the fact that both scales are correlated to the factor impulsivity (Smits, & Boeck, 2006), with high scores in the fun seeking scale and low in the Conscientiousness scale.

Regarding the BASD scale, an opposing result to Smits and Boeck (2006) was gained. In this study, a negative correlation could be observed. The higher the Conscientiousness scores, the more cautious a person can be described. This would speak for the result that being cautious diminishes the urge to achieve a particular goal.

The internal correlations of the BIS/BAS scale reveals that the BASR scale was positively correlated to the BIS, BASF and BASD scale. Although, these findings are consistent with Jorm and colleagues (1999), Smits and Boeck (2006) could only observe the positive correlation between BASR and BIS, but not the correlations to BASD and BASF.

The results of the actual study would indicate that fun seeking and drive are low if the sensitivity to positive reward is high and further that the BIS is more activated when positive rewards are a possible outcome.

7.10.1. Correlations with the components of interest

Analysis was not only done for the personality dimensions themselves, but the relationship to the components was taken into account.

There were only three significant correlations. The Conscientiousness scale of the NEO-FFI was found to be positively correlated to the FRN's amplitude on both electrodes for winning in the human vs. human condition, which means that more negative FRN amplitudes were found when Conscientiousness scores were high. Splitting the results for the two players, it became obvious that only the winner showed a significant correlation for that finding. No clear explanation could be found for that finding.

The drive scale of the BIS/BAS was correlated to the FRN's amplitude when winning in the human vs. human condition. As the BASD assesses the insistent desire to achieve a goal (Smits, & Boeck, 2006), the positive correlation can be explained by the wish to win against a human opponent, as this is seen as the desired goal in that game.

Another significant correlation was found for the BASR scale and the P300's amplitude in the PC vs. human condition when winning. This seems to be an argumentative result, as the P300 component and the BASR are both sensitive to gains and rewards. BASR indicates sensitivity to positive rewards (Carver, & White, 1994). When splitting the results for winners and losers, the correlation between the component P300 and the scores reached in the BASR scales were significant only for the loser.

Further, the scores were also split in high and normal scoring participants. No participant fell below the lower cut off point, which means no low-scoring participant took part in that study.

High Neuroticism scores were defined as a score over 30.31 points (Borkenau, & Ostendorf, 1993). 19 participants exceeded that score and 23 participants scored in the normal range. High scores were significantly correlated with the FRN's amplitude size in the PC vs. human condition when winning. It is in line with Hirsh and Inzlicht's (2008) finding about the correlation to the uncertainty of an event: High scoring participants might not expect to win and therefore, elicit larger FRN amplitudes if this is the case. Unfortunately, it is not possible to investigate if winners and/or losers scored high on the Neuroticism scale as no such clustering of the sample was made. No differences could be found in the normal scoring group, which is also in line with Hirsh and Inzlicht (2008).

Another significant result was found for high scores in Conscientiousness. The cut off point was set with 38 points (Borkenau, & Ostendorf, 1993). For Conscientiousness, 37 participants exceeded the cut off point and only five fell in the normal-scoring range. As well as for neuroticism, the FRN's amplitude for gains but also for losses was larger in the human vs. human condition when scoring high in the Conscientiousness scale.

There were no significant results regarding the personality dimension Extraversion. This was against the assumption stated in the hypotheses section because it is one of the best investigated personality dimensions correlated to the neuronal processing mechanism.

The findings concerning personality are subject to some limitations. Those limitations contribute to the fact that no clear comment can be made on some of the results.

There was no personality screening before the experiment. Participants had to fill out the online questionnaires and no exclusion was made if a certain personality criterion was not met. Participants were invited to the lab without forming personality clusters.

In the lab, participants were randomly assigned to be the winner or loser. Again the personality factor was not taken into account.

It is not possible to split the sample in winners and losers to explore the personality differences, as the sample is becoming too small. The number of high scoring and normal-scoring participants in Neuroticism was approximately balanced but, for example, the Extraversion scale showed 37 high-scoring and only five normal-scoring participants.

So the results regarding the personality have to be interpreted with caution.

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9. Appendix

9.1. Introduction to the game (example for player 1) in German

Instruktion Spieler 1 (blau)

Sie werden nun ein **Reaktionsspiel** in zwei verschiedenen Versionen spielen. Zuerst spielen beide Spieler alleine gegen den Computer-Gegner und anschließend spielen Sie gegen die zweite anwesende Person. Die genaue Reihenfolge wird vorab von der Versuchsleitung bestimmt.

Ihre Aufgabe im Reaktionsspiel ist immer dieselbe: Jeder neue Durchgang startet mit der Präsentation eines Fadenkreuzes, das lediglich dazu dient, Ihren Blick auf die Mitte des Bildschirms zu lenken. Anschließend wird kurz ein **schwarzes ausgemaltes Quadrat** eingeblendet. Das ist Ihr **Zielreiz**. Jetzt müssen Sie so schnell wie möglich mittels Tastendruck **(linke Pfeiltaste)** reagieren. Auch Ihr Gegenspieler (sowohl Mensch als auch Computer) hat diese Aufgabe. Anschließend erhalten Sie und Ihr Gegenspieler Feedback, ob sie beide erfolgreich waren oder nicht. Haben Sie entsprechend schnell reagiert, wird Ihnen ein Punkt auf Ihrem Punktekonto gutgeschrieben. Waren Sie hingegen zu langsam, gehen Sie in dieser Runde leer aus und erhalten somit keinen Punkt gutgeschrieben.

Es ist möglich, dass beide Spieler in einem Durchgang schnell genug reagiert haben und beiden wird jeweils ein Punkt gutgeschrieben. Es ist aber auch möglich, dass nur ein Spieler entsprechend schnell reagiert hat. Dann gewinnt nur dieser Spieler einen Punkt. Wenn beide Spieler zu langsam reagiert haben, werden keinem Punkte gutgeschrieben – beide Spieler gehen somit leer aus.

Bitte beachten Sie:

In jedem Durchgang erhalten Sie sowohl Feedback bzgl. Ihrer Leistung als auch Feedback bzgl. der Leistung Ihres Gegenspielers. Sie sind Spieler 1 – Ihr Feedback (0 oder 1 Punkt erspielt) wird immer separat in blauer Farbe eingeblendet, die erspielten Punkte von Spieler 2 werden immer separat in grüner Farbe eingeblendet. Blockweise erhalten Sie oder Ihr Gegenspieler zuerst Feedback.

Nachdem Ihnen und Ihrem Gegenspieler gezeigt wurde, ob sie in der letzten Runde einen Punkt erspielt haben oder nicht, wird anschließend immer der Gesamtpunktestand beider Spieler präsentiert (Punktestand von Spieler 1 immer in blau, Punktestand von Spieler 2 immer in grün).

Wenn Sie alleine gegen den Computer spielen und Ihr realer Gegenspieler pausiert, sehen Sie als Spieler 1 genau wie vorher Ihre erspielten Punkte in blauer Farbe als Feedback, die Punkte des Computer-Gegners werden in grüner Farbe eingeblendet. Nach dem individuellen Feedback für Sie und Ihren Computer-Gegner wird Ihnen ebenfalls der Gesamtpunktestand beider Spieler präsentiert - Ihr Gesamtpunktestand in blau und der Ihres Computer-Gegners in grün.

Nachdem beide Spieler gegen den Computer gespielt haben, erscheint eine Grafik, die die Gewinnhäufigkeit beider Spieler mittels blau und grün gefärbter Balken darstellt. Somit können Sie sehen, wie Sie im Vergleich zu Ihrem Gegenspieler abgeschnitten haben.

Ziel beider Spiele ist es, so viele Punkte wie möglich zu sammeln, indem Sie schnell genug nach Erscheinen des schwarzen Quadrats mittels Tastendruck (linke Pfeiltaste) reagieren. Bitte drücken Sie erst ab Erscheinen des Quadrats und geben Sie nur einen Tastendruck ab.

Während Sie gegen den Computer-Gegner spielen, hat Ihr realer Gegner eine Spielpause, in der Fragebögen ausgefüllt werden. Spielt Ihr realer Gegner gegen den Computer-Gegner, dann haben Sie eine Spielpause – hier werden wir Ihnen einige Fragebögen vorlegen, die Sie bitte zügig ausfüllen.

Vor Spielbeginn werden für beide reale Spieler einige **Trainingsdurchgänge** stattfinden, in denen noch nicht um Geld gespielt wird. Dies soll dazu dienen, sich mit dem Reaktionsspiel vertraut zu machen.

Es wird während der Spiele immer wieder kurze Pausen zur Erholung geben. In diesen Pausen werden wir Ihnen zusätzlich kurze Fragen vorlegen, die Sie bitte ebenfalls ausfüllen.

Wir bitten Sie weiters während der Spiele und auch während der Pausen **nicht mit ihrem Gegenspieler zu reden**, um ähnliche Bedingungen für alle Spieler zu schaffen. Danke!

Die gesammelten Punkte werden nach den Spielen pro Spieler zusammengezählt und nach einem fixen Schema in Geld umgerechnet. Je mehr Punkte Sie gesammelt haben,

desto mehr Geld bekommen Sie. Für die Teilnahme an der Studie erhalten Sie € 10,- fix. Der schlussendliche Gewinn hängt von Ihrer Leistung während der beiden Spiele ab. Ein zusätzlicher Gewinn von € 15,- pro Spiel ist möglich – somit sind € 40,- der maximal mögliche Gewinn.
Bei weiteren Fragen wenden Sie sich bitte an die Versuchsleiterinnen!

9.2. Questions between each single session (six measurements) in German

Wie fühlen Sie sich im Moment?

unglücklich	0	1	2	3	4	5	6	glücklich
unzufrieden	0	1	2	3	4	5	6	zufrieden

Wie wahrscheinlich werden Sie beim nächsten Durchgang gewinnen?

unwahrscheinlich	0	1	2	3	4	5	6	sehr wahrscheinlich

Wie gern wollen Sie weiterspielen?

gar nicht	0	1	2	3	4	5	6	sehr gerne

9.3. Questions between each single condition (example for human opponent; 2 measurements) in German

Bitte beantworten Sie folgende Fragen auf einer 7-Punkte Skala (von 0="überhaupt nicht/überhaupt keine" bis 6="sehr/sehr viel") in Bezug auf das Spiel gegen einen menschlichen Gegenspieler! Kennzeichnen Sie Ihre Antwort, indem Sie die betreffende Zahl ankreuzen!

Wie interessant fanden Sie dieses Spiel?

0 1 2 3 4 5 6

Wie viel Aufmerksamkeit widmeten Sie ihrem Feedback?

0 1 2 3 4 5 6

Wie viel Aufmerksamkeit widmeten Sie dem Feedback Ihres Gegenspielers?

0 1 2 3 4 5 6

Wie sehr freuten Sie sich über Ihren Gewinn?

0 1 2 3 4 5 6

Wie traurig waren Sie über Ihren Verlust?

0 1 2 3 4 5 6

Wie sehr ärgerten Sie sich über Ihren Verlust?

0 1 2 3 4 5 6

Wie sehr ärgerten Sie sich, wenn Ihr Gegenspieler gewann?

0 1 2 3 4 5 6

Wie sehr freuten Sie sich, wenn Ihr Gegenspieler verlor?

0 1 2 3 4 5 6

Wie traurig waren Sie, wenn Ihr Gegenspieler gewann?

0 1 2 3 4 5 6

Wie sehr freuten Sie sich, wenn Ihr Gegenspieler gewann?

0 1 2 3 4 5 6

Wie traurig waren Sie, wenn Ihr Gegenspieler verlor?

0 1 2 3 4 5 6

Wie wichtig war es Ihnen zu gewinnen?

0 1 2 3 4 5 6

Wie wichtig war es Ihnen, dass Ihr Gegenspieler verliert?

0 1 2 3 4 5 6

Wie motiviert waren Sie während des Spiels?

0 1 2 3 4 5 6

Wie sympathisch fanden Sie Ihren Gegenspieler?

0 1 2 3 4 5 6

Wie nahe fühlten Sie sich Ihrem Gegenspieler?

0 1 2 3 4 5 6

Wie viel Rivalität/Feindseligkeit spürten Sie während des Spiels?

0 1 2 3 4 5 6

Beim Spiel war es mein Hauptziel, mehr Punkte zu erreichen als mein Gegenspieler.

0 1 2 3 4 5 6

Ich war während des Spiels konzentriert.

0 1 2 3 4 5 6

Ich war ein sehr kompetenter Spieler.

0 1 2 3 4 5 6

Mein Gegenspieler war ein sehr kompetenter Spieler.

0 1 2 3 4 5 6

9.4. Descriptive statistic

9.4.1. ANOVA: components

gender	player	N	gender	player	N
male	winner	10	female	winner	11
	loser	12		loser	9
		22			**20**
			Total: 42		

Table 7: descriptive statistic for the component ANOVAs calculation split by gender and player

9.4.2. ANOVA: PANAS

player	N	player	N	total
winner	21	loser	20	**41***

Table 8: descriptive statistic for the PANAS ANOVA calculation split by player

* no results were obtained from one person for the second measurement

9.5. FRN – amplitude:

means and standard deviations for the significant results

electrode	mean	standard deviation
Fz	3.981	0.098
FCz	3.607	0.101

Table 9: means and standard deviations for the main factor electrode

valence	mean	standard deviation
gain	3.000	0.116
loss	4.588	0.101

Table 10: means and standard deviations for the main factor valence

condition	mean	standard deviation
PC vs. human	4.533	0.110
human vs. human	3.055	0.125

Table 11: means and standard deviations for the main factor condition

electrode * valence		mean	standard deviation
Fz	gain	3.071	0.130
	loss	4.891	0.106
FCz	gain	2.929	0.127
	loss	4.284	0.115

Table 12: means and standard deviations for the interaction electrode * valence

electrode * condition		mean	standard deviation
Fz	PC vs. human	4.958	0.114
	human vs. human	3.005	0.124
FCz	PC vs. human	4.109	0.119
	human vs. human	3.105	0.146

Table 13: means and standard deviations for the interaction electrode * condition

player * valence		mean	standard deviation
winner	gain	2.631	0.164
	loss	5.153	0.142
loser	gain	3.369	0.165
	loss	4.022	0.144

Table 14: means and standard deviations for the interaction player * valence

player * condition		mean	standard deviation
winner	PC vs. human	4.777	0.155
	human vs. human	3.006	0.176
loser	PC vs. human	4.289	0.156
	human vs. human	3.103	0.178

Table 15: means and standard deviations for the interaction player * condition

condition * valence		mean	standard deviation
PC vs. human	gain	3.359	0.104
	loss	5.708	0.183
human vs. human	gain	2.642	0.183
	loss	3.467	0.104

Table 16: means and standard deviations for the interaction condition * valence

player * electrode * valence			mean	standard deviation
winner	Fz	gain	2.824	0.183
		loss	5.397	0.149
	FCz	gain	2.438	0.179
		loss	4.908	0.162
loser	Fz	gain	3.319	0.185
		loss	4.384	0.150
	FCz	gain	3.420	0.181
		loss	3.660	0.163

Table 17: means and standard deviations for the interaction player * electrode * valence

player * electrode * condition			mean	standard deviation
winner	Fz	PC vs. human	5.131	0.160
		human vs. human	3.091	0.174
	FCz	PC vs. human	4.424	0.167
		human vs. human	2.922	0.206
loser	Fz	PC vs. human	4.785	0.162
		human vs. human	2.919	0.176
	FCz	PC vs. human	3.793	0.168
		human vs. human	3.287	0.208

Table 18: means and standard deviations for the interaction player * electrode * condition

player * valence * condition			mean	standard deviation
winner	gain	PC vs. human	2.846	0.147
		human vs. human	2.417	0.258

	loss	PC vs. human	6.709	0.258
		human vs. human	3.596	0.146
loser	gain	PC vs. human	3.872	0.148
		human vs. human	2.867	0.260
	loss	PC vs. human	4.706	0.260
		human vs. human	3.339	0.148

Table 19: means and standard deviations for the interaction player * valence * condition

player * electrode * valence * condition				**mean**	**standard deviation**
winner	Fz	gain	PC vs. human	3.164	0.181
			human vs. human	2.484	0.284
		loss	PC vs. human	7.097	0.252
			human vs. human	3.697	0.136
	FCz	gain	PC vs. human	2.528	0.147
			human vs. human	2.349	0.303
		loss	PC vs. human	6.321	0.281
			human vs. human	3.495	0.196
loser	Fz	gain	PC vs. human	4.305	0.183
			human vs. human	2.333	0.287
		loss	PC vs. human	5.265	0.255
			human vs. human	3.504	0.137
	FCz	gain	PC vs. human	3.438	0.148
			human vs. human	3.401	0.306
		loss	PC vs. human	4.148	0.283
			human vs. human	3.173	0.198

Table 20: means and standard deviations for the interaction player * electrode * valence * condition

9.6. FRN – latency:

means and standard deviations for the significant results

electrode	mean	standard deviation
Fz	279.181	1.334
FCz	274.762	1.486

Table 21: means and standard deviations for the main factor electrode

valence	mean	standard deviation
gain	270.589	2.212
loss	283.353	0.857

Table 22: means and standard deviations for the main factor valence

condition	mean	standard deviation
PC vs. human	287.443	1.604
human vs. human	266.500	1.980

Table 23: means and standard deviations for the main factor condition

player	mean	standard deviation
winner	286.484	1.766
loser	267.458	1.783

Table 24: means and standard deviations for the between-subject factor player

player * valence		mean	standard deviation
winner	gain	277.595	3.114
	loss	295.373	1.207
loser	gain	263.583	3.143
	loss	271.333	1.218

Table 25: means and standard deviations for the interaction player * valence

player * condition		mean	standard deviation
winner	PC vs. human	292.816	2.258
	human vs. human	280.152	2.787

loser	PC vs. human	282.069	2.279
	human vs. human	252.847	2.812

Table 26: means and standard deviations for the interaction player * condition

condition * valence		**mean**	**standard deviation**
PC vs. human	gain	277.008	3.307
	loss	297.878	0.903
human vs. human	gain	264.171	3.574
	loss	268.828	1.512

Table 27: means and standard deviations for the interaction condition * valence

player * electrode * condition			**mean**	**standard deviation**
winner	Fz	PC vs. human	293.891	2.577
		human vs. human	282.859	3.159
	FCz	PC vs. human	291.741	2.444
		human vs. human	277.445	3.165
loser	Fz	PC vs. human	287.972	2.601
		human vs. human	252.000	3.188
	FCz	PC vs. human	276.167	2.466
		human vs. human	253.694	3.194

Table 28: means and standard deviations for the interaction player * electrode * condition

electrode * valence * condition			**mean**	**standard deviation**
Fz	gain	PC vs. human	281.902	3.784
		human vs. human	263.670	4.509
	loss	PC vs. human	299.961	0.349
		human vs. human	271.189	1.098
FCz	gain	PC vs. human	272.113	3.422
		human vs. human	264.673	3.406
	loss	PC vs. human	295.794	1.792
		human vs. human	266.467	2.604

Table 29: means and standard deviations for the interaction electrode * valence * condition

gender * player * electrode			mean	standard deviation
male	winner	Fz	286.000	2.718
		FCz	285.500	3.028
	loser	Fz	271.333	2.481
		FCz	264.083	2.765
female	winner	Fz	290.750	2.591
		FCz	283.636	2.888
	loser	Fz	268.639	2.865
		FCz	265.778	3.192

Table 30: means and standard deviations for the interaction gender * player * electrode

player * valence * condition			mean	standard deviation
winner	gain	PC vs. human	289.432	4.655
		human vs. human	265.759	5.032
	loss	PC vs. human	296.200	1.272
		human vs. human	294.545	2.129
loser	gain	PC vs. human	264.583	4.698
		human vs. human	262.583	5.078
	loss	PC vs. human	299.556	1.283
		human vs. human	243.111	2.148

Table 31: means and standard deviations for the interaction player * valence * condition

9.7. P300 – amplitude:

means and standard deviations for the significant results

valence	mean	standard deviation
gain	4.003	0.185
loss	5.070	0.082

Table 32: means and standard deviations for the main factor valence

condition	mean	standard deviation
PC vs. human	3.959	0.142
human vs. human	5.114	0.143

Table 33: means and standard deviations for the main factor condition

player	mean	standard deviation
winner	5.241	0.151
loser	3.832	0.153

Table 34: means and standard deviations for the main factor player

player * valence		mean	standard deviation
winner	gain	3.943	0.260
	loss	6.540	0.116
loser	gain	4.064	0.263
	loss	3.601	0.117

Table 35: means and standard deviations for the interaction player * valence

condition * valence		mean	standard deviation
PC vs. human	gain	3.883	0.219
	loss	4.035	0.131
human vs. human	gain	4.124	0.257
	loss	6.105	0.104

Table 36: means and standard deviations for the interaction condition * valence

9.8. P300 – latency:

means and standard deviations for the significant results

condition	mean	standard deviation
PC vs. human	342.391	1.378
human vs. human	289.245	2.490

Table 37: means and standard deviations for the main factor condition

player	mean	standard deviation
winner	304.664	2.061
loser	326.972	2.080

Table 38: means and standard deviations for the main factor player

player * condition		mean	standard deviation
winner	PC vs. human	344.309	1.940
	human vs. human	265.018	3.505
loser	PC vs. human	340.472	1.958
	human vs. human	313.472	3.537

Table 39: means and standard deviations for the interaction player * condition

condition * valence		mean	standard deviation
PC vs. human	gain	332.177	1.960
	loss	352.604	1.262
human vs. human	gain	296.390	4.484
	loss	282.101	1.697

Table 40: means and standard deviations for the interaction condition * valence

player * valence * condition			mean	standard deviation
winner	gain	PC vs. human	323.855	2.759
		human vs. human	284.891	6.312
	loss	PC vs. human	364.764	1.776
		human vs. human	245.145	2.389
loser	gain	PC vs. human	340.500	2.784
		human vs. human	307.889	6.371
	loss	PC vs. human	340.444	1.793
		human vs. human	319.056	2.411

Table 41: means and standard deviations for the interaction player * valence * condition

9.9. PANAS: means and standard deviations for the significant results

affect	mean	standard deviation
positive	30.222	0.907
negative	13.482	0.462

Table 42: means and standard deviations for the main factor affect

player * affect	mean	standard deviation

winner	positive	32.119	1.267
	negative	13.238	0.645
loser	positive	28.325	1.298
	negative	13.725	0.661

Table 43: means and standard deviations for the interaction player * affect

time * affect		**mean**	**standard deviation**
before experiment	positive	31.365	0.934
	negative	12.621	0.296
after experiment	positive	29.079	1.246
	negative	14.342	0.711

Table 44: means and standard deviations for the interaction time * affect

player * affect * time			**mean**	**standard deviation**
winner	positive	before experiment	31.381	1.305
		after experiment	32.857	1.740
	negative	before experiment	13.143	0.414
		after experiment	13.333	0.993
loser	positive	before experiment	31.350	1.338
		after experiment	25.300	1.783
	negative	before experiment	12.100	0.424
		after experiment	15.350	1.017

Table 45: means and standard deviations for the interaction player * affect * time

9.10. Questions between each condition:

means and standard deviations for the significant results

sadness after a loss	**mean**	**standard deviation**
PC vs. human	2.79	1.646
human vs. human	2.14	1.586

Table 46: means and standard deviations for the factor sadness after a loss

winner's sadness after a loss	**mean**	**standard deviation**

PC vs. human	2.62	1.627
human vs. human	1.76	1.446

Table 47: means and standard deviations for the winner's sadness after a loss

winner's attention to own feedback	**mean**	**standard deviation**
PC vs. human	4.19	1.601
human vs. human	4.81	1.470

Table 48: means and standard deviations for the winner's attention to own feedback

loser's interest in game	**mean**	**standard deviation**
PC vs. human	2.90	1.758
human vs. human	2.38	1.936

Table 49: means and standard deviations for the loser's interest in the game

loser's competence feeling	**mean**	**standard deviation**
PC vs. human	3.20	1.196
human vs. human	2.45	1.395

Table 50: means and standard deviations for the loser's competence feeling

9.11. Questions between each session:

means and standard deviations for the significant results

happiness in the PC vs. human condition	**mean**	**standard deviation**
first measurement	4.02	1.137
last measurement	3.67	1.443

Table 51: means and standard deviations for the factor happiness in the PC vs. human condition

motivation in the PC vs. human condition	**mean**	**standard deviation**
first measurement	4.71	1.367
last measurement	4.29	1.582

Table 52: means and standard deviations for the factor motivation in the PC vs. human condition

motivation in the human vs. human condition	mean	standard deviation
first measurement	4.07	1.879
last measurement	2.24	2.022

Table 53: means and standard deviations for the factor motivation in the human vs. human condition

loser's happiness in the PC vs. human condition	mean	standard deviation
first measurement	3.71	1.189
last measurement	3.24	1.375

Table 54: means and standard deviations for the loser's happiness in the PC vs. human condition

winner's motivation in the human vs. human condition	mean	standard deviation
first measurement	4.95	1.203
last measurement	2.81	2.015

Table 55: means and standard deviations for the winner's motivation in the PC vs. human condition

loser's motivation in the PC vs. human condition	mean	standard deviation
first measurement	4.52	1.692
last measurement	3.67	1.826

Table 56: means and standard deviations for the loser's motivation in the PC vs. human condition

loser's motivation in the human vs. human condition	mean	standard deviation
first measurement	3.19	2.040
last measurement	1.67	1.906

Table 57: means and standard deviations for the loser's motivation in the human vs. human condition

winner's anticipation to win in the human vs. human condition	mean	standard deviation

first measurement	4.14	1.014
last measurement	4.76	1.546

Table 58: means and standard deviations for the winner's anticipation to win in the human vs. human condition

loser's anticipation to win in the PC vs. human condition	**mean**	**standard deviation**
first measurement	2.86	1.236
last measurement	1.71	1.347

Table 59: means and standard deviations for the loser's anticipation to win in the PC vs. human condition

9.12. Documentation of the different steps during the study in German

Datum	**Inhalt**
31/01/12	1. Treffen mit Daniela Pfabigan, Mikhail Votinov und Andrea Waldl
29/02/12	Treffen mit Andrea Waldl: Überlegungen bezüglich Fragestellungen für die Diplomarbeit
23/02/12	2. Treffen mit Daniela Pfabigan, Mikhail Votinov und Andrea Waldl: Vorstellung des Tasks, Überlegungen bezüglich Fragestellungen
03/04/-24/05/12	Erwerb der Laborberechtigung (genaue Auflistung der Daten: Laborberechtigungsschein)
30/04/12	Treffen mit Andrea Waldl: Überlegungen bezüglich Fragestellungen für die Diplomarbeit, Planung: Planungsreferat
02/05/12	3. Treffen mit Daniela Pfabigan, Mikhail Votinov und Andrea Waldl: Entscheidung über Vorgabe des Tasks und Fragebögen
08/05/12	Treffen mit Andrea Waldl: letzte Feinheiten bezüglich des Planungsreferats geklärt
30/05/12	4. Treffen mit Daniela Pfabigan, Mikhail Votinov und Andrea Waldl: Änderungen am Task
Juni 2012	Onlineversionen des Fragebogens erstellen

01/07/-14/09/12	Datensammlung: Beantwortung des Fragebogens mit anschließender EEG-Ableitung (Details zu den VPNs und Datum: Protokollbögen)
17/09/12	5. Treffen mit Daniela Pfabigan, Mikhail Votinov und Andrea Waldl: weitere Schritte, Preprocessing
18/09/12	SPSS-Template und Dateneingabe
21/09/12	6. Treffen mit Daniela Pfabigan und Andrea Waldl: Anwendung der Scripts für Preprocessing
24/09/12	Start: Datenauswertung – Preprocessing
08/10/12	Ende: Datenauswertung – Preprocessing
15/10/12	7. Treffen mit Daniela Pfabigan, Mikhail Votinov und Andrea Waldl: xls-files/set-files zusammenfügen, Trigger umbenennen, Trigger einfügen (Scripts programmieren)
04/11/12	Start: Datenauswertung – xls-files und set-files zusammenfügen, Trigger umbenennen, Trigger einfügen
07/11/12	Ende: Start: Datenauswertung – xls-files und set-files zusammenfügen, Trigger umbenennen, Trigger einfügen
08/11/12	8. Treffen mit Daniela Pfabigan und Andrea Waldl: Datenauswertung – Epochierung, Artefaktkorrektur
09/11/12	Start: Epochierung
11/11/12	Ende: Epochierung
19/11/12	Start: Artefaktkorrektur
11/12/12	Ende: Artefaktkorrektur
17/12/12	9. Treffen mit Daniela Pfabigan, Mikhail Votinov und Andrea Waldl: merging, averaging, Peak-finding, sLoreta
17/12/-19/12/12	merging und averaging der competition Daten
02/01/13	1. Treffen mit Daniela Pfabigan: sLoreta

02/01/13	Augenkanäle entfernen; Daten für sLoreta exportieren
03/01/13	Start sLoreta: erste Analysen der competition Daten
06/01/13	Start: Peak-finding competition Daten
12/01/13	Ende: Peak-finding competition Daten
12/01/- 13/01/13	merging und averaging der solo Daten
18/01/13	Start: Peak-finding solo Daten
18/01/13	Ende: Peak-finding solo Daten
21/01/13	Start: SPSS-Analyse
31/01/13	peak-finding: Korrekturen der Ausreißer
04/03/13	10. Treffen mit Daniela Pfabigan und Mikhail Votinov: Besprechen der sLoreta- und SPSS-Ergebnisse
06/03/13	Ende: SPSS-Analyse
10/03/13	Ende: sLoreta
14/03/13	Treffen mit Andrea Waldl: Auswertungsreferat
15/03/13	11. Treffen mit Daniela Pfabigan, Mikhail Votinov und Andrea Waldl: Besprechen des Auswertungsreferats

10. Curriculum Vitae (in German)

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L e b e n s l a u f

Geburtstag	Linz, 09. Februar. 1988
Staatsbürgerschaft	Österreich
Familienstand	ledig
Schulische Ausbildung	* 4 Jahre Volksschule Arbing * 4 Jahre Hauptschule Baumgartenberg * 5 Jahre Handelsakademie in Perg * Psychologiestudium (12. Semester) * Psychotherapeutisches Propädeutikum (Abschlussprüfung ist noch zu absolvieren) * Ernährungswissenschaften (2. Semester)
Berufserfahrung	* Ferialpraktikum Firma Baumschlager (Steuerberatung, Schwertberg) * Ferialpraktikum OÖ Landeserholungsheim (Bad Hall) als Zimmermädchen/Küche/Service * Au-Pair in Frankreich * pädagogische Mitarbeiterin bei Feriencamps der Kinderfreunde OÖ & Mühlviertel * Teamleitung bei Feriencamps der Kinderfreunde OÖ

	* Geringfügige Tätigkeit: H & M * Psychologisches Pflichtpraktikum: Neurolopsychologisches Zentrum (Baumgartner Höhe, Wien) * Praktikum an der SFU-Ambulanz (Sigmund Freud Universität Wien)
Besondere Kenntnisse	**Sprachkenntnisse** * Englisch und Französisch einschließlich Handelskorrespondenz * Grundkenntnisse in Russisch **EDV- und Textverarbeitungskenntnisse** Word, Excel, PowerPoint, Internet, SPSS/PASW
Sonstiges	* Führerschein (B) * Erste Hilfe Kurs (Februar 2012) * Auslandssemester Perth, Australien WS 2011/12