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DIPLOMARBEIT

Titel der Diplomarbeit

ESTIMATED MATE VALUE AND CEREBRAL PROCESSING OF FACES IN HUMANS – AN EEG-STUDY

angestrebter akademischer Grad

Magistra der Naturwissenschaften (Mag.rer.nat.)

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Wien, im Juli 2009

Table of Contents

Abstract	3
Zusammenfassung	5
1. Introduction	7
1.1 Human Mating Behaviour	8
1.2 Face Perception.....	17
1.3 Predictions	28
2. Material & Method.....	31
2.1 Subjects.....	31
2.2 Stimulus Material	33
2.3 Study Design.....	34
2.4 Electroencephalography (EEG).....	37
2.5 Data processing.....	42
2.6 Analysis of behavioural and electrophysiological data	44
3. Results.....	48
3.1 Behavioural data	48
3.2 EEG-Data.....	50
3.3 Summary of results	68
4. Discussion	70
4.1 Discussion of the behavioural observations	70
4.2 Discussion of the electrophysiological observations.....	71
4.3 Implications for future research.....	76
References.....	79
Index of tables and figures.....	87
Abbreviations.....	88
Appendices	89
Acknowledgments.....	94
Curriculum vitae	95
Lebenslauf	96

Abstract

According to current ERP (event-related potential) literature attractiveness might be able to modulate early face processing ERPs. As one's mate value is also assessed by one's physical appearance one aim of this study was to investigate possible influences of mate choice decisions on early ERPs (P100, N170, and the early part of the LPC). Another focus was laid on possible alterations of ERP patterns as a function of menstrual cycle phase respectively of using hormonal contraceptives.

EEG data from 24 men and 21 women was collected. Stimulus material comprised a set of front-view photographs of 100 female and 100 male faces with neutral facial expression.

In men, female faces rated as a short-term mate elicited significant higher P100 amplitudes than female faces rated as a long-term partner. As the P100 which is debated for being crucial in face processing was not observable in naturally cycling women it is weakening the discussed findings for its face specificity and arises the question of sex differences in face processing. A N170 was observed in all subjects with its neural generators being localized in the fusiform gyrus, which is in line with previous studies. Furthermore, the findings of this study suggest that steroid hormone concentrations might have an influence on brain functioning in women, although evidence is weak.

To conclude, the P100 might reflect a categorization process on a level of fine physiognomic facial features that could be sufficient for men's appraisal of women's mate value within a glance.

(246 words)

Zusammenfassung

EEG-Studien im Zusammenhang mit der Verarbeitung von Gesichtern konnten einen Einfluss von Attraktivität auf frühe Ereigniskorrelierte Potenziale (ERPs) zeigen. Da sich der Partnerwert einer Person unter anderem auch aufgrund seines physischen Erscheinungsbildes erschließt, war es Ziel dieser Studie zu untersuchen, ob die Partnerwahl (Langzeitpartner oder Kurzzeitpartner) ERPs beeinflusst (P100, N170 und der frühe Anteil der LPC). Weiters wurden auch mögliche Auswirkungen der unterschiedlichen Phasen des weiblichen Menstruationszyklus sowie die Einnahme hormoneller Verhütungsmittel auf die frühen ERPs untersucht.

Es wurden die EEG-Daten von 24 Männern und 21 Frauen aufgenommen, als Stimuli dienten Frontalfotos von 100 männlichen und 100 weiblichen Gesichtern.

Weibliche Gesichter, die als Kurzzeitpartner bewertet wurden, riefen in Männern eine signifikant höhere Amplitude der P100 hervor als weibliche Gesichter, die als Langzeitpartner bewertet wurden. Diese frühe Komponente konnte bei natürlich menstruierenden Frauen nicht beobachtet werden, was die ihr in vorangegangenen Studien eingeräumte wesentliche Rolle in der Gesichtsverarbeitung bezweifeln lässt. Außerdem stellt sich die Frage, ob es mögliche Geschlechtsunterschiede in der Gesichtsverarbeitung gibt. Die N170 wurde in allen Versuchspersonen beobachtet und ihre neuronalen Generatoren im Gyrus fusiformis lokalisiert, was Ergebnisse früherer Studien bestätigt. Weiters legen die Beobachtungen in der vorliegenden Studie nahe, dass die Konzentrationen von Steroidhormonen einen Einfluss auf Gehirnfunktionen von Frauen haben können, wenn auch die Anzeichen dafür nur sehr schwach sind.

Die P100 spiegelt möglicherweise einen Kategorisierungsprozess wieder, der auf feinen physiognomischen Unterschieden basiert, und für Männer ausreichend sein könnte um den Partnerwert einer Frau innerhalb eines Augenblickes beurteilen zu können.

(243 Wörter)

1. Introduction

Face perception in humans is a highly developed skill and it is very important in our everyday social relationships. As pointed out by Haxby and Gobbini (2007) “[...] *face perception allows rapid access to information about that person that is essential for effective social interactions.*” We derive vital information as for example on the emotional state, age, sex of a person only by looking at his/her face and a great number of psychological phenomena are connected to how attractive a face is judged. In several studies in the field of Social Psychology it was shown that attractive individuals gain more advantages than unattractive persons. For example, Sigall and Ostrove (1975) found lighter sentences in lawsuits being given to attractive females, and Langlois et al. (2000) postulated in a meta-analysis and review of 919 studies that attractive persons are judged more positive concerning their personal traits.

Research on face perception has focused mainly on discrimination of faces from other (non-face) stimuli. Being interested in the field of social neuroscience I wanted to find an answer to the question, whether there were distinct cues in human faces that might lead to a different perception and processing that can be measured by electroencephalography (EEG). Among the different problems of biological survival of humans such as food acquisition, habitat selection and so on is finding an appropriate mate. Considering that human evolution occurred mainly in hunter and gatherers societies many characteristics of human bodies and behaviours should reflect the features that were most useful for survival in our ancestral environments. Against the background that men and women evolved distinct mechanisms for mate choice I developed a growing interest whether there are different patterns in brain activity due to persons being considered to be a long-term mate on the one hand and persons being considered to be a short-term mate on the other hand. So the aim of this study was to investigate possible effects of different mating preferences of young heterosexual men and women on their perception and their processing of faces of the opposite sex due to their subjective estimated mate value by the means of EEG.

In the following the theoretical concepts of human mating strategies as well as human face perception and face processing will be presented. This chapter ends with the predictions made in the context of this study.

1.1 Human Mating Behaviour

Finding the ideal mate to settle down is quite an important thing for most people. In a study by Miller and colleagues (2002) around 99% of female and male participants reported the wish to find a partner for an exclusive long-term relationship within the next five years. The biological importance of mating is quite obvious and could easily be viewed on aspects of survival of the whole group and species. “[...] *sexual reproduction entails combining one’s own genes with another individual’s genes to produce offspring. Through mate choice animals can influence the quality of the genes passed on to their offspring from their sexual partner, and the quality of the parental care those offspring will receive*” (Miller & Todd, 1998, p. 190). Humans – as any other species on earth – pursue sexual reproduction and according to Trivers’ (1972) theory about asymmetrical parental investment and sexual selection this always means different costs and goals for both of the two sexes. Trivers defined parental investment as “*any investment by the parent in an individual offspring that increases the offspring’s chances of surviving (and hence reproducing) at the cost of the parent’s ability to invest in other offspring*” (Trivers, 1972, p. 139). In this definition investment includes physiological costs (as the production of the female ovum or the male sperm cells) as well as investment in form of feeding and guarding the offspring. Among most mammals females are the more heavily investing sex, and this is also true for humans. Women have to carry the costs of pregnancy and lactation, which restricts the number of children they can give birth to. In contrast, the minimal investment of a man for producing offspring is the contribution of sperm, which leads to the fact, that men can have hypothetically a much higher number of offspring than women. Even the initial parental investment (at the moment of fertilisation) is characterised by disproportionateness in size of the sex cells.

Based on the statistical terms type I (false positive) error and type II (false negative) error, the Error Management Theory (Haselton & Buss, 2000) described two errors made in decision processes under uncertainty. As the costs of these two errors are mostly asymmetrical humans are considered to have developed systems biased towards the error that costs less. Haselton and Buss (2000) tried to find an answer to the question why women’s sexual intent is perceived differentially by men and women. Men usually show overperception of women’s sexual intent, and women tend to underestimate men’s commitment. The so called “sexual overperception bias” in men is explained with the attempt to minimize the costs of missed sexual opportunities: “*Ancestral men who tended to falsely infer a prospective mate’s sexual intent (a false-positive error) paid the fairly low*

costs of failed sexual pursuit. [...] In contrast, men who tended to falsely infer that a women lacked sexual intent (a false-negative error) paid the cost of losing a sexual opportunity and hence a reproductive opportunity. In the currency of natural selection [...] the latter error was more costly” (Haselton & Buss, 2000, pp. 82). On the other hand, women show the so called “commitment-skepticism bias”. The problem about commitment is that it can not be directly observed. The costs a woman had to carry when betrayed about commitment by the potential mate (type I error/false positive error) compared to the costs of failing to detect existing commitment (type II error/false negative error) were more costly. *“An ancestral woman who consented to sex with a man who abandoned her shortly thereafter because of his low level of commitment could have suffered the costs of [...] pregnancy, raising a child without an investing mate, a reduction in her mate value, and reputational damage*” (Haselton & Buss, 2000, p. 83).

In “The Descent of Man, and Selection in Relation to Sex”, published 1871, Darwin defined sexual selection as *“competition within one sex for members of the opposite sex and [...] differential choice by members of one sex for members of the opposite sex”*. Based on that Trivers postulated *“Where one sex invests considerably more than the other, members of the latter will compete among themselves to mate with members of the former”* (Trivers, 1972, p. 173). In other words and in terms of human mating patterns, females (the sex that invests more in offspring) are choosier about whom they want to mate, and males (the less investing sex) are more competitive for females (“intrasexual competition” or “male-male competition”). (Trivers, 1972)

According to the Sexual Strategies Theory by Buss and Schmitt (1993) there are two different strategies, in which both sexes may engage and which are associated with different costs and benefits. On the one hand is the so called short-term mating, which describes mating relationship of short duration (e.g. brief affairs, one-night stands), on the other hand is the longer lasting long-term mating (e.g. marriages). As most people have more than one relationship in their lifetime, relationships of short durations as well as those of long or intermediate durations are parts of the behavioural repertoire of mating in humans.

Buss and Schmitt gave human mating an evolutionary perspective and postulated that short-term and long-term mating strategies are inherent and evolved solutions in form of distinct psychological mechanisms to adaptive problems: *“Humans seek particular mates to solve specific adaptive problems that their ancestors confronted during the course of human evolution; humans’ mate preferences and mating decisions are hypothesized to be*

strategic products of selection pressures operating during ancestral conditions” (Buss & Schmitt, 1993, p. 205). Adaptive problems in the context of mating include sexual accessibility, fertility assessment, commitment seeking, resource procurement, paternity certainty, assessment of mate value, and – of course – parental investment.

As already mentioned above, different minimal investments have to be made by men and women for producing offspring resulting in different problems for the two sexes. Trivers identified two main problems, desertion and cuckoldry: “[...] *the individual initially investing more (usually the female) is vulnerable to desertion. On the other hand, in species with internal fertilization and strong male investment, the male is always vulnerable to cuckoldry. Each vulnerability has led to the evolution of adaptations to decrease vulnerability and to counter-adaptations*” (Trivers, 1972, p. 173). Buss and Schmitt (1993) elaborated this assumption on mate selection problems and identified distinct problems inherent to both long-term and short-term mating strategies (Tab. 1).

Table 1. Mate selection problems.

Different problems men and women are confronted with in context of short-term and long-term mating (after Buss & Schmitt, 1993, p. 207).

Type of mating	Men	Women
Short term	1. Problem of partner number 2. Problem of identifying which women are sexually accessible 3. Problem of minimizing cost, risk, and commitment 4. Problem of fertility	1. Problem of immediate resource extraction 2. Problem of evaluating short-term mates as possible long-term mates 3. Problem of gene quality 4. Problem of mate switching, mate expulsion, or mate backup
Long term	1. Problem of paternity confidence 2. Problem of female reproductive value 3. Problem of commitment 4. Problem of good parenting skills 5. Problem of gene quality	1. Problem of identifying men who are able to invest 2. Problem of identifying men who are willing to invest 3. Problem of physical protection 4. Problem of commitment 5. Problem of good parenting skills 6. Problem of gene quality

Men’s Mating Strategies according to Buss and Schmitt (1993)

Men pursue long-term and short-term mating strategies and both types of mating come along with certain problems (Tab. 1). Sensitive to the temporal context of mating, men’s mate preferences as well as the employed strategy differ. The advantage of a long-term

partnership is the possibility for a man to monopolize a woman's entire reproductive capacity. Preferred long-term mates are young and physically attractive women, who seem to be loyal and faithful. These female features are indicators for the female reproductive value (youthfulness and attractiveness) and for paternity certainty (loyalty and fidelity). Men engaging in long-term mating try to solve the problem of paternity certainty and the problem of female reproductive value. One problem a man is confronted with when pursuing a short-term sexual relationship, is that a woman's ovulation is concealed. For being a successful short-term mater a man has to identify women who are fertile and sexually accessible. The advantage of short-term partnerships is the possibility to inseminate a number of fertile women (to "solve" the problem of number). Hypothetically, a man can produce offspring whenever he copulates, whereas the number of offspring a woman can have is limited (the limiting factors are the fertile days during ovulation, a nine month pregnancy, and her age dependent fertility). In other words a man can increase his reproductive success by increasing the number of his sexual partners. Therefore men are hypothesized to devote a larger amount of their mating effort to short-term strategies, *"greatly relaxing the standards that a short-term mate must meet, [and] requiring less time to elapse before sexual intercourse"*. (Buss & Schmitt, 1993, p. 226)

Hirsch and Paul (1996) distinguish between two courtship tactics: the so called "quality strategy" (which equates to males pursuing long-term mating strategy and implies pair bond with paternal investment) and the "quantity strategy" (the short-term maters). In an experiment they found out that behaviours judged to be honest were referred to quality strategists while, in contrast, behaviours judged exploitive were associated with quantity strategists. The latter one is connected with tactics of threatening and talking about sex. There are two different quantity strategies: *"commodifiers who trade resources for sex and predators who exploit"* (Paul & Hirsch, 1996, p. 71). The former one is associated with honest advertisement and resource expenditures as time, energy, and money, which are known to be costly signals and therefore used by high-quality potential mates. Quality strategists also appear to be reluctant in starting sexual relations too quickly. This could be an advantage, because he can collect evidence of a female's quality as a mother and mate, and her fidelity and his paternity certainty.

Women's Mating Strategies according to Buss and Schmitt (1993)

Women also show both mating-strategies in their behavioural repertoire, which are associated with distinct problems (Tab. 1). There exist several observable cues that are

linked to a man's mate value (Fig. 1). Different benefits can be derived by a woman when pursuing long-term or short-term relationships. The fundamental benefit inherent to a long-term relationship for a woman is access to enduring provision of resources by the man. Therefore women should have evolved preferences for males who are not only showing the ability but also are willing to invest resources in her and in offspring. Women should attend to distinct observable cues in this context as income, status, or generosity.

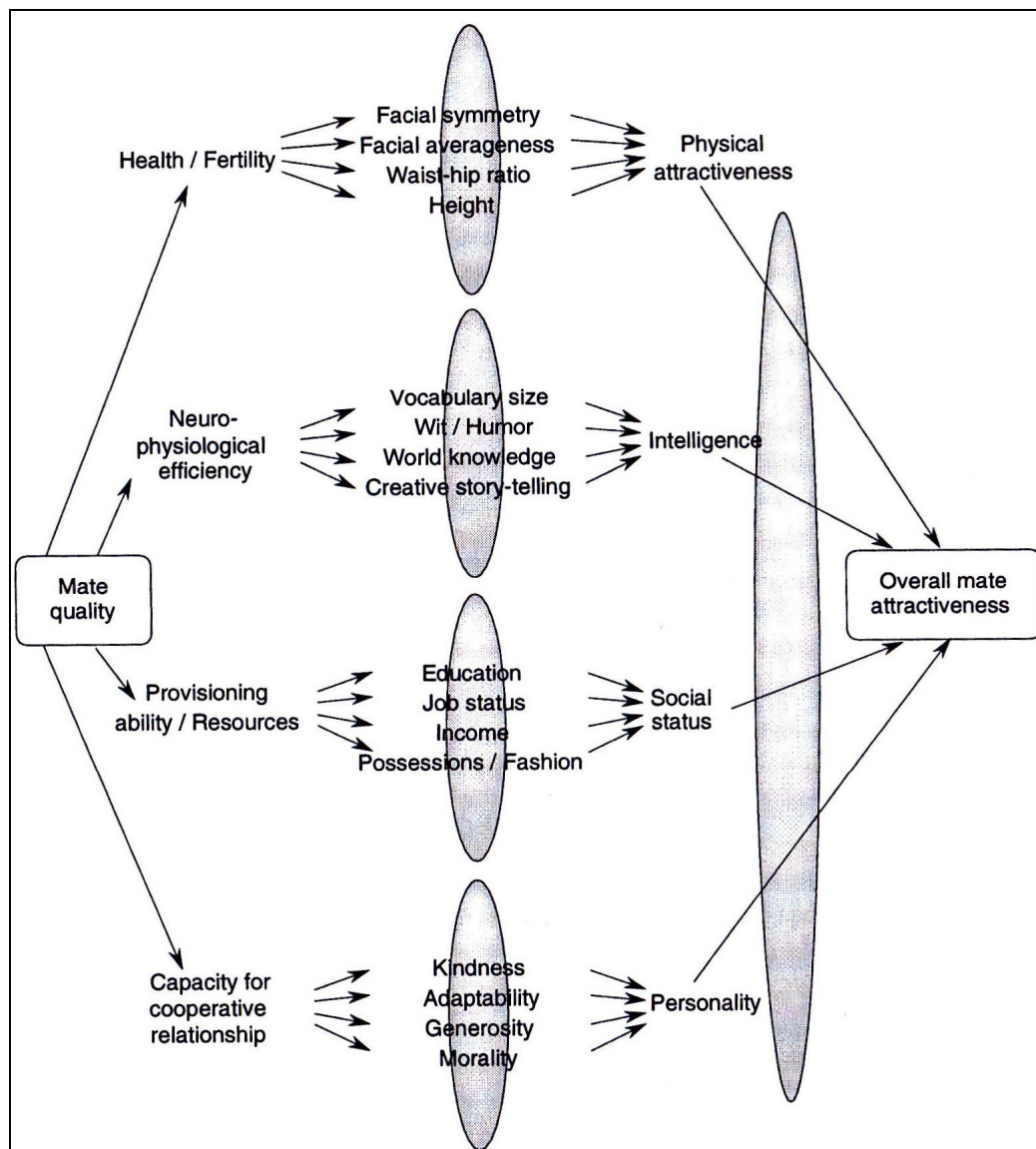


Figure 1. The two-stage lens model by Miller and Todd (1998) (derived from ideas of Buss & Schmitt, 1993)

The primary goal in mate choice is assessing a mate's quality, which consists of traits that are not observable directly (health, neurophysiologic efficiency, etc.). By perceiving the outcomes (middle column) of these traits, attributions to physical attractiveness, intelligence, social status, and personality traits are made resulting in an estimation of overall attractiveness as a potential mate.

Short-term relationships can be advantageous for a woman, too. It might be a way to extract resources immediately, or to evaluate a man for a prospective long-term partner.

Women find promiscuity and already being committed (e.g., being already in a partnership) highly undesirable for a short-term mate, whereas men are not bothered in the reverse case. This can be seen as evidence for the assessment of potential long-term mates through short-term relationships (Buss & Schmitt, 1993). Last but not least it can bring the possibility of better genes. Evidence for this latter point comes from a study by Gangestad and colleagues (2001): women in a fixed relationship reported greater sexual interest in other men during their fertile days of the menstrual cycle, with their partners being more attentive at this time and more proprietary.

Gangestad and Simpson (2000) stressed the importance of contextual effects on mating strategies of females in the first line, to which men somehow “react”. Basically, men and women were selected to pursue long-term strategies, but depending on the quality of the environment, mating tactics may have to be changed. It might have been necessary for women to “*trade off evidence of a man’s genetic fitness for evidence of his ability and willingness to invest in offspring*” due to cost-benefit considerations (Gangestad & Simpson, 2000, p. 586). In a difficult environment heavy investment of both parents in offspring was essential. So women might have been attracted to men offering her availability and willingness to invest, resulting in pursuing long-term mating tactics. In contrast, in some environments genetic fitness of offspring was more important (e.g., due to prevalent pathogens), and therefore women showed short-term mating and extra-pair mating tactics in their behavioural repertoire to a greater extent. “*The mating tactics and preferences of women accordingly reflected the nature and quality of the environments in which they lived*” (Gangestad & Simpson, 2000, p. 586). Men “reacted”: if women demanded resources and heavy investment, most men offered these features, whereas if women demanded genetic fitness of the prospective mate, men – especially those who fulfilled this criterion – engaged more in short-term respectively extra-pair mating tactics. Only high quality mates in terms of genetic fitness could have successfully pursued short-term mating relationships at any time. (Gangestad & Simpson, 2000)

So it seems that men and women showing both mating strategies (long-term bonds as well as short-term sexual relationships) in their behavioural repertoire, seem to pursue a context-dependent mixed strategy in general (Buss & Schmitt, 1993; Hirsch & Paul, 1996; Haselton & Buss, 2000; Gangestad & Simpson, 2000).

The Role of Facial Physical Appearance

In the past decades a growing body of evidence has indicated the biological importance of facial attractiveness and its influence on mate choice decisions. It seems that “[...] *our concepts of physical beauty are rooted in our biology, shaped by natural selection, and not merely acquired tastes determined by culture and advertising, as powerful as those influences may be*” (Ellison, 2008, p. 13). Assessment of a person’s attractiveness appears to be of such an eminent importance that judgements are accurate even when the face could not have been perceived consciously (Olson & Marshuetz, 2005).

In a study by Baudouin and Tiberghien (2004), female faces rated due to their attractiveness by male judges showed three characteristics: symmetry, averageness, and distinct size of individual facial traits (big eyes, prominent and high cheek bones, a small chin, and thick lips were indicators for a higher degree of perceived attractiveness). These three characteristics can be seen as three approaches accounting for perceived attractiveness. (Thornhill & Gangestad, 1999; Scheib et al., 1999; Baudouin & Tiberghien, 2004; Schaefer et al., 2006)

Facial physical appearance respectively its attractiveness seems to play a crucial role in choosing a mate respectively assessing the mate value of a potential candidate. Phenotypic cues are used to assess genotypic quality (Scheib et al., 1999). Attractive women radiate youthfulness and fertility (Johnston, 2000). Measured bilateral symmetry of facial traits seems to be a good predictor for its perceived attractiveness. In this context, fluctuating asymmetry is of great interest. Fluctuating asymmetry is defined as the lack of symmetry in traits that are symmetrical at a population level. It is thought to be dependent on the organism’s inability to resist pathogens and perturbations during development. But symmetry appears not to be the only facial trait affecting facial attractiveness (Grammer & Thornhill, 1994; Scheib et al., 1999). An average face is always a symmetrical face, too, and may therefore be a signal of quality for being resistant against environmental perturbations. To bring it to the point: facial attractiveness seems to be a marker for reproductive fitness (Thornhill & Gangestad, 1999; Johnston, 2006).

As could be shown by Rodes and colleagues (2005), attractiveness enhanced mating success for men as well as for women, indicating that both sexes select partners with traits perceived as attractive. They also found that sexual dimorphism was associated with sexual behaviours, meaning that men with masculine faces are having more short-term mates and extra-pair copulations, and women with more feminine faces are having more long-term

relationships. These effects were not observed in women using oral contraception (Little et al., 2001).

There are distinct facial features that develop under the influence of sex steroids (namely estrogen and testosterone) and are known as the so called (sex-) hormone markers. Therefore faces are believed to provide much biological relevant information for the beholder. A high estrogen-to-testosterone ratio in women in puberty, for example, produces enlargement of the lips and upper cheeks, which is mediated by deposit of fat tissue. These facial characteristics can enhance the perceived facial attractiveness of women (Grammer & Thornhill, 1994; Baudouin & Tiberghien, 2004; Schaefer et al., 2006). There is a preference for feminized shapes of female faces rather than for average female faces (Perrett et al., 1998). Male facial characteristics are influenced by testosterone, e.g. with a high level of this sex hormone resulting in a longer and broader lower jaw, more pronounced cheekbones, and more prominent brow ridge (Grammer & Thornhill, 1994; Penton-Voak & Perrett, 2000; Johnston et al., 2001; Johnston, 2006). Women have stronger preferences for masculinity in male faces when women are either living in a fixed partnership, or desiring a short-term sexual relationship; a bias towards more feminine male faces appears for potential long-term mates (Little et al., 2001). Increased masculine facial architecture is attributed with dominance, coldness, and dishonesty. These personal traits are not desirable for a long-term partner but the good-gene benefits might be a trade-off.

As a male's genetic quality can not be assessed directly, women attend to signals that serve as indicators for the male's genetic quality. According to Zahavi's handicap principle (Zahavi & Zahavi, 1997), these signals¹ (e.g., behaviours or physical features) are cost-intensive and therefore are handicaps and signals for overall condition and genetic quality at the same time. They are perceived to be honest and reliable, because only the males with great fitness can afford to develop such signals (and females prefer mates with these characteristics). In humans, high levels of the former mentioned steroid hormones are a burden for the immune system. By displaying facial features developed under their influence men advertise their immunological competence (immunocompetence) and hence genetic quality (Penton-Voak & Perret, 2000; Johnston et al., 2001).

¹ The classic example in this context is the tail of the peacock. A strong, healthy peacock can afford the additional costs of producing a long tail (which is a constraint when escaping from a predator) with bright and shiny colours. With signalling that he can afford this costly feature he suggests to be a high quality potential mate for a peahen.

Another approach that should be mentioned is to measure prenatal ratios of testosterone to oestrogen by assessing the length ratio of the second to the fourth digit (2D:4D). Fink and colleagues (2005) investigated the relationship between this ratio and facial shape. They found that males have lower 2D:4D ratios than females. Furthermore, facial characteristics known as typical male correspond with low 2D:4D ratios and the opposite was true for typical female facial traits.

Penton-Voak and colleagues (1999) showed that woman's preference for male face shapes changes in dependence of the phase of the menstrual cycle (in naturally cycling women). Phase of high conception risk was defined as time between the end of menses and ovulation², whereas low conception risk phase was defined as the time after ovulation and before the onset of menses. In a first experiment, female participants had to rate faces according to their perceived facial attractiveness. Females in low conception risk phase preferred more feminine male faces, in contrast to females in high conception risk phase preferred faces that were less feminine/more masculine. In a second experiment, participants were instructed to select the most attractive face for a long-term partner or for a short-term partner. During high conception risk phase, the male face shape preferred for a short-term relationship was less feminine. Attractiveness ratings for potential long-term partners were not affected and remained unchanged. In a follow-up study, Penton-Voak and Perrett (2000) provided more evidence for the cyclic changes of female preferences for male faces. It seems that when conception is most likely, female preference for testosterone-related facial characteristics increases. These traits are associated with good health and may honestly advertise immunocompetence and be therefore more desirable (Penton-Voak & Perrett, 2000; Johnston et al., 2001; Little et al., 2001; Waynforth et al., 2005).

Roney and Simmons (2008) could show that women's estradiol concentration (which is systematically varying across the menstrual cycle and peaking shortly before ovulation) is associated with their preference for testosterone mediated facial cues in men. At days of high estradiol concentrations this preference increases. No correlations have been found when the concentrations of progesterone and testosterone of women were examined. A possible linkage – which one might assume after studying the presented data – between concentrations of the luteinizing hormone (peaking exactly at the time of ovulation) and this aforementioned preference shifts was not investigated.

² Ovulation was assumed to occur 14 days before the onset of menses.

Alas, little research has been done accounting for possible influences of the hormonal changes during the menstrual cycle as well as accounting for possible effects of hormonal contraceptives use. This study aims to focus on these topics in connection to the perception of human faces.

1.2 Face Perception

“We react strongly to faces, and we read a lot into them”, a quotation from Ellison (2008) emphasizes the human face being one of the most important stimuli we perceive. Within a glance, we derive information about a person’s identity, about the mood, the age, the sex, the direction of the gaze and so forth. The ability to extract these pieces of information rapidly just by looking in someone’s face is very important for normal social interactions. Even newborns show an orientating bias towards faces (and face-related stimuli) (Valenza et al., 1996), which seems to persist across the whole lifespan.

What is a face?

At this point it should be clarified what refers to the term “face”, so in the following some definitions from different sources are given.

In „Duden - Das große Wörterbuch der deutschen Sprache in acht Bänden“ (1993) the face is defined as *“[...] durch Augen, Nase und Mund geprägte Vorderseite des menschlichen Kopfes vom Kinn bis zum Haaransatz”*³ (Drosdowski, p. 1314).

Following definitions are given for the term “face” in the online Oxford Dictionary of English: *“(1) the front part of a person’s head from the forehead to the chin, or the corresponding part in an animal. (2) an expression on someone’s face. (3) the surface of a thing, especially one presented to the view or with a particular function. (4) a vertical or sloping side of a mountain or cliff.”* (Online Oxford Dictionary of English⁴) As one can see, there are several totally different meanings, whereas only the first given definition is meaningful in the context of this study.

Another definition found in the world wide web is more extensive: *“The face forms a part of the human body: the front of the head.”* and *“The term face refers to the central sense organ complex, for those animals that have one, normally on the ventral surface of the head and can depending on the definition in the human case, include the hair, forehead,*

³ Loose translation: “the front of a human head from the chin to the hairline characterised by eyes, nose, and mouth.”

⁴ http://www.askoxford.com/concise_oed/face?view=uk (accessed on 12.04.2009)

eyebrow, eyes, nose, ears, cheeks, mouth, lips, philtrum, teeth, skin, and chin. The face has uses of expression, appearance, and identity amongst others. It also has different senses like smelling, tasting, hearing, and seeing." (Wikipedia⁵)

As it can be seen there is disagreement among these three citations, whether the hair and the ears are part of the face. Central traits as the eyes, the nose and the mouth are agreed to be facial parts.

The stimulus material used in the experiment consists of front-view photographs of human faces where hair and ears can be seen as well, providing a realistic and natural situation (for examples of used stimuli faces see figure 6).

Perception and Processing of Faces in Humans

The question to which extent the function of the brain is domain-specific (composed of special-purpose mechanisms, each processing a specific kind of information; this concept is also known as the Swiss Army knife-view of brain functions, a term introduced by Cosmides & Tooby, 1994, cited in Kanwisher, 2006) or domain-general is a longstanding debate in the field of cognitive science. In this context the so called Face Specificity Hypothesis should be mentioned. According to this theory, face perception is considered to be implemented in its own special cortical network, that is not shared with (many) other cognitive functions (Kanwisher et al., 1997; Allison et al., 1999; Kanwisher, 2006; for a review, see Kanwisher & Yovel, 2006). Using fMRI (functional magnetic resonance imaging) an area in the fusiform gyrus was found to be significantly more active in response to passively viewed faces rather than to objects (Kanwisher et al., 1997). This area was named fusiform face area (FFA). The response to faces (front-view or three-quarter-view faces) was stronger than to houses, human hands, and scrambled faces, with a greater activation found in the right than in the left hemisphere. It should not be unmentioned that additionally to the activation in the FFA a greater face dependent activation was found in the superior temporal sulcus in the right hemisphere in seven of fifteen participants. (Kanwisher et al., 1997)

Observations of patients suffering from acquired prosopagnosia support the view of the existence of a specialized neural system for face perception. Prosopagnosia is a syndrom, where the ability to recognize familiar faces is impaired. In extreme cases patients are not able to recognize their reflection in a mirror. It is associated with lesions in

⁵ <http://en.wikipedia.org/wiki/Face> (accessed on 12.04.2009)

occipitotemporal cortex, and is – in most cases, although not all – related to both hemispheres. These findings of observed lateralization of face processing as reported above are consistent with findings that damage only in the right (but not in the left) hemisphere can sometimes be sufficient to produce the clinical picture of prosopagnosia. Further evidence for face specific brain areas came from single-cell recordings in non-human primates (macaques), where neurons (in the superior temporal sulcus and in the inferior temporal gyrus) respond selectively to faces (Kobatake & Tanaka, 1994, cited in Kandel, 2000).

In spite of being still controversially debated, more and more evidence is pointing towards a domain-specific functioning of the brain in context to human face perception.

“[...] the fact that special-purpose cortical machinery exists for face perception suggests that a single general [...] theory of visual recognition may be less successful than a theory that proposes qualitatively different kinds of computations for the recognition of faces compared with other objects” (Kanwisher et al., 1997, p. 4310).

Models of Face Perception

A very influential theory about face processing was set up by Bruce and Young (1986; Fig. 2). They differentiate between three hierarchical levels: the lowest level respectively the early stage of processing consists of structural encoding (extraction of physiognomic characteristics needed for producing representations or descriptions of faces), followed by the face recognition units (FRU; containing structural information about known faces) and as a last step the person identity nodes (PIN; providing specific information about persons as their interests or their occupation).

According to this model the name of a person is stored separately. The recognition of a known face depends mainly on these levels. Processing of an unfamiliar face involves more steps, beginning with structural encoding and followed by expression analysis, facial speech analysis, and directed visual processing. (Eysenck & Keane, 2002)

This model has some limitations. It proposes that the retrieval of a person's name requires an autobiographical analysis (PIN) first, which is not true as shown by several studies. Another point of criticism is that some persons are able to retrieve a person's name and face, but not any semantic information about the person which is not in line with the model. Burton and Bruce refined this model and developed the “interactive activation and competition model” (1993) – following a more connectionist approach – to account for some of the deficits. The most important difference to the former model concerns the storage of autobiographical and name information. According to Burton and Bruce both

kinds of information are stored in the semantic information units (SIU). Another deficit inherent to both models is the lack of any connection to the underlying cognitive brain structures involved in face processing. (Eysenck & Keane, 2002)

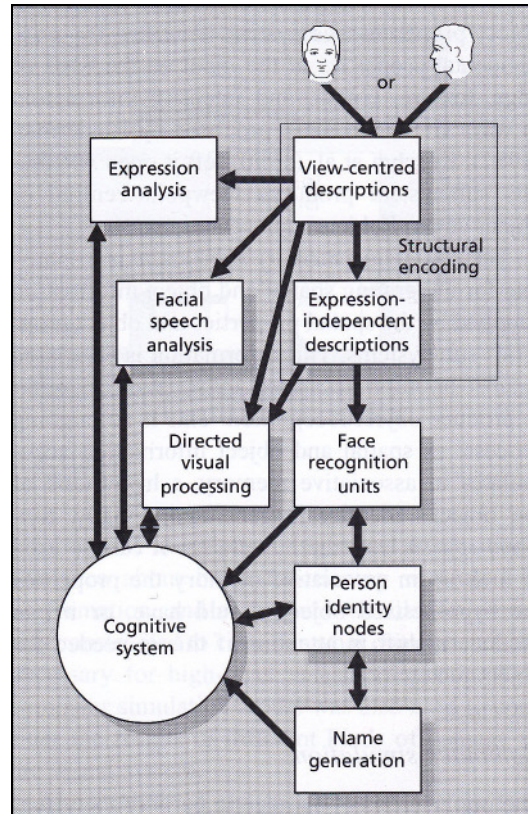


Figure 2. Bruce and Young's model of face recognition (1986) (after Eysenck & Keane, 2002, p. 106)
The starting point in this model is a structural encoding of a seen face. Different steps are following, dependent if the face is familiar or unknown to the beholder.

In the following, models of face processing giving functional descriptions of the areas involved in face processing will be described: the “dual route model” as suggested by Johnson (2005) and the “distributed human neural system for face perception”-model set up by Haxby, Hoffmann, and Gobbini (2000; refined 2007 by Gobbini and Haxby for the recognition of familiar faces).

The “dual route model of face processing” (Fig. 3) as suggested by Johnson (2005) proposes two separate routes - a subcortical and a cortical one. According to this model the subcortical route is characterized by its initial rapid activation and involves the superior colliculus, the pulvinar, and the amygdala. It supports the detection of faces. The subcortical route is suggested to modulate the activity of areas, which are fed by the cortical one, before or during their processing of visual information (Johnson, 2005). Cortical processing comprises face identification, facial expression, and gaze. The

anatomical structures involved are the fusiform gyrus, the inferior occipital gyrus, the amygdala, the orbitofrontal cortex, the sensorimotor cortex, the superior temporal sulcus, and the superior temporal gyrus.

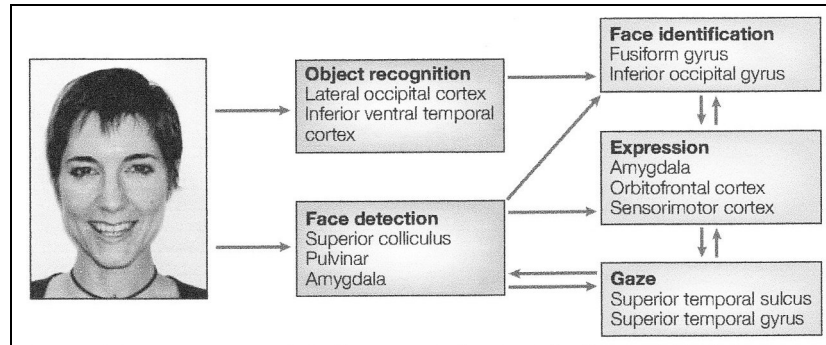


Figure 3. The dual route model as suggested by Johnson (2005)

One subcortical and one cortical route are involved in face processing. Cortical processing consists of face identification (fusiform gyrus and inferior occipital gyrus), facial expression (amygdala, orbitofrontal cortex, sensorimotor cortex), and gaze (superior temporal sulcus, superior temporal gyrus), and is modulated by the faster subcortical route.

Some evidence for this model comes from patients with epilepsy. Recordings from intracranial ERPs showed activation in the amygdala spreading to the occipitotemporal, to the anterior temporal, and to the orbitofrontal cortex. The problem of this model is that it is based on research with stimuli consisting of fearful faces and therefore it should be questioned if this is an appropriate approach for investigating the processing of faces in general.

Another model set up by Haxby et al. (2000; Fig. 4) proposes that human face perception involves numerous bilateral brain regions. It is a somehow hierarchical model consisting of a core system for visual analysis of a face, and an extended system *“that can be recruited to act in concert with the regions in the core system to extract meaning from faces”* (Haxby et al., 2000, p. 233).

The core system comprises regions in occipitotemporal visual extrastriate cortex: the inferior occipital gyrus, the lateral fusiform gyrus, and the superior temporal sulcus. According to this model, the lateral fusiform gyrus is mainly involved in the perception of invariant, static facial features, and the superior temporal sulcus is mainly involved in the perception of changeable, dynamic aspects of a face. Invariant aspects of a face specify identity (recognition of individuals), whereas changeable aspects – including the eye gaze, facial expression of emotions, lip movement and so forth – facilitate social communication. Invariant and changeable aspects are considered to be processed relatively independent from each other, because the identification of a familiar face does not depend on the facial

expression of a distinct moment. The inferior occipital gyri are suggested to provide input to both, the lateral fusiform gyrus and to the superior temporal sulcus (Haxby et al., 2000; Haxby et al., 2002). Evidence for the participation of these brain regions in face perception and processing comes from functional imaging studies (e.g., Kanwisher et al., 1997; Linkenkaer-Hansen et al., 1998; Hoffmann et al., 2000, Herrmann et al., 2005b; Ishai et al., 2005) as well as from single-cell recordings in macaques (Kobatake & Tanaka, 1994, cited in Kandel, 2000).

The extended system comprises additional regions in other parts of the brain that are recruited for further processing of information derived from a face. For example, the perception of emotional facial expressions leads to activation in areas involved in processing of emotions, as in the amygdala, in the insula, and in other regions of the limbic system; the perception of the direction of the eye gaze elicits activity in parietal regions which are associated with spatial attention. (Haxby et al., 2000)

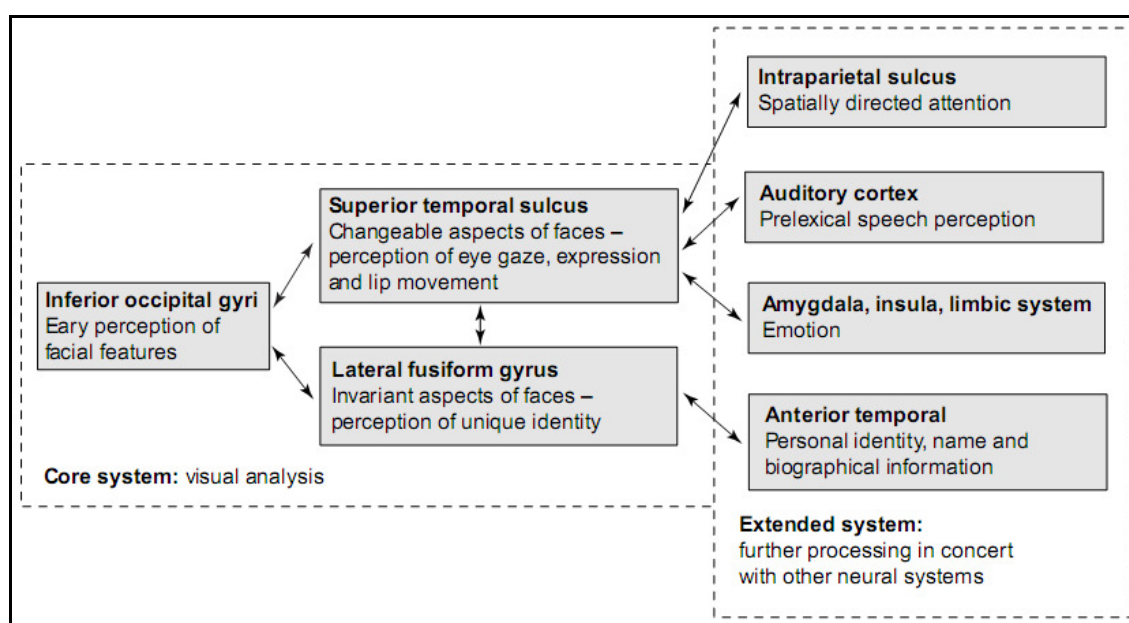


Figure 4. Model of the distributed human neural system for face perception by Haxby, Hoffman and Gobbini (2000)

The model consists of a core system for the visual analysis of a face, and of an extended system for further processing. The various involved areas with their connected functions are described.

Further evidence for the model by Haxby, Hoffman and Gobbini (2007) comes from an fMRI study by Ishai and colleagues (2005). They found bilateral activation with stronger responses in the right hemisphere in the inferior occipital gyri, the fusiform gyri, the superior temporal sulci (comprising the core system of the model by Haxby et al, 2000), amygdala, hippocampus, in the inferior frontal gyri, and in the orbitofrontal cortex (which

can be compared to the extended system). Neural responses were evoked by passive viewing of faces indicating that the mere perception of a face is sufficient to activate the neural network including the visual cortex, the limbic system, and the prefrontal cortex. Gobbini and Haxby (2007) proposed a modified version of their aforementioned model of distributed neural systems for face perception focussing on components that are substantial for the recognition of familiar faces (Fig. 5). Three main components were extracted for this model: analysis of the visual appearance of a familiar face (which accounts for the core system), the representation of person knowledge, and the representations of different emotions (the latter two account for the extended system). The extended system for recognition of familiar faces comprises a set of brain areas that might participate in encoding person knowledge (for example, the anterior paracingulate and the posterior superior temporal sulcus deal with the retrieval of personal traits, attitudes, and so forth). At least three neural structures are involved in representations of different emotions and in responses modulated by the familiarity of faces. (Gobbini & Haxby, 2007)

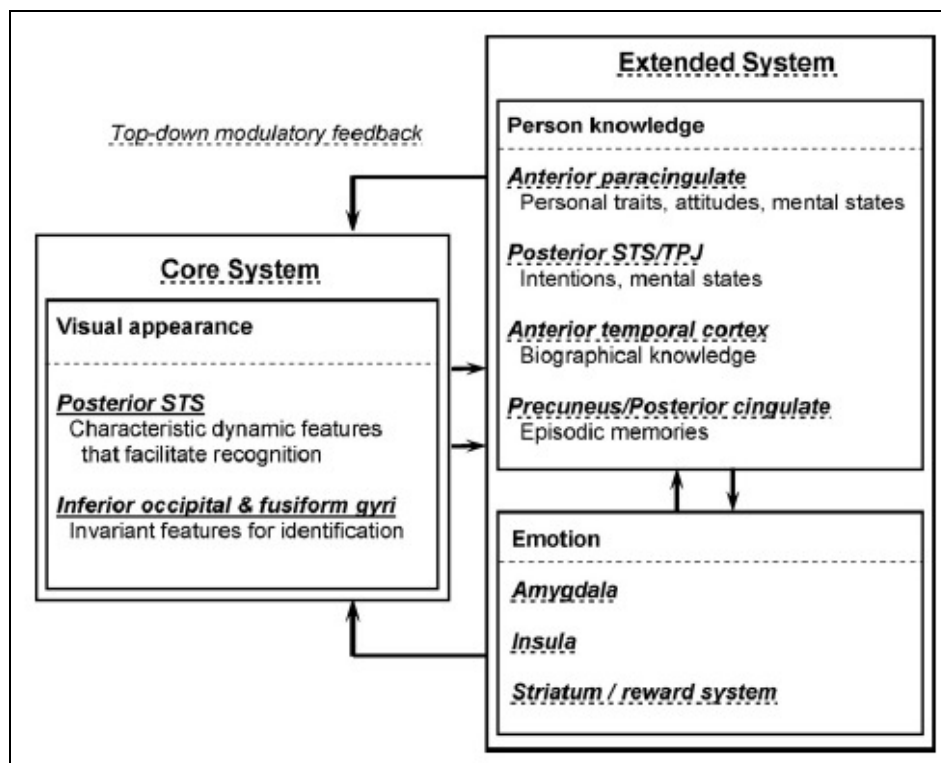


Figure 5. Model for recognition of familiar faces by Gobbini and Haxby (2007)

This model consists of a core system and an extended system, again. Face-responsive areas in the superior temporal sulcus and in the fusiform gyrus are mainly dealing with the encoding of faces, while the extended system is involved in further processing with other neural systems.

It is underlined in all of the aforementioned models that not only visual areas but also other cortical as well as subcortical areas are involved in the perception of faces in humans. All

these areas seem to influence themselves reciprocally at least to some degree. This circumstance is not surprising, seeing that faces are very important stimuli in our daily social world and reading them accurately is essential for social communication.

Event-Related Potentials (ERPs) and the Perception of Faces

In this section the focus lies on the three ERP components investigated in this study, namely the P100, the N170, and the P300, and their role in the perception of faces and face-related stimuli. An ERP is an electrophysiological response to a stimulus and resulting waveforms show distinct patterns of positive (e.g., P100) and negative (e.g., N170) voltage deflections, called peaks or components. The P100 peaks around 100–130 ms with a typical onset around 60–90 ms after stimulus onset. The N170 has its maximum around 150–200 ms after stimulus onset. Both show largest amplitudes at lateral occipital electrode sites. The P300 is a positive deflection in the time range of around 300–700 ms. For details on electroencephalography and ERPs see next chapter (sub chapter “Electroencephalography”).

P100 and N170

Both components are very early brain responses whose underlying cognitive processes in context of face perception in humans are still objects of more (P100) or less (N170) heavy debates. The amplitude of the P100 is considered to be modulated by low-level physical features (e.g., like contrast or luminance), or by attentional effects (Luck et al., 2000; Luck, 2005). But there is a growing body of evidence that the P100 might also play a role in face processing.

In an EEG-study by Bentin and colleagues (1996) they investigated ERPs evoked by human faces, animal faces, human hands, and inanimate non face stimuli (e.g., cars, furniture). They reported a N170 component that was largest over the occipitotemporal cortex with a larger amplitude over the right than over the left hemisphere. This lateralization effect was also reported in other studies, even if not always significant and not displayed by all subjects. Significantly higher amplitudes of the P100 and N170 to faces compared to non facial stimuli (Bentin et al., 1996; Linkenkaer-Hansen et al., 1998; Eimer & McCarthy, 1999; Watanabe et al., 1999, 2005; Streit et al., 2000; Sagiv & Bentin, 2001; Pizzagalli, 2002; Liu et al., 2002; Herrmann et al., 2005b; Xu et al., 2005) were observed. This leads to the assumption that the N170 might reflect structural encoding of faces.

As suggested in a MEG-study by Liu and colleagues (2002) and in an EEG-study by Herrmann and colleagues (2005a), the preceding P100 might reflect processes of early categorization (face/non face) while the N170 might reflect processing of the individual characteristics of faces.

For faces presented upside-down - the so called face inversion effect⁶ - the amplitude of the N170 did not change while its latency was delayed (Bentin et al., 1996), while others report increased amplitudes of both the P100 and the N170 combined with delayed latencies (Linkenkaer-Hansen et al., 1998). These findings are accompanied by observations of behavioural studies of increased reaction times in face recognition tasks due to inverted faces.

The sources of the P100 component were localized in the fusiform gyrus and in the inferior occipital gyrus (Liu et al., 2002; Herrmann et al., 2005a; Watanabe et al., 2005), those of the N170 in the fusiform gyrus (Watanabe et al., 1999; Pizzagalli, 2002; Iidaka, 2005), in the inferior occipital gyrus (Bentin et al., 1996; Linkenkaer-Hansen et al., 1998; Herrmann et al., 2005b) and in the superior temporal sulcus (Watanabe et al., 2005).

Pizzagalli and colleagues (2002) described modulations of the P100 as well as of the N170 to affective judgements (liking versus disliking) of faces. Rigoulot and colleagues (2008) reported modulations of the N170 amplitude according to the emotional content of a face (happy, fearful, and neutral). Utama and colleagues (2009) found that the P100 correlates significantly with the accurate recognition of facial emotion (stimuli faces showed the seven emotions according to Ekman: anger, disgust, fear, happiness, sadness, and surprise) while the N170 was modulated by the perceived intensity level of the emotion, resulting in higher amplitudes when intensity increased. Therefore they propose a phased processing of facial emotion with a rapid (P100) detection followed by a detailed processing including the assessment of intensity shortly afterwards (N170).

In sum, it seems that the N170 is a face selective response reflecting a process specific to the identification of faces (processing of the configural information of facial features) and being possibly affected by emotion. The questions to what extent the P100 contributes to face processing and what cognitive processes it might reflect is still under debate. The P100 might reflect a stage of face categorization processing (Liu et al., 2002; Herrmann et al., 2005b; Utama et al., 2008).

⁶ The so called face inversion effect describes that we take longer and are less accurate in recognizing an inverted face as compared to an upright face.

P300/LPC (Late Positive Component)

As the P300 – also known as LPC (late positive component) – is considered to be an endogenous component its response depends more on internal factors. Usually, the P300 is described to show highest amplitudes at midline electrodes sites (Luck, 2005) with a scalp distribution following $Fz > Cz > Pz$ (e.g., Johnston & Oliver-Rodriguez, 1997; Oliver-Rodriguez et al., 1999; Delplanque et al., 2006; Werheid et al., 2007; Zimmermann, 2008; van Lankveld & Smulders, 2008). Even though this component was the object of many studies there is still no consensus about the neural or cognitive processes the LPC might reflect. The following characteristics are ascribed to the P300: (1) an inverse relationship with subjective stimulus probability, (2) a proportional relationship with task relevance, and (3) a relationship to the affective value of a stimulus. As the third mentioned point seems to be more relevant for the current study I will focus here on findings in this regard.

According to the emotional value theory, the P300/LPC component might reflect an affective encoding of stimulus material. Johnston, Miller, and Burleson (1986; cited in Oliver-Rodriguez et al., 1999) described a U-shaped function of the P300 amplitude depending on the emotional value of the used stimuli. Accordingly, stimuli with high negative or high positive affective value seem to elicit larger P300 amplitudes than neutral stimuli. In contrast, in other studies (Johnston & Oliver-Rodriguez, 1997; Werheid et al., 2007) higher P300 amplitudes were reported responding to attractive as opposed to non-attractive faces. Delplanque and colleagues (2006) and van Lankveld and Smulders (2008) reported similar results.

Identical pictures elicit different P300 amplitudes at different phases of the menstrual cycle (Johnston & Wang, 1991; cited in Oliver-Rodriguez et al., 1999). For example, women in the high progesterone phase showed larger P300 responses (as well as higher pleasantness ratings) to identical pictures of babies compared to the low progesterone phase. “[...] *a stimulus will be considered relevant if it is emotionally significant to the subject, whether that significance is established by task instructions or by his or her internal states or past experiences. [...] From an adaptive viewpoint, emotionally significant stimuli have utility for the accomplishment of survival and reproductive functions.*” (Oliver-Rodriguez et al., 1999, p. 177)

In all these studies task relevance and stimulus probability were experimentally controlled and therefore can not be taken into account for explanations of the results. Taken together, this can be seen to provide further evidence for the emotional value theory of the P300.

Effects of menstrual cycle phase and oral contraceptive use on brain functions

Because of the aforementioned female preference shift for men during the menstrual cycle (reported for the first time by Penton-Voak et al., 1999; Penton-Voak & Perrett, 2000), one aim of this study was to investigate if there are different neural responses in women in the follicular phase compared to the luteal phase, accordingly. The follicular phase of the menstrual cycle is characterized by low concentrations of estrogens and progesterone while the luteal phase is characterized by high concentrations of estrogens (namely estradiol) and progesterone. Another focus of this study was on possible effects caused by the use of oral contraceptives.

Little is known about how fluctuations in endogenous hormone concentrations do influence brain activity during cognitive tasks. These effects of hormones are considered to be relatively transient and dependent on their particular concentrations. Changes in EEG alpha activity were reported to differ significantly over the menstrual cycle (Creutzfeld et al., 1976; Wuttke et al., 1975, both cited in Ehlers, 1996). During the luteal phase an increased alpha rhythm was observed. This finding was accompanied by better performances in psychometric tests dealing with reaction time, simple arithmetics and spatial orientation (Ehlers et al., 1996). Other studies reported similar results. Hampson and Kimura (1992, cited in Maki & Resnick, 2001) found out that in naturally cycling women increases of estrogen (due to natural fluctuations) are associated with improvements in cognitive tasks in which women usually perform better (e.g., verbal articulation, fine motor skills) and with declines in those in which males usually perform better (e.g., visuospatial tests).

Rosenberg and Park (2002) reported an improvement in verbal memory in the follicular phase compared to the luteal phase. Women using hormonal contraceptives remained constant. In contrast, Mordecai et al. (2008) found no differences in the verbal memory when women's performance in the follicular phase was compared to the luteal phase.

Another evidence for different performances across the menstrual cycle comes from a study about the accuracy of facial emotion recognition (Derntl et al., 2008). Women showed a higher accuracy in recognizing the facial expression during their follicular phase compared to accuracy during their luteal phase.

P300 amplitudes in response to emotional stimuli were found to vary with the menstrual cycle (Johnston & Wang, 1991; cited in Oliver-Rodriguez et al., 1999). Women in the high progesterone phase showed larger P300 responses (as well as higher pleasantness ratings) to identical pictures of babies, for example, compared to the low progesterone phase. Krug

et al. (2000) found a generally enhanced P300 (280-500ms post stimulus) in naturally cycling women during their luteal phase. This effect occurred independently from stimulus and task.

Many studies in this field produced contradictory results. One problem might be the inconsistency in assessing the concentrations of estrogen and progesterone in women in different menstrual cycle phase. There are studies where women were tested twice, others in which women were tested five times during cycle. Some use blood (e.g., Derntl et al., 2008) or saliva sample others just count days (e.g., Mordecai et al., 2008) or rely on measurements of oral temperature (e.g., Beaudoin & Marrocco, 2005).

All in all, for a better understanding of how hormones influence brain activity and stimulus processing, possible effects should be considered when designing studies with female participants. As mentioned above, a focus of the present study was to examine possible effects on neural responses due to the menstrual cycle phase (follicular versus luteal phase) as well as to the use of hormonal contraceptives.

1.3 Predictions

The aim of this study was to investigate the early brain processes according to subjective estimated partner preferences. Based on the aforementioned theoretical background and results of previous studies, predictions for this study were derived which are presented below. Predictions for the behavioural data comprise the reaction times (time measured from stimulus onset until a judgment was made by the test person) in association with subjective mate choice. Predictions for the results of the analysis of electrophysiological data contain peak amplitude analysis and latency analysis of early components of the EEG as well as analysis of source localisation with sLORETA.

Behavioural Data

I do not expect any difference in reaction time neither within the male nor within the female participants of the study concerning the answering categories “preferred as a long-term partner” (LT) and “preferred as a short-term partner” (ST), because both have the same significance and none is more important than the other.

Electrophysiological Data

Predictions are derived from results of neuroscientific research in the field of perception and processing of faces.

1. As the stimulus material in this study consists exclusively of human faces, I expect the occurrences of the P100 and of the N170 component in men and women.
 - a. It is assumed that the latency of the P100 is varying substantially depending on the contrast of the used stimulus in the experiment (Luck, 2005) and for inverted faces (Linkenkaer-Hansen et al., 1998). Therefore I do not expect any modulations, because the stimulus faces converted into grey scale should not differ in contrast and they were not presented inverted.
 - b. Latency modulations of the N170 have been observed only in the context of inverted faces. As the faces in this study are presented upright and therefore not converted I do not expect any effects on the latency of this component.
 - c. No differences for the peak amplitude of both the P100 and the N170 are expected in association with subjective partner preferences. As I consider that faces chosen for a potential mate – be it in a long-term or short-term context – are those that are liked and perceived attractive, and peak amplitude modulations have been described to appear for liked versus disliked (Pizzagalli et al., 2002) or for attractive versus unattractive faces (Zimmermann, 2008), no differences are expected to occur.
 - d. As the neural sources generating the P100 component have been described so far to be localized in the fusiform gyrus and in the inferior occipital gyrus (Liu et al., 2002; Herrmann et al., 2005a; Watanabe et al., 2005), while those of the N170 to be localized in the fusiform gyrus (Watanabe et al., 1999; Pizzagalli, 2002; Iidaka, 2005), in the inferior occipital gyrus (Bentin et al., 1996; Linkenkaer-Hansen et al., 1998; Herrmann et al., 2005b), and in the superior temporal sulcus (Watanabe et al., 2005), I expect similar results for my study with women showing a more bilateral activation and men showing a more lateralized activation in the right hemisphere.
2. The predictions for modulations of the P300 are less clear. On the one hand, mate choices “preferred as a short-term partner” and “preferred as a long-term partner” may be associated with different levels of sexual arousal. On the other hand, as faces clearly

identified as potential mates, be it a short-term partner or a long-term partner, are both stimuli of high relevance they may both enhance the P300 amplitude in similar ways.

3. As variations due to menstrual cycle have been described so far I will put a focus on possible differences of women in their follicular phase (high conception risk) compared to women in the luteal phase (low conception risk). The study will focus also on women using hormonal contraceptives.

2. Material & Method

This section provides information on the female and male subjects participating in this experiment as well as on the design of the study and a detailed description of data acquisition. The steps in (pre-) processing the data and the methods used for analysis will also be presented in this chapter.

Collection and (pre-) processing of data took place at the BRL (Brain Research Lab, Institute for Clinical, Biological and Differential Psychology) of the Faculty of Psychology of the University of Vienna from November 2006 until April 2008.

2.1 Subjects

25 right-handed heterosexual women and 25 right-handed heterosexual men aged between 19 and 35 with a mean age of 25.98 ($SD \pm 3.198$) years participated in this experiment. Handedness was determined with the Edinburgh Handedness Inventory (Oldfield, 1971). All participants were heterosexual by self-report and reported to have normal or corrected to normal vision. Furthermore all subjects reported to have no neurological or mental illness and no current medication. The participants were drawn by advertisement and/or word-of-mouth recommendation.

As most of the participants were university students, the lowest level of education reported by 36 test persons was the school-leaving exam (Matura), the remaining 14 participants reported to have a university degree. All 50 subjects were EU-citizens.

The questionnaires and further procedure

At the beginning of the experiment each test person was informed about the procedure of this experiment and about the application of the electrodes in a verbal and a written form. The participants had to sign a declaration of consent (“Probandeninformation und Einverständniserklärung zur EEG-Ableitung”; released by the BRL) and fill in the test for handedness (Edinburgh Handedness Inventory) afterwards. Then the electrodes used for the EEG recording were applied while the test persons were informed and instructed how to fulfil the tasks for this experiment accurately. At the end of the testing (after the EEG-recording) the subjects were required to complete a questionnaire (for details see appendix 1) while the Easy Cap with its electrodes was removed. The questionnaire included questions concerning demographic data such as age, sex, education, occupation and income, as well as sexual orientation and current medication. Female participants were also

asked about the usage of hormonal contraceptives and about information on their cycle. At the end the participants were debriefed.

Female subjects

According to the questionnaire women had to answer questions concerning their menstrual cycle. The purpose was to build groups within the female participants of high and low conception risk. Following Gangestad and Thornhill (1998) and Penton-Voak and Perrett (2000), ovulation was assumed to occur 14 days before the onset of menses. The time after ovulation and before the onset of the following menstruation (the luteal phase) and during menstruation was defined as phase of low conception risk. The time between the end of menses until ovulation (the follicular phase) was defined as high conception risk phase (days 6-14 since onset of the last menses of the participant). Therefore all female participants had to report the exact date (which day of month) of the onset of the last menstruation they had before the experiment and the estimated average length of their cycle. They were also asked to report via email or phone the exact date of the onset of the following menstruation after the experiment had taken place. With this obtained data the phase of cycle (ovulating or not ovulating at the time of testing) respectively the phase of conception risk (high/low) was determined. Of those women reporting regular menstrual cycle and not using any hormonal contraceptives at the time of testing only four women were classified to be in a phase of high conception risk and nine women were classified to be in a phase of low conception risk. One woman had observed cycle duration of 50 days and therefore was not included in further analysis. Eleven of the 25 female subjects reported the usage of hormonal contraceptives and therefore formed one sub sample.

Two female participants had to be excluded from all further analysis for having no regular menstrual cycle. Another woman was excluded only from the behavioural analysis of reaction time according to technical problems. Due to EEG data artefacts another three participants (one male, two females) were excluded from further electrophysiological analysis.

Two female participants had to be excluded from all further analysis for having no regular menstrual cycle. An additional woman was excluded only from the behavioural analysis of reaction time due to technical problems. Due to EEG data artefacts another three participants (one man, two women) were excluded from further electrophysiological analysis.

2.2 Stimulus Material

The stimulus material consisting of 200 front-view photographs of young Caucasians (100 females and 100 males) has been derived from three different previously conducted studies. All these facial photographs were made under standardized conditions which mean that all faces have neutral facial expressions without glasses or any other facial modifications like jewellery or piercing and were not familiar to the participants of this EEG study. The pictures have been scaled into same pixel size as well as same physical size (3x5 cm, 139x185 pixels) and were converted into grey-scale (this was done with the program ImageMagick). The stimuli were presented via a personal computer. During the EEG measurement they were displayed in the centre of a LCD monitor with a resolution of 1024x768 pixels. For examples of used stimuli faces see figure 6.



Figure 6. Examples of a female and a male face used as stimuli in the study.

100 front-view photographs of females and 100 front-view photographs of males with neutral facial expression were used as stimuli for this experiment. Stimuli were transformed into grey scaled pictures of same size and presented during EEG recording.

The first subset of pictures consists of 106 standardized front-view photographs from young men (50) and women (56) used in a geometric morphometrics study by Fink and colleagues, 2005. These faces had been landmarked and rated with respect to their attractiveness and if they are preferred as a long-term or a short-term partner.

The second subset consists of 50 standardised front-view photographs taken from male students during a university course at the University of Göttingen in 2006.

The third subset consists of 44 photos from the Akira Gomi sample, which have already been landmarked and rated according to their attractiveness (Thornhill & Grammer, 1999, Schaefer et al., 2006).

2.3 Study Design

The EEG-experiment consisted of three main sessions and prior test sessions. In these sessions the stimulus faces (consisting of 100 male and 100 female front-view photographs) were shown in randomised order each time to avoid order effects.

For the chronology in the presentation of one stimulus face see figure 7.

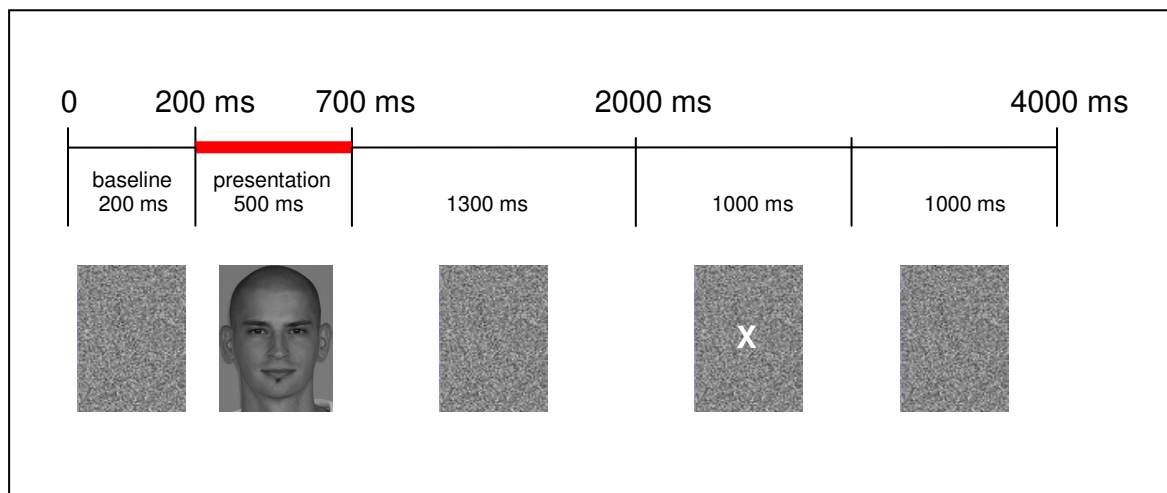


Figure 7. Timeline of one trial as used in this experiment for the presentation of the faces.

The total duration of one trial was 4000 ms, whereas a face was shown for 500 ms after a baseline of 200 ms. In the remaining time (the following 3300 ms after the presentation of the face) as well as at the baseline a noise picture was presented. From 2000 ms to 3000 ms after beginning of the trial the noise picture had a fixation cross in its middle. In this time window the participants were allowed to blink.

The test session

For the test sessions a different set of 15 photographs of faces was shown that was only used in these session to give the participant the possibility to get familiar with the task. In this phase they were trained to carry out the respective task accurately which means to press a key within a distinct time window and to blink when the fixation cross on a noise picture was shown (Fig. 7). Every participant had to do a test session before each of the three main sessions. In case of appearing difficulties the test session had to be passed again until the task performance was accurate.

The three main sessions

In the first main session the subjects were asked to distinguish between male and female faces. This task was defined to ensure that the participants' attention was paid to the stimulus faces. Participants were given the following instruction: „In the middle of the screen in front of you faces will be presented. Before and thereafter you will see a noise

picture. Your task is to distinguish between male and female faces. For male faces press key 1, for female faces press key 2 with the index finger of your right respective left hand. Please do not press a key until you see the noise picture following the presentation of the face. Please blink when you see a cross in the middle of the screen. Try to avoid blinking at other points in time because the collected data might then not be usable for subsequent analysis. Note that the stimulus faces will be presented in fixed intervals, unaffected by your keystroke. Now you will start with a test session to get familiar with the task. Afterwards, the first main session will be carried out“. As this is just a loose translation of the instruction given in German language, see appendix 2 for the original German text.

Participants had to rest their two index fingers on two buttons and press the corresponding one not before the offset of the stimulus-picture (to avoid artefacts by muscular activity). A schematic drawing of the answering box can be seen in figure 8. The EEG-data obtained in the first session was then grouped by the subjective ratings of the faces and used for further statistical analysis. The collected EEG-data from the latter session did not go into statistical analysis. This helped to avoid possible repetition effects, as described for ERPs by Schweinberger and colleagues (1995).

In the ensuing second respectively in the third session the assessment of the ratings of partner preferences (respectively the attractiveness judgements; for details see the study in the centre of the diploma thesis of Zimmermann, 2008) of the shown face took place.

For the second respectively third block they were instructed in the following way: „In the next session the same faces are presented again in randomly order. You should rate them according to their mate value estimated by you. The following ratings can be given: “preferred as a long-term partner”, “rather preferred as a long-term partner”, “rather preferred as a short-term partner”, and “preferred as a short-term partner”. Please rest your left and your right index fingers between the keys of the answering box. Key 1 is assigned with the subjective rating “preferred as a long-term mate”, key 2 with “rather preferred as a long-term mate”, key 3 with “rather preferred as a short-term mate”, and key 4 with “preferred as a short-term mate”. If you are of the opinion that a presented face is not suitable as a potential partner for you, you can press the key assigned with “rather preferred as a short-term mate”. In this session, please press the accurate key as fast as possible without thinking and make intuitive decisions“. As this is just a loose translation of the instruction given in German language, see appendix 3 for the original German text.

According to Buss and Schmitt (1999) the term short-term mating was defined as a mating relationship lasting for a few months or even a single night (one-night stand). Long-term mating is characterised by a long duration, as long marriages for example.

Male subjects had to rate female stimulus faces and female subjects had to rate male stimulus faces according to their perceived mating value. They could choose between the following judgments: the presented face is “preferred as a long-term partner” (LT), was “rather preferred as a long-term partner” (rLT), was “rather preferred as a short-term partner” (rST) or “preferred as a short-term partner” (ST). Because of the need of an answering possibility for not considering the shown face as a partner at all, the participants were instructed to press the key assigned with “rather preferred as a short-term partner” in that case, too. This produced quite a big problem that should be avoided in follow-up studies. This very category then had an ambiguous meaning and therefore accuracy of subsequent interpretation was impossible. Due to this fact I had to exclude all trials in connection with the rating “rather preferred as a short-term partner”: this category contained more than it was labelled for. For not having a disequilibrium in ratings the “rather preferred as a long-term partner”-category was excluded as well. The result was that only two (of originally four) categories were taken into account for further analysis of behavioural as well as electrophysiological data.



Figure 8. Schematic drawing of the answering box.

In the first main session/first block the keys numbered with “2” and “3” were assigned with male and female (counterbalanced). Subjects were instructed to rest their left and right index finger on these keys during task processing. The keys numbered with “1” to “4” were used for the assessment of the subjective ratings for partner preferences. Key assignment from 1 to 4 was in ascending order from “preferred as a short-term partner”, via “rather preferred as a short-term partner” and “rather preferred as a long-term partner” to “preferred as a long-term partner” or in descending order (counterbalanced). The red crosses between the keys 1 and 2 as well as between 3 and 4 mark the position where the left and the right index finger were rested before respectively after a rating of the shown stimulus face was given. These positions were defined to facilitate the pressing of the keys without looking at them (blind) and for having equally distanced answering ways.

The assignments of the answering keys were counterbalanced within the female and within the male subjects as well as between the two sexes to avoid any handedness and lateralization effects.

2.4 Electroencephalography (EEG)

Introduced by Hans Berger in 1929, electroencephalography – in short EEG – is a non invasive method within cognitive neuroscience. Generally, the EEG-signal is recorded from the scalp surface and it measures the electric activity of the brain by changes in voltage over time. It has an excellent temporal resolution but lacks spatial resolution (the opposite is true for imaging techniques like fMRI⁷ or PET⁸). With novel methods like sLORETA (for further information see sub chapter “sLORETA – Standardized Low Resolution Electromagnetic Tomography”) it is nowadays possible to localize the underlying neural generators of such a signal.

Measured voltages on the scalp surface are generated by summed (excitatory or inhibitory) postsynaptic potentials of populations of neighbouring neurons. A single activated neuron creates a tiny dipole, which can sum up with dipoles from many other neurons resulting in measurable voltage on the scalp surface. Summation requires that the dipoles have the same orientation and they must occur at approximately the same time. This is the case in cortical pyramidal cells, which are aligned perpendicular to the surface of the cortex. If the neurons are orientated randomly they would cancel each other.

EEG data is considered to consist of the signal and noise. The noise is stochastically distributed and unrelated to the signal. As the recorded signal is time-locked to the stimulus and most of the noise occurs randomly the noise can be averaged out with averaging of repeated responses (described in more detail in the next chapter).

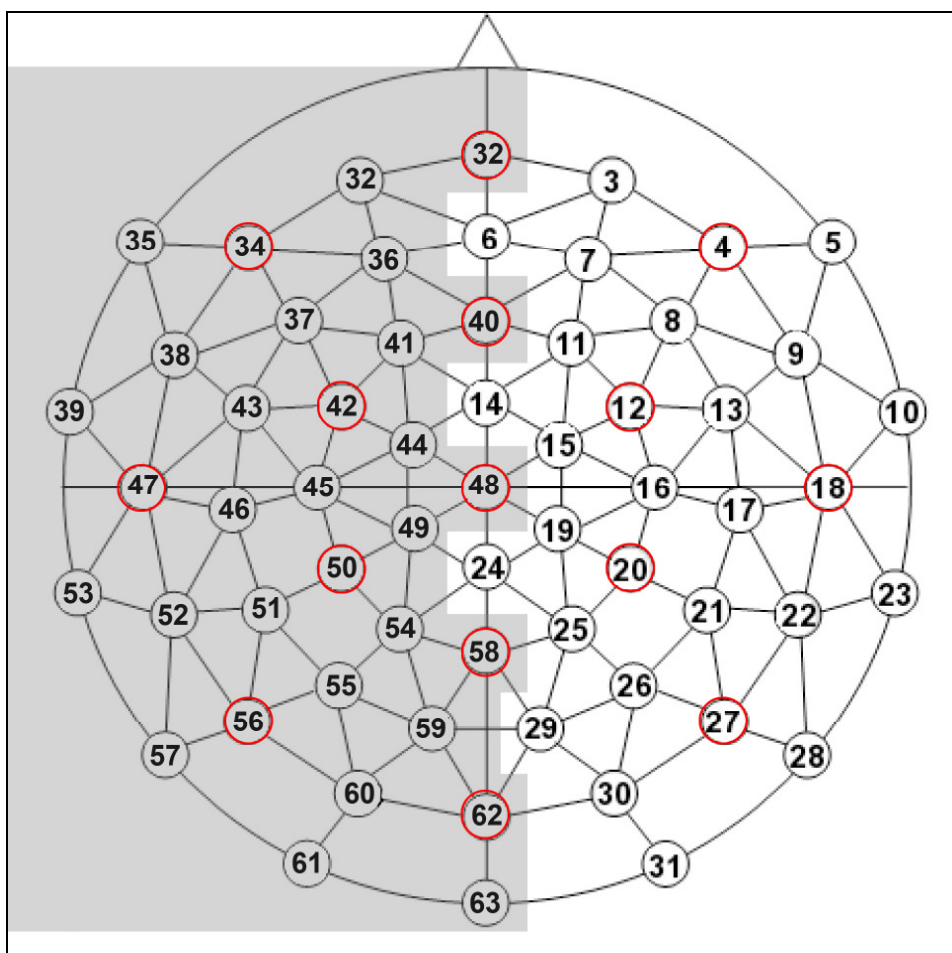
Event-related potentials – in short ERPs – are electric potentials that are evoked by any stimulus, be it e.g. visual, auditory, gustatory, olfactory, or somatosensory. In other words, an ERP is an electrophysiological response to a stimulus. Resulting waveforms consist of a distinct pattern of positive and negative voltage deflections, called peaks or components. P and N are used to indicate positive-going or negative-going peaks (typically, negative peaks are plotted upward while positive peaks are plotted downward) and the number gives the latency of the peak. Among the early ERPs evoked by visual stimuli are the so called P100 and N170. The P100 – marking a positivity and peaking around 100–130 ms and a typical onset around 60–90 ms after stimulus onset – is largest at lateral occipital electrode sites. The N170 – marking a negativity and peaking around 150–200 ms after stimulus onset – is largest at lateral occipital electrode sites as well. Later responses are called endogenous components for their dependence more on internal factors (e.g., P300).

⁷ fMRI measures the haemodynamic response related to neural activity.

⁸ PET: positron emission tomography; it measures metabolic activity.

More detailed information about EEG and ERP technique can be found in Luck (2005), for example.

Application of Electrodes



All cephalic electrodes were referenced against the average of two noncephalic electrodes applied on the vertebra prominens (the seventh cervical vertebra; because of its characteristic long and prominent spinous processus it is easy to feel for it when ones head is forward-turned with the chin pressed to the chest) and on the sternal end of the right clavícula. With a potentiometer the two reference electrodes were weighted for not having an influence by heartbeat.

One mass electrode attached on the forehead was also applied.

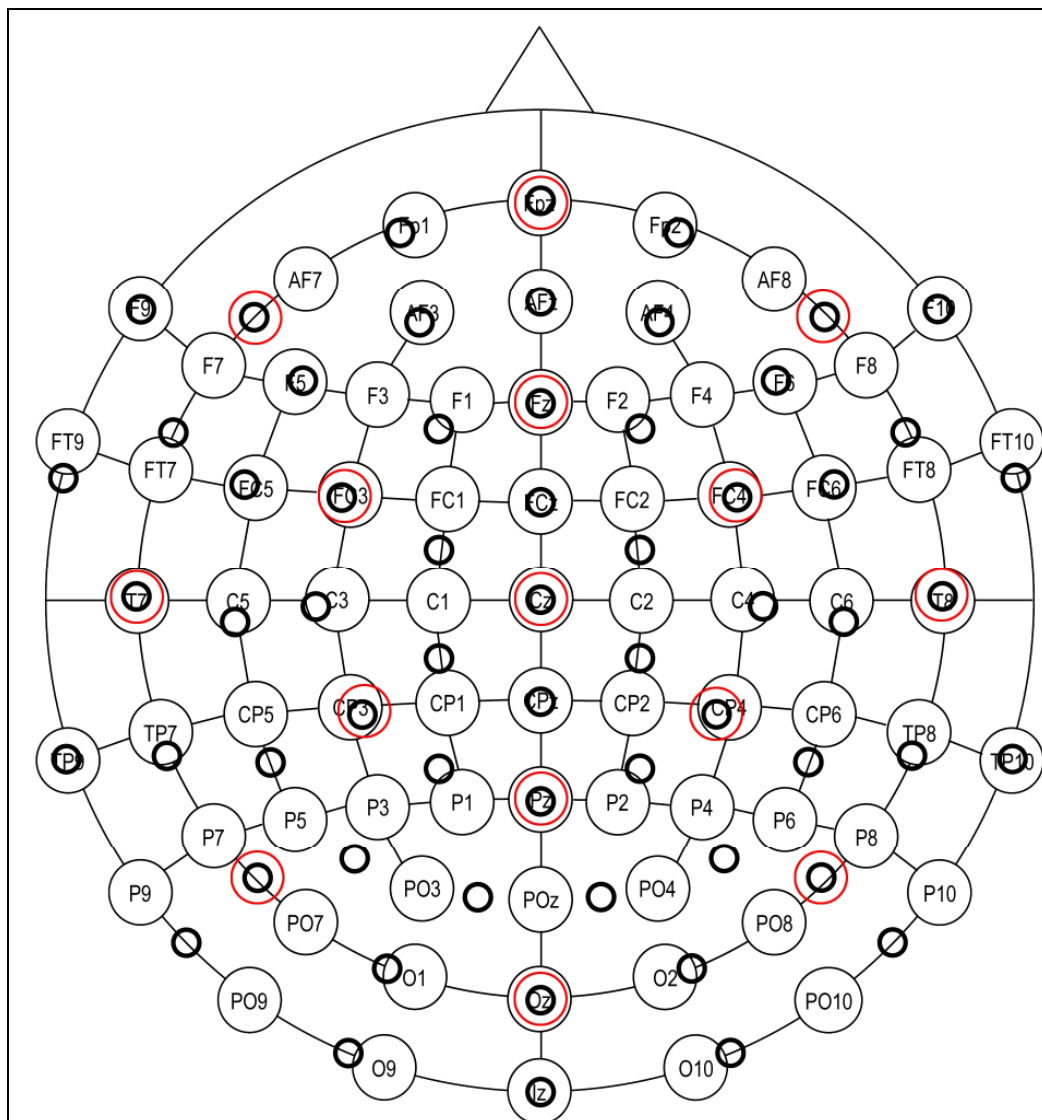


Figure 10. Comparison of the electrode setting of the EEG recording cap to electrode positions of the 10/10 system.

The bold circles mark the positions of the 61 cephalic electrodes of the M10 montage setting of the Easy cap, those with an additional red circle are the electrodes that were used for subsequent statistical analysis. The lighter and bigger grey circles mark the single positions of electrodes following the 10/10 system.

The electrode positions as used in the experimental setting of the current study were nearest neighbours to the following Talairach-electrodes-positions: AFp6, F8h, FFT10h,

AFz, AFF4h, FFC6h, FT8h, FTT10h, FFC2, FC4h, FCC6h, FCz, FCC2, C4, CCP6h, T8h, CCP2, CP4h, CPP6h, TP8h, TP10h, CPz, P2, PPO4, PP08h, P10h, PO2, POO6, POO10, Fpz, Afp5, F7h, FFT9h, AFF3h, FFC5h, FT7h, FTT9h, Fz, FFC1, FC3h, FCC5h, FCC1, C3, CCP5h, T7h, Cz, CCP1, CP3h, CPP5h, TP7h, TP9h, P1, PP03, PP07h, P9h, Pz, P01, P005, P009, Oz, Iz.

For recording of the eye potentials (EOG, electrooculography) four electrodes were used (for the position of these electrodes see figure 11). Two of them - for the horizontal EOG (HEOG) - were applied on the outer canthi of the left and the right eye in a horizontal line with the two pupillae. Another two - for the vertical EOG (VEOG) - were attached below the left eye and above the left margo supraorbitalis (above the eyebrow) in a vertical line with the left pupilla.



Figure 11. Position of the electrodes used for the electrooculography (EOG).

Two horizontal HEOG electrodes and two vertical VEOG electrodes were attached for each subject. The red circles symbolize the positions of each single EOG electrode; the thin black lines show one vertical line that passes the left pupilla and one horizontal line through the left and the right pupillae.

Thus it was possible to compute EOG coefficients (one for the HEOG, one for the VEOG) which were necessary for an EOG correction of the EEG signal. The HEOG coefficient needed to reach a value of 1.00, the VEOG coefficient a value around 0 (whereas a value of 0.1 for the latter one was tolerated).

The fitting of the EEG recording cap (Easy Cap)

Because of different head circumferences within the sample Easy Caps with different sizes were used. For that purpose the head circumference of each participant was measured first to determine the right size of EEG recording cap.

To achieve the most accurate position of the Easy Cap, in the following step the position of Cz (Vertex; the uppermost point of the head) was determined and marked with a make-up pen (in generally well tolerated by the skin and easy to remove). Then the fitting Easy Cap was placed in such a way that the electrode position Cz was where the vertex was marked. To avoid the cap getting out of place the sockets of the three most frontal electrodes

(numbered with 3, 32 and 33; Fig. 9) were stuck to the skin with special adhesive plasters (so called washers). Additionally a breast belt was used, to which the Easy Cap was connected.

Then the skin surface below the electrode sockets was cleaned with alcohol with the help of a cotton swab. With a fine and thin canula (a hollow sterile needle) the scalp surface was gently scratched ("skin scratching"). This was done to decrease the contact resistance between the scalp surface and the electrode. The sockets with the electrodes were carefully filled with a syringe containing degassed electrode paste (an isotonic mixture containing starch and sodium chloride – NaCl) to avoid the occurrence of any air bubbles.

The Recording and Registration of the EEG

For EEG registration a 64 channel DC-amplifier was used. The sampling rate of the EEG signal was defined with 250 Hz (which equals one data point for each electrode every 4 ms). An online band-pass filter from DC – 100 Hz and a 50 Hz-notch filter (the latter helps to filter out noise from electrical devices) were applied. Additionally, a 16 Hz low-pass filter was used.

After application of the electrodes as described in the chapter before and before the recording was started, impedance values for all applied electrodes were checked. The critical value was defined with $3\text{k}\Omega$ which means every electrode had to meet the criterion to be below or equal to $3\text{k}\Omega$. Ideally, the observed impedance value was around $1\text{k}\Omega$, which was true for most of the cases.

The subject was then seated in a semi-dark, electrically shielded and sound-proof room, where the electrodes were connected to the EEG amplifier. The observed potentials were checked for being in the range between $\pm 8000\text{ mV}$ and for drifting. In this connection insufficient results could have been due to a defect electrode, bubbles of air in the electrode paste, inadequate skin scratching or a bent cable (transmission between the single electrodes to the signal amplifier).

Before the beginning of the task processing comprising three main sessions/blocks with prior test sessions, participants had to perform the EOG task for obtaining the EOG coefficients. For this purpose a small red spot appeared alternating at the middle left and at the middle right edge of the LCD monitor (HEOG task) respectively in the middle of the bottom edge and at the top edge (VEOG task). The test period was started when obtained values for the coefficients were sufficient.

For the period of testing the participants sitting in the recording chamber were observed with a camera. This was done for reasons of security and on the other hand to give the test persons the possibility to contact the experimenter.

When the subjects had finished the last task, the EEG recording was stopped. The Easy Cap and the separately attached electrodes (the four for the recording of EOG, the two reference electrodes and the mass electrode) were gently removed. Remaining electrode paste was removed with cotton pads. Afterwards the participants were given the possibility to wash and dry their hair. As a last step the debriefing of the subjects concerning the purpose of the experiment took place.

Finally the used Easy Cap and all electrodes and sockets were carefully cleaned with tepid water and afterwards put in a disinfectant solution for a defined time. The same was done with the syringe used for the electrode paste. After this procedure of disinfecting all these materials were rinsed with water again and let dry.

2.5 Data processing

Pre-processing of the EEG data

The most common causes for artefacts are eye movements and blinks. Therefore, as a first step in pre-processing the electrophysiological data was to undertake a correction in this regard. Automatic EOG correction was applied, which was possible because of the computation of a HEOG coefficient and a VEOG coefficient as described above (see the preceding section), as well as an automatic blink correction. An additional 30 Hz low-pass filter was also applied.

According to the subjective ratings concerning mating preference, the trials within each participant were grouped. That means for every subject four categories of trial classes due to the four different ratings (“preferred as a long-term partner”, “rather preferred as a long-term partner”, “rather preferred as a short-term partner”, “preferred as a short-term partner”) were created. For the male subjects female stimulus faces (and for female subjects male stimulus faces respectively) from the first block were grouped after the subjective rating obtained in the second respectively the third block.

Artefact exclusion

Reasons for eliminating buffers were any kinds of muscle artefacts, vitiation of the baseline and too short answering latencies (i.e. when the rating was made within 500 ms after stimulus onset, which was defined as analysing window; Fig. 7).

All buffers of each single subject were visually inspected for possible artefacts due to muscle activity and for drifts. The most common sources producing artefacts are movements of the eyes and the head, blinking, damaged and/or drifting electrodes or a bent transmission cable. If such an abnormality occurred the concerning buffer was eliminated. To achieve a high level of accuracy this procedure of visual inspection was done twice.

The baseline was defined as a prestimulus interval of 200 ms (as recommended by Luck, 2005) before stimulus presentation/stimulus onset and should not be afflicted with any artefacts. I assumed this period to be unaffected by the stimulus. The baseline represented the “zero point” and when measuring mean amplitudes and/or peak amplitudes it was done in reference to this baseline. For this reason the baseline should not contain large differences in amplitude.

The participants were instructed to press one answering button not before the presentation of the stimulus face was finished. In cases of violating this directive by a judgment made earlier, which means within the analysing window of 500 ms, the related buffer/trial was excluded from further analysis.

Averaging and Grand Means

EEG data is considered to consist of the signal plus random noise. The signal is assumed to be identical in each buffer within a particular condition. The noise – as mentioned above – is stochastically distributed and unrelated to the stimulus. The quality of such a signal is defined with a signal-to-noise ratio (S/N ratio); it compares the power of the desired signal to the power of the “background noise”. By averaging trials together the remaining noise gets smaller; it decreases as a function of square root of the number of trials averaged together, whereas the S/N ratio increases as a function of the square root of the number of trials.

So after grouping the trials according to the ratings for each test person (as described in the section “Pre-processing of the EEG data”), all trials of one category per participant and per channel were averaged together.

Because these averages still contained a certain degree of noise so called Grand Means were generated. This helped to increase the S/N ratio as high as possible for the current

sample. A Grand Mean is an average across all study participants. Thus, averages of the single participants per category were averaged together, resulting in having one Grand Mean for all male test persons as well as one Grand Mean for all female test persons with high conception risk for one distinct category, for instance.

2.6 Analysis of behavioural and electrophysiological data

All statistics were computed with the statistical software package SPSS 13.0. Other programs involved in analysing the data were sLORETA for source localization and GRACE for plotting single ERP waveforms (for details see below).

Level of significance for all analyses is defined by a p -value ≤ 0.05 ; a statistic trend is defined by a p -value ≤ 0.1 .

Analysis of behavioural data

Behavioural data consisted of the frequencies and of the observed reaction times of the subjective partner preference ratings (from the second or the third main session; see chapter 2.2, section “Study design”). The analysis for female and male participants was done separately.

For analysis the natural logarithm of the reaction times in milliseconds was calculated and tested for homoscedasticity (homogeneity of variances). As they were found to be heterogenic for the male as well as for the female sample, the median for each test person for each category was computed. Because of these data following a normal distribution a paired-sample t -test was calculated.

Statistical analysis of electrophysiological data

As a first step a global analysis over 15 selected (of originally 61) electrodes was computed (as mentioned before for all three sub samples separately). This reduction of number of electrodes was done to decrease degrees of freedom. Electrodes were selected for being equally spaced distributed on the head surface and showing typical patterns for their particular region. For position of these electrodes see figure 9, for their position in relation to the 10/10-system see figure 10.

The analysing window of 500 ms was split into timeframes of 100 ms duration each using a moving average window (timeframes of 100 ms with 50 ms overlapping). Table 2 provides an overview of the computed timeframes of this study. Mean amplitude values

were computed for each electrode and timeframe for every subject. Then repeated measurements ANOVA over all electrodes and categories (the remaining categories were LT and ST) were computed for each timeframe separately. For non-sphericity had to be assumed Greenhouse-Geisser adjustment on resulting values was applied.

Table 2. Number of extracted timeframes with specification of the corresponding time sequence in regard to the stimulus onset.

“tf 1” is synonym with the first timeframe which starts with stimulus onset and lasts for 100 ms. The mean amplitude values for each of these 10 timeframes were computed in line with the definition of the analysing window of 500 ms beginning with the onset of the presentation of the stimulus face.

<i>timeframe</i>	<i>Time sequence referring to stimulus onset</i>
tf 1	0–100 ms
tf 2	50–150 ms
tf 3	100–200 ms
tf 4	150–250 ms
tf 5	200–300 ms
tf 6	250–350 ms
tf 7	300–400 ms
tf 8	350–450 ms
tf 9	400–500 ms
tf 10	450–550 ms

As being discussed for potentially playing a crucial role in face perception, the EEG components P100 and N170 were investigated by an analysis of their peak amplitudes and by an analysis of the peak latencies computing *t*-tests on the relevant electrodes. This means that for each test person and each rating the maximum/minimum voltage value (the maximum one in case of the P100, the minimum one in case of the N170) at a distinct time (around 100 ms post stimulus for the P100 and around 170 ms post stimulus for the N170 – for the test persons the ideal time window was determined after visual inspection) was specified. Then within every sample/sub sample these resulting values were compared due to the subjective mating preference. Peak analyses were performed for the electrodes 27, 28, 56 and 57, for the occurrences of the P100 and the N170 waveform at these electrode sites could have been expected according to the literature (Bentin et al., 1996; Linkenkaer-Hansen et al., 1998; Watanabe et al., 1999; Sagiv & Bentin, 2001; Herrman et al., 2005; Watanabe et al., 2005; Luck, 2005; Utama et al., 2009). The aim was to investigate possible differences in amplitude and/or latency due to the subjective partner preference and differences in amplitude in the left compared to the right hemisphere.

As a third component an early part of the P300 (or LPC – late positive complex) ranging from 300 ms to 500 ms – in accordance to the analysing window – was analysed. In contrast to the P100 and N170, the latter one was studied by comparisons of mean amplitudes of distinct electrodes of the central line, for the P300 was not accessible by marking a peak for being a long component. As this component is reported to show highest amplitude at midline electrodes, electrodes 6 (AFz), 48 (Cz), and 58 (Pz) were selected for an analysis in this regard. Therefore it was analysed by a repeated measurements ANOVA using electrodes (3) and answering categories LT and ST (2) as within subject-factor and for females additional between subject-factors (high/low conception risk (2) or use/non-use of hormonal contraceptives (2)). Being stimuli of high social and biological relevance, possible effects of faces rated as long-term or as short-term partner on the P300 component were investigated.

GRACE

For visualising the ERP waveforms for single electrodes, GRACE was the program of choice. It served for macroscopic inspection of single person averages per category as well as of the Grand Mean across all the subjects per category. Plots used in this study are made with this program.

sLORETA – Standardized Low Resolution Electromagnetic Tomography

The free academic software package sLORETA (Pascual-Marqui, 2002) was used to perform an analysis of source localization, namely of the P100 and the N170 component (also done by Herrmann et al., 2005b; Utama et al., 2009, for example). With this software it is possible to compute images of the centre of an electric neural activation from EEG.

EEG is a non-invasive method that possesses a very high temporal resolution, but lacks of spatial resolution (the opposite is true for fMRI or PET). The EEG signal is recorded from the scalp surface which can be compared to a two dimensional space. Its sources are located in the cortex, which is a three dimensional space. Consequently, from a known single dipole in the cortex it is hypothetically possible to predict the localization of a potential on the scalp (the so called “forward problem”). The so called “inverse problem” describes the process of deducing the localization of dipoles on the basis of a known voltage distribution on the scalp. This problem is not that easy to solve because there is an infinite number of possible assemblies of dipoles that could produce that distribution. In literature this is known as the “non-uniqueness of the inverse solution”. The sLORETA

software provides a solution to the inverse problem with zero localization error (under ideal conditions).

sLORETA is a tomographic method for electric neuronal activity through which localization inference is based on images of standardized current density. Therefore the brain is divided into voxels which leads to a solution space containing 6239 voxels with a resolution of 5mm. A pattern of activation can be found which fits the surface voltage pattern best.

The basic assumption of the sLORETA technique for estimating the electric neuronal generators is “[...] *that the voltage will change gradually (across the volume of the brain or across the cortical surface) and selects the distribution of source magnitudes that is maximum smooth*” (Luck, 2005, p. 284). Existing sharp borders between neighbouring anatomical areas may lead to a change in current flow, so this method should only be used in an experimental design, where activation in a distinct area, not in neighbouring areas, is expected (which is true for the present study). This constraint makes the sLORETA technique suitable for finding the centre of activation but not for assessing the extent of activation.

When compared to other solutions of the inverse problem, sLORETA yields the most exact localization (under ideal conditions it localizes exactly) and is therefore the method chosen in this study. For more technical details on sLORETA see Pascual-Marqui (2002), for further reading and more techniques concerning ERP localization see Luck (2005).

3. Results

This section is divided into two main parts. In the first part an insight into the behavioural data consisting of the frequencies of the different ratings of partner preference and the analysis of the reaction time (due to the given rating) will be given. In the second section the results of the neurophysiologic data obtained by EEG will be presented. This includes a global analysis of the electrophysiological data as well as peak analysis and latency analysis of early components observed in the EEG-data. Additional results of source localization of the P100 and of the N170 using the software sLORETA will be shown.

All analyses were done for men and women separately. The female sample consisted of three sub-samples: (1) naturally cycling women in a phase of high conception risk (HCR), (2) naturally cycling women in a phase of low conception risk (LCR), and (3) women using hormonal contraceptives (HC).

3.1 Behavioural data

The behavioural data-set consists of the subjective ratings of the opposite-sex stimuli faces being considered either as a long-term partner or as a short-term partner and the time every single test person needed to give his/her subjective rating.

Two women (for having irregularities in their menstrual cycle) had to be excluded from the behavioural data analysis, leaving a sample of 25 men and 23 women. Due to a technical problem (no reaction times were recorded) another woman had to be excluded from analysis of reaction time, leaving a sample of 25 men and 22 women.

Ratings of Partner Preference

As described above the participants were asked to rate each stimulus face according to its estimated partner value. Table 3 provides an overview on the absolute and the relative frequencies of the ratings either “preferred as a short-term partner” (ST) or “preferred as a long-term partner” (LT). Results of female subjects are shown for the distinct sub sample (for details of the frequencies in association with the excluded “rather”-categories see appendix 4).

In women, the category with the smallest number of ratings is “preferred as a long-term partner” (LT) which is consistent through all sub-samples. For the males the opposite is true.

Table 3. Absolute and relative frequencies of all given ratings of subjective mating preference.

Presented ratings are split by sex. Results of female subjects are shown for the distinct sub-sample (females having a high and those having a low risk for conception as well as females using hormonal contraceptives). One rating from an ovulating woman (high conception risk) is missing as well as 5 ratings from not ovulating women (low conception risk) and 9 from female subset of participants using hormonal contraceptives. A total of 21 ratings are missing from male test persons. Missing data results from not giving any response to a stimulus face.

Answering categories	Absolute frequencies		Relative frequencies	
	LT	ST	LT	ST
Males rating female faces (n=25)	503	416	54.7	45.3
Females rating male faces (n=23)	422	620	40.5	59.5
Female sub-sample HCR (n=4)	86	113	43.2	56.8
Female sub-sample LCR (n=8)	182	240	43.1	56.9
Female sub-sample HC (n=11)	154	267	36.6	63.4

LT = preferred as a long-term partner; ST = preferred as a short-term partner; HCR = Sub-sample of female participants in a high conception risk phase rating male stimulus faces; LCR = Sub-sample of female participants in a low conception risk phase rating male stimulus faces; HC = Sub-sample of women using hormonal contraceptives rating male stimulus faces

Analysis of Reaction Time

Reaction time was defined as the time between the onset of the presentation of the stimulus face until one of the possible four keys was pressed.

Because of the above mentioned problem underlying the category rST, both “rather”-categories (rST, rLT) were excluded leaving only the two categories LT and ST for the analysis of reaction time. Analyses were done for the males and the females separately, so computations were done with two – a male and a female – data-sets.

Reaction times per subject and per category (ST and LT) were checked for homoscedascity of variances first. Resulting in having heterogenic variances the median for each person per category was computed. As these data followed a normal distribution a paired sample *t*-test was computed for males and females separately. For an overview, the means of the reaction times for the two partner preferences LT and ST are displayed for the male sample and for the female sub-samples in table 4.

No differences of reaction times for the rated preferences for mating were observed in the male sample. In the female sample reaction times did not show any difference when

controlled for the phase of conception risk (high/low). The use of hormonal contraceptives had no influence on reaction times concerning different mating preferences as well.

Table 4. Means of reaction times in men and women according to the partner preferences LT and ST. Mean reaction times in milliseconds (M) and standard deviation (SD) for the two different mate choice categories LT and ST are presented. Results of female subjects are shown for the distinct sub-sample (females having a high and those having a low risk for conception as well as females using hormonal contraceptives).

Answering categories	M		SD	
	LT	ST	LT	ST
Males rating female faces (n=25)	1192.1	1187.5	326.2	323.0
Female sub-sample HCR (n=4)	1199.2	1177.2	85.9	148.4
Female sub-sample LCR (n=8)	1275.3	1213.3	230.2	165.6
Female sub-sample HC (n=11)	1251.6	1281.7	288.1	408.3

LT = preferred as a long-term partner; ST = preferred as a short-term partner; HCR = Sub-sample of female participants in a high conception risk phase rating male stimulus faces; LCR = Sub-sample of female participants in a low conception risk phase rating male stimulus faces; HC = Sub-sample of women using hormonal contraceptives rating male stimulus faces

3.2 EEG-Data

One man and two women had to be excluded from the analysis of the electrophysiological data because of massive muscle artefacts. Another two women were also dismissed for having irregularities in their cycle length (39 and 50 days). Hence EEG-data of 24 men and 21 women were analysed. All analyses were done for men and women separately.

The female participants rating male stimuli faces were divided into three sub-samples: (1) naturally cycling women in a phase of high conception risk (HCR; $n = 4$), (2) naturally cycling women in a phase of low conception risk (LCR; $n = 7$), and (3) women using hormonal contraceptives (HC; $n = 10$). For reasons of comparability naturally cycling women ($n = 4$; mean cycle length of 27.50 days, $SD \pm 2.646$) were juxtaposed to four (out of seven) randomly drawn naturally cycling women in a phase of low conception risk ($n = 4$; mean cycle length of 30.25 days, $SD \pm 3.01$). Results for the female subjects are presented with naturally cycling women in a high versus low phase of conception risk, and naturally cycling women in a low phase of conception risk versus women using hormonal contraceptives. For number of buffers in analyses see appendix 5.

The analysis of the electrophysiological data includes the following sub chapters: At first a global analysis of mean amplitudes will be shown. Then the focus will be on the P100 component, starting with peak amplitude analysis and a peak latency analysis, followed by source localization using sLORETA. Next, the N170 component will be investigated, including the same steps as the aforementioned P100. In the end the early part of the P300 will be analysed.

Global analysis of mean amplitudes

Repeated measurements ANOVA was computed over electrodes and answering category LT or ST for each single timeframe (Tab. 1). In the following all analyses will be presented for male and female subjects separately, with the female sample divided in two sub samples.

Electrode – as a factor – showed a significant main effect in nearly all timeframes in each sample as expected for healthy subjects and is therefore not reported furthermore.

Male sample

Repeated measurements ANOVA was performed with electrodes (15) and mate choice categories “preferred as a long-term partner” (LT) and “preferred as a short-term partner” (ST) (2) as within subject factors on each timeframe.

In timeframe 1 (0–100 ms) a trend could be observed in the interaction between electrode and answering category ($p = 0.091$), which reached significance in timeframe 2 (50–150 ms; $p = 0.026$).

Despite the aforementioned significant main effect of the factor electrode, no other significant main effects or significant interactions were observed nor were any statistical trends found.

Naturally cycling women in high versus low conception risk phase

Repeated measurements ANOVA was performed with electrodes (15) and mate choice categories LT and ST (2) as within subject factors and high/low conception risk (2) as between subject factor on each timeframe separately.

Despite the aforementioned significant main effect of the factor electrode, no other significant main effects or significant interactions were observed nor were any statistical trends found.

Naturally cycling women in low phase of conception risk versus women using hormonal contraceptives

Repeated measurements ANOVA was performed with electrodes (15) and mate choice categories LT and ST (2) as within subject factors and use/non-use of hormonal contraceptives (2) as between subject factor on each timeframe separately.

Following trends were observed: in timeframe 2 (50–150 ms) and timeframe 3 (100–150 ms) a trend in the interaction between electrode and use of hormonal contraceptives ($p = 0.075$ and $p = 0.057$).

Despite the aforementioned significant main effect of the factor electrode, no other significant main effects or significant interactions were observed nor were any statistical trends found.

Peak analysis of the P100

For the analysis of peak amplitude of the P100 the following electrodes were selected: 27 and 28 on the right side, 56 and 57 on the left side (as described in detail in chapter 2.7). A comparison of the amplitude values due to the subjective partner preference was computed and differences in hemisphere were investigated. Females participants were controlled for phase of conception risk respectively usage of hormonal contraceptives, additionally.

Male sample

Differences were observed concerning the different partner preferences LT and ST in electrode 28 ($p = 0.019$). Estimated short-term partner evoked a stronger positive deflection than estimated long-term partner. For electrode 27 only a trend could be observed (for absolute mean amplitude values see table 5). No differences were observed at the corresponding electrodes on the left hemisphere (Tab. 6, Fig. 12 & 13).

Table 5. Effect caused by mate preference on the P100 in male subjects.

Mean amplitudes in μV (M) and standard deviation (SD) for the P100 component for the two different mate choice categories LT and ST in males at the investigated electrodes. In the last line resulting p -values when LT was compared to ST at a distinct electrode are displayed.

	LT		ST		p
	M	SD	M	SD	
<i>Electrode 27</i>	2.34	3.47	4.13	4.01	0.052
<i>Electrode 28</i>	1.28	3.26	3.31	3.26	0.019
<i>Electrode 56</i>	1.09	3.41	2.14	4.35	>0.1
<i>Electrode 57</i>	0.90	3.97	1.56	4.04	>0.1

Peak amplitudes of the P100 were significantly higher in the right (electrode 27) compared to the left (electrode 56) hemisphere ($p = 0.021$). For the comparison of electrode 28 with electrode 57 a trend could be observed with $p = 0.081$ (mean amplitude values are displayed in table 6).

Table 6. Effect caused by hemisphere on the P100 in men.

Mean amplitudes (M) in μV and standard deviation (SD) for the P100 component at the investigated electrodes.

	M	SD
<i>Electrode 27</i>	3.24	3.81
<i>Electrode 56</i>	1.62	3.91
<i>Electrode 28</i>	2.30	3.39
<i>Electrode 57</i>	1.23	3.98

For the P100 waveform in regard to the mate choice categories LT and ST of men viewing female faces displayed at the four investigated electrodes see figures 12 and 13.

Naturally cycling women in high versus low conception risk phase

No differences in the P100 amplitude were evoked by the subjective partner preferences LT or ST. No differences in the amplitude could be observed in regard to high versus low conception risk phases as well as no differences in the P100 amplitude were observed, when right and left hemispheres were compared.

For the P100 waveform in regard to the answering categories “preferred as a long-term partner” and “preferred as a short-term partner” of naturally cycling women in high versus low conception risk phase looking at male stimulus faces displayed at the four investigated electrodes (electrodes 27, 28, 56, 57) see figures 14 and 15.

Naturally cycling women in low phase of conception risk versus women using hormonal contraceptives

No differences in the P100 amplitude appeared in relation to subjective partner preferences LT or ST. The evoked potentials of the ST-category did not differ from those of the LT-category (for the P100 waveform see figures 16 and 17; for a description of further results see page 60).

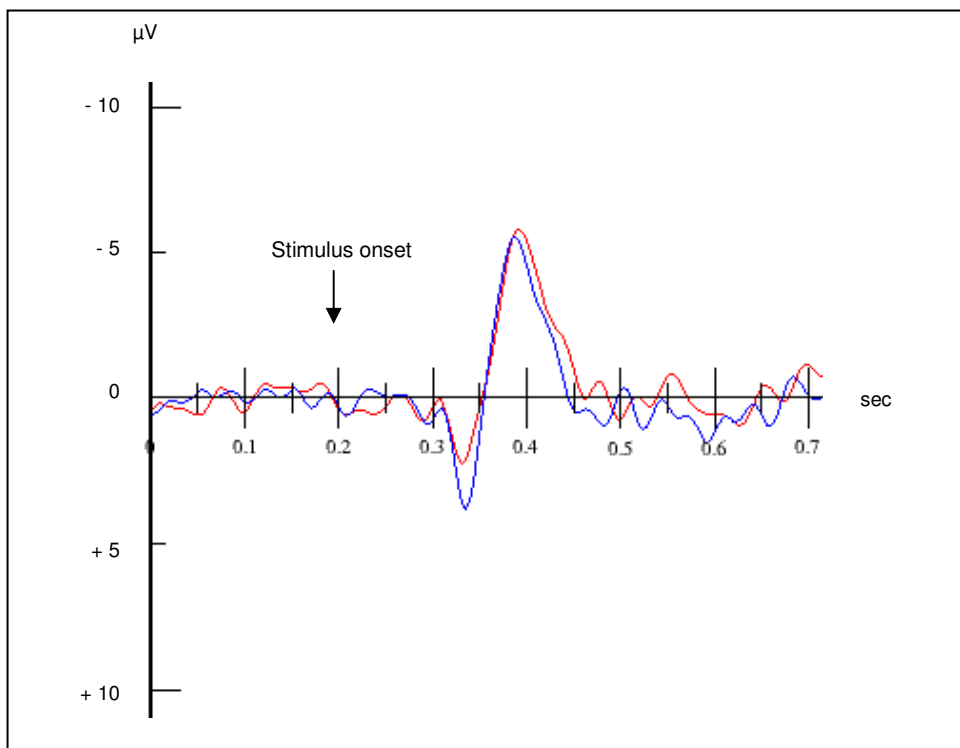
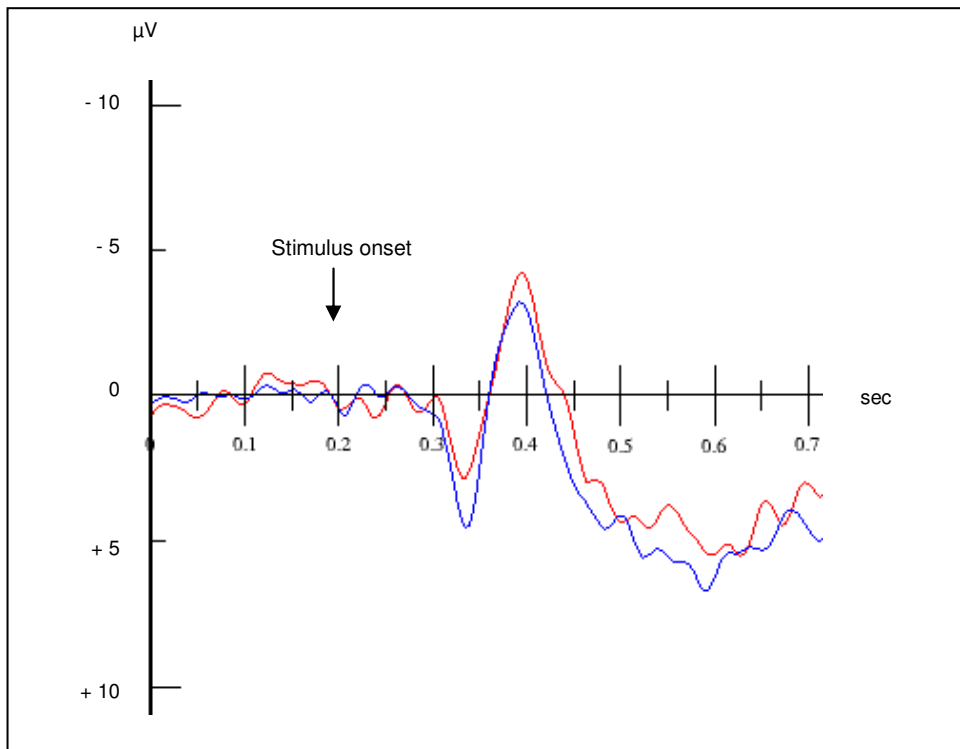


Figure 12. P100 and N170 waveform at the electrodes 27 (upper panel) and 28 (lower panel) in men of the answering categories LT and ST.

The red line corresponds to the answering category LT, the blue one to ST. Note that the baseline ranges from 0 to 0.2 sec. Stimulus presentation starts at 0.2 sec and lasts until 0.7 sec. For the corresponding electrode on the other hemisphere see electrode 56 and 57 respectively (Fig. 13).

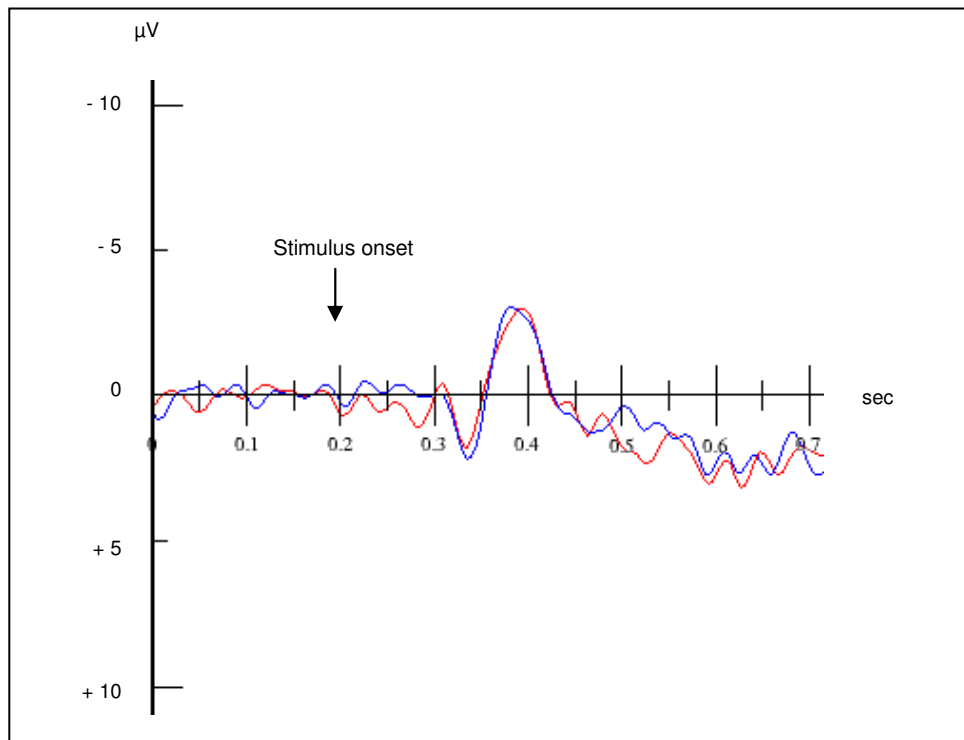
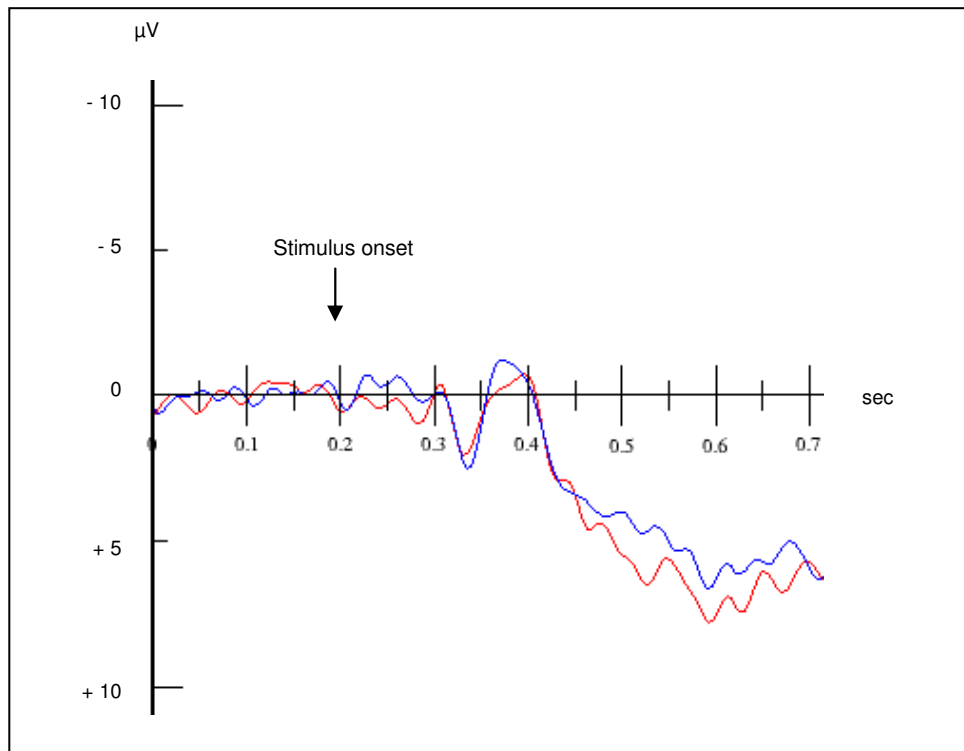


Figure 13. P100 and N170 waveform at the electrodes 56 (upper panel) and 57 (lower panel) in men of the answering categories LT and ST.

The red line corresponds to the answering category LT, the blue one to ST. Note that the baseline ranges from 0 to 0.2 sec. Stimulus presentation starts at 0.2 sec and lasts until 0.7 sec. For the corresponding electrode on the other hemisphere see electrode 27 and 28 respectively (Fig. 12).

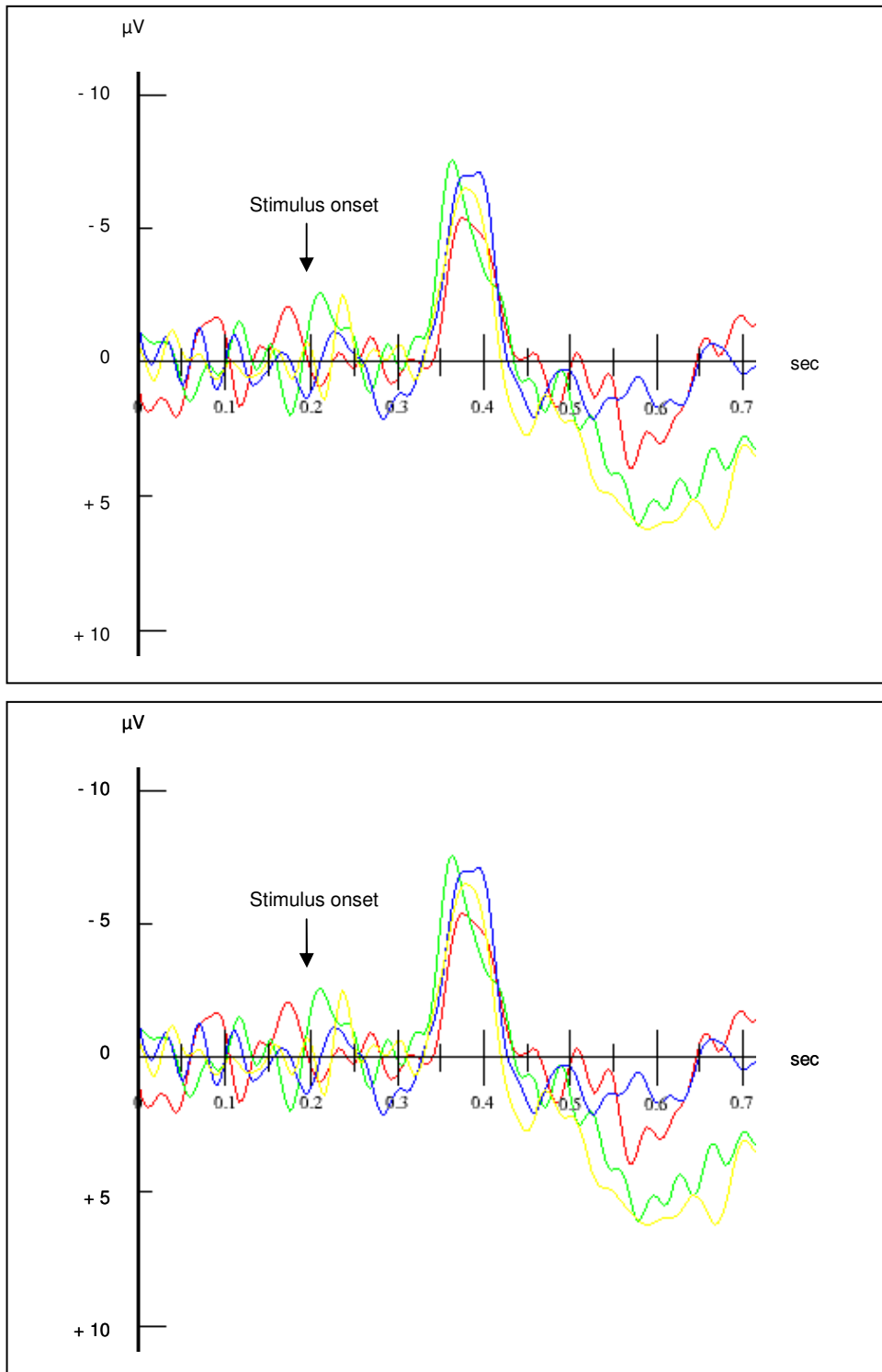


Figure 14. P100 and N170 waveform of the answering categories LT and ST at the electrodes 27 (upper panel) and 28 (lower panel) in naturally cycling women in a high versus low conception risk.

The red and the blue line represent women in a high conception risk phase, with red corresponding to the answering category LT and blue corresponding to the answering category ST. The green and the yellow line represent women with low conception risk, with green corresponding to the answering category LT and yellow corresponding to the answering category ST. Note that the baseline ranges from 0 to 0.2 sec. Stimulus presentation starts at 0.2 sec and lasts until 0.7 sec. For the corresponding electrode on the other hemisphere see electrode 56 and 57 respectively (Fig. 15).

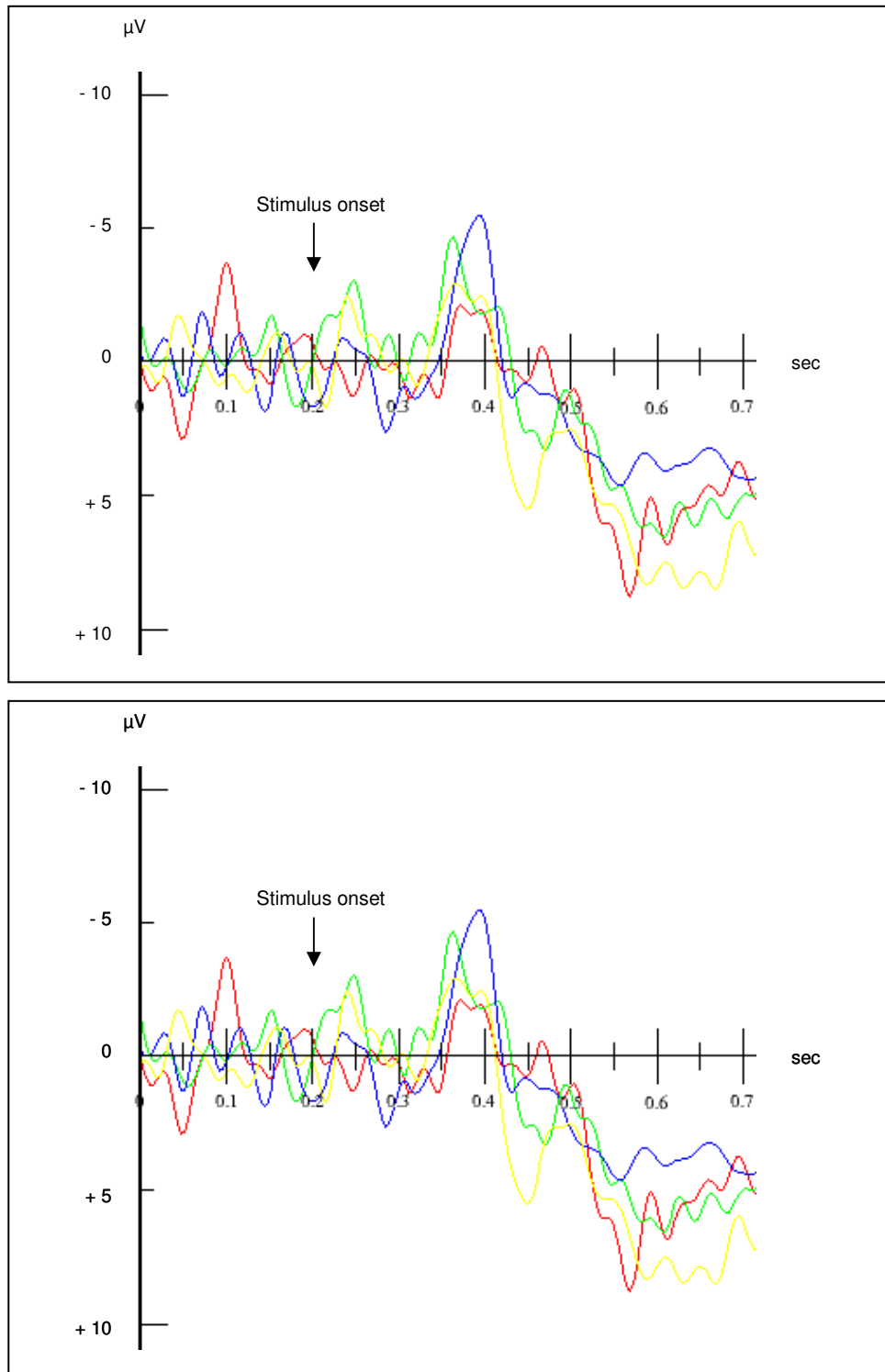


Figure 15. P100 and N170 waveform of the answering categories LT and ST at the electrodes 56 (upper panel) and 57 (lower panel) in naturally cycling women in a high versus low conception risk.

The red and the blue line represent women in a high conception risk phase, with red corresponding to the answering category LT and blue corresponding to the answering category ST. The green and the yellow line represent women with low conception risk, with green corresponding to the answering category LT and yellow corresponding to the answering category ST. Note that the baseline ranges from 0 to 0.2 sec. Stimulus presentation starts at 0.2 sec and lasts until 0.7 sec. For the corresponding electrode on the other hemisphere see electrode 27 and 28 respectively (Fig. 14).

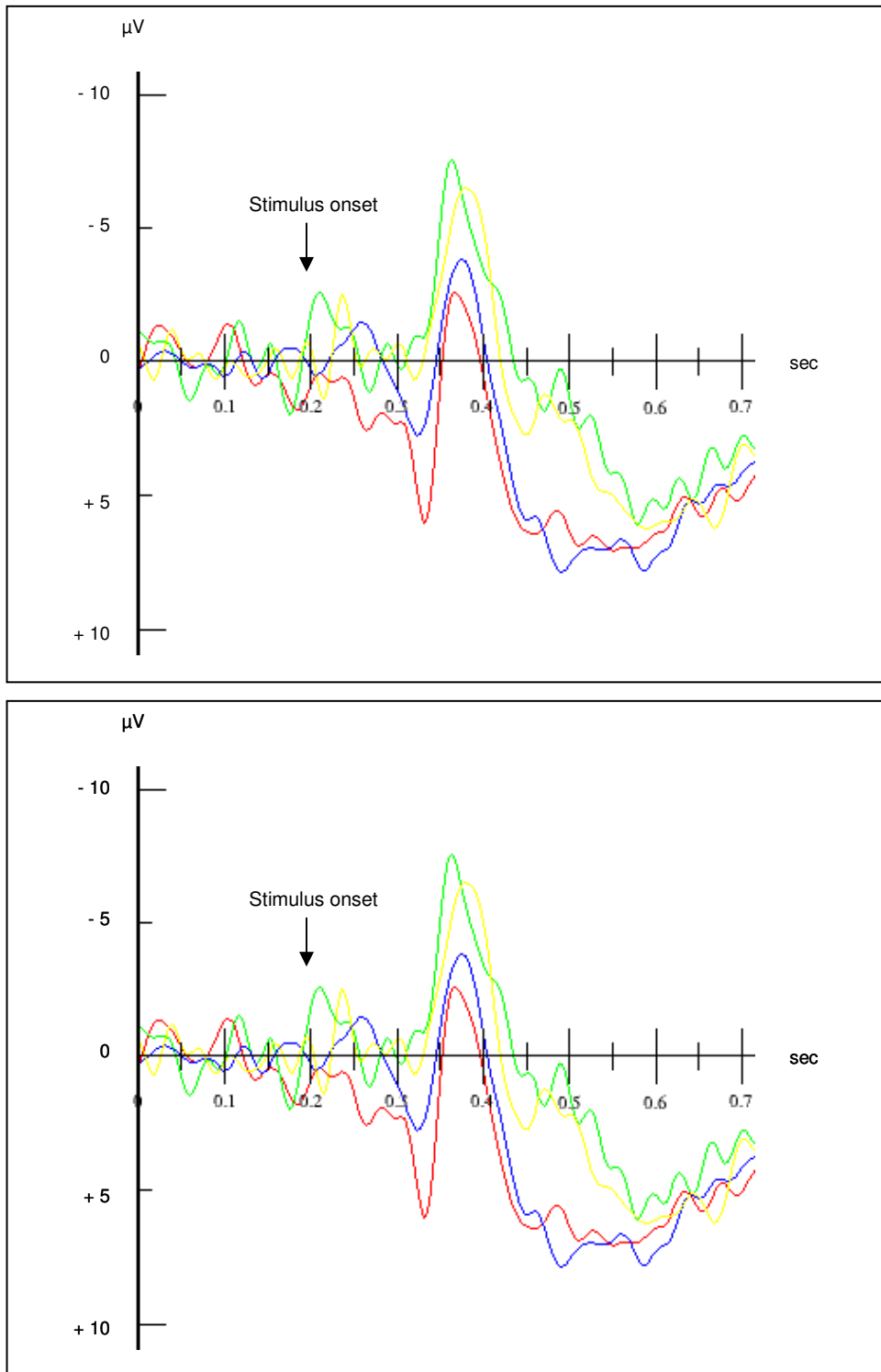


Figure 16. P100 and N170 waveform of the answering categories LT and ST at the electrodes 27 (upper panel) and 28 (lower panel) in naturally cycling women with a low conception risk versus women using hormonal contraceptives.

The red and the blue line represent women using hormonal contraceptives, with red corresponding to the answering category LT and blue corresponding to the answering category ST. The green and the yellow line represent women with low conception risk, with green corresponding to the answering category LT and yellow corresponding to the answering category ST. Note that the baseline ranges from 0 to 0.2 sec. Stimulus presentation starts at 0.2 sec and lasts until 0.7 sec. For the corresponding electrode on the other hemisphere see electrode 56 and 57 respectively (Fig. 17).

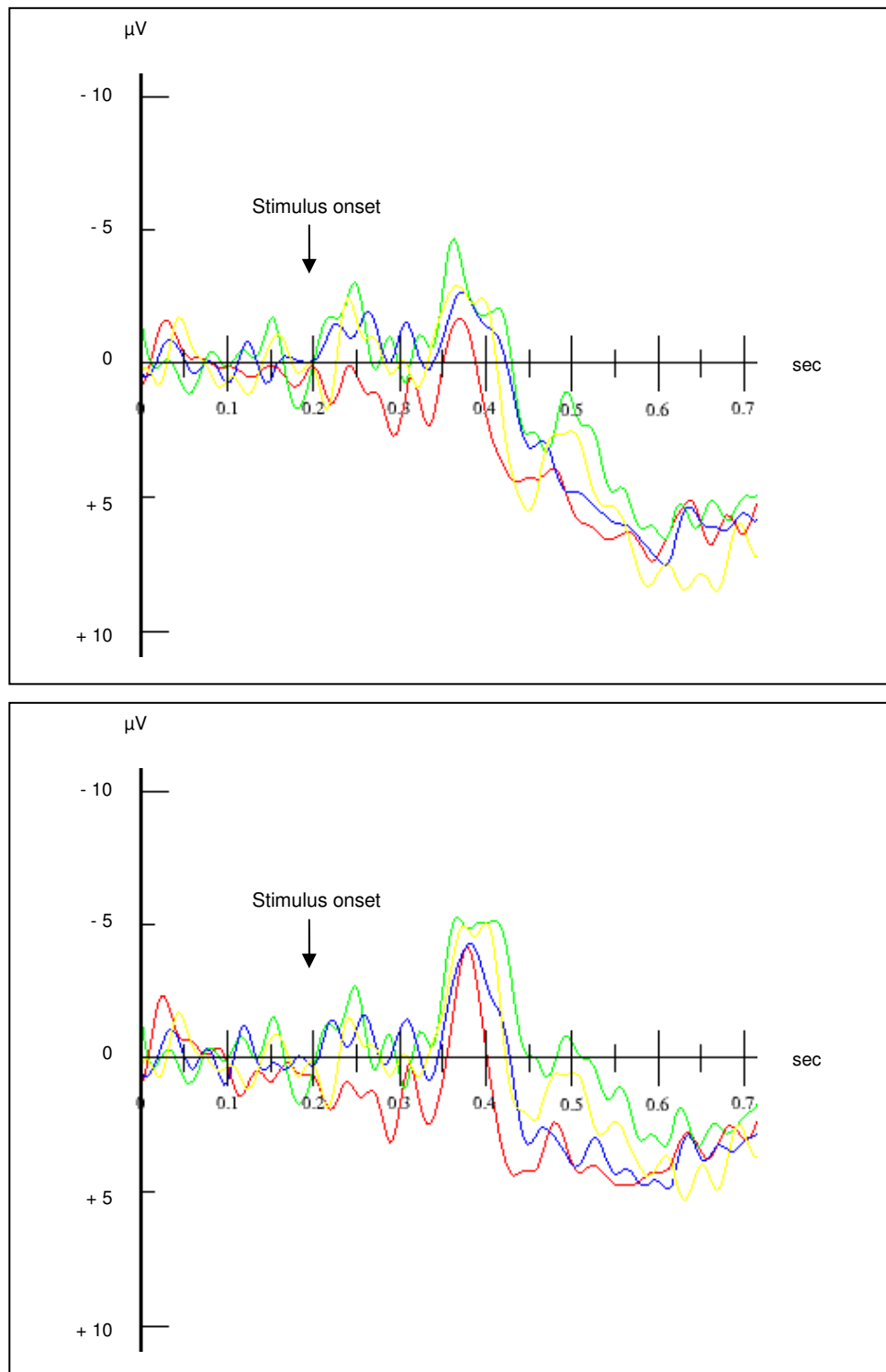


Figure 17. P100 and N170 waveform of the answering categories LT and ST at the electrode 56 (upper panel) and 57 (lower panel) in naturally cycling women with a low conception risk versus women using hormonal contraceptives.

The red and the blue line represent women using hormonal contraceptives, with red corresponding to the answering category LT and blue corresponding to the answering category ST. The green and the yellow line represent women with low conception risk, with green corresponding to the answering category LT and yellow corresponding to the answering category ST. Note that the baseline ranges from 0 to 0.2 sec. Stimulus presentation starts at 0.2 sec and lasts until 0.7 sec. For the corresponding electrode on the other hemisphere see electrode 27 and 28 respectively (Fig. 16).

Significant differences (respectively a statistical trend) were observed when naturally cycling women in a low phase of conception risk were compared to women using hormonal contraceptives, resulting in a stronger positivity of the investigated component in women using hormonal contraceptives (E27: $p=0.032$; E28: $p=0.006$; E56: $p=0.072$; E57: $p=0.042$). Mean amplitudes (and standard deviations) at the four electrodes of naturally cycling women in a low phase of conception risk and women using hormonal contraceptives can be seen in table 7.

Table 7. Effect of use of hormonal contraceptives on the P100 component.

Mean amplitudes in μV (M) and standard deviation (SD) for the P100 component at the investigated electrodes comparing naturally cycling women in a low phase of conception risk with women using hormonal contraceptives. In the last line resulting p -values of the comparison of the two female groups at a specific electrode are displayed.

	<i>Naturally cycling women in a low phase of conception risk</i>		<i>Women using hormonal contraceptives</i>		<i>p</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	
<i>Electrode 27</i>	1.24	3.55	3.30	5.10	0.032
<i>Electrode 28</i>	0.62	1.73	3.77	5.70	0.006
<i>Electrode 56</i>	0.87	2.11	1.92	3.65	0.072
<i>Electrode 57</i>	0.53	1.28	1.77	3.33	0.042

No differences in the P100 amplitude were observed, when right and left hemispheres were compared.

For the P100 waveform in regard to the answering categories LT and ST of naturally cycling women in a low conception risk phase looking at male stimulus faces compared to women using hormonal contraceptives displayed at the four investigated electrodes (electrodes 27, 28, 56, 57) see figures 16 and 17.

Latency analysis of the P100

Neither in the male nor in the female sample were any differences observed.

Source localization of the P100 with sLORETA

As described in chapter 2.7 the centre of activation for the P100 was defined by using the sLORETA software. Below, the results with a visualisation for each sample are shown.

Male sample

For males sLORETA found the centre of activation to be in Brodman area (BA) 18 (inferior occipital gyrus, occipital lobe; Fig. 18 and 19).

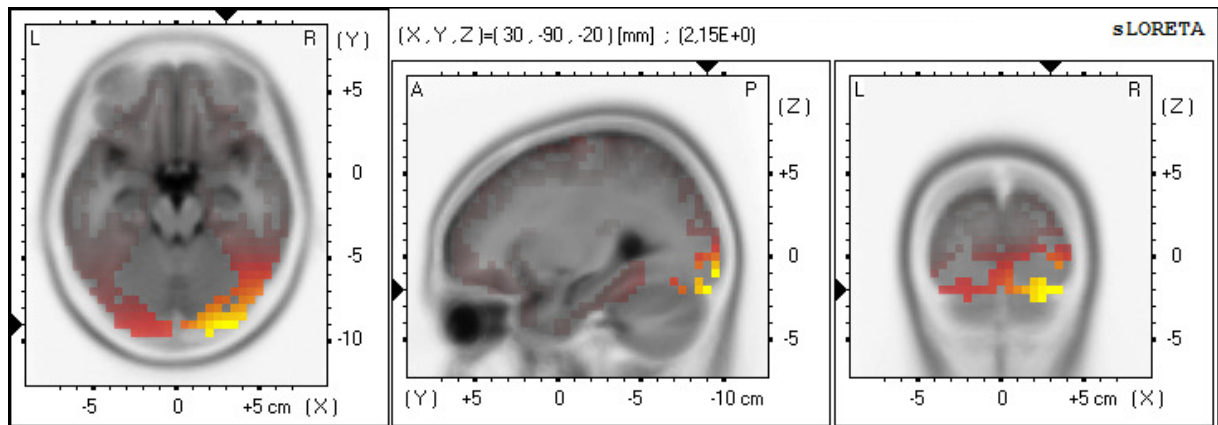


Figure 18. Visualisation of the P100 in male subjects viewing female faces rated as LT.

Centre of activation was found to be in BA 18 (inferior occipital gyrus, occipital lobe). A transversal, a sagittal and a coronal view are presented. Coloured areas symbolize centres of activation, with yellow marked regions having a higher level of activation than red ones.

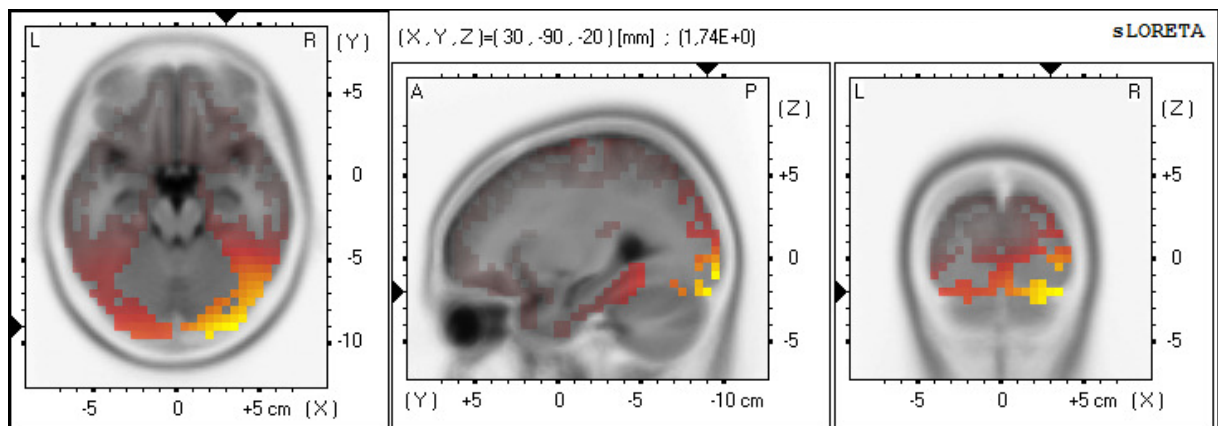


Figure 19. Visualisation of the P100 in male subjects viewing female faces rated as ST.

Centre of activation was found to be in BA 18 (inferior occipital gyrus, occipital lobe). A transversal, a sagittal and a coronal view are presented. Coloured areas symbolize centres of activation, with yellow marked regions having a higher level of activation than red ones.

Naturally cycling women in high versus low conception risk phase

As no differences were found in analysis of the P100 within this sample, source localization was done for women with normal cycle together. The centre of activation was found to be in BA 18 (inferior occipital gyrus, occipital lobe; Fig. 20).

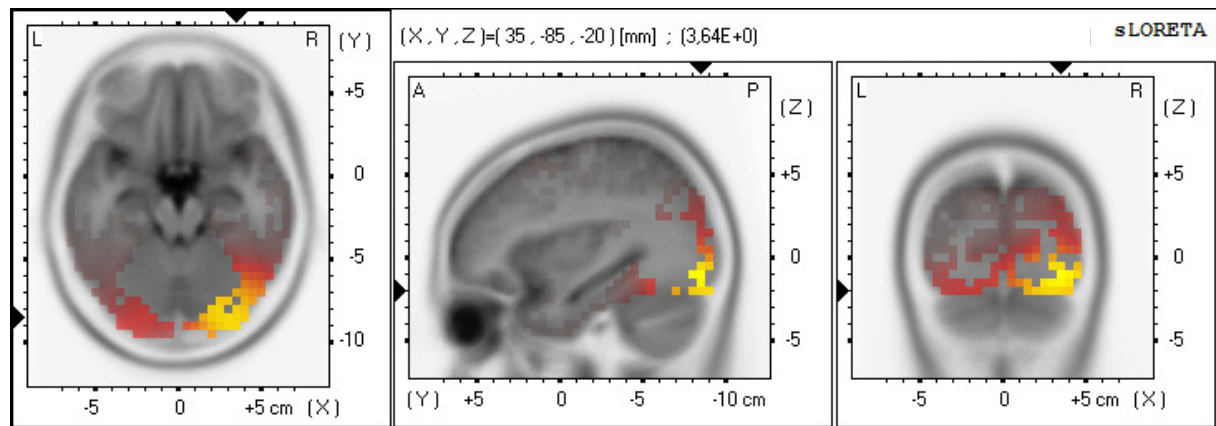


Figure 20. Visualisation of the P100 in naturally cycling women looking at male faces.

Centre of activation was found to be in BA 18 (inferior occipital gyrus, occipital lobe). A transversal, a sagittal and a coronal view are presented. Coloured areas symbolize centres of activation, with yellow marked regions having a higher level of activation than red ones.

Naturally cycling women in low phase of conception risk versus women using hormonal contraceptives

As reported above, for naturally cycling females in a low conception risk phase the centre of activation was found to occur in BA 18, in the inferior occipital gyrus and the occipital lobe.

For women using hormonal contraceptives the centre of activation is located in BA 18 (inferior occipital gyrus, occipital lobe; Fig. 21).

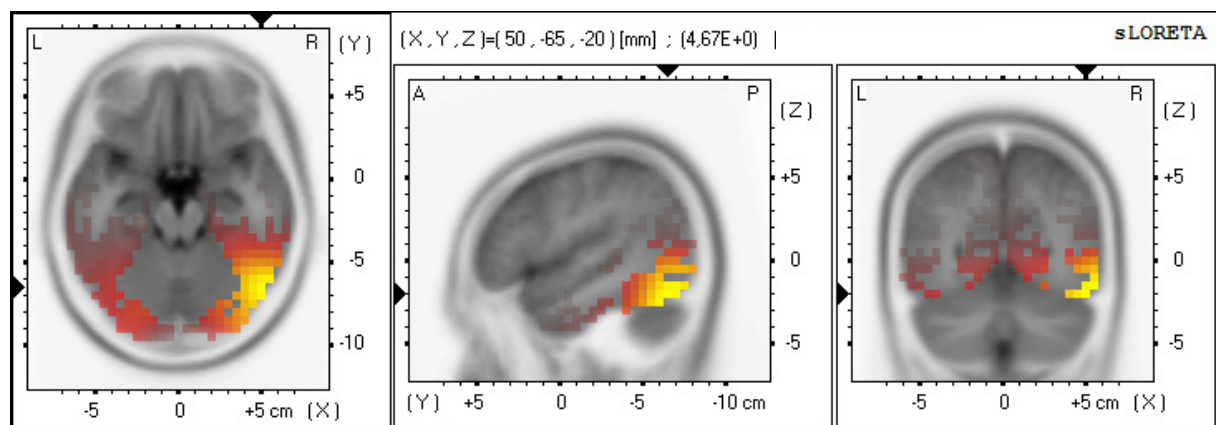


Figure 21. Visualisation of the P100 in women using hormonal contraceptives viewing male faces.

Centre of activation was found to be in BA 18 (inferior occipital gyrus, occipital lobe). A sagittal, a transversal and a coronal view are presented. Coloured areas symbolize centres of activation, with yellow marked regions having a higher level of activation than red ones.

Peak analysis of the N170

Male sample

No differences in amplitude values in the N170 due to the subjective mating preference were found. Significant differences were observed for the right and left hemisphere, resulting in higher amplitude values for the N170 component on the right hemisphere (electrode 27 compared to electrode 56: $p=0.014$; electrode 28 compared to electrode 57: $p=0.044$).

For mean amplitudes at the investigated electrodes see table 8. For the N170 waveform see figures 12 and 13.

Table 8. Comparison of hemisphere of the N170 component in male subjects.

Mean amplitudes in μV (M) and standard deviation (SD) for the N170 component in men at the investigated electrodes.

	<i>M</i>	<i>SD</i>
<i>Electrode 27</i>	-2.59	5.18
<i>Electrode 56</i>	-1.05	4.98
<i>Electrode 28</i>	-3.81	4.90
<i>Electrode 57</i>	-1.81	4.66

Naturally cycling women in high versus low conception risk phase

No differences in the N170 amplitude were evoked by the subjective partner preferences LT or ST. Neither when high and low conception risk phase nor when left and right hemispheres were compared, could differences in the amplitude be observed. For the N170 waveform see figures 14 and 15.

Naturally cycling women in a low phase of conception risk versus women using hormonal contraceptives

No differences in the N170 amplitude were evoked by the subjective partner preferences LT or ST and no differences were observed when right and left hemispheres were compared.

No difference in amplitude was observed when women using hormonal contraceptives were compared to naturally cycling females in a low phase of conception risk. Again, no differences in amplitude were found when the left hemisphere was compared to the right.

For the N170 waveform see figures 16 and 17.

Latency analysis of the N170

Neither in the male nor in the two female samples were differences in peak latency of the N170 component observed.

Source localization of the N170 with sLORETA

Male sample

Visualisation and source localization were done for the N170 using sLORETA software. The centre of activation was found to be in BA 19 (fusiform gyrus, occipital lobe; Fig. 22).

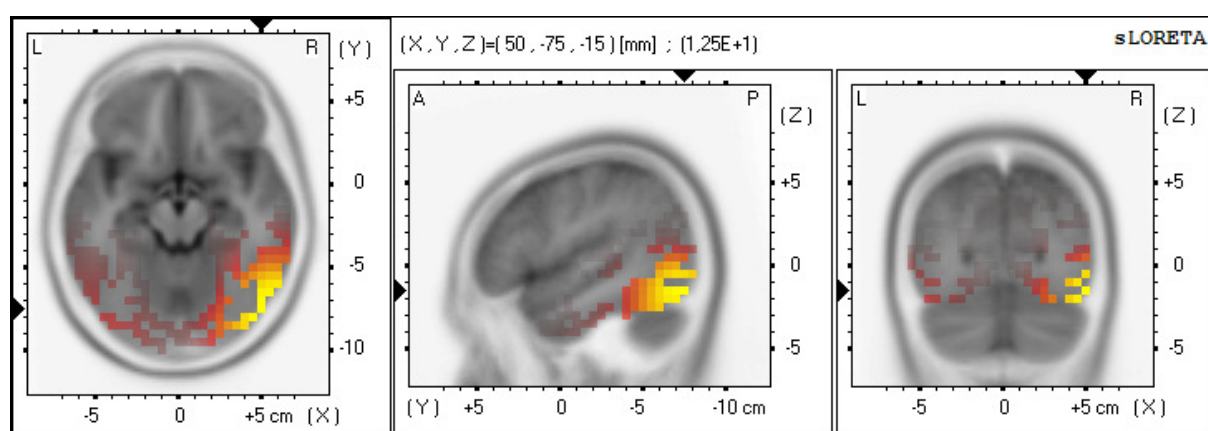


Figure 22. Visualisation of the N170 in male subjects when female faces were seen.

Centre of activation was found to be in BA 19 (fusiform gyrus, occipital lobe). A transversal, a sagittal and a coronal view are presented. Coloured areas symbolize centres of activation, with yellow marked regions having a higher level of activation than red ones.

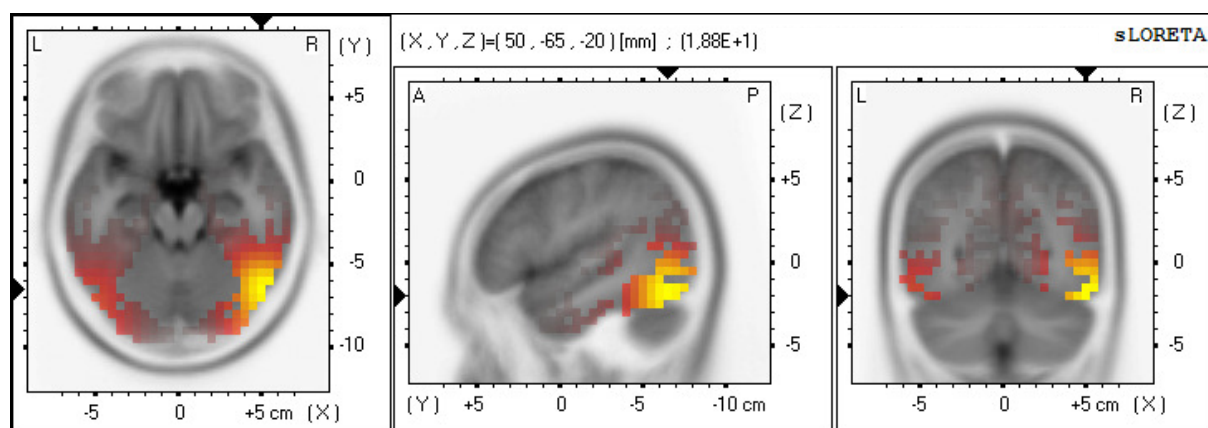


Figure 23. Visualisation of the N170 in naturally cycling women looking at male faces.

Centre of activation was found to be in BA 19 (fusiform gyrus, occipital lobe). A transversal, a sagittal and a coronal view are presented. Coloured areas symbolize centres of activation, with yellow marked regions having a higher level of activation than red ones.

Naturally cycling women in high versus low conception risk phase

The centre of activation for the N170 in naturally cycling females was found to be in BA 19 (fusiform gyrus, temporal lobe; Fig. 23).

Naturally cycling women in a low phase of conception risk versus women using hormonal contraceptives

For women using hormonal contraceptives sLORETA localizes the centre of activation in BA 19 (fusiform gyrus, occipital lobe) as displayed in figure 24.

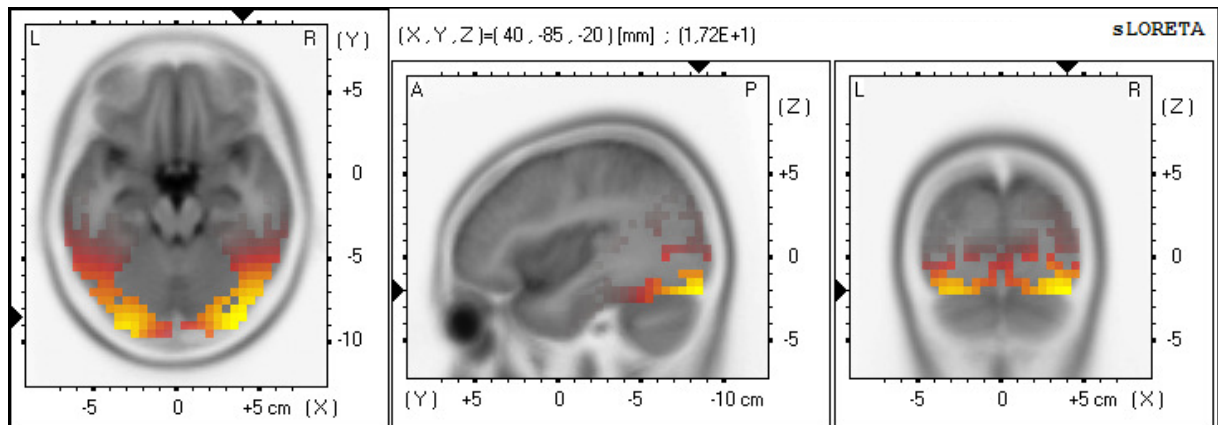


Figure 24. Visualisation of the N170 in women using hormonal contraceptives looking at male faces. Centre of activation was found to be in BA 19 (fusiform gyrus, occipital lobe). A transversal, a sagittal and a coronal view are presented. Coloured areas symbolize centres of activation, with yellow marked regions having a higher level of activation than red ones.

Mean amplitudes analysis of the P300

As the analysing window consisted of the first 500 ms after stimulus onset only an early part (300–500 ms) of the P300 component was investigated.

Male sample

No differences according to the two different mating preferences LT and ST were found in the early portion of the P300.

A significant main effect of electrode position was found from timeframe 6 to timeframe 10. E58 (Pz) showed significant higher amplitudes than the more anterior E6 (AFz) and E48 (Cz) in these timeframes ($p \leq 0.001$ each).

Naturally cycling women in high versus low conception risk phase

No differences according to the two different mating preferences LT and ST were found in the early part of the P300 as well as no differences according to high or low conception risk.

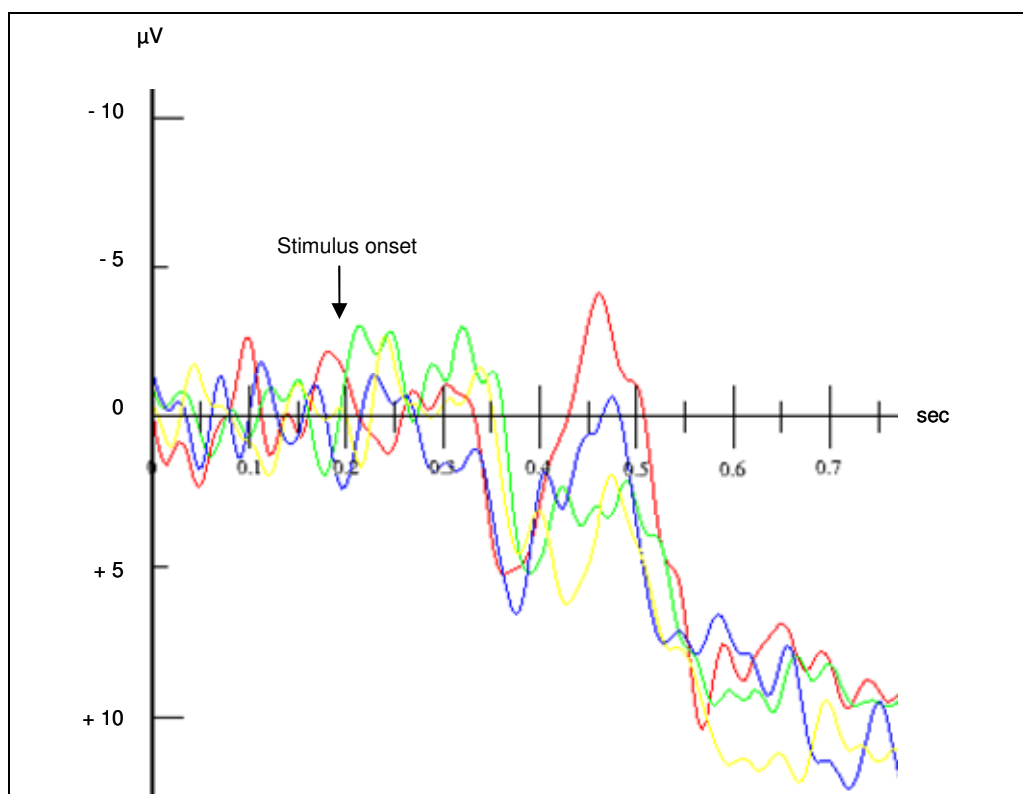
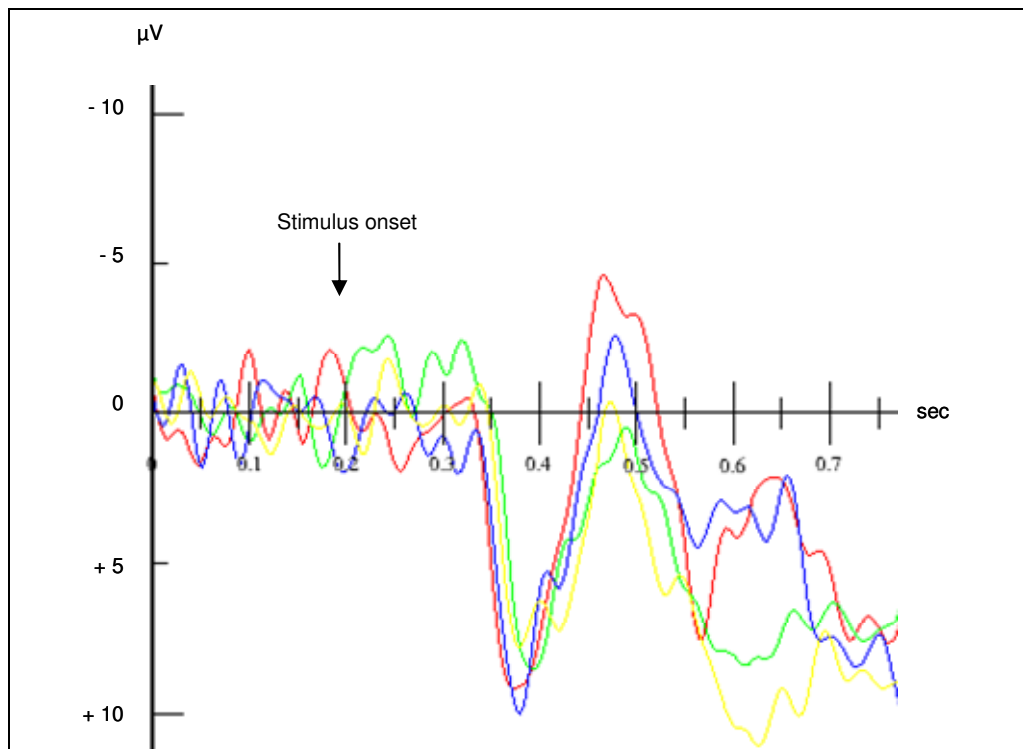


Figure 25. P300 waveform of the answering categories LT and ST at the electrodes 48 (Cz; upper panel) and 58 (Pz; lower panel) in naturally cycling women in high versus low conception risk.

The red and the blue line represent women in a high conception risk phase, with red corresponding to the answering category LT and blue corresponding to the answering category ST. The green and the yellow line represent women with low conception risk, with green corresponding to the answering category LT and yellow corresponding to the answering category ST. Note that the baseline ranges from 0 to 0.2sec. Stimulus presentation starts at 0.2sec and lasts until 0.7sec.

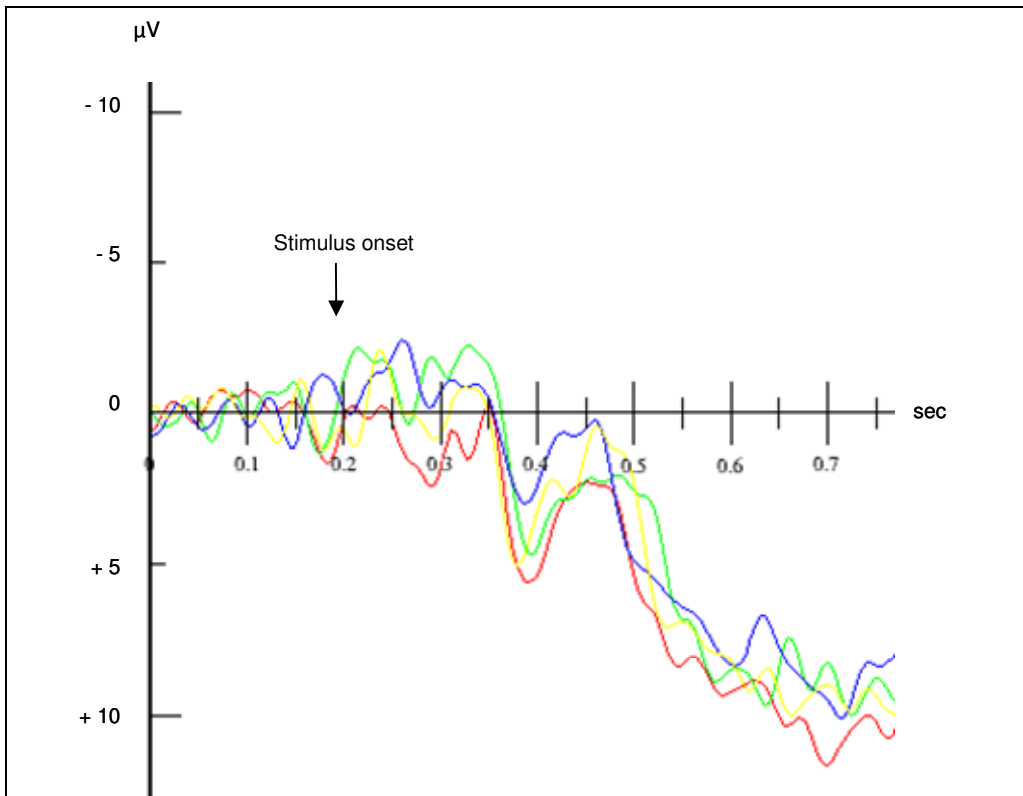
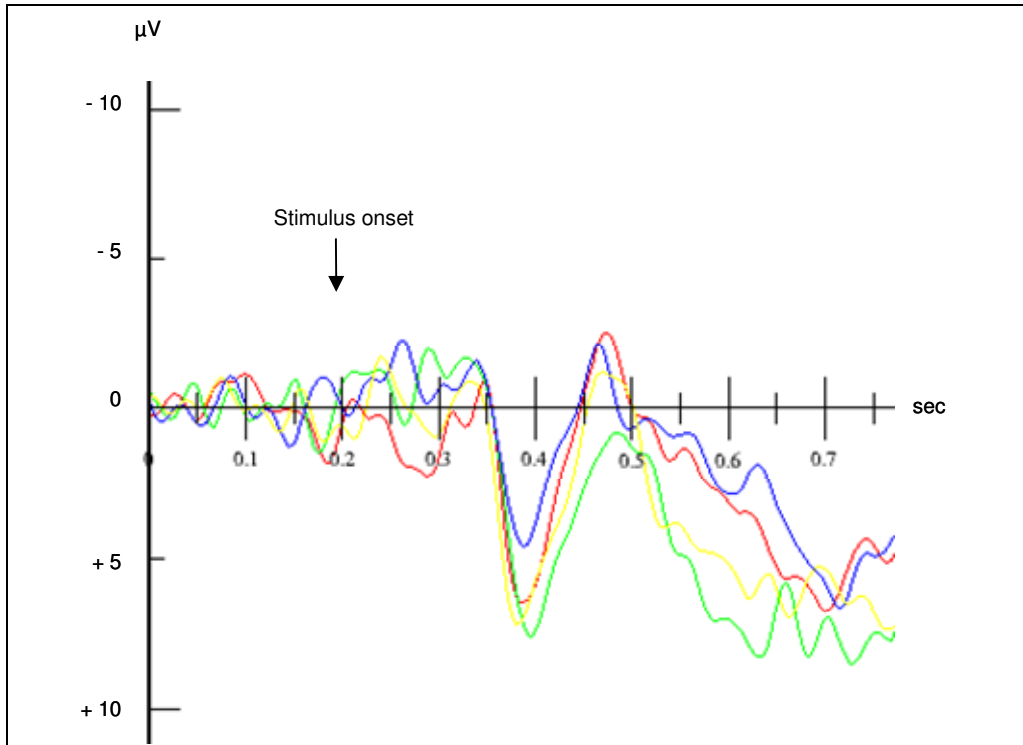


Figure 26. P300 waveform of the answering categories LT and ST at the electrodes 48 (Cz; upper panel) and 58 (Pz; lower panel) in naturally cycling women with a low conception risk versus women using hormonal contraceptives.

The red and the blue line represent women using hormonal contraceptives, with red corresponding to the answering category LT and blue corresponding to the answering category ST. The green and the yellow line represent women with low conception risk, with green corresponding to the answering category LT and yellow corresponding to the answering category ST. Note that the baseline ranges from 0 to 0.2 sec. Stimulus presentation starts at 0.2 sec and lasts until 0.7 sec.

A significant main effect of electrode position was found from timeframe 7 to timeframe 10. Electrode 58 (Pz) showed significant higher amplitudes than the more anterior electrode 6 (AFz) and electrode 48 (Cz) in these timeframes (timeframe 7: $p=0.004$; timeframe 8: $p=0.013$; timeframe 9: $p=0.010$; timeframe 10: $p=0.003$).

For details of the P300 waveform see figure 25.

Naturally cycling women in a low phase of conception risk versus women using hormonal contraceptives

No differences according to the two different mating preferences (LT and ST) were found in the early part of the P300 as well as no differences according to the use of hormonal contraceptives were observed.

A significant main effect of electrode position was found from timeframe 6 to timeframe 10. Electrode 58 (Pz) showed significant higher amplitudes than the more anterior electrode 6 (AFz) and electrode 48 (Cz) in these timeframes ($p \leq 0.001$ each, except timeframe 9 with $p=0.001$).

For details of the P300 waveform see figure 26.

3.3 Summary of results

To remain focused for the following discussion of results, the aforementioned findings will be presented in a short and concise way.

Around 60% of all female ratings were allotted to the ST-category and only around 40% to the LT-category. This result was also displayed in each of the three female sub-samples. Men rated more balanced, with around 45% allotted to the ST-category and around 55% allotted to the LT-category.

Men and women rating photographs of opposite-sex face showed no differences in behaviour when reaction times for the given answer for mating preference were compared. As indicated by the global analysis, female faces rated as short-term partner elicited higher positive amplitudes in the P100 component in male subjects than faces rated as long-term partner.

No differences in peak amplitude of the P100 were observed when naturally cycling women in a low conception risk phase were compared to women in a high conception risk phase. Women using hormonal contraceptives showed significant higher positive peak amplitudes in three of four investigated electrodes (at the fourth electrode only a statistical trend in the same direction was found) than naturally cycling women in a low phase of

conception risk, which was advertised by the results of the global analysis. A visual inspection of the waveform of the P100 component in women shows that only women using hormonal contraceptives seem to generate a positive peak in the above described time range. In naturally cycling women this component is not observable.

The peak amplitudes of the P100 and the N170 in the male sample were higher in the right than in the left hemisphere. This finding could not be observed in the female sample.

No modulations of the peak amplitude of the N170 component were found as well as of the latencies of the P100 and the N170 were observed – neither in the male sample nor in the female samples.

Visualisation of the P100 showed the centre of activation in the inferior occipital gyrus (BA 18), for the N170 it was found in the fusiform gyrus (BA 19). These results are valid for the male subjects as well as for naturally cycling women and for women using hormonal contraceptives.

Last but not least no variations in connection with different mating preferences were observed in the early portion of the P300 component. Electrode 58 showed higher (more positive) amplitudes when compared to the more anterior electrode 6 (AFz) and electrode 48 (Cz) with the pattern $Pz > Cz > AFz$. These results were observed in the male sample as well as in the female samples.

4. Discussion

4.1 Discussion of the behavioural observations

The frequencies of the ratings

The major problem when discussing the subjective ratings of partner preferences is the circumstance that there was no possibility to reject someone completely as a partner. If a seen face was not considered as a partner the participants were given the instruction to rate with rST. Therefore the two “rather”-categories (rST, rLT) were excluded from further analysis. As a disadvantageous consequence only comparing explicit mate choices (ST, LT) was possible which should not be disregarded while further reading and therefore results have to be interpreted cautiously.

Women tended slightly to select the ST-category (“preferred as a short-term partner”) rather than the LT-category (“preferred as a long-term partner”) with about 57% of the ratings of naturally cycling women, and around 63% of the ratings of women using hormonal contraceptives allotted to the ST-category and around 37% respectively 43% to the LT-category. There are some possible reasons for a woman to choose the ST-category over the LT-category: (1) a short-term relationship can still turn into a long-term relationship (Buss & Schmitt, 1993) and (2) the consequences for making a poor choice of a long-term mate are potentially more severe for a woman than for a man. Accordingly, males tended to rate more balanced, with around 45% allotted to the ST-category and around 55% allotted to the LT-category. This might be due to the fact that men’s minimal investment in offspring is less in comparison to women (Trivers, 1972) and because of pursuing both strategies in their mating-behaviour repertoire.

The reaction time

As predicted, neither within men nor within women, reaction times differed for the different mate choices LT and ST, which is in line with the aforementioned hypothesis of perceptual vigilance. There are studies reporting variations in reaction time for making a decision on the attractiveness or unattractiveness of faces and other stimuli (Aharon et al., 2001 Werheid et al., 2007; Zimmermann 2008). Here in both cases (LT-choice versus ST-choice) subjects made a decision for a seen face being a possible mate, which can be considered to have a positive impact. Besides, I suggest that someone chosen as a potential mate is perceived to be attractive per se by the beholder.

Little is known about the effect of endogenous hormone concentrations or of using hormonal contraceptives on reaction times. There were also no differences when women were compared due to their menstrual cycle phase (follicular versus luteal phase) respectively due to the usage of hormonal contraceptives. Women using hormonal contraceptives did not differ in their reaction time when compared to natural cycling women in the luteal phase. The findings of this study indicate that the concentration levels of steroid hormones do not modulate reaction time behaviour to biological relevant stimuli in women. Beaudoin and Marrocco (2005) reported slower reaction times for naturally cycling women on their day of ovulation compared to pre- and post-ovulatory days. I only discriminated between phases of high (follicular phase) and low (luteal phase) conception risk and maybe therefore no differences were found in the current study in naturally cycling women as well as in women using hormonal contraceptives.

4.2 Discussion of the electrophysiological observations

The early ERPs (event-related potentials): P100 and N170

All subjects elicited a N170 in response to the presented faces. This was expected as the N170 is believed to be a face specific response (Bentin et al., 1996; Linkenkaer-Hansen et al., 1998; Eimer & McCarthy, 1999; Watanabe et al., 1999, 2005; Streit et al., 2000; Sagiv & Bentin, 2001; Pizzagalli, 2002; Liu et al., 2002; Herrmann et al., 2005b; Xu et al., 2005) and the stimulus material consisted exclusively of human faces.

It seems that perceived attractiveness (Zimmermann, 2008) as well as judgements of liking versus disliking (Pizzagalli et al., 2002) have an influence on the N170 resulting in different peak amplitudes. In the present study, peak amplitude of the N170 component (evoked in all subjects) was not found to vary as a function of mate choice, neither in men nor in naturally cycling women respectively women using hormonal contraceptives. Analysed data consisted of true mate choice categories, regardless of being LT and ST. Any faces not considered as a partner were selected through the mate choice category rST which did not go into statistical analysis (as well as the rLT-category). Therefore the data in the present study was connected to mate choice and therefore to attractiveness respectively liking. This might be an explanation for the absence of differences in the peak amplitude of the as a chosen mate is always attractive and/or someone liked in the eye of the beholder.

Surprisingly, only in males and in females using hormonal contraceptives a P100 preceding the N170 component has been observed. It seems that women using hormonal contraceptives were the only females generating this early ERP. To my knowledge, such observations have not been described previously. Despite of numerous studies dealing with the P100 in the context of processing of faces in humans none of them investigated sex differences in the ERP patterns or took into account the use of hormonal contraceptives respectively the menstrual cycle. In future, it should be paid attention to possible effects caused by sex. This view is also supported by a study by Oliver-Rodriguez and colleagues (1999), who found sex differences in the P300 component in a time range between 300–1000 ms poststimulus, with men showing much larger amplitudes than regular cycling women not using any hormonal contraceptives. As far as I know sex differences in this context have not been described yet, therefore this observation should be object of further investigations. Besides, as it is still a point of debate whether the P100 is a response that is specific for faces the current results indicate that it is not, as this component was only observed in parts of my sample.

It is hard to explain why in naturally cycling women – independently of being in high or low conception risk phase – no P100 was observed while in women using hormonal contraceptives this ERP in contrast was quite prominent (Fig. 16). The small number of subjects and the small number of buffers can not supply a satisfying explanation for the absence of the P100 in naturally cycling women. There is a large body of evidence for effects of testosterone, progesterone, and estrogens on cognitive abilities and brain functioning. Variations could have been found along the menstrual cycle as well as in women using hormonal contraceptives in comparison to women not using hormonal contraceptives (e.g., Schöning et al., 2007; Mordecai et al., 2008; for a review see Maki & Resnick, 2001). Psychological phenomena, as mood change for example, are discussed to be side effects of oral contraceptive use (Oinonen & Mazmanian, 2001). Effects of hormonal contraceptive use on cognitive performance tasks could have been shown by Wright and Badia (1999). They also reported higher alertness for women using hormonal contraceptives compared to naturally cycling women in their follicular and in their luteal phase – an effect possibly mediated by steady high endogenous concentrations of progesterone and estrogens. As already mentioned, the P100 is believed to vary due to attentional effects with higher paid attention resulting in higher amplitudes. Taken together this might give an explanation for the absence of the P100 component in naturally cycling

women and the observation of this component in hormonal contraceptive using women because of their increased attentiveness.

Using sLORETA, the centre of activation within the time range of the P100 was found to be in the inferior occipital gyrus (BA 18) for all samples of the current study which is in line with previously conducted studies on the perception of human faces (Liu et al., 2002; Herrmann et al., 2005a; Watanabe et al., 2005). The sources of the N170 were – as revealed by sLORETA – localized in the fusiform gyrus (BA 19), which also replicates findings of earlier studies (Watanabe et al., 1999, 2005; Pizzagalli, 2002; Herrmann et al., 2005b; Iidaka, 2005; Zimmermann, 2008) in which the presentation of human faces evoked the same response. These activated brain areas are part of the core system of the face processing model postulated by Haxby, Hoffmann, and Gobbini (2000) (Fig. 4) and mark early stages in face processing.

As expected furthermore, all women – those who were naturally cycling and those using hormonal contraceptives – showed a bilateral activation with no differences in the degree of activation in the two hemispheres. In contrast, men showed a lateralized activation resulting in significant differences of the investigated electrode sites (right versus left). Both, the P100 and the N170 peaked higher in the right hemisphere compared to the left. These are exactly the results that were observed by Proverbio and colleagues (2006) in context of face processing. A great amount of studies have already shown sex dependent differences in the degree of lateralization in association with other cognitive operations such as e.g., mental rotation tasks, in which men showed a dominance in the right hemisphere while women seemed to be bilaterally distributed.

As a stunning finding of the current study, in males female faces considered as a potential short-term partner elicited a higher positive amplitude in the P100 component than female faces considered as a potential long-term partner. This supports the basic assumption that men and women use different criteria for their decision making. It seems that in men the early stages of decision making (distinguishing between a potential short-term and long-term mate) appear to begin in the time range of the P100 component on the basis of frugal visual information derived. In addition to physical attractiveness, the mate value of a person comprises certain characteristics such as material and emotional commitment, intelligence, social status, personality traits and so forth (Fig. 1). As men are considered to rely more on physical cues of attractiveness concerning their mate choice than women do (Buss & Schmitt, 1993; Thornhill & Gangestad 1999; Johnston, 2000, 2006; Buss, 2004) it may be that their appraisal of a women's mate value is within a glance. This would also

explain why no differences in the early ERPs were found in women as their mate choice decisions are more cognitive based and therefore their assessment of men's mate value requires more time. According to Buss and Schmitt (1993) men are confronted with the so called problem of number. Unlike women men can increase their reproductive success by increasing the number of inseminated women. A missed opportunity for copulation might therefore produce higher costs for men than for women (Trivers, 1972; Haselton & Buss, 2000). A recognition mechanism for rapid detection of mate value would provide a solution to this problem.

Interesting in this context is the finding by Utama and colleagues (2009) who found that the P100 was significantly correlated with the accurate recognition of a facial emotion and the N170 with the intensity level of the emotion. According to that the P100 might reflect a categorization process on a level of fine physiognomic facial features that might also be affected by the perception of facial cues leading towards a short-term respectively long-term mate decision.

Furthermore, no modulations of the latencies of both early ERPs were observed. According to literature delayed latencies have been observed in association with the presentation of inverted human faces (Bentin et al., 1996; Linkenkaer-Hansen et al., 1998), in case of the P100 additionally in association with contrast effects of the presented stimuli (Luck, 2005). As the presented faces were orientated upright and effects of altering contrast were avoided by using grey-scaled photographs, this observation concerning the latencies of the P100 and the N170 were in line with my predictions based on earlier studies (Bentin et al., 1996; Linkenkaer-Hansen et al., 1998; Luck, 2005).

Variations in amplitude of the P100 have been described to be connected to attentional effects, resulting in higher amplitudes for attended stimuli (Haxby et al., 2000; Luck et al., 2000; Luck, 2005). The finding of this study that women selected for short-term mates evoked higher peak amplitudes than women selected for long-term mates can be explained that the former mate choice category is associated with an increase of attentiveness by perhaps an increase of sexual arousal mediated by a stimulus of this class.

The Late Positive Complex (LPC) or P300

The P300 amplitudes followed the expected pattern of $Pz > Cz > AFz$, which was observed in men as well as in naturally cycling women and women using hormonal contraceptives, being in line with observations of earlier studies (Johnston & Oliver-Rodriguez, 1997; Oliver-Rodriguez et al., 1999; Delplanque et al., 2006; Werheid et al., 2007; van Lankveld & Smulders, 2008; Zimmermann, 2008).

Different mate choice strategies (LT respectively ST) did not elicit differences in the response of the P300. The LPC is known to be influenced by the probability of occurrence of a stimulus and by task relevance (the classic experiment in this context is based on the so called oddball paradigm). Both stimulus probability and task relevance did not change during the experiment. Due to the design of the study the analysed trials were collected in the first session, in which the subjects had to distinguish between the sexes of the presented faces. In total 100 female and 100 male faces were presented in random order, making their occurrence equally probable. Task difficulty was not altered and subjects were not given the instruction to make mate decisions until the second session (respectively the third session). Accordingly, I did not expect that stimulus probability or task relevance would influence the P300 in this study.

According to the emotional value theory of the P300 this component might also reflect the subjective affective value of a perceived stimulus. Faces clearly identified as potential mates, be it a short-term partner or a long-term partner, are both stimuli of high relevance. Therefore – as suggested by the results of the current study – the affective value of both can be considered to be equally high. Alas, due to the exclusion of the rLT and rST categories and due to the fact that there was no answering category such as “not considered as a partner” no comparisons could be made with classes evoking a lower level of arousal. As variations in amplitude due to menstrual cycle phase have been described a focus in this study was laid upon possible difference of women in their follicular phase (high conception risk) compared to women in the luteal phase (low conception risk). An additional focus was laid upon women using hormonal contraceptives. In previous studies emotionally charged stimuli were shown to alter the P300 amplitudes depending on the menstrual cycle phase. Women in their follicular phase showed larger amplitudes in the P300 as a response to affect laden stimuli (Johnston & Wang, 1991; cited in Oliver-Rodriguez et al., 1999; Krug et al. 2000). Here in this study, the statistical analysis of the P300 did not reveal any evidence for such an effect. However, a visual inspection of the plot of the P300 (Fig. 25) at electrode 48 (Pz) may suggest that there are changes depending on the menstrual cycle phase. Around 350 to 500 ms post stimulus it seems that women in a low conception risk phase (luteal phase) do show a greater P300 amplitude compared to women in a high conception risk phase (follicular phase), although not reaching statistical significance. Similar patterns are displayed around 350 to 450 ms when women in their luteal phase are compared to women using hormonal contraceptives. Due to the experimental design only the early part of the LPC – lasting from 300 ms to 500 ms

– was available for analysis. With a different design with a larger analysing window possible alterations within a broader range would have been possible to be analysed. These observations based on a macro visual inspection might indicate that the aforementioned effects probably caused by different steroid hormone concentrations do exist and therefore should be taken into consideration when conducting an ERP study.

4.3 Implications for future research

Due to some limitations but also findings of this present study several requirements for continuative studies arise. Beside the problems which are inherent to every experimental test design I want to point out some details of the current study that might need to be improved in a follow-up study.

As a first issue the small number of female test persons having a high conception risk at the time of testing should be addressed. Only four women were among this sample. One reason for that was that women were asked about their cycle on the day they participated in this study and not before (then they could have been invited to show up on a distinct day). Besides, a more precise determination (e.g., saliva sample) of the phase of menstrual cycle would be appreciable to make more detailed assertions about the endogenous steroid hormone levels.

The next point that needs to be stressed one more time is the fact of having a small amount of buffers for each test person. The intermediate categories (rST and rLT) had to be excluded as mentioned above (see chapter 2). So firstly only two (ST and LT) out of originally four categories could be analysed, and secondly these remaining categories contained less buffers than the “rather”-categories.

The participants should be given at least three answering categories in the context of mate choice: (1) preferred as a long-term partner, (2) preferred as a short-term partner, and (3) not considered as a partner. An analysis of the latter category is missing in this study (as it was not possible to assess). It would have been quite interesting to investigate possible effects arising from distinguishing between a potential mate versus no potential mate. Furthermore, I assume that choosing a person as a potential partner might lead to some sort of arousal that might be missing when viewing opposite-sex faces with a very low or even none perceived mate value.

There are also questions and implications arising from the results of the present study. Two important topics should be mentioned in this context: (1) possible sex differences should be considered in regard to electrophysiological investigations in future, and (2) the

underlying study gives support to the assumption that the use of hormonal contraceptives has an impact on human perception and cognitive functioning as could have been already shown by previous studies and should therefore be considered in prospective studies with female participants.

References

- Aharon A., Etcoff N., Ariely D., Chabris C.F., O'Connor E., Breiter H.C. (2001). Beautiful faces have variable reward value: fMRI and behavioural evidence. *Neuron*, 32, 537–551.
- Allison T., Puce A., Spencer D.D., McCarthy G. (1999). Electrophysiological Studies of Human Face Perception. I: Potentials Generated in Occipitotemporal Cortex by Face and Non-face Stimuli. *Cerebral Cortex*, 9, 415-430.
- Baudouin J.-Y., Tiberghien G. (2004). Symmetry, averageness, and feature size in the facial attractiveness of women. *Acta Psychologica*, 117, 313-332.
- Bayer U., Kessler N., Güntürkün O., Hausmann M. (2008). Interhemispheric interaction during the menstrual cycle. *Neuropsychologia*, 46, 2415-2422.
- Beaudoin J., Marrocco R. (2005). Attentional validity effect across the human menstrual cycle varies with basal temperature changes. *Behavioural Brain Research*, 158, 23-29.
- Bentin S., Allison T., Puce A., Perez E., McCarthy G. (1996). Electrophysiological studies of face perception in humans. *Journal of Cognitive Neuroscience*, 8, 551-565.
- Buss D.M., Schmitt D.P. (1993). Sexual Strategies Theory: An Evolutionary Perspective on Human Mating. *Psychological Review*, Vol. 100, No. 2, 204-232.
- Buss D.M. (2004). *Evolutionary Psychology: the new science of the mind*. Allyn and Bacon, 2nd edition.
- Delplanque S., Silvert L., Hot P., Rigoulot S., Sequeira H. (2006). Arousal and valence effects on event-related P3a and P3b during emotional categorization. *International Journal of Psychophysiology*, 60, 315-322.
- Derntl B., Kryspin-Exner I., Fernbach E., Moser E., Habel U. (2008). Emotion recognition accuracy in healthy young females is associated with cycle phase. *Hormones and Behavior*, 53, 90-95.
- Drosdowski G. (1993). *Duden - Das große Wörterbuch der deutschen Sprache in acht Bänden*. Dudenverlag, Mannheim, volume 3, 2nd edition.
- Eagly A.H., Wood W. (1999). The origins of sex differences in human behaviour: Evolved dispositions versus social roles. *American Psychologist*, 54, 408-423.

- Ehlers C.L., Phillips E., Parry B.L. (1996). Electrophysiological Findings during Menstrual Cycle in Women with and without Late Luteal Phase Dysphoric Disorder: Relationship to Risk for Alcoholism? *Society of Biological Psychiatry*, 39, 720-732.
- Eimer M., McCarthy R.A. (1999). Prosopagnosia and structural encoding of faces: evidence from event-related potentials. *Neuroreport*, Vol. 10, No. 2, 255-259.
- Ellison P.T. (2008). Beauty: In the gonads of the beholder - and the beheld. *Hormones and Behavior*, 53, 11-13.
- Eysenck M.W., Keane M.T. (2002). Cognitive Psychology. A Student's Handbook. Psychology Press Ltd, Sussex, New York, 4th edition.
- Fink B., Grammer K., Mitteroecker P., Gunz P., Schaefer K., Bookstein F.L., Manning J.T. (2005). Second to fourth digit ratio and face shape. *Proceedings of the Royal Society London B*, 272, 1995-2001.
- Gangestad S.W., Thornhill R. (1998). Menstrual cycle variation in women's preferences for the scent of symmetrical men. *Proceedings of the Royal Society London B*, 265, 927-933.
- Gangestad S.W., Simpson J.A. (2000). The evolution of human mating: Trade-offs and strategic pluralism. *Behavioral and Brain Sciences*, 23, 573-644.
- Gangestad S.W., Thornhill R., Garver C.E. (2002). Changes in women's sexual interest and their partner's mate-retention tactics across the menstrual cycle: evidence for shifting conflicts of interest. *Proceedings of the Royal Society London B*, 269, 975-982.
- Grammer K., Thornhill R. (1994). Human (Homo sapiens) Facial Attractiveness and Sexual Selection: The Role of Symmetry and Averageness. *Journal of Comparative Psychology*, Vol. 108, No. 3, 233-242.
- Gobbini M.I., Haxby J.V. (2007). Neural systems for recognition of familiar faces. *Neuropsychologia*, 45, 32-41.
- Haselton M.G., Buss D.M. (2000). Error Management Theory: A New Perspective on Biases in Cross-Sex Mind Reading. *Journal of Personality and Social Psychology*, Volume 78, Number 1, 81-91.
- Haxby J.V., Hoffmann E., Gobbini M.I. (2000). The distributed human neural system for face perception. *Trends in Cognitive Science*, Volume 4, Issue 6, 223-233.
- Haxby J.V., Gobbini M.I. (2002). Human Neural Systems for Face Recognition and Social Communication. *Society of Biological Psychiatry*, 51, 59-67.

- Haxby J.V., Gobbini M.I. (2007). The perception of emotion and social cues in faces. *Neuropsychologia*, 45.
- Hirsch L.R., Paul L. (1996). Human Male Mating Strategies: I. Courtship Tactics of the „Quality“ and „Quantity“ Alternatives. *Ethology and Sociobiology*, 17, 55-70.
- Herkner W. (2003). Lehrbuch Sozialpsychologie. Verlag Hans Huber, Bern, 2nd edition.
- Herrmann M., Ehlis A.-C., Ellgring H., Fallgatter A. (2005a). Early stages (P100) of face perception in humans as measured with event-related potentials (ERPs). *Journal of Neural Transmission*, 112, 1073-1081.
- Herrmann M., Ehlis A., Muehlberger A., Fallgatter A. (2005b). Source Localization of Early Stages of Face processing. *Brain Topography*, Vol. 18, No. 2, 77-85.
- Hoffmann E., Haxby J.V. (2000). Distinct representations of eye gaze and identity in the distributed human neural system for face perception. *Nature Neuroscience*, 3, 80-84.
- Iidaka T., Matsumoto A., Haneda K., Okada T., Sadato N. (2006). Hemodynamic and electrophysiological relationship involved in human face processing: Evidence from a combined fMRI-ERP study. *Brain and Cognition*, 60, 176-186.
- Ishai A., Schmidt C.F., Boesiger P. (2005). Face perception is mediated by a distributed cortical network. *Brain Research Bulletin*, 67, 87-93.
- Johnson M.H. (2005). Subcortical Face Processing. *Nature Reviews*, 6, 766-774.
- Johnston V.S., Oliver-Rodriguez J.C. (1997). Facial Beauty and the Late Positive Component of Event Related Potentials. *Journal of Sex Research*, 34, 188-198.
- Johnston V.S. (2000). Female facial beauty: The fertility hypothesis. *Pragmatics and Cognition*, Vol. 8, No. 1, 107-122.
- Johnston V.S., Hagel R., Franklin M., Fink B., Grammer K. (2001). Male facial attractiveness: Evidence for hormone-mediated adaptive design. *Evolution and Human Behavior*, 22, 251-267.
- Johnston V.S. (2006). Mate choice decisions: the role of facial beauty. *Trends in Cognitive Sciences*, 10, 9-13.
- Kandel E.R., Schwartz J.H., Jessel T.M. (Eds.) (2000). Principles of Neural Science. McGraw-Hill, New York.
- Kanwisher N., McDermott J., Chun M.M. (1997). The Fusiform Face Area: A Module in Human Extrastriate Cortex Specialized for Face Perception. *The Journal of Neuroscience*, Vol. 17, No. 11, 4302-4311.

- Kanwisher N., Moscovitch M. (2000). The Cognitive Science of Face Processing: An Introduction. *Cognitive Neuropsychology*, 17, 1-11.
- Kanwisher N., Yovel G. (2006). The Fusiform Face Area: A Cortical Region Specialized for the Perception of Faces. *Philosophical Transactions of the Royal Society of London B*, 29, 2109-2118.
- Kanwisher N. (2006). What's in a Face? *Science*, 311, 617-618.
- Krug R., Plihal W., Fehm H.L., Born J. (2000). Selective Influence of the menstrual cycle on perception of stimuli with reproductive significance: An event-related potential study. *Psychophysiology*, 37, 111-122.
- Langlois J.H., Kalakanis L., Rubenstein A.J., Larson A., Hallam M., Smoot M. (2000). Maxims or Myths of Beauty? A Meta-Analytic and Theoretical Review. *Psychological Bulletin*, Vol. 126, Issue 3, 390-423.
- Linkenkaer-Hansen K., Palva J., Sams M., Hietanen J., Aronen H., Ilmoniemi R. (1998). Face-selective processing in human extrastriate cortex around 120 ms after stimulus onset revealed by magneto- and electroencephalography. *Neuroscience Letters*, Vol. 253, Issue 3, 147-150.
- Little A.C., Jones B.C., Penton-Voak I.S., Burt D.M., Perrett D.I. (2002). Partnership status and the temporal context of relationships influence human female preferences for sexual dimorphism in male face shape. *Proceedings of the Royal Society London B*, 269, 1095-1100.
- Little A.C., Burriss R.P., Jones B.C., DeBruine L.M., Caldwell C.A. (2008). Social influence in human face preference: men and women are influenced more for long-term than short-term attractiveness decisions. *Evolution and Human Behavior*, 29, 140-146.
- Liu J., Harris A., Kanwisher N. (2002). Stages of processing in face perception: an MEG study. *Nature Neuroscience*, Vol. 5, No. 9, 910-916.
- Luck S.J., Woodman G.F., Vogel E.K. (2000). Event-related studies of attention. *Trends in Cognitive Science*, Vol. 4, No. 11, 432-440.
- Luck S. J. (2005). An introduction to the event-related potential technique. The MIT Press, Cambridge.
- Maki P.M., Resnick S.M. (2001). Effects of Estrogen on Patterns of Brain Activity at Rest and during Cognitive Activity: A Review of Neuroimaging Studies. *NeuroImage*, 14, 789-801.

- Miller G.F., Todd P.M. (1998). Mate choice turns cognitive. *Trends in Cognitive Science*, Vol. 2, No. 5, 190-198.
- Miller L.C., Putcha-Bhagavatula A., Pederson W.C. (2002). Men's and Women's Mating Preferences: Distinct Evolutionary Mechanism? *Current Directions in Psychological Science*, Vol. 11, No. 5, 88-93.
- Mordecai K.L., Rubin L.H., Maki P.M. (2008). Effects of menstrual cycle phase and oral contraceptives use on verbal memory. *Hormones and Behavior*, Volume 54, Issue 2, 286-293.
- Oinonen K.A., Mazmanian D. (2001). To what extent do oral contraceptives influence mood and affect? *Journal of Affective Disorders*, 70, 229-240.
- Oldfield R.C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia*, 9, 97-113.
- Oliver-Rodriguez J.C., Guan Z., Johnston V.S. (1999). Gender differences in late positive components evoked by human faces. *Psychophysiology*, 36, 176-185.
- Olson I.R., Marshuetz C., (2005). Facial Attractiveness Is Appraised in a Glance. *Emotion*, Volume 5, Number 4, 498-502.
- Palermo R., Rhodes G. (2007). Are you always on my mind? A review of how face perception and attention interact. *Neuropsychologia*, 45, 75-92.
- Pascual-Marqui R.D. (2002). Standardized low resolution brain electromagnetic tomography (sLORETA): technical details. *Methods & Findings in Experimental & Clinical Pharmacology*, 24D, 5-12.
- Paul L., Hirsch L.R. (1996). Human Male Mating Strategies: II. Moral Codes of the „Quality“ and „Quantity“ Strategists. *Ethology and Sociobiology*, 17, 71-86.
- Picton T.W., Bentin S., Berg P., Donchin E., Hillyard S.A., Johnson R., JR, Miller G.A., Rotter W., Ruchkin D.S., Rugg M.D., Taylor M.J. (2000). Guidelines for using human event-related potentials to study cognition: Recording standards and publication criteria. *Psychophysiology*, 37, 127-152.
- Pizzagalli D.A., Lehmann D., Hendrick A.M., Regard M., Pascual-Marqui R.D., Davidson R.J. (2002). Affective Judgments of Faces Modulate Early Activity (~160 ms) within the Fusiform Gyrus. *NeuroImage*, 16, 663-677.
- Penton-Voak I.S., Perrett D.I., Castles D.L., Kobayashi T., Burt D.M., Murray L.K., Minamisawa R. (1999). Menstrual cycle alters face preference. *Nature*, Volume 399, 741-742.

- Penton-Voak I.S., Perrett D.I. (2000). Female preference for male faces change cyclically: Further evidence. *Evolution and Human Behavior*, 21, 39-48.
- Perrett D.I., Lee K.J., Penton-Voak I., Rowland D., Yoshikawa S., Burt D.M., Henzi S.P., Castles D.L., Akamatsu S. (1998). Effects of sexual dimorphism on facial attractiveness. *Nature*, 394, 884-887.
- Proverbio A.M., Brignone V., Matarazzo S., Del Zotto M., Zani A. (2006). Gender differences in hemispheric asymmetry for face processing. *BMC Neuroscience*, 7, 44.
- Rhodes G., Simmons L.W., Peters M. (2005). Attractiveness and sexual behaviour: Does attractiveness enhance mating success? *Evolution and Human Behavior*, 26, 186-201.
- Rigoulot S., D'Hondt F., Taisne M., Defoort-Dhellemmes S., Honoré J., Sequeira H. (2008). Neural processing of peripherally presented emotional faces: An ERP study. *International Journal of Psychophysiology*, 69, 174.
- Roney J.R., Simmons Z.L. (2008). Women's estradiol predicts preference for facial cues of men's testosterone. *Hormones and Behavior*, 53, 14-19.
- Rosenberg L., Park S. (2002). Verbal and spatial functions across the menstrual cycle in healthy young women. *Psychoneuroendocrinology*, 27, 835-841.
- Sagiv N., Bentin S. (2001). Structural Encoding of Human and Schematic Faces: Holistic and Part-Based Processes. *Journal of Cognitive Neuroscience*, Vol. 13, No. 7, 937-951.
- Schaefer K., Fink B., Grammer K., Mitteroecker P., Gunz P., Bookstein F.L. (2006). Female appearance: Facial and bodily attractiveness as shape. *Psychology Science*, volume 48, Number 2, 187-204.
- Scheib J.E., Gangestad S.W., Thornhill R. (1999). Facial attractiveness, symmetry and cues of good genes. *Proceedings of the Royal Society London B*, 266, 1913-1917.
- Schöning S., Engelen A., Kugel H., Schäfer S., Schiffbauer H., Zwitterlood P., Pletziger E., Beizai P., Kersting A., Ohrmann P., Greb R.R., Lehmann W., Heindel W., Arolt V., Kontad C. (2007). Functional anatomy of visuo-spatial working memory during mental rotation is influenced by sex, menstrual cycle, and sex steroid hormones. *Neuropsychologia*, 45, 3203-3214.
- Schweinberger S.R., Pfütze E.-M., Sommer W. (1995). Repetition Priming and Associative Priming of Face Recognition: Evidence From Event-Related Potentials. *Journal of Experimental Psychology*, Vol. 21, No. 3, 722-736.

- Sigall H., Ostrove N. (1975). Beautiful but dangerous: Effects of offender attractiveness and nature of the crime on juridic judgment. *Journal of Personality and Social Psychology*, Volume 31, Issue 3, 410-414.
- Streit M., Wölwer W., Brinkmeyer J., Ihl R., Gaebel W. (2000). Electrophysiological correlates of emotional and structural face processing in humans. *Neuroscience Letters*, 278, 13-16.
- Thornhill R., Gangestad S.W. (1999). Facial attractiveness. *Trends in Cognitive Sciences*, Vol. 3, No. 12, 452-460.
- Tovée M.J. (1995). What are faces for? *Current Biology*, Volume 5, Number 5, 480-482.
- Trivers R. (1972). Parental investment and sexual selection. In B. Campbell (Ed.), *Sexual selection and the descent of man*, 136-179.
- Utama N.P., Takemoto A., Koike Y., Nakamura K. (2009). Phased processing of facial emotion: An ERP study. *Neuroscience Research*, 64, 30-40.
- Valenza E., Simion F., Cassia V.M., Umiltà C. (1996). Face Preference at Birth. *Journal of Experimental Psychology*, Vol. 22, No. 4, 892-903.
- van Lankveld J.J.D.M., Smulders F.T.Y. (2008). The effect of visual sexual content on the event-related potential. *Biological Psychology*, 79, 200-208.
- Watanabe S., Kakigi R., Koyama S., Kirino E. (1999). Human face perception traced by magneto- and electro-encephalography. *Cognitive Brain Research*, 8, 125-142.
- Watanabe S., Miki K., Kakigi R. (2005). Mechanisms of face perception in humans: A magneto- and electro-encephalographic study. *Neurophysiology*, 25, 8-20.
- Waynforth D., Delwadia S., Camm M. (2005). The influence of women's mating strategies on preference for masculine facial architecture. *Evolution and Human Behavior*, 26, 409-416.
- Werheid K., Schacht A., Sommer W. (2007). Facial attractiveness modulates early and late event-related brain potentials. *Biological Psychology*, 76, 100-108.
- Wright K., Badia W. (1999). Effects of menstrual cycle phase and oral contraceptives on alertness, cognitive performance, and circadian rhythms during sleep deprivation. *Behavioural Brain Research*, 103, 185-194.
- Xu Y., Liu J., Kanwisher N. (2005). The M170 is selective for faces, not for expertise. *Neuropsychologia*, 43, 588-597.
- Zahavi A., Zahavi A. (1997). *The handicap principle: A Missing Piece of Darwin's Puzzle*, Oxford University Press.

- Zimmermann E. (2008). Cerebral processing of faces: an EEG study on perceived facial attractiveness. Diploma thesis, Department of Anthropology, University of Vienna.
- Zöfel P. (1992). Statistik in der Praxis. Gustav Fischer Verlag Stuttgart-Jena, 3rd edition.

Index of tables and figures

Tables

- Table 1. Mate selection problems. p. 10
Table 2. Number of extracted timeframes with specification of the corresponding time sequence. p. 45
Table 3. Absolute and relative frequencies of all given ratings of subjective mating preference. p. 49
Table 4. Means of reaction times in men and women according to the partner preferences LT and ST. p. 50
Table 5. Effect caused by mate preference on the P100 in male subjects. p. 52
Table 6. Effect caused by hemisphere on the P100 in men. p. 53
Table 7. Effect of use of hormonal contraceptives on the P100 component. p. 60
Table 8. Comparison of hemisphere of the N170 component in male subjects. p.63

Figures

- Figure 1. The two-stage lens model by Miller and Todd (1998). p. 12
Figure 2. Bruce and Young's model of face recognition (1986). p. 20
Figure 3. The dual route model as suggested by Johnson (2005). p. 21
Figure 4. Model of the distributed human neural system for face perception by Haxby, Hoffman & Gobbini 2000. p. 22
Figure 5. Model for recognition of familiar faces by Gobbini and Haxby (2007). p. 23
Figure 6. Examples of a female and a male face used as stimuli in the study. p. 33
Figure 7. Timeline of one trial as used in this experiment for the presentation of the faces. p. 34
Figure 8. Schematic drawing of the answering box. p. 36
Figure 9. Electrode setting used for this experiment. p. 38
Figure 10. Comparison of the electrode setting of the EEG recording cap to electrode positions of the 10/10 system. p. 39
Figure 11. Position of the electrodes used for the electrooculography (EOG). p. 40
Figure 12. P100 and N170 waveform at the electrodes 27 (upper panel) and 28 (lower panel) in men of the answering categories LT and ST. p. 54
Figure 13. P100 and N170 waveform at the electrodes 56 (upper panel) and 57 (lower panel) in men of the answering categories LT and ST. p. 55
Figure 14. P100 and N170 waveform of the answering categories LT and ST at the electrodes 27 (upper panel) and 28 (lower panel) in naturally cycling women in a high versus low conception risk. p. 56
Figure 15. P100 and N170 waveform of the answering categories LT and ST at the electrodes 56 (upper panel) and 57 (lower panel) in naturally cycling women in a high versus low conception risk. p. 57
Figure 16. P100 and N170 waveform of the answering categories LT and ST at the electrodes 27 (upper panel) and 28 (lower panel) in naturally cycling women with a low conception risk versus women using hormonal contraceptives. p. 58
Figure 17. P100 and N170 waveform of the answering categories LT and ST at the electrode 56 (upper panel) and 57 (lower panel) in naturally cycling women with a low conception risk versus women using hormonal contraceptives. p. 59
Figure 18. Visualisation of the P100 in male subjects viewing female faces rated as LT. p. 61
Figure 19. Visualisation of the P100 in male subjects viewing female faces rated as ST. p. 61
Figure 20. Visualisation of the P100 in naturally cycling women looking at male faces. p. 62
Figure 21. Visualisation of the P100 in women using hormonal contraceptives viewing male faces. p. 62
Figure 22. Visualisation of the N170 in male subjects when female faces were seen. p. 64
Figure 23. Visualisation of the N170 in naturally cycling women looking at male faces. p. 64
Figure 24. Visualisation of the N170 in women using hormonal contraceptives looking at male faces. p. 65
Figure 25. P300 waveform of the answering categories LT and ST at the electrodes 48 (Cz; upper panel) and 58 (Pz; lower panel) in naturally cycling women. p. 66
Figure 26. P300 waveform of the answering categories LT and ST at the electrodes 48 (Cz; upper panel) and 58 (Pz; lower panel) in naturally cycling women with a low conception risk versus women using hormonal contraceptives. p. 67

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Abbreviations

BA	Brodman area
EEG	Electroencephalography
EOG	Electrooculography
ERP	Event-related potential
FFA	Fusiform face area
fMRI	Functional magnetic resonance imaging
HEOG	Horizontal → EOG
LPC	Late Positive Component
LT	Answering category “preferred as a long-term partner”
MEG	Magnetoencephalography
PET	Positron emission tomography
rLT	Answering category “rather preferred as a long-term partner”
rST	Answering category “rather preferred as a short-term partner”
ST	Answering category “preferred as a short-term partner”
STS	Superior temporal sulcus
VEOG	Vertical → EOG

Appendices

Appendix 1. The Questionnaire used in this experiment. Female participants were pleased to answer all questions, male participants were given the same one but told not to answer questions concerning cycle and usage of hormonal contraceptives.

PROBANDENNUMMER:

Angaben zur Person

Alter: _____

Geschlecht: ☐ männlich ☐ weiblich **Nationalität:** _____

Wo sind Sie aufgewachsen? ☐ Stadt ☐ Land

Höchste abgeschlossene Ausbildung: _____

Beruf: _____

Studienrichtung (wenn Student): _____

Monatsnettoeinkommen: ☐ 0-499 ☐ 500-999 ☐ 1000-1999 ☐ 2000-2999 ☐ 3000-mehr Euro

Fehlsichtigkeit: ☐ ja ☐ ja, aber korrigiert ☐ nein

Sexuelle Ausrichtung: ☐ heterosexuell ☐ homosexuell ☐ bisexuell

Beziehungsstand: ☐ Single ☐ in fester Beziehung seit: _____

Sind Sie auf Partnersuche? ☐ ja ☐ nein

Könnten Sie sich vorstellen, einen One-night-stand zu haben? ☐ ja ☐ nein

Nehmen Sie die Pille? ☐ ja seit: _____
 ☐ nein nicht mehr seit: _____

Haben Sie innerhalb der letzten 3 Monate Medikamente, Hormonpräparate oder Psychopharmaka eingenommen?

☐ ja ☐ nein

Wenn ja, welche? _____

Durchschnittliche Zykluslänge: _____

Erster Tag der letzten Menstruation: _____

Appendix 2. Instruction for the first main session in German (original text).

“Du wirst jetzt in der Mitte des Bildschirms Gesichter sehen. Davor und danach kommt ein Rauschbild. Deine Aufgabe ist, das Geschlecht des Gesichts zu nennen. Für männliche Gesichter drücke bitte Taste 1, für weibliche Taste 2, jeweils mit dem Zeigefinger der rechten bzw. der linken Hand. Bitte warte mit dem Tastendruck bis das Gesicht weg ist und das Rauschbild zu sehen ist. Wenn das X, das Fadenkreuz, kommt, blinze bitte. Wenn Du an anderer Stelle im Experimentverlauf blinzelst, kann es sein, dass wir die Daten nicht verwenden können. Die Bilder kommen in fixen Abständen unabhängig von Deinem Tastendruck. Nun machen wir einen Übungsdurchgang; danach startet das Experiment.”

Appendix 3. Instruction for the second respectively third main session in German (original text).

“Im nächsten Block siehst Du nun wieder die gleichen Gesichter in zufälliger Reihenfolge und sollst sie jetzt nach ihrem Partnerwert bewerten. Folgende Bewertungen sind möglich: Langzeitpartner, eher Langzeitpartner, eher Kurzzeitpartner, Kurzzeitpartner. Bitte verwende wieder Deine beiden Zeigefinger und positioniere sie zwischen den Tasten. Langzeitpartner ist die ganz rechte/linke Taste, dann kommt eher Langzeitpartner, dann eher Kurzzeitpartner, dann ganz links/rechts Kurzzeitpartner. Wenn das gezeigte Gesicht für Dich als Partner überhaupt nicht infrage kommt, kannst Du für diesen Fall die Bewertung eher Kurzzeitpartner verwenden. Bitte drücke die Taste aber jetzt so schnell wie möglich, ohne lange darüber nachzudenken, sondern triff die Entscheidung mehr aus dem Bauch heraus.“

Appendix 4. Absolute and relative frequencies of all given ratings of subjective mating preference.

One rating from an ovulating woman is missing as well as 5 ratings from not ovulating women and 9 from female subset of participants using hormonal contraceptives. A total of 21 ratings are missing from male test persons. Missing data comes due to not given any respond to a stimulus face.

<i>All female participants rating male stimuli faces</i>				
Categories	ST	rST	rLT	LT
Absolute frequencies	620	849	594	422
Relative frequencies (%)	25%	34%	24%	17%
<i>Female participants ovulating ratings male stimuli faces</i>				
Categories	ST	rST	rLT	LT
Absolute frequencies	113	103	97	86
Relative frequencies (%)	28%	26%	24%	22%
<i>Female participants not ovulating rating male stimuli faces</i>				
Categories	ST	rST	rLT	LT
Absolute frequencies	240	357	216	182
Relative frequencies (%)	24%	36%	22%	18%
<i>Female participants using hormonal contraceptives rating male stimuli faces</i>				
Categories	ST	rST	rLT	LT
Absolute frequencies	267	389	281	154
Relative frequencies (%)	24%	36%	26%	14%
<i>Male participants rating female stimuli faces</i>				
Categories	ST	rST	rLT	LT
Absolute frequencies	416	782	778	503
Relative frequencies (%)	17%	32%	31%	20%

LT = preferred as a long-term partner; rLT = rather preferred as a long-term partner; rST = rather preferred as a short-term partner; ST = preferred as a short-term partner

Appendix 5. Absolute frequencies of buffers remaining after visual inspection and artefact exclusion for the subjective mating preferences ST (“preferred as short-term partner”) and LT (“preferred as a long-term partner”).

One buffer contained the electrophysiological data obtained during processing of one single item. Female participants rating male stimuli faces are presented twice with different sample size according to be able to compare this group with the female sample of ovulating women as well as with the female sample of women using hormonal contraceptives.

Answering categories	Absolute frequencies	
	LT	ST
Males rating female faces (n=24)	435	388
All Females rating male faces (n=21)	346	402
Female sub sample HCR (n=4)	82	93
Female sub sample LCR (n=7)	136	144
Female sub sample HC (n=10)	128	165
HCR = Sub-sample of women in a high conception risk phase rating male stimulus faces; LCR = Sub-sample of women in a low conception risk phase rating male stimulus faces; HC = Sub-sample of women using hormonal contraceptives rating male stimulus faces		

Acknowledgments

I want to thank my two supervisors, Peter Walla and Katrin Schäfer, for their guidance and motivation. They had always time for my questions and problems and gave me helping support, when I needed it.

Thank you Elisabeth for being my partner in this study and for becoming more than that for me!

I also want to thank Bernhard Fink for giving his permission to use his data for stimulus material.

A special thanks to Ulrich Leodolter, who supported this study with a lot of technical input, as well as to the other good souls of this house, namely Maria Richter, Maria Furtlehner, Daniela Pfabigan and Florian Fischmeister.

My gratitude further goes to Alexandra Rutschmann and Sonja Windhager for their help in data analysis.

Thanks to all fifty participants for supporting this study by investing a lot of time and patience! Thank you very much!

I would like to say a special thanks to my Mam for reading this piece of work more often than she ever wished to, for her motivation and her endless love and faith in me! Thank you Dad for not always understanding but always loving me!

Thank you Andreas, thank you Micha, thank you Susu, thank you Wolfgang for always “sailing right behind”!

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