Meaning in words - How social context amplifies cerebral processing of emotional language

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Zusammenfassung

Sprache ist eine einzigartige und zutiefst menschliche Fähigkeit. Obwohl in ihrem Wesen symbolhaft und abstrakt, ermöglicht sie uns dennoch eine detailierte und eindeutige Informationsweitergabe. Die Fähigkeit, sich mit anderen und über andere auszutauschen ist für Menschen als soziale Wesen höchst bedeutsam. Aus diesem Grund ist uns das Urteil anderer über uns oft extrem wichtig, was dem Gesagten häufig enorme Emotionalität verleiht. Obwohl wir heutzutage ein umfassendes Verständnis der neuronalen Grundlagen von emotionaler Sprachverarbeitung haben, gibt es jedoch bislang kaum Studien zum sozial-kommunikativen Einfluss auf diese Sprachverarbeitung.

In meiner Dissertation untersuchte ich solche sozial-kommunikativen Einflüsse am Beispiel verschiedener Kommunikationspartner auf die emotionale Sprachverarbeitung. In drei Studien wurden systematisch die Identität und Kompetenz eines vermeintlichen Kommunikationspartners variiert. Dieser Partner gab personenbezogenes Feedback anhand von positiven, negativen und neutralen Adjektiven, während ein Vielkanal-Elektroenzephalogramm (EEG) abgleitet wurde. Tatsächlich erfolgte in allen Bedingungen Zufallsfeedback, eine unterschiedliche Verarbeitung konnte also lediglich auf die attribuierten Sendereigenschaften zurückgeführt werden. Anhand von Ereigniskorrelierten Potentialen (EKPs) wurde der Einfluss der Sendereigenschaften, des emotionalen Feedbackgehalts und deren Zusammenspiel untersucht. In den Studien I und II wurde zur Etablierung des Paradigmas zunächst ein menschlicher Sender mit einem zufällig agierenden Computer verglichen (ungleiche Kompetenz, ungleiche Senderidentität). Hierbei wurde sowohl die Antizipation (Studie I) des Feedbacks, als auch die neuronale

Reaktion auf das Feedback selbst getestet (Studie II). In Studie III wurde der menschliche Sender mit einem sozial-intelligenten Computer verglichen (ähnliche Kompetenz, ungleiche Senderidentität). In der vierten Studie wurde schließlich ein Experte (Psychotherapeut) mit einem Laien und einem zufällig agierenden Computer verglichen (ungleiche Kompetenz aber Experte und Laie sind beide menschliche Sender).

Für die Antizipation zeigte sich eine extrem frühe einsetzende und generell stärkere Verarbeitung für menschliches Feedback. Auf späten EKP-Komponenten zeigte sich zusätzlich eine besonders starke Verarbeitung für die Antizipation von emotionalem menschlichen Feedback. Die Effekte des tatsächlichen Feedback waren noch einmal deutlich stärker ausgeprägt. Hier zeigten sich große Effekte auf frühen und späten EKP-Komponenten, sowohl für Feedback von vermeintlich menschlichen Sendern, als auch für emotionales Feedback. Weiterhin zeigte sich, dass insbesondere emotionales Feedback vom menschlichen Sender am stärksten verarbeitet wurde. In Studie IV konnte schließlich gezeigt werden, dass 'Expertenfeedback' zu der stärksten Verarbeitung überhaupt führt. Lokalisationen der Generatoren im Gehirn zeigten in allen Studien eine stärkere sensorisch-visuelle Verarbeitung für 'menschliches' und emotionales Feedback. Studien III und IV wiesen zusätzlich stärkere somatosensorische und frontale Effekte für die 'menschlichen' Sender auf.

Insgesamt zeigt sich, dass nicht allein der emotionale Gehalt, sondern vor allem der kommunikative Kontext einen großen Einfluss auf die Sprachverarbeitung hat. Wir scheinen automatisch und intensiv Kontextfaktoren bei der Sprachverarbeitung zu berücksichtigen. Zum einen wirkt sich 'Expertise' bereits auf sehr frühen EKP-Komponenten aus, besonders relevant scheint jedoch menschliches Feedback zu sein, für das eine erhöhte sensorische, teilweise sogar somatosensorische und frontale Verarbeitung gezeigt wurde. Dies zeigt, dass in menschlichen Interaktionen Sprache deutlich intensiver verarbeitet wird, welches insbesondere für emotionale Sprache gilt. Die Dissertation zeigt damit erstmals, dass in realistischeren Kommunikationssituationen eine andere, da um ein vielfaches verstärkte, Verarbeitung von (emotionaler) Sprache stattfindet. Hierbei scheinen zunächst Senderinformation berücksichtigt zu werden, während erst auf späteren Komponenten der emotionale Gehalt verarbeitet wird. Modernste Lokalisationsmethoden wurden hierbei genutzt um zur hochauflösenden zeitlichen Information (*wann*) auch eine robuste Lokalisierung (*wo*) der kortikalen Generatorenstrukturen zu liefern.

Summary

Language is a unique and core human ability. Language is abstract and arbitrary and yet it enables us to communicate with each other. Language allows communication and communication is inherently social. Communicating with and about others is of highest interest for humans, as humans are social beings. This is why receiving human feedback is often extremely emotional. Although we have an extensive knowledge about the neuronal bases of emotional language processing, there are only a few studies yet conducted to investigate socio-communicative influences on language processing.

In my dissertation I examine the influence of a social communicative partner on emotional language processing. Three studies systematically manipulated the expertise and identity of putative interaction partners. These interaction partners gave feedback on positive, negative and neutral adjectives while a high-density

Electroencephalogram (EEG) was recorded. Actually, in all conditions random feedback was presented, thus a differential processing could only be attributed to sender characteristics. By means of event-related potentials (ERPs), the influence of sender characteristics, emotional content and their interaction was observed. In studies I and II - as a proof of principle - a 'human sender' was compared to a random computer (unequal expertise, unequal humanness). In this study, both feedback anticipation (study I) as well as feedback presentation was investigated (study II). In study III the 'human sender' was compared to a socially intelligent computer (similar expertise, unequal humanness). Eventually, in a fourth study a 'human expert' was compared to a 'layperson' and a random computer sender (unequal expertise, but the 'expert' and 'layperson' were both 'humans').

During anticipation of 'human' feedback, an extremely early enhanced general processing was found. On later stages a more intense processing of emotional adjectives was found in the 'human sender' condition. In general, effects during feedback presentation were substantially larger than during feedback anticipation. Here, large effects were found on early and late ERP components, for both human-generated and emotional feedback. Further, emotional feedback given by a 'human' was additionally amplified. Eventually, in study IV 'expert-feedback' was processed most intensely, followed by 'layperson-feedback' and finally 'computer-feedback'. Localization methods found enhanced sensory processing for 'human-generated' and emotional feedback. Studies III and IV showed additionally increased activations in somatosensory and frontal effects for 'human senders'.

Overall, these experiments showed that not only emotional content but particularly also communicative context influences language processing. We automatically seem to take context factors into account when processing language. Here, 'expertise'

results in an enhanced processing aldready on early and highly automatic stages, while supposed humanness seems to be of highest relevance: 'Human-generated' feedback led to enhanced processing in sensory, but also somatosensory and frontal areas. This shows that in human interactions language is amplified processed, which is especially true for emotional language. This dissertation shows for the first time that in realistic communicative settings (emotional) language processing is altered. Here, it seems that first sender information is processed, while emotional content affects later processing stages. The use of state of the art source localization methods enabled to get next to the extremely high temporal resolution (*when* something happens), a good and reliable spatial resolution (*where* something happens) of the cortical generator structures of the ERP effects.

1 Chapter I: Cerebral processing of emotion, language and social context - a brief overview

Abstract language is *the* central ability of human beings. Other skills, like problem solving, remembering, or basic communication can be observed in many species. Primates can even use social cues (Silk, 2007) and distinguish between intentional and accidental human actions (Wood, Glynn, Phillips, & Hauser, 2007). In contrast, language, in a narrow sense, is a unique human skill (Sherwood, Subiaul, & Zawidzki, 2008). One might even speculate that the 'Great Leap Forward' in our intellectual growth is based on the appearance of language, later fostered through the development of written language. At least, the contribution of language to the intellectural development can be observed at the individual level (Herrmann, Call, Hernández-Lloreda, Hare, & Tomasello, 2007; Vygotsky, Hanfmann, & Vakar, 2012). This connection between language and cognition has led to broad debates to which extent language might influence cognition (Casasanto, 2008) and recently also discussed in neuroscientific models as a prerequisite to discriminate emotions (Barrett, Lindquist, & Gendron, 2007). The importance of language is also reflected in our brains, where scientists have identified central brain areas which are cruical for language production and comprehension.

Next to these cognitive aspects, language has also an inherently social function. There are various theories about how and why language evolved at all. One idea of the origin of language is that communication about people not immediately present was necessary when social groups became larger (Aiello & Dunbar, 1993). Language not only enables to communicate with other people but also about other people not present. This social communication is arguably in most cases also highly emotional. As emphasized above, language is abstract and arbitrary. For example, love is just a word. However, although this is a simple array of letters, it is not only social, but also highly emotional. Language statements therefore differ in their emotional quality. We learn to relate certain meanings to words. We intuitively notice the emotional difference between for example terror, table and triumph. Unsurprisingly, research on emotional language processing, specifically on the neuronal processing of emotional language processing, has gained increased attention in the last years. However, so far the social influences on language processing have not been investigated. Subsequently, in this dissertation the impact of the social communicative context on emotional language processing is investigated by using neuroscientific methods.

1.1 Neuroscientific methods to investigate emotional language processing

The cerebral correlates of emotional language processing have been investigated for decades now. To this end neuroscientific experiments typically use Electroencephalography / Magnetoencephalography (EEG / MEG) or functional Magnetic Resonance Imaging (fMRI) as methods to study the response to single words or short sentences. These methods differ in their spatial and temporal resolution: EEG / MEG has an extremely high temporal resolution, enabling to track changes in less than a millisecond. The EEG detects the postsynaptic firing of huge horizontally oriented cell assemblies. Here, most often raw EEG /MEG recordings are converted to time-frequency representation or into event-related potentials (ERPs / MEFs). ERPs enable to investigate systematic brain responses towards stimuli, either time- or phase-locked. However, the signal at the scalp is very small in its amplitude. So only when large cell assemblies systematically fire in response to a stimulus, meaningful ERPs can be recorded, as these are averaged brain response to a stimulus. In general ERPs are qualified by their temporal and topographical appearance, and their polarity denoting whether the amplitude is either a positive or a negative deflection. Thus the N100 and P100 would be amplitudes occurring approximately 100 milliseconds (ms) after stimulus onset, either with a negative (N100), or a positive (P100) amplitude. Actually, for most ERP components the temporal occurrence depends heavily on e.g. the accessed modality, stimulus property and the given task. So it is more common to name ERP components according to the relative appearance, e.g. N1 or P1. The N1 indicates here, that it is the first negative amplitude after stimulus onset, (and it occurs roughly between 100 to 150ms in visual word studies). However, MEG and especially EEG have a rather poor spatial resolution.

Magnetic Resonance Imaging (MRI) on the other hand is supposed to have a much better spatial resolution, but comes at the cost of a relatively bad temporal resolution. This method basically uses a strong magnetic field, forcing all water protons to orient in one direction and measures the time needed to reorient. Based on this information, the existence of different matter densities meshes is inferred and structural images are created. For study purposes, functional Magnetic Resonance Imaging (fMRI) measures changes in the hemodynamic blood flow. This is not a direct measure of neuronal activity. However, firing neurons need energy and this energy is consumed from oxygen in the blood. Oxygen deprived blood flows off and the need for oxygen triggers an increased supply of fresh blood. Thus, strong activity leads to an increased blood supply, which is detectable by the fMRI. This results in an initial dip in the measured blood-oxygen-level, followed by a much larger increase. However, this process is rather slow, as the so called blood-oxygen-level dependent (BOLD) response takes time, peaking between 4 to 6 seconds after stimulus onset.

To overcome the problems of having either a good temporal or a good spatial resolution, recent advantages in source estimations have improved the possibility to detect cortical generators for ERP differences at the scalp. First, for the EEG signal recorded from the scalp, an inverse solution has to be calculated to estimate the cortical generators. This is frequently labeled to be an 'ill-posed' problem (Friston et al., 2008; Litvak et al., 2011; Litvak & Friston, 2008; Lopez, Litvak, Espinosa, Friston, & Barnes, 2013; Mattout, Phillips, Penny, Rugg, & Friston, 2006), as a small number of electrodes are used to estimate an almost infinite number of dipoles. Litvak and colleagues (2011) stated this to be an estimation of the body shape by its shadow. There is no unique solution to reconstruct the recorded brain activity, but many different possibilities (Mattout et al., 2006). Nevertheless, these source estimation results from EEG and MEG show a very good overlap with fMRI results (Henson, Wakeman, Litvak, & Friston, 2011).

1.2 An overview on emotion models

The attempt to define emotions has been made since the beginning of psychology (James, 1884, 1890). Although everyone knows what emotions are (until asked for a definition, as pointed out by Fehr & Russell, 1984), there is not one single definition of emotions. As a working definition Kleinginna and Kleinginna (1981; p. 355) give:

> *"Emotion is a complex set of interactions among subjective and objective factors, mediated by neuronal/hormonal systems, which can (a) give rise to affective experiences such as feelings of arousal, pleasure/displeasure; (b) generate cognitive processes such as emotionally relevant perceptual effects, appraisal, labeling processes; (c) activate widespread physiological adjustments to the arousing*

> *conditions; and (d) lead to behavior that is often, but not always, expressive, goal-directed, and adaptive."*

Models of emotion broadly fall into those which regard emotions as discrete categories and others which use a dimensional approach. Theories which proposes discrete emotion categories are for example Ekman’s theory of (at least some) basic emotions (Ekman, 1972, 1992; Ekman et al., 1987). These are advocated to be universal, biologically based and cannot be further subdivided (Ekman & Cordaro, 2011; Izard, 2011). Other approaches use a prototypical approach (Fehr & Russell, 1984), but further differentiate between these prototypical emotion components on the one hand and 'core affect' on the other hand. This 'core affect' can be regarded to reflect the dimensional model of emotion, and it has been suggested that the appropriateness of a categorical or dimensional model highly depend on the experimental approaches (Russell, 2003; Russell & Barrett, 1999).

Dimensional models of emotion can be traced back to the very beginning of psychology as a discipline. Already in 1897 Wilhelm Wundt used three dimensions to classify emotions (roughly these were valence, arousal and tension; Wundt, 1980). In modern psychology, Osgood and colleagues started to explore the emotional space of single written words (Osgood, 1952; Osgood, Suci, & Tannenbaum, 1957), extracting three dimensions: emotional evaluation, potency and activity. Building upon these findings, a popular model of emotion was developed by James Russell (Russell, 1980): The circumplex model of affect states, that emotions can be described solely by relative position on the dimensions 'valence' and 'arousal' (Russell, 1980). Other dimensional models further differentiate between positive and negative affect, suggesting two separate systems (D. Watson & Tellegen, 1985), as valence and arousal seem not to be fully independent from each other (Ito, Cacioppo, & Lang, 1998).

Neuroscientific support can be found for basic emotion models (Vytal & Hamann, 2009), as well as for dimensional models of emotion (Gerber et al., 2008). Although dimensional models have been criticized to neglect the complexity of emotions (Fontaine, Scherer, Roesch, & Ellsworth, 2007; Scherer, 2005), psychophysiological research has mainly adopted a two-dimensional model of emotion (Cacioppo & Gardner, 1999; Cacioppo, Gardner, & Berntson, 1999; Lang, Greenwald, Bradley, & Hamm, 1993). The reasons are manifold: First, such a model allows a numerical manipulation of emotional dimensions in experimental settings. Further, the existence of the valence dimension has been validated across cultures (Russell, 1991), and all cultures posses words to distinguish between pleasantness and unpleasantness (Wierzbicka, 1999). Moreover, for different types of stimuli (e.g. pictures, sounds and words) such a two-dimensional space has been found (Bradley & Lang, 1999, 2007; Lang, Bradley, & Cuthbert, 2008). Finally, the distinction between arousal and valence is sufficient to explain most psychophysiological and neuroscientific findings for emotional stimuli (Bradley, Codispoti, Cuthbert, & Lang, 2001; Lang, Bradley, & Cuthbert, 1997; Lang et al., 1993). Thus, in this work, the two-dimensional model of Lang and colleagues (Lang et al., 1993) is used to characterize our emotional categories (see Figure 1), as measured by the Self-Assessment Manikins (Bradley & Lang, 1994).

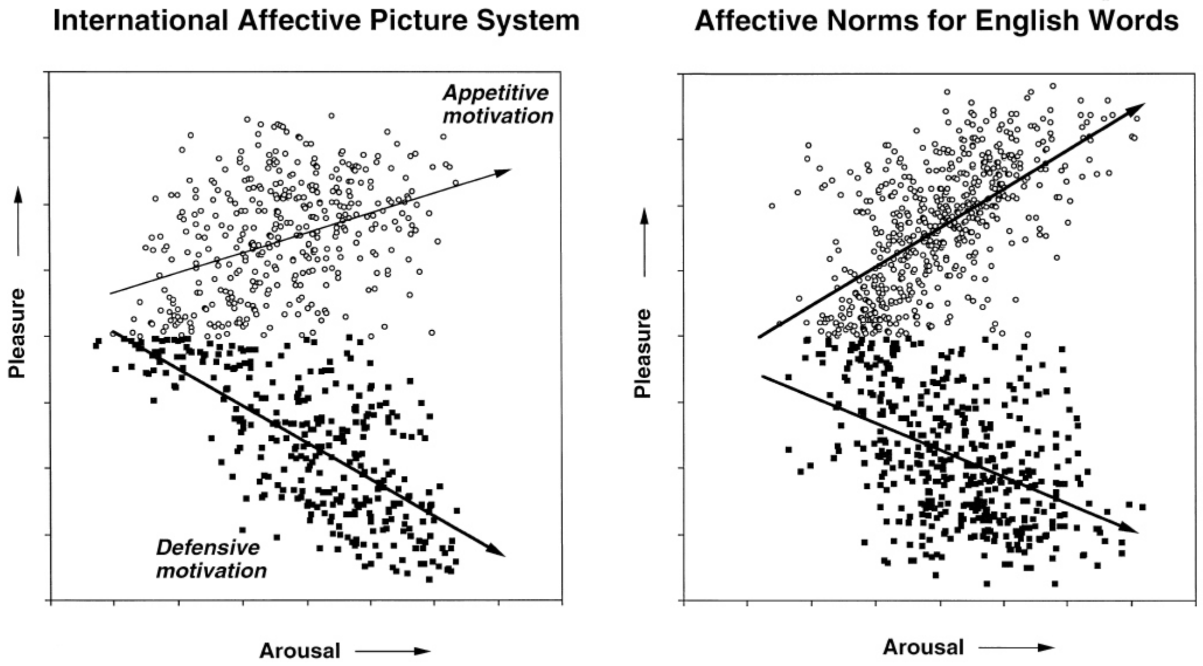

Figure 1: The two-dimensional emotion model of arousal and affect. Displayed is the rated space on the pleasure and arousal for pictures (left) and words (right). Results show an increase in arousal at both ends of the rated valence. This figure is taken and adapted from Bradley et al. (2001).

In neuroscientific experiments, emotion effects seem to be comparable across various different visual modalities. This points to an similar system in emotion processing: EPN and LPP enhancements are observed for words, gestures, faces and also pictures (Flaisch, Häcker, Renner, & Schupp, 2011; Frühholz, Jellinghaus, & Herrmann, 2011; Kissler, Herbert, Peyk, & Junghofer, 2007; Kissler, Herbert, Winkler, & Junghofer, 2009; Schacht & Sommer, 2009a; Schupp, Flaisch, Stockburger, & Junghofer, 2006). Similarly to overlapping ERP findings, fMRI studies show emotion-induced enhanced activations in primary visual, subcortical, cingulate and frontal areas (Viinikainen et al., 2010; Bradley et al., 2003; Hamann & Mao, 2002; Schupp, Junghöfer, Weike, & Hamm, 2003; Vuilleumier, Armony, Driver, & Dolan, 2001; Flaisch et al., 2015; for reviews see Zald, 2003; Phan, Wager, Taylor, & Liberzon, 2002). This overall prioritized processing of emotional compared to neutral content is described by various theories on how the brain deals with emotion (e.g. Dalgleish, 2004; Lang et al., 1997; LeDoux, 1998; Mather, Clewett, Sakaki, & Harley, 2015; Pourtois, Schettino, & Vuilleumier, 2013).

1.3 Neurophysiological models of emotion processing

1.3.1 A brief overview on physiological models of emotion processing

Biological or neurophysiological models of emotion processing also started with James (James, 1884, 1890). According to the James-Lange hypothesis, emotions are generated by distinct body-states (see also Figure 2 for a short chronological overview). This idea was later rejected by Walter Cannon, who argued that body-states are too slow, unspecific and in cats, surgical resections of body projections to the brain did not impair emotional behavior (Cannon, 1927) The Cannon-Bard theory proposed that the hypothalamus would be the relevant brain for generating emotions.

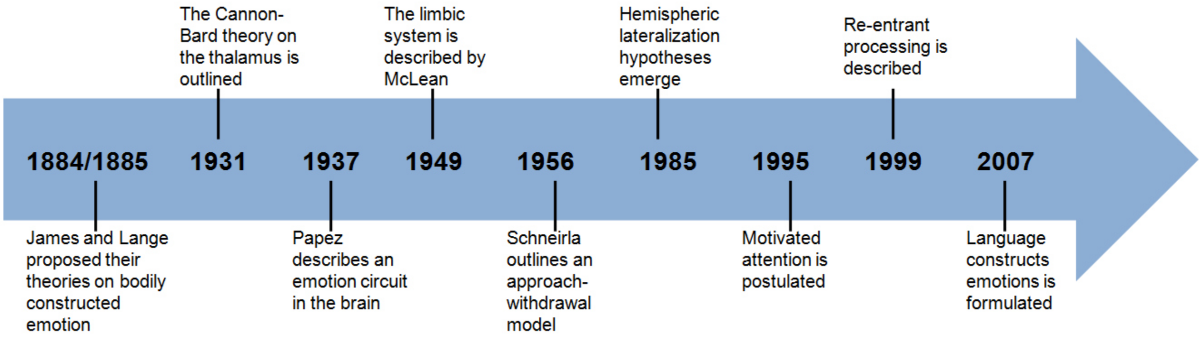

Figure 2: A highly selective and non-extensive timeline of (neuro)physiological emotion theories.

Later, the idea of the Papez circuit (Papez, 1937) and the Limbic system (MacLean, 1949; Maclean, 1955) was basically, that a number of subcortical brain regions, which interact with each other, would be responsible to generate emotions. In a synthesis, Schachter and Singer proposed that both, bodily sensations and cognitive attribution of these body responses are necessary to form emotions (Schachter & Singer, 1962).

1.3.2 Identified key structures in the brain

Central key structures were also identified, mostly by lesion studies: In monkeys, the loss of the bilateral temporal lobes (Klüver & Bucy, 1937), more precisely (but sufficiently only) the loss of the bilateral amygdala (Weiskrantz, 1956) resulted in a strange and impaired socio-emotional behavior. Regarding humans, such symptoms seem to only occur after extensive removal of the bilateral temporal lobes (Terzian & Dalle Ore, 1955). However, the amygdala was soon identified to be crucial for fear recognition (Adolphs, Tranel, Damasio, & Damasio, 1994) and fear conditioning (Blanchard & Blanchard, 1972; LeDoux, 1989, 1992). Since Phineas Gage (Harlow, 1868) also the prefrontal cortex (PFC) has been identified to be responsible for emotion regulation and behavioral adjustment. Reminiscent of James' conceptualization, the somatic marker hypotheses by Damasio and colleagues assumes, that participants with prefrontal cortex damage are not able to access information provided by their visceral projections (Damasio, 1996). Other relevant regions seem to be the insula in disgust (Gray, Young, Barker, Curtis, & Gibson, 1997; Phillips et al., 1997) and pain processing (Adolphs, 2009), the anterior cingulate cortex as a integrating structure in emotion experience (Bush, Luu, & Posner, 2000) in and the hypothalamus and striatum which are thought to be part of the reward system, including the PFC and the amygdala (Dalgleish, 2004). For an overview of the most relevant structures in emotion processing see Figure 3.

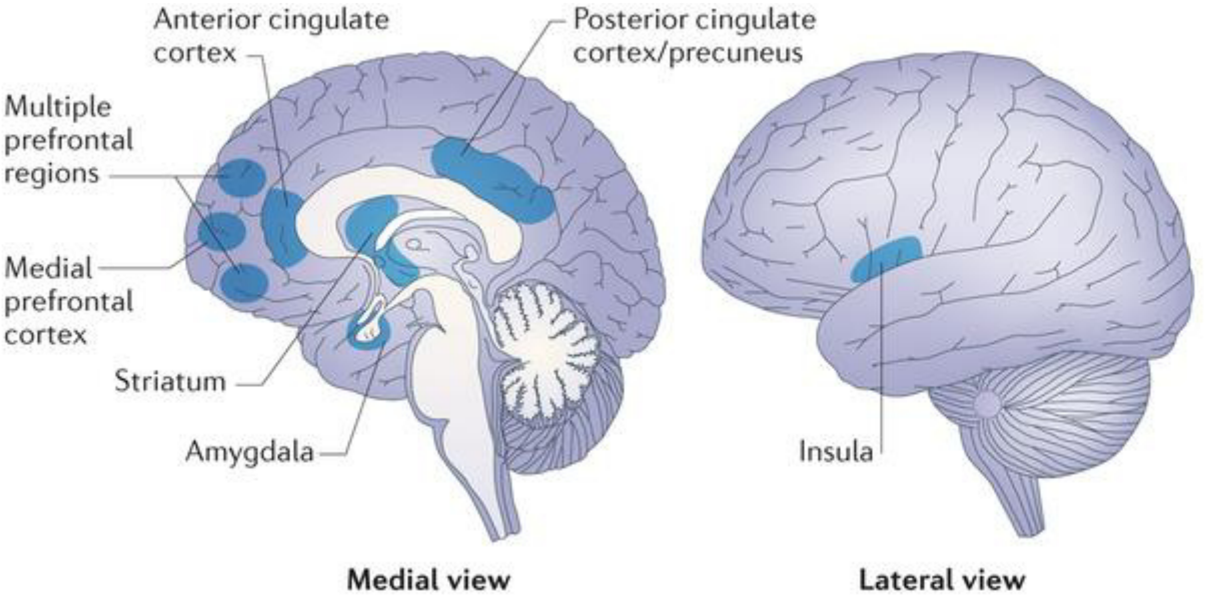

Figure 3: Brain structures involved in emotional processing. The figure is taken from Tang, Hölzl & Posner (2015).

1.3.3 Current brain models of emotion processing

Most early theories proposed a single system, relevant to generate emotions (e.g. James, 1884; Cannon, 1927; Maclean, 1955; Papez, 1937). Later two-dimensional theories proposed a differentiation between two systems (see also Figure 2). For example the hemisphere hypotheses assumes a brain asymmetry, e.g. for negative (right hemisphere) and positive (left hemisphere) affect processing (Davidson, 1998; Davidson, Kalin, & Shelton, 1992; Silberman & Weingartner, 1986), or two systems for approach and withdrawal behavior (Davidson, Ekman, Saron, Senulis, & Friesen, 1990; Schneirla, 1959). In line with such approach and withdrawal theories, the so called model of Motivated Attention from Lang and colleagues explains enhanced ERP and fMRI responses to emotional content (Lang, 1995; Lang et al., 1997; Schupp, Cuthbert, et al., 2004). This idea originates from strong similarities of neurophysiological responses to emotional content compared to responses elicited by explicitly instructed attention to stimuli. EEG studies show increased EPN amplitudes for both, attended (e.g. by counting stimuli) and emotional stimuli (Junghöfer et al., 2001; Schupp et al., 2003, 2006, 2007). Further, larger visual activity has been found by fMRI studies in responses to emotional pictures as well as for attended ones, suggesting a similar underlying mechanism (Bradley et al., 2003; Lang et al., 1998). The model of Motivated Attention states therefore that emotional content itself attracts visual attention which leads to the increased visual processing of emotional stimuli (Lang et al., 1997; Schupp, Cuthbert, et al., 2004).

Neurophysiologically, this might be based on re-entrant processing of emotional stimuli, through bi-directional signaling from the amygdala to visual cortices (Sugase, Yamane, Ueno, & Kawano, 1999; Vuilleumier, 2005). The basic idea is that as soon as the amygdala encounters emotional salient stimuli there is a feedback signaling to visual cortices, and at the same time these sensory areas provide an updating of the processed visual stimulus (Vuilleumier, 2005). In line with the re-entrant hypothesis, strong reciprocal connections between amygdala and inferotemporal visual cortex are reported (Sabatinelli, Bradley, Fitzsimmons, & Lang, 2005) and emotional LPP modulations have been found to be correlated with subcortical and visual fMRI signals (Sabatinelli, Keil, Frank, & Lang, 2013; for co-activations of cortical and subcortical structures, see also a meta-analysis from Kober et al., 2008).

Although a strict distinction between brain regions involved in cognitive and affective processing might be problematic (Pessoa, 2008), and likely several different pathways are involved in emotion processing (Pessoa & Adolphs, 2010), recent models on the processing of emotion in the brain still suggest that the amygdala is the key hub for projections to sensory areas and regulating motor responses and behavioral adjustments (Pourtois et al., 2013). In addition, the allocation of resources towards (arousing) emotional stimuli is thought to be also based on noradrenergic projections of the locus coeruleus (Mather et al., 2015; Mather & Sutherland, 2011). These noradrenergic projections are responsible for suppressing irrelevant neuronal activity and thus increasing sensitivity towards arousing stimuli. This model tries to explain conflicting findings of either enhanced or reduced perception (Keil & Ihssen, 2004; Padmala & Pessoa, 2008), or memory performance (Knight & Mather, 2009; Sakaki, Fryer, & Mather, 2014), for (arousing) emotional stimuli.

1.4. Language processing

1.4.1 Neurophysiological bases of language processing

More than hundred years ago, based on language impairments of patients with circumscribed lesions, two crucial brain regions were identified for speech production and comprehension and named after their discoverers (Broca, 1865; Wernicke, 1874, 1886). Lesions in the left inferior frontal gyrus, Brocas area (Dronkers, Plaisant, Iba-Zizen, & Cabanis, 2007), resulted in an inability to produce speech, while patients with damage to Wernickes area, which is located in the superior temporal gyrus, spoke fluently but meaningless. Nowadays, Broca area has been suggested to play a crucial role in binding of linguistic information (Hagoort, 2005). Recently, this area has been found to be active before but rather inactive during actual speech production (Flinker et al., 2015). Based on this, it has been suggested that this region, due to its reciprocal interactions with temporal and frontal areas, has a mediator function between sensory information and speech production (Flinker et al., 2015).

Research on language processing using ERPs has differentiated between early and late stages of processing. The exact temporal processing of written language has found to be influenced by various parameters, for example word frequency, word length or the orthographic neighbors (Hauk, Davis, Ford, Pulvermüller, & Marslen-Wilson, 2006). Regarding visual word processing, primary sensory analysis occurs in visual areas (Friederici, 2011). After initially visual processing and lexical access, Sereno and Rayner (2003) suggested that word-specific information is retrieved from about 200ms after word onset (see Figure 4 for a simplistic overview). In general the authors also point out that N400 effects can start as early as 200ms or as late as 600ms after word onset (Sereno & Rayner, 2003). The N400 is generally one of the most widely investigated components, and can be found both in studies on auditory and visual language comprehension (Kutas & Federmeier, 2011; Kutas & Hillyard, 1980). A widely accepted idea is that at the N400 semantic-lexical integration takes place (Brown & Hagoort, 1993; Friederici, 2011) and is not generated by a static cortical source but by multiple waves in

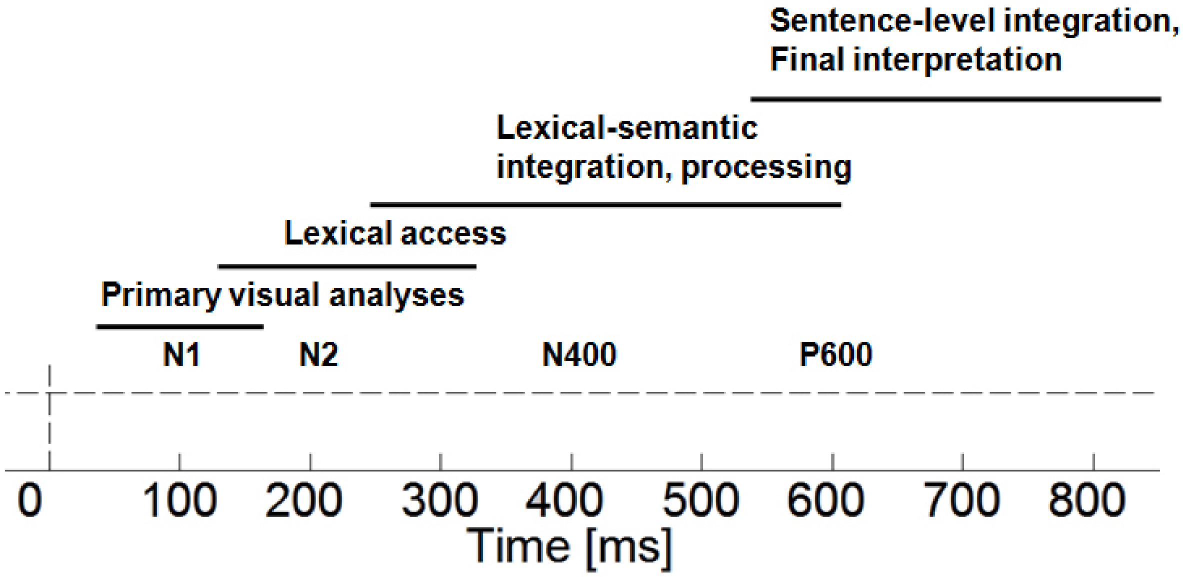

Figure 4: A simplistic model of visual language processing based on Sereno & Rayner (2003) and partly Friederici (2011).

different areas starting approximately 250ms after stimulus onset (Kutas & Federmeier, 2011).

For written language, a region located in the left fusiform gyrus, called the Visual Word Form Area (VWFA), has been identified to be a key structure in processing the language information (Dehaene & Cohen, 2011; McCandliss, Cohen, & Dehaene, 2003; Szwed et al., 2011; Yarkoni, Speer, Balota, McAvoy, & Zacks, 2008). Sometimes it is referred to as an 'expert' region (McCandliss et al., 2003), similar to the fusiform face area for faces, located in the right fusiform gyrus. Although existence of the VWFA has been questioned by other researchers (Price & Devlin, 2003), lesions to the VWFA has shown to result in pure alexia (L. Cohen et al., 2003; Pflugshaupt et al., 2009; Starrfelt, Habekost, & Leff, 2009), and electrical stimulation of this area induced alexia, but preserved the ability to name objects (Mani et al., 2008). The VWFA activity is thought to reflect the integration of orthography and word meaning (Yarkoni et al., 2008). Further, its activity also predicts memory for words (Mei et al., 2010).

1.4.2 Language as prerequisite for emotion perception

Recently, researchers proposed that language is necessary to infer from brain states the concrete experience of distinct emotion categories (Barrett et al., 2007; Lindquist & Gendron, 2013; Lindquist, Wager, Kober, Bliss-Moreau, & Barrett, 2012). The hypothesis of discrete emotion categories (e.g. Ekman, 1992), is questioned as (modular) brain responses to emotional stimuli seem to be neither sufficiently specific enough, nor were brain stimulations able to induce single emotional states (Lindquist et al., 2012). Further, the consistent co-activations in brain networks supporting language, namely the anterior temporal lobes (ATL) and the ventrolateral prefrontal cortex (VLPFC), are seen as a proof of psychological constructionist view (Russell, 2003), where the labeling of states is necessary to experience discrete emotional states (Lindquist et al., 2012). Thus, language is needed as a tool to classify and differentiate between emotional states.

1.5 Emotional language processing

1.5.1 ERPs findings of emotional language processing

Coming to emotional language processing, a vast number of studies document the different processing of emotional compared to neutral content. Reviews on the amplified responses for emotional language have been conducted for ERPs (Kissler, Assadollahi, & Herbert, 2006) or ERPs and fMRI (Citron, 2012; Kissler, 2013). Regarding ERPs, emotional words have been found to be processed with priority on early, presumably highly automatic, as well as on late, more controlled stages. Consistently, emotional words elicit a larger Early Posterior Negativity (EPN), which is a negative deflection, posterior on the scalp, peaking between 200 and 300ms. In some instances, the EPN is also reported to occur later, between 350 to 500ms (Palazova, Mantwill, Sommer, & Schacht, 2011; Schacht & Sommer, 2009a, 2009b). The EPN can be found across various language tasks, ranging from silent reading (Herbert, Junghofer, & Kissler, 2008; Kissler et al., 2007, 2009), to lexical decision (Hofmann, Kuchinke, Tamm, Võ, & Jacobs, 2009; Palazova et al., 2011; Scott, O'Donnell, Leuthold, & Sereno, 2009), or word identification tasks (Hinojosa, Méndez-Bértolo, & Pozo, 2010). It is thought to be a marker of early attention, where emotion effects are mostly attributed to stimulus arousal (Kissler et al., 2007), although stimulus properties also seem to influence the EPN (Bayer, Sommer, & Schacht, 2012a; Palazova et al., 2011). In the EPN time window, emotional words are faster differentiated from pseudo words, suggesting a fast salience/valence extraction already at this stage (Kissler & Herbert, 2013) and emotional primes accelerate lexical decision tasks (Kissler & Kössler, 2011), possibly by activating a speeded salience decoding. However, emotion effects might even occur at earlier stages: Combined EEG/MEG studies reported an ultra-rapid differentiation between emotional and neutral words starting as early as from 80ms onwards (Keuper et al., 2013, 2014).

In contrast to such highly automatic processing stages, the Late Positive Potential or Late Positive Complex (LPP, LPC) is believed to be involved in more elaborate stimulus evaluation (Bayer, Sommer, & Schacht, 2010; Herbert et al., 2008; Herbert, Kissler, Junghöfer, Peyk, & Rockstroh, 2006; Hinojosa et al., 2010; Hofmann et al., 2009; Kanske & Kotz, 2007; Kissler et al., 2009). Depending on the modality and task the LPP peaks between 400 and 1000ms. Sometimes it is distinguished between early (~400-650ms) and late (~650-900ms) portions of the LPP. The LPP is believed to be more influenced by the given task or context. For example, in one study an emotional LPP enhancement was found only in a lexical and a semantic but not in a syntactic decision task (Schacht & Sommer, 2009b). In another experiment emotional LPP enhancement occurred in a word identification task only when words had to be identified among pseudowords (Hinojosa et al., 2010). The LPP has been related to episodic memory encoding (Dolcos & Cabeza, 2002) and emotional LPP enhancements have been further related by source estimations to occipital generators (Moratti, Saugar, & Strange, 2011; Sabatinelli, Lang, Keil, & Bradley, 2007). Lately, a significant relationship between the BOLD signal and the LPP were found in visual, temporal, medial frontal, orbitofrontal areas as well as with the amgydala and insula (Liu, Huang, McGinnis-Deweese, Keil, & Ding, 2012).

1.5.2 Brain structures involved in emotional language processing

So far by using fMRI, stronger visual (Compton, 2003; Demirakca et al., 2009; Straube, Sauer, & Miltner, 2011) and amygdala responses are observed in response to emotional words (Hamann & Mao, 2002; Herbert et al., 2009; Kensinger & Schacter, 2006; Nakic, Smith, Busis, Vythilingam, & Blair, 2006; Straube et al., 2011). Further, emotional words lead to stronger inferior frontal gyrus activations (Briesemeister, Kuchinke, Jacobs, & Braun, 2015; Kuchinke et al., 2005), while positive compared to negative words seem to be stronger processed in anterior cingulate regions (Kuchinke et al., 2005). On the other hand, also negative compared to neutral words have shown to result in stronger responses in the anterior (Nakic et al., 2006) and posterior parts of the cingulum (Demirakca et al., 2009; Nakic et al., 2006). In line with this, both negative and positive word valence has been shown to activate the anterior cingulum (Lewis, Critchley, Rotshtein, & Dolan, 2007), the orbitofrontal cortex (Demirakca et al., 2009; Lewis et al., 2007) and for positive words the medial frontal cortex (Briesemeister et al., 2015). Some studies also report a left-lateralization for emotional compared to neutral words, either in the left amygdala and hippocampus (Strange & Dolan, 2001), the left fusiform gyrus (Q. Luo et al., 2004) or broader left-lateralized networks (Kuchinke et al., 2005). In summary, emotional words seem to activate visual, cingulate, frontal as well as subcortical regions, including the amygdala, similar to the identified key structures in emotion processing (see Paragraph 1.3.2 and also Figure 3 above).

1.6 Social context

1.6.1 Context modulations of emotion processing

Context in general can be defined rather broad and thus context can be established in by variety of different manipulations. In this broad sense, context has been shown to affect emotional content processing in various ways. For example, the so called ‘Kuleshov Effect’ - a commonly used method in movies - shows a differential emotion attribution of identical faces, when these faces are either shown in an emotionally salient or in a neutral context (Kuleshov, 1974). In an adaptation of the ‘Kuleshov Effect’, fMRI measures showed interactions in the amygdala when subtle happy faces were shown in negative context (Mobbs et al., 2006). On the other hand, ERP modulations were not found towards fearful faces depending on the background, but to the background when fearful faces were presented (Wieser & Keil, 2013). But context can also be purely descriptive: Surprised faces were regarded to be happy or afraid, depending on the preceding sentence (Kim et al., 2004).

So the context can be established by rather subtle and simple descriptive manipulations. Considering language, a couple of studies investigated the effect of self-reference on visual word processing (Herbert, Herbert, Ethofer, & Pauli, 2011; Herbert, Pauli, & Herbert, 2011; Shestyuk & Deldin, 2010; L. A. Watson, Dritschel, Obonsawin, & Jentzsch, 2007). Herbert and her colleagues manipulated self-reference by the use of self- or other related personal pronouns (*my* fear, *his* fear). They showed self-reference effects starting from 200ms onwards and interaction in the LPP, showing a additional increase of self-related emotional words (Herbert, Herbert, et al., 2011; Herbert, Pauli, et al., 2011). In other studies participants had to judge presented positive or negative words were self-descriptive or not (Shestyuk & Deldin, 2010; L. A. Watson et al., 2007). Watson and colleagues found an interaction at the N400, where only negative self related words led to an increased N400, suggesting a self-positivity bias (L. A. Watson et al., 2007). In another study, depressive patients and healthy controls judged the self-descriptiveness of emotional words (Shestyuk & Deldin, 2010). They found a strong self-reference enlargement already at the P2 component. Further, an interaction of self-reference and emotion occurred, where depressives had a strong P2 enlargement for negative self-descriptive words, while healthy controls exhibited a positivity bias. Such early effects of self-reference are also reported by studies using whole sentences, but measuring responses towards the onset of the critical final word (Fields & Kuperberg, 2012). Here, P1 and N1 enlargements for self-referent sentences were found, as well as an interaction at the late stages. However, in the LPP a neutral enhancement was observed and interpreted to reflect a ceiling effect: The authors suggested that neutral content could be amplified more easily under self-reference (Fields & Kuperberg, 2012). Thus self-reference shows modulations of early and late components. Here, mostly an increase of early and late components is found and interactions of self-reference and emotional content are most consistently found at later stages, namely at the LPP. Interestingly, in an fMRI experiment inducing self-reference, participants were requested to think about memories or associations related to presented emotional and neutral words, and subsequently had to rate the valence and arousal of each word (Posner et al., 2009). Rated valence extremes were highly correlated with activity in broad frontal and anterior and posterior parts of the cingulum (Posner et al., 2009).

1.6.2 Social context modulations of emotion processing

Although such self-reference manipulations show alteration of emotional processing, these might underestimate the influence of social context on emotional language processing. As pointed out, it has been suggested that language is necessary to describe and label emotions. However, in contrast to naive assumptions word-meaning is not fixed. We need to have knowledge about the context to decode the given meaning (Fauconnier, 1994; p. xviii). Some words for example are used ambiguously in everyday life, as 'extinguished' might be either good in a context of fighting a fire, or bad, when it describes the disappearance of a species. But even typically high emotional words with a clear meaning, like 'cold' as a word with negative valence, changes the emotional meaning in a given context: Being a cold person is certaintly negative (as a central trait, see Asch, 1946), but beeing cold in a sport match (e.g. scoring in the last seconds in basketball) or in the job (e.g. performing a difficult surgery) is highly positive. Language might construct emotion, but context influences language meaning. We need to have contextual information to actually evaluate the valence of a single word or short phrase language statement. Some theories even state, that word-meaning is directly adopted from interaction with others (Blumer, 1969). This emphasizes the social aspect in language processing. Interestingly, in this regard some theories argue that language evolved as a social bonding mechanism, allowing people to communicate about people not immediately present (Aiello & Dunbar, 1993). This underlines the social function of language and we have to keep in mind that most human beings desperately struggle to belong to a social group (Baumeister & Leary, 1995; Leary & Downs, 1995), as this seems to be biologically based and an evolutionary advantage to be part of a group. For instance, after events of social rejection our memory for social information is selectively enhanced (Gardner, Pickett, & Brewer, 2000). And both behaviorally and neuroscientifically the influence from the own (liked) social group has long-lasting effects on our own preferences (Izuma & Adolphs, 2013)

So what constitutes social context? Interacting with other humans seem to generate a social context. Further, humans certaintly have a tendency to anthropomorphism, stating human-like abilities to non-human agents (Epley, Waytz, & Cacioppo, 2007). But so far, research for interactions with computers, machines or social robots suggest that these partners are not treated in the same way as actual humans. For example, in a so called 'trust game', participants could increase their monetary reward based on decisions by interaction partners (Phan, Sripada, Angstadt, & McCabe, 2010), where in the 'ultimate game' monetary reward were offered by their interaction partners (Harlé, Chang, van ’t Wout, & Sanfey, 2012). Here, participants responded strongly to unfair behaviors from interaction partners, but not when these partners were introduced as computers (Harlé et al., 2012; Phan et al., 2010). The perceived intentionality by human partners might play a role (Singer, Kiebel, Winston, Dolan, & Frith, 2004), while computers are mostly seen to be disempassionated. However, human-computer differences seems to increase the more personal it gets. For instance, participants show less interpersonal display to computers during interaction (Aharoni & Fridlund, 2007) and empathy (Rosenthal-von der Pütten et al., 2014) and mentalizing (Chaminade et al., 2012; Kircher et al., 2009) in response to computers.

Thus, social context induced by 'human' presence has a huge and manifold impact on stimulus processing, affecting various brain structures. A number of fMRI experiments inducing social exclusion found enhanced activity in the dorsal anterior cingulate cortex, the amygdalae, the anterior insulae and the periaqueductal gray (for an overview see Eisenberger & Cole, 2012). On the other hand social reward seems to enhance activity in reward related areas, such as the ventral striatum, the anterior cingulate cortex and medial prefrontal cortex (e.g. Izuma, Saito, & Sadato, 2008, 2010; Korn, Prehn, Park, Walter, & Heekeren, 2012). Regarding such social feedback sutdies, mentalizing about the intentions from the given sender likely play an important role. Meta-analyses point to the cortical midline structures, the medial prefrontal cortex and the posterior cingulate cortex (PCC) as the central hubs for mentalizing (Northoff & Bermpohl, 2004; Uddin, Iacoboni, Lange, & Keenan, 2007). Autistic patients have typically a deficit in mentalizing and also less functional connectivity between these regions (Weng et al., 2010). Further, stronger frontal activity is found when people have to mentalizing about humans compared to objects or when they interact with human compared to computer partners (Ciaramidaro, Becchio, Colle, Bara, & Walter, 2013; Kircher et al., 2009; Wolf, Dziobek, & Heekeren, 2011). To summarize, in social context, a number of brain structures are involved: For reward processing and future predictions the orbitofrontal cortex and ventral striatum, for negative feedback assessment the anterior cingulate region and the insulae (Adolphs, 2009) and for simulation other people´s mental states and empathy the premotor cortex and the insulae (Adolphs, 2009). In addition, the cortical midline structures are involved in mentalizing about the interactive partner and in different self-reflective processes (Lieberman, 2007). Finally, induced salience by the social context might lead to e.g. increased amygdala activations.

Considering EEG research, social context has been shown to strongly affect our processing of, in fact, identical sensory stimuli (Bublatzky & Schupp, 2012; Suess, Rabovsky, & Rahman, 2014; Wieser et al., 2014). Context manipulations affect our processing of various stimuli. The semantic knowledge about a person modulates the processing of inherently neutral faces (Klein, Iffland, Schindler, Wabnitz, & Neuner, 2015; Rahman & Sommer, 2012; Suess et al., 2014)

For example, negative, neutral or positive information about a given face (Klein et al., 2015; Suess et al., 2014), or the threat to hold a public speech (Wieser, Pauli, Reicherts, & Mühlberger, 2010) showed significant modulations of early sensory components towards faces (N170, EPN). Biographical information showed modulations starting as early as from the P1 component onwards (Rahman & Sommer, 2012). Further, in line with considerations about similarities between social and physical threat, the threat to receive electric shocks showed early (P1, P2) and late (LPP) ERP component modulations (Bublatzky, Flaisch, Stockburger, Schmälzle, & Schupp, 2010; Bublatzky & Schupp, 2012), but larger P1 response can be also found when participants experience group pressure (Trautmann-Lengsfeld & Herrmann, 2013). Finally, N1 enlargement can be found in putatively collaborative joint-tasks (Baess & Prinz, 2014).

1.7 Scope of the dissertation: Investigating the impact of social communicative context on emotional language processing

As noted above, combined EEG/MEG studies show that an ultra-rapid differentiation between emotional and neutral words is possible (Keuper et al., 2013, 2014), and even C1 responses have been reported for fearful faces (Pourtois, Grandjean, Sander, & Vuilleumier, 2004). However, such early findings are otherwise mostly found for conditioned responses towards stimuli (Hintze, Junghöfer, & Bruchmann, 2014; Keil, Stolarova, Moratti, & Ray, 2007; Rehbein et al., 2015). However, social context seems not only to increase stimulus salience, and amplify the cortical reactions towards such stimuli, but to speed-up these responses. ERPs on emotional language processing have recently started to investigate the impact of the given context on the brain responses (Fields & Kuperberg, 2012; Herbert, Herbert, et al., 2011; Herbert, Pauli, et al., 2011; Rohr & Rahman, 2015).

In this dissertation, I investigated the impact of the social communicative context on the cortical processing of emotional language in a series of ERP studies. Here, the social context manipulation was based purely on participants' attributions: Participants were simply told that they would receive social feedback from different senders. To this aim, a short and structured video interview was recorded, which putatively was the basis for the evaluation. However, there were no actual differences between the conditions, so communicative context effects can be based only on the participants' mind. We expected two important influencing factors when receiving social feedback. The first, and arguably most important, was supposed humanness and the second the supposed expertise. Human evaluations influence us strongly, and although computer algorithms might even be more accurate (cf. Youyou, Kosinski, & Stillwell, 2015), we expected a much stronger impact from 'human sender' compared to a 'computer' on feedback processing. Secondly, expertise contributes to the persuasiveness of messages (Collins & Stukas, 2006) and therefore we expected that a 'human expert' would have a stronger impact on feedback processing compared to a 'human layperson'.

An evaluation of one's personality can be seen as a highly social situation. This evaluation was performed by affirming or rejecting negative, neutral, and positive adjectives. Color changes on these adjectives signaled if a sender decided that a given adjectives would be descriptive or not descriptive for the participant. As a proof of principle, in the first experiment it was investigated if feedback from a putative 'human sender' differed from random computer feedback. These two senders differed both in their ascribed expertise, but also in the humanness. Here, both the anticipation (first study) of the feedback during the word presentation, as well as the actual feedback (second study) were separately examined. In the third study, basically, the very same experiment was performed. However, the cover story was changed: Here, differences in expertise were controlled, as both the 'human' and the 'computer sender' were introduced to be equally able to give personality feedback. However, these two senders still differed in their humanness. Finally, in the fourth study, the ascribed 'humanness' was controlled by having two 'human senders', but levels of expertise were varied, as one sender was a putative 'expert' (psychotherapist), and one a 'layperson'. In a control condition a random computer gave feedback, in order to compare effects to a baseline. In this experiment, trial numbers were increased and a minor change in the experiment was made: In addition to the video interview, participants had to fill in a short personality questionnaire, which putatively was handled to the two 'human senders'.

This straight-forward research design enables to investigate the influence of humanness and of expertise separately from each other. It gives the possibility to examine the temporal characteristic of language based feedback anticipation and feedback processing. Current advances in source estimation procedures are used to combine the high temporal resolution of EEG with a reasonable and reliable spatial resolution in source space. The cortical generators of the scalp differences are identified and statistical differences in their degree of activity are tested. This combination is intended to provide data needed to develop a provisional model on how the brain deals with socio-emotional language information.

2 Chapter II: Studies on social-communicative context amplifications of emotional language processing

2.1 Study I: It's all in your head – how anticipating evaluation affects the processing of emotional trait adjectives

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[1] Except for the omission of the abstract and the renumbering of the sections, tables and figures according to the overall structure of this thesis the present chapter is identical to the original paper.

2.1.1 Introduction

Language serves many different functions, ranging from the communication of facts and knowledge, to the communication of socio-emotional evaluations. In fact, symbolic interactionism theory suggests, that language meaning is derived from interaction with others (Blumer, 1969). This interaction is supposed to connect the identities of the communicating partners (Burke, 1980). For humans, communication using emotionally relevant language is of special interest (Barrett et al., 2007; Lieberman et al., 2007). Accordingly, newspapers and advertisers often select emotional words for their headlines, as their processing is prioritized (for a review see e.g. Citron, 2012; Kissler et al., 2006; Zald, 2003). However, influence of the social communicative context on emotional word processing has not been addressed elaborately. The present study aims to do so by creating an evaluative context and investigating whether processing of emotion-laden language differs in anticipation of personality evaluation.

So far processing of emotional language has been mostly investigated in the absence of communicative context. Neuroscience research has shown that brain event-related potentials (ERPs) differentiate between emotional and neutral contents during reading (Kissler & Herbert, 2013; Kissler et al., 2007) and in lexical (Schacht & Sommer, 2009a, 2009b), grammatical (Kissler et al., 2009) or evaluative decision tasks (Naumann, Maier, Diedrich, Becker, & Bartussek, 1997). Emotion effects are most consistently reflected in a larger early posterior negativity (EPN) arising from about 200 ms, which is thought to reflect mechanisms of perceptual tagging and early attention (Kissler & Herbert, 2013; Kissler et al., 2007). A more pronounced late parietal positivity (LPP) from about 500ms after word presentation, has been implicated in elaborative evaluation and memory processing of emotional words (Herbert et al., 2008, 2006; Hofmann et al., 2009; Kanske & Kotz, 2007; Kissler et al., 2009; Schacht & Sommer, 2009b).

Previous work showed that establishing a self referential context can alter word processing at early (Fields & Kuperberg, 2012), as well as late processing stages (Herbert, Herbert, et al., 2011; Herbert, Pauli, et al., 2011; Shestyuk & Deldin, 2010; L. A. Watson et al., 2007). This implies self-reference as one important source of plasticity in emotion word processing.

According to symbolic interactionism, the discursive context in which emotional language is embedded should likewise be an important source of plasticity in word processing. In social communication, participants have expectations about their communicative partners and react to violations of these expectations (J. K. Burgoon et al., 2000; M. Burgoon, Dillard, & Doran, 1983). Therefore, establishing a socially relevant communicative context, rather than solely self-relevance, can be expected to alter the way emotional language is processed.

Receiving feedback from another person regarding one’s own personality represents a highly salient social context. For some people receiving feedback may even pose a social threat, since humans have a strong need to belong to a community (Baumeister & Leary, 1995), seek approval by others (Izuma et al., 2010; Romero-Canyas et al., 2010), and try to avoid unfavorable evaluations (Carleton, Collimore, McCabe, & Antony, 2011; Leary, 1983). Electrophysiologically, social threat has been shown to affect early visual ERP components and frontal EEG asymmetry (Baess & Prinz, 2014; Crost, Pauls, & Wacker, 2008; Trautmann-Lengsfeld & Herrmann, 2013). For example, when participants due to group pressure agreed with a wrong answer option, the P1 was reduced compared to a perceptually identical condition (Trautmann-Lengsfeld & Herrmann, 2013). The P1 is one of the first evoked visual potentials. It reflects sensory registration and it is found to be larger for attended stimuli (Mangun & Hillyard, 1991). Influence of social setting is also reported for the N1 (Baess & Prinz, 2014). In a Go/Nogo paradigm, the N1 was found to be larger when both participants had to react in Go trials(Baess & Prinz, 2014). The N1 is thought to be a marker of visual discrimination (Edward K. Vogel & Luck, 2000) and decreases with repetition (Carretié, Hinojosa, & Mercado, 2003). Like the P1, the N1 increases when stimuli are attended (Hillyard, Teder-Sälejärvi, & Münte, 1998). P1/N1 modulations have been occasionally reported for emotional stimuli (Keil et al., 2007; Pourtois et al., 2004; Steinberg, Brockelmann, Rehbein, Dobel, & Junghofer, 2013) and recent evidence shows that also social context may change very early sensory processing.

These EPR findings are complemented by fMRI results showing a regionally distinct processing of social feedback. Social feedback has been shown to activate reward system structures such as the medial prefrontal cortex and the ventral striatum as well as the anterior cingulate cortex, involved in pain processing (Davey, Allen, Harrison, Dwyer, & Yücel, 2010; Eisenberger, Inagaki, Muscatell, Haltom, & Leary, 2011; Izuma et al., 2008, 2010; Korn et al., 2012; Somerville, Heatherton, & Kelley, 2006; Somerville, Kelley, & Heatherton, 2010). Together EEG and fMRI data indicate that effects of social feedback on brain physiology can be observed in artificial laboratory conditions using highly temporally and spatially resolving imaging methods.

As humans constantly make predictions about the future (Koster-Hale & Saxe, 2013; Seth, 2013), even the anticipation of socially relevant feedback, for example delivered as gestural approval or disapproval (‘thumbs up’ or ‘thumbs down’). The present study aims to do so by creating an evaluative context and investigating whether processing of emotion-laden language differs in anticipation of personality evaluation. Produces distinct cerebral activities (Kohls et al., 2013). In this study, the avoidance of social punishment and the anticipation of social reward led to enhanced activity in the ventral striatum and nucleus accumbens (Kohls et al., 2013). This indicates that both the fear of socially unfavorable evaluations and hope of acceptance are central human motives that modulate reward system biology.

The anticipation of socio-emotional language feedback, arguably the most common source of socially relevant feedback, has not yet been investigated. However, there is information on the effects of anticipatory anxiety on ERPs: Research demonstrates unspecific sensitizing effects of threat of shock, reflected in more positive-going early ERPs during threat-cue processing (Bublatzky & Schupp, 2012). Trials signaling a possible electric shock, lead to a larger P1 and P2, as well as a larger parietal LPP compared to trials signaling safety (Bublatzky et al., 2010; Bublatzky & Schupp, 2012). Moreover, anticipatory anxiety has been reported to specifically accentuate the processing of emotional pictures, surprisingly leading to a larger EPN for positive pictures when trials are signaling a possible electric shock (Bublatzky et al., 2010). Using anticipation of speaking in public as a threat induction, a different study reported the arguably more intuitive finding of accentuated processing of negative stimuli: Participants were told that they would supposedly held a speech in public after completing a face perception task. Compared to a control condition this led to a larger N170 and EPN for angry faces in the face perception task (Wieser et al., 2010).

Anticipation of verbal social feedback likely involves a phase of self-reflection, akin to self-referential processing, perhaps combined with anticipatory anxiety of negative feedback. The intensity of these processes may depend on both the message and the sender of the feedback. Existing studies of emotion word processing have focused on the processing of single words in psycho-linguistic tasks, devoid of social context. However, word meaning will change depending on attributed sender characteristic and direction of communication. In ecologically valid situations, already an inferred psychological context or a psychological attribution to another individual may constitute presence or absence of an interaction. For instance, feedback in the form of the adjective ‘boring’ should be more important if another human is the putative sender rather than a computer. Likewise, ‘boring’ may be regarded as more intense, when it is used to characterize oneself as a person rather than one’s teaching lesson. Similarly, an adjective like ‘cheap’ may be relatively neutral when describing an object, but becomes highly negative when it is used to characterize a person.

Against this background, the present study examines the influence of the putative sender on processing of negative, neutral and positive written adjectives in a social evaluative context. Participants were told that either an unknown other person would evaluate them based on his/her first impression, or a computer program would randomly highlight trait adjectives. In reality, both conditions were random and perceptually identical. We expected that anticipation of feedback by another person would generally change stimulus processing (sensitizing effects, Bublatzky & Schupp, 2012; Wieser et al., 2010) and investigated whether this occurs at early perceptual (P1, N1), mid-latency (EPN) or late (LPP) processing stages. Moreover, we examined valence-specific interactions between feedback content and evaluative context (human, computer). Generally, in the context of being evaluated by another person, negative and positive trait adjectives can be expected to induce larger P1, N1, EPN or LPP amplitudes, reflecting fear of unfavorable evaluations and social rejection (Eisenberger et al., 2011; Masten et al., 2009; Somerville et al., 2006) or hope of acceptance by others (Izuma et al., 2010; Romero-Canyas et al., 2010; Simon, Becker, Mothes-Lasch, Miltner, & Straube, 2014).

Against this background, we evaluate the sequence of early (P1, N1), mid-latency (EPN) and late visually evoked potentials in response to adjectives presented as potential trait-feedback by another human or a randomly acting computer.

2.1.2 Method

Participants

18 participants were recruited at the University of Bielefeld. They gave written informed consent according to the Declaration of Helsinki and received 10 Euros for participation. The study was approved by the Ethics Committee of the University of Konstanz. Due to experimentation errors, two datasets had to be excluded, leaving 16 participants for final analysis. The resulting 16 participants (12 females) were 24.40 years on average (*SD*=0.66). All participants were native German speakers, had normal or corrected-to-normal visual acuity, and were right-handed. Twelve participants were undergraduate students; four had already received their Bachelor's or Master's degree. Screenings with the German version of the Beck Depression Inventory and the State Trait Anxiety Inventory (Hautzinger, Keller, & Kühner, 2009; Spielberger, Sydeman, Owen, & Marsh, 1999), revealed no clinically relevant depression (*M*=4.12; *SD*=4.54) or anxiety scores (*M*=35.94; *SD*=3.06).

Stimuli

Adjectives were previously rated by 20 students in terms of valence and arousal using the Self-Assessment Manikins (Bradley & Lang, 1994). Raters had been specifically instructed to consider adjective valence and arousal in the context of being described by another person with this respective adjective. 150 adjectives (60 negative, 30 neutral, 60 positive) were selected and matched in their linguistic properties, such as word length, frequency, familiarity and regularity (see Table 1). Importantly, negative and positive adjectives differed only in their valence. As there is a lack of truly neutral trait adjectives, neutral adjectives were allowed to differ from emotional adjectives on rated concreteness next to valence and arousal.

Table 1: Comparisons of negative, neutral and positive adjectives by One-Way-ANOVAs

Variable	Negative adjectives (n=60)	Neutral adjectives (n=30)	Positive adjectives (n=60)	F (2,147)
Valence	3.10^a (0.84)	5.01^b (0.32)	7.01^c (0.90)	371.05***
Arousal	4.57^a (0.85)	3.30^b (0.66)	4.40^a (0.85)	25.93***
Abstractness	3.24^a (1.03)	5.07^b (1.46)	3.16^a (1.27)	28.10***
Word length	8.93 (2.65)	9.23 (2.94)	9.15 (2.48)	0.16
Word frequency (per million)	4.64 (8.56)	4.34 (6.26)	4.78 (8.05)	0.03
Familiarity (absolute)	21805.77 (39221.26)	18832.23 (48387.29)	19331.85 (42795.46)	0.07
Regularity (absolute)	261.58 (551.78)	165.97 (378.73)	239.06 (388.71)	0.44
Neighbors Coltheart (absolute)	3.45 (4.44)	2.53 (3.42)	3.78 (4.70)	0.83
Neighbors Levenshtein (absolute)	6.13 (6.48)	4.93 (4.14)	6.60 (6.26)	0.76

Note: *** = $p \leq 0.001$. Standard deviations appear in parentheses below means; means in the same row sharing the same superscript letter do not differ significantly from one another at $p \leq 0.05$; means that do not share subscripts differ at $p \leq 0.05$ based on LSD test post-hoc comparisons.

Procedure

Participants were told that they would be rated by an unknown other person or would see ratings generated randomly by a computer program. All subjects underwent both conditions. Sequence was counterbalanced across participants.

Upon arrival, participants were asked to describe themselves in a brief structured interview in front of a camera. They were told that their self-description was videotaped and would be shown to a second participant next door. The interview contained four questions encouraging the participant to talk about their strengths and weaknesses, as well as giving a short biography overview. After the interview, participants filled out a demographic questionnaire as well as BDI and STAI whilst the EEG was applied. To ensure face validity, a research assistant left the testing room a couple of minutes ahead of the fictitious feedback, guiding an 'unknown person' to a laboratory room next to the testing room. Stimuli were presented within a desktop environment of a fictitious program, allegedly allowing instant online communication (see Figure 5). Network cables and changes of the fictitious software

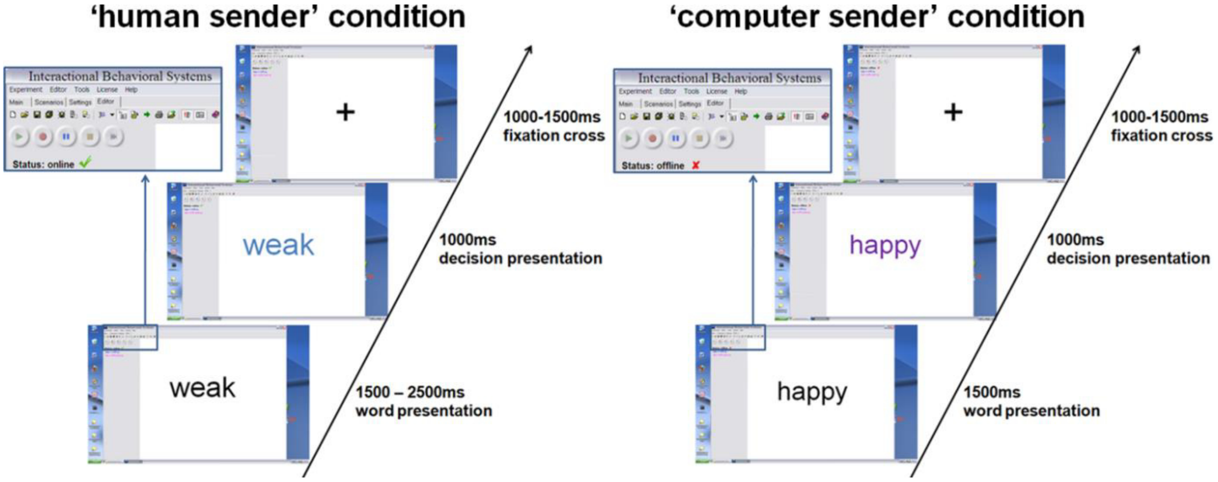

Figure 5:Trial presentation using the fictitious interactive software. Each trial started with a presented trait adjective.

desktop image showing a ‘neurobehavioral interactive systems’ environment were implemented to enhance credibility. The 60 negative, 30 neutral and 60 positive adjectives were randomly presented and feedback upon was randomly generated in both conditions. All adjectives were first presented in black. After a fixed (computer) or variable (human) time interval a color change indicated the feedback on a certain adjective. The presented results relate to the pre-feedback period, when all stimuli still appeared in black. Half of all adjectives were endorsed, leading to 30 affirmative negative, 30 neutral and 30 affirmative positive decisions. While the presented feedback was randomly generated in both conditions, twenty additionally inserted highly negative adjectives were defined to be always rejected in the ratings to further increase credibility, since it would appear very unlikely for somebody to endorse extremely negative traits in a hardly known stranger. These additional trials were excluded from further analysis. The desktop environment and stimulus presentation were created using Presentation (www.neurobehavioralsystems.com). In the ‘human’ condition between 1500 and 2500ms after adjective onset, color changes indicated a decision by the supposed interaction partner. This manipulation simulated variable decision latencies in humans. The decision was communicated via color change (blue or purple) of the presented adjective, indicating whether the respective adjective applied to the participant or not. Color–feedback assignments were counterbalanced. In the computer condition, corresponding color changes always occurred at 1500ms, conveying the notion of constant machine computing time. In both conditions color changes lasted for 1000ms, followed by a fixation cross for 1000 to 1500ms. After testing, participants responded to a questionnaire asking them to rate their confidence in truly being judged by another person in the ‘human’ condition, on a five point Likert-scale.

EEG recording and analyses

EEG signals were recorded from 128 BioSemi active electrodes (www.biosemi.com). Four additional electrodes measured horizontal and vertical eye-movement. Recorded sampling rate was 2048Hz. Pre-processing was done using SPM8 for EEG (http://www.fil.ion.ucl.ac.uk/spm/). Although perhaps best known as a toolbox for the analysis of functional magnetic resonance data, SPM provides a unitary framework for the analysis of neuroscience data acquired with different technologies, including EEG and MEG using the same rationale (Litvak et al., 2011; Penny & Henson, 2007). Offline, data were re-referenced to average reference, downsampled to 250Hz and butterworth band-pass filtered from 0.166 to 30 Hz. Recorded eye movements were subtracted from EEG data. Filtered data were segmented from 100ms before word onset until 1000ms after word presentation. 100ms preceding word onset were used for baseline-correction. Automatic artifact detection was used for trials exceeding a threshold of 160µV. Data were averaged, using the robust averaging algorithm of SPM8, excluding possible further artifacts. Overall, less than 1 percent of all electrodes were interpolated and on average 15.25 percent of all trials were rejected, leaving on average 50.85 trials for emotional words and 25.43 trials for neutral words for each communicative sender. Artifact rejection rate did not differ between both senders ($F(1,15) = 0.32$, $p = .58$), nor between negative, neutral and positive content ($F(2,30) = 0.26$, $p = .78$). There was also no interaction between sender and emotional content regarding artifact rejection rate ($F(2,30) = 0.09$, $p = .91$).

Statistical analyses

EEG scalp-data were statistically analyzed with EMEGS (http://www.emegs.org/, Peyk, De Cesarei, & Junghöfer, 2011). Two (sender: human versus computer) by three (emotion: positive, negative, neutral) repeated measure ANOVAs were set-up to investigate main effects of the communicative sender, emotion and their interaction in time windows and electrode clusters of interest. If Mauchly's Tests of Sphericity yielded significance, degrees of freedom were corrected according to Greenhouse-Geisser as Greenhouse-Geisser ϵ's were below 0.75. Partial eta-squared (partial η^2) was estimated to describe effect sizes, where $\eta^2 = 0.02$ describes a small, $\eta^2 = 0.13$ a medium and $\eta^2 = 0.26$ a large effect (J. Cohen, 1988). Time windows were segmented from 50 to 100ms to investigate P1 and from 100 to 150ms to investigate N1 effects (Bublatzky & Schupp, 2012; Fields & Kuperberg, 2012), from 210 to 260ms to investigate EPN effects (Kissler et al., 2007) and from 400 to 700ms to investigate LPP effects (Bublatzky & Schupp, 2012; Schupp, Junghöfer, Weike, & Hamm, 2004). For the P1 a fronto-central cluster was investigated (thirteen electrodes: FFC1h, FFCz, FFC2h, FC1h, FCz, FC2h, FCC1h, FCC2h, C1, C1h, Cz, C2h, C2), while for the N1 time window a parietal cluster of nineteen electrodes was examined (CCP1h, CCPz, CCP2h, CP1h, CPz, CP2h, CP2, CPP1, CPz, CPP2, P1, Pz, P2, PPO1, PPOz, PPO2, PO1, POz, PO2, POO1, POOz, POO2; see Figure 6). For the EPN time window, two symmetrical occipital clusters of eleven electrodes each were examined (left: I1, OI1, O1, PO9, PO9h, PO7, P9, P9h, P7, TP9h, TP7; right: I2, OI2, PO10, PO10h, PO8, P10, P10h, P8, TP10h, TP8).

LPP topographies have found to vary, with some authors reporting more parietal others more fronto-central distributions, or even both in one study (Kissler et al., 2009). Since the present data revealed conspicuous differences both at fronto-central and at parietal sites two electrode groups of interest were analyzed for this component. For the LPP time window a fronto-central cluster (fourteen electrodes: F1h, Fz, F2h, FFC1h, FFCz, FFC2h, FC1h, FCz, FC2h, FCC1h, FCC2h, C1, Cz, C2)

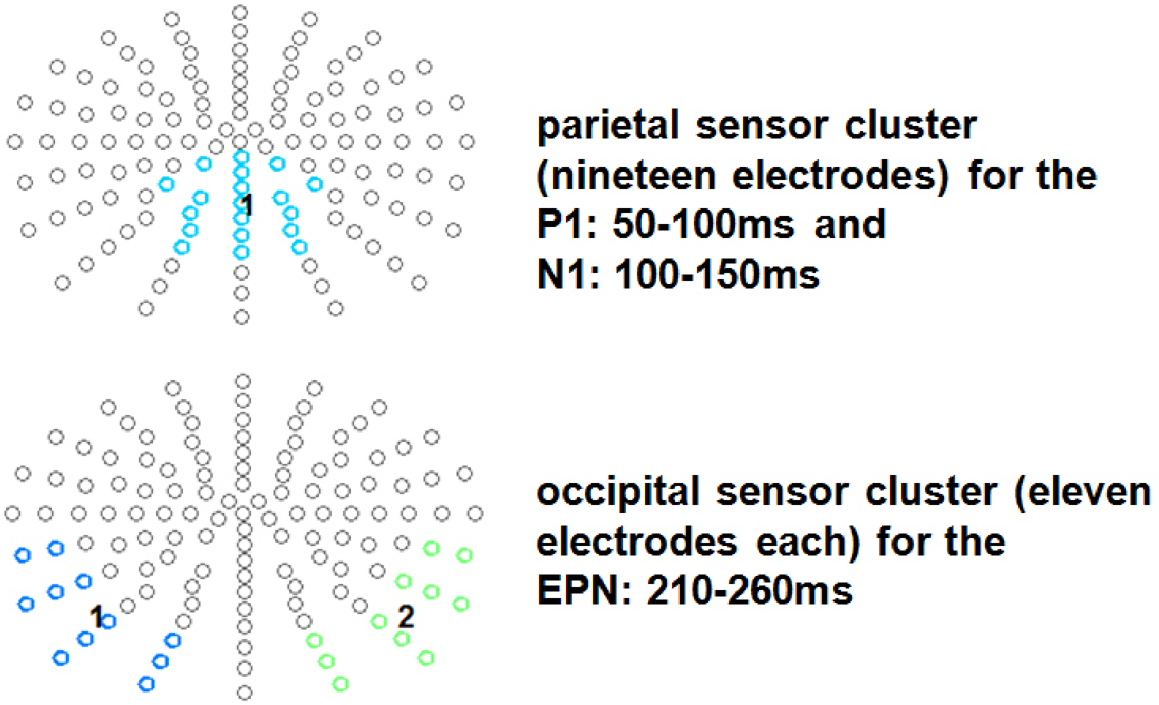

Figure 6: Selected electrode clusters for the early time windows. Selected electrodes are highlighted by color.

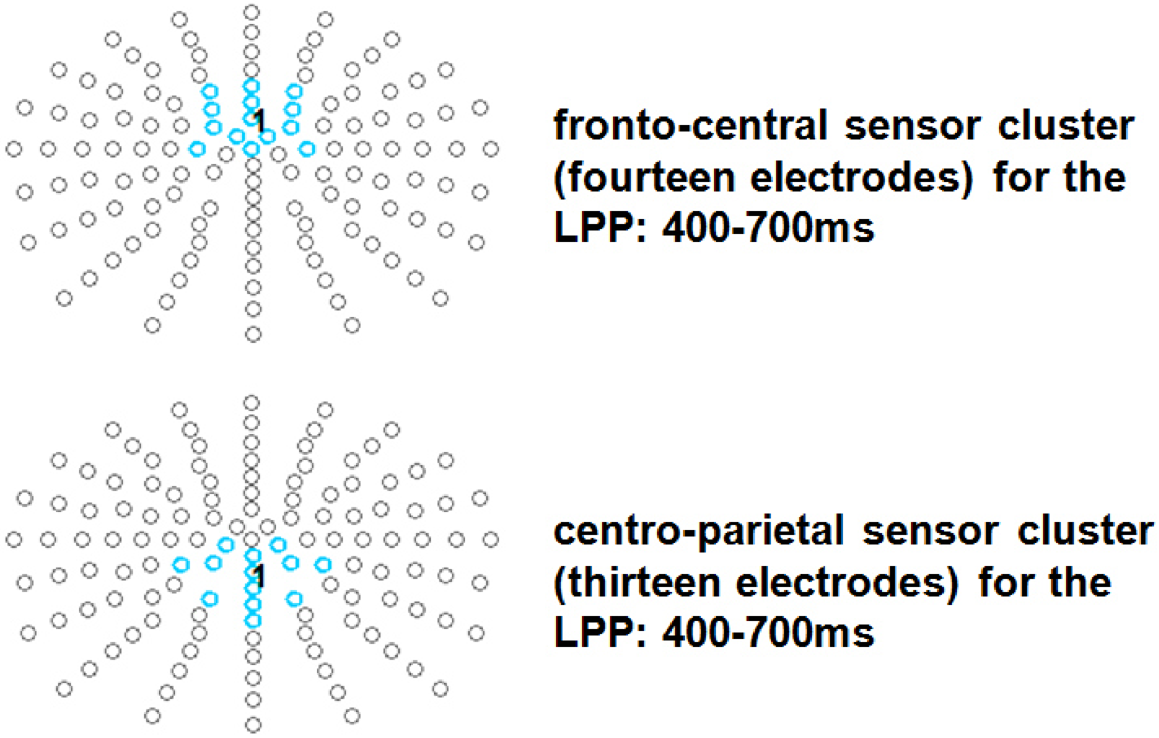

Figure 7: Selected electrode clusters for the late time window. Selected electrodes are highlighted by color.

and a centro-parietal cluster were investigated (thirteen electrodes: CCP1h, CCPz,CCP2h, CP1, CP1h, CPz, CP2h, CP2, CPPz, P1, Pz, P2, PPOz; see Figure 7).

2.1.3. Results

Questionnaire data

After debriefing, two participants stated that they were strongly convinced that they had been rated by another person in the 'human' evaluation condition, six participants said they quite convinced, four participants somewhat convinced, and two participants said they were little convinced. Mean credibility was 3.4 (*SD* = 1.02) on a Liktert-scale ranging from one to five.

P1

No significant main effects of sender $F(1,15) = 0.18$, $p = .68$, emotion $F(2,30) = 0.12$, $p = .89$, partial $\eta^2 = .05$ and no interaction $F(2,30) = 0.52$, $p = .59$, partial $\eta^2 = .05$ was observed over fronto-central regions.

N1

A significant main effect was observed for the communicative sender over the parietal sensor cluster between 100 and 150ms $F(1,15) = 7.51$, $p < .05$, partial $\eta^2 = .33$ (see Figure 8). The putative 'human sender' evoked a significantly larger N1 compared to the computer sender. There was no main effect of emotion $F(2,30) = 0.83$, $p = .44$, partial $\eta^2 = .05$ and no interaction between sender and emotion $F(2,30) = 0.27$, $p = .76$, partial $\eta^2 = .02$.

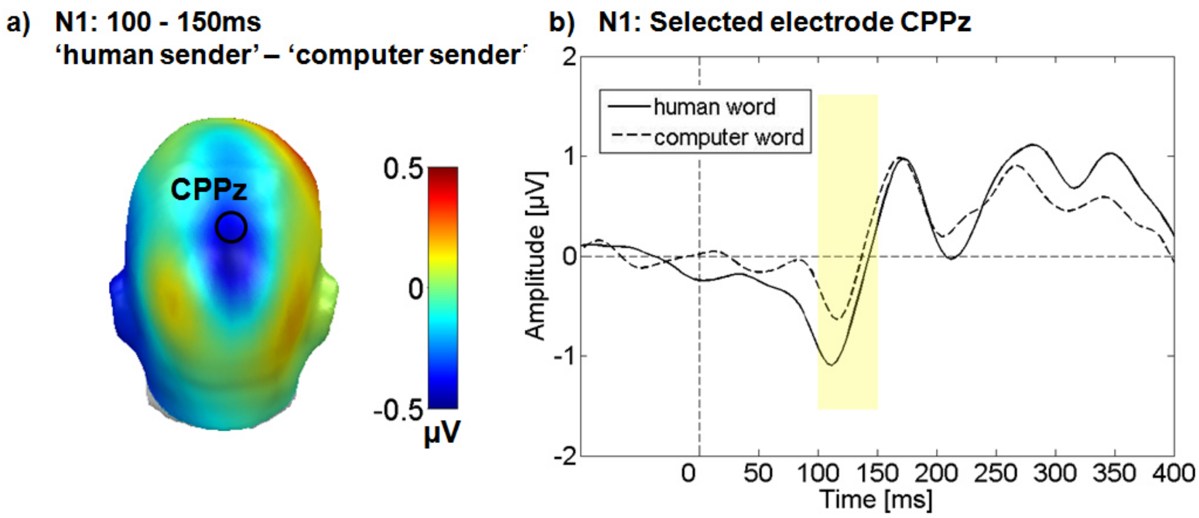

Figure 8: Results for the main effect of communicative source at the N1. a) Difference topographies. Blue color indicates more negativity and red color more positivity in the 'human sender' condition**. b)** Selected electrodes CPPz, displaying the time course over parietal sites.

EPN

A significant interaction between sender and emotion was observed over occipital sensors during the EPN $F(2,30) = 3.95$, $p < .05$, partial $\eta^2 = .21$. This interaction was based on a larger EPN for emotional adjectives within the 'human sender' compared to a larger EPN for neutral adjectives within the computer sender. However, within the 'human sender' post-hoc comparisons showed only a trend for a larger negativity for positive compared to neutral adjectives ($p = .06$) and no differences between negative and neutral words ($p = .55$). Within the 'computer sender' neutral words elicited a trend- level larger EPN compared to negative words ($p = .08$) but not compared to positive words ($p = .28$). There were no main effects of the sender $F(1,15) = 0.79$, $p = .38$, partial $\eta^2 = .05$ or of the emotional content $F(2,30) = 0.91$, $p = .41$, partial $\eta^2 = .06$ in the EPN time window.

LPP

Over the fronto-central electrode cluster, a significant main effect for emotion was observed $F(2,30) = 3.49$, $p < .05$, partial $\eta^2 = .19$ (see Figure 9). Post-hoc comparisons revealed, that positive adjectives elicited a larger LPP compared to neutral adjectives ($p < .05$), while negative compared to neutral adjectives elicited a larger amplitude only in tendency ($p = .13$). Positive and negative words did not differ from each other ($p = .59$). Over the fronto-central cluster there was no main effect of sender $F(1,15) = 0.30$, $p = .59$, partial $\eta^2 = .02$ nor an interaction between sender and emotion $F(1.27,19.11) = 0.20$, $p < .83$, partial $\eta^2 = .01$.

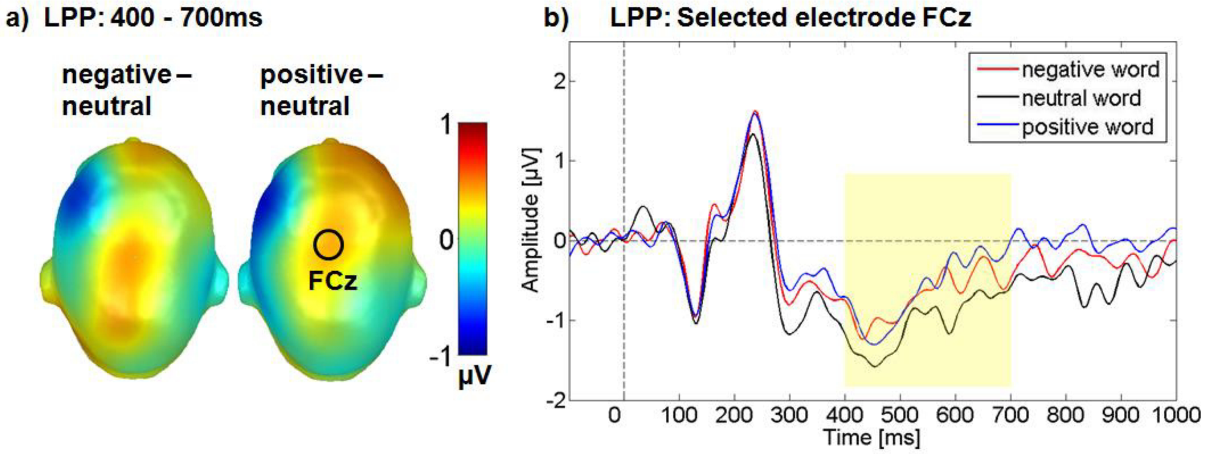

Figure 9: Main effect for the emotional content in the LPP time window. a) Head Models for the post-hoc comparisons within the respective emotion. Blue color indicates more negativity and red color more positivity for the respective difference. **b)** Selected elect FCz showing the enhanced positivity for positive and as a trend also for negative adjectives compared to neutral adjectives.

Over the centro-parietal electrode group a significant interaction between the communicative sender and emotional content was found $F(2,30) = 3.46$, $p < .05$, partial $\eta^2 = .19$ (see Figure 10). Post-hoc comparison showed, that within the ‘human sender’ negative words elicited a significantly larger LPP compared to neutral adjectives ($p < .01$), while the somewhat larger LPP for positive words compared to neutral words did not reach significance ($p = .15$). Negative and positive words did not differ from each other ($p = .17$). Within the 'computer sender' no differences were found in any comparison (*ps* > .49). Over the centro-parietal cluster there were no main effects of sender $F(1,15) = 0.23$, $p = .64$, partial $\eta^2 = .02$ or emotion $F(2,30) = 1.31$, $p = .29$, partial $\eta^2 = .08$.

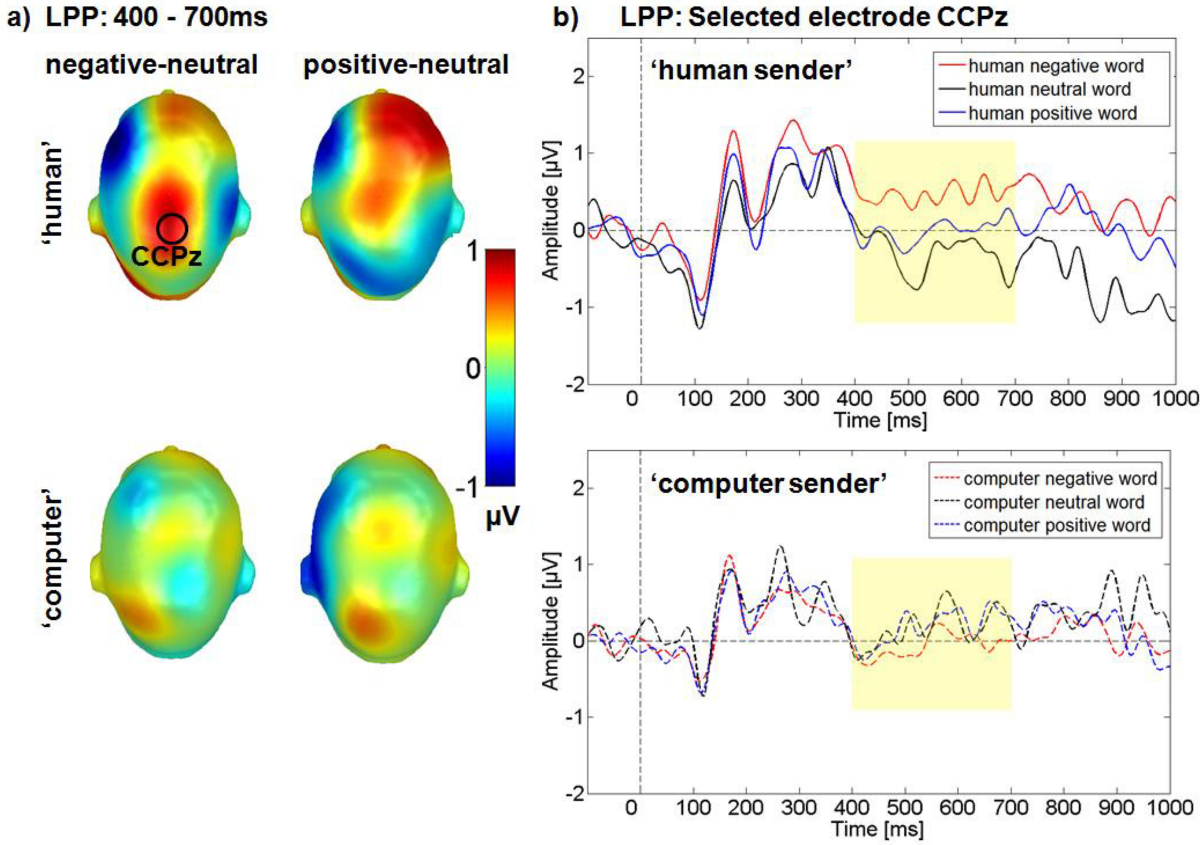

Figure 10: Interaction between communicative sender and emotional content in the LPP time window. a) Head Models for the post-hoc comparisons within the respective communicative sender**.** Blue color indicates more negativity and red color more positivity for the respective difference. **b)** Selected electrode CCPz showing the larger positivity for negative compared to neutral adjectives within the 'human sender' and small differences between emotional and neutral adjectives within the 'computer sender'.

2.1.4. Discussion

We hypothesized that anticipating an evaluative decision from a human sender would lead to altered processing of trait adjectives by the recipient. A 'computer sender' was introduced as a source of random evaluation to provide a maximal contrast between both conditions, while maintaining identical perceptual input. The data reveal effects of sender and emotion as well as interactions. For the ‘human sender’, a significantly larger N1 between 100 and 150ms after adjective onset was detected over parietal areas. Starting with the EPN, effects of emotion interacted with perceived sender and in the LPP window, both main effects of sender and emotion as well as their interaction was observed. In the following, we will discuss these findings against the background of the current literature.

An early-onset effect of the ‘human sender’ condition, already in the N1 window, is in line with earlier findings of rapid effects of self-relevance (Fields & Kuperberg, 2012), as well as with sensitizing effects of social threat (Wieser et al., 2010). Within the broader context of the ERP literature, N1 effects suggest more tonic attention orienting towards stimuli supposedly sent by a human. Tonic effects of attention deployment have first been observed by Eason and Harter (1969), who also were the first to demonstrate similar effects of volitional attention and threat of an electric shock on visual stimulus processing.

A main effect of emotion was observed in the LPP time window over a fronto-central electrode cluster. Here, positive and in tendency also negative words elicited a larger positivity compared to neutral words. Descriptively, ERPs differed earlier between emotional and neutral adjectives (see Figure 10), but interaction effects may have canceled out by stronger main effects of emotion. Brain topographies in the LPP time window differed somewhat between negative and positive adjectives. For the emotion main effect over the fronto-central cluster, a larger positivity was only found for positive adjectives, while for the interaction over the centro-parietal cluster the post-hoc comparison was only significant for negative adjectives (see Figures 9, 10). LPP topography variations have been found to vary in the same study (Kissler et al., 2009), but not such valence dependent variability. It may be hypothesized that both arousal dependent and valence specific processing, relying on partly differing generator structures exist in the LPP time window regarding positive and negative adjectives.

Processing of positive and negative adjectives was expected to differ between the social evaluation and the feedback condition as reflected in an interaction between emotional content and communicative sender. Early interactions – between 210 and 260ms – were found over the occipital region. However, post-hoc comparisons revealed no clearly significant differences within the respective senders. Descriptively, within the 'human sender' there was a larger EPN for emotional words, while for the 'computer sender' the EPN was somewhat more pronounced for neutral words. Such early (210-260 ms) valence-specific modulations are relatively rare, previous work reported mainly arousal effects in this time window. However, Field & Kuperberg (2012) reported very early effects of an established self-referential context on word processing. Therefore, it may be specific to the present experimental setting and may be further enhanced by the presently used blocked design.

Between 400 and 700 ms a larger positivity for negative adjectives compared to neutral adjectives was observed over parietal sites within the 'human sender'. The comparison between positive and neutral adjectives, while qualitatively similar did not reach significance. For the 'computer sender' no differential processing of negative, neutral and positive adjectives could be observed over central sites and in late time windows. The interaction effects indicate that the also reported LPP emotion main effect may be driven partly by the 'human sender' (see Figures 9 and 10). Such emotion main effects in the LPP time window have been reported previously in typical psycho-linguistic experiments that did not explicitly manipulate context (Herbert et al., 2008, 2006; Hofmann et al., 2009; Kanske & Kotz, 2007; Kissler et al., 2006, 2009; Schacht & Sommer, 2009b). However, as some studies do not find late emotion effects (Rellecke, Palazova, Sommer, & Schacht, 2011) it may be helpful to consider the communicative context. The present data suggest that emotional differences largely derive from the adopted communicative context or are at least amplified by it. By contrasting a meaningless and a meaningful passive visual word processing condition the differentiation between emotional and neutral words is heightened. Generally, the LPP is associated with elaborative processing and larger LPPs have been shown to predict better subsequent memory(Dolcos & Cabeza, 2002), one might speculate that contextual factors can determine whether emotional material is only transiently attended at early processing stages or elaborated on and committed to memory.

An interaction of emotion with the anticipatory context is in line with findings from shock-threatening (Bublatzky et al., 2010) or from socially threatening situations (Wieser et al., 2010). However, this is the first study which investigated anticipatory effects in a socially relevant communicative context, as extant studies focus on processing of the feedback decision, typically also using fMRI (Davey et al., 2010; Izuma et al., 2008, 2010; Korn et al., 2012; Somerville et al., 2006, 2010). Due to the higher time resolution of the EEG, we were able to investigate how the anticipated feedback on trait adjectives changes in response to the putative sender identity in distinct processing phases. Here, in addition to sensitizing effects due to threat or self-relevance (Bublatzky et al., 2010; Bublatzky & Schupp, 2012; Fields & Kuperberg, 2012) the anticipation of human-generated evaluations led to differential processing of negative adjectives, which was pronounced at later stages.

Descriptively, larger differences between emotional and neutral words within the ‘human sender’ compared to the ‘computer sender’ condition could be observed already at the EPN. Emotional words may initially capture more attention resources, but ongoing processing led to a pronounced differentiation between emotional and neutral words, reflected in the enhanced central positivity in the LPP time window for emotional words. As sensitizing effects of threat have previously been found to accentuate selectively positive (Bublatzky et al., 2010) or negative (Wieser et al., 2010) stimulus processing, in this social communicative setting more complex motives may play a role. This could be explained by considerations that humans, in the absence of conflicting evidence, tend to view themselves positively (self-positivity bias), but also fear unfavorable evaluation (Carleton et al., 2011; Eisenberger et al., 2011; Leary, 1983; Masten et al., 2009; Somerville et al., 2006) and seek approval and acceptance by others (Izuma et al., 2010; Romero-Canyas et al., 2010). Perhaps these different motifs play a role at distinct processing stages, maybe even by partly distinct cortical generator structures.

Overall, we cannot exclude that some relevant effects remained undetected, due to the limited number of trials in each cell resulting in limited power. Still, we observed considerable main and interaction effects, suggesting that the study design was able to detect differences between the two putative senders and their effect on processing of emotional trait adjectives during feedback anticipation. Furthermore, credibility ratings for the ‘human sender’ condition indicate successful experimental manipulation of the respective conditions. Self-reported credibility was not significantly correlated with N1 sender differences (two-tailed Pearson correlation $r = -.11$, $p = .70$, $N = 16$; two-tailed Spearman correlation $r_s = -.31$, $p = .25$, $N = 16$), making it unlikely that sender main effects could be explained entirely by credibility. A limitation of the presented study may be the generation of adequate neutral trait adjectives. Although all adjectives were tightly matched for all linguistic characteristics, neutral adjectives differed from negative and positive adjectives in arousal and in concreteness. Still, this could neither account for sender differences nor for the valence-specific accentuation of positive or negative contents. Remarkably, the results suggests that in spite of identical perceptual input, the processing of a message, as reflected by electro-cortical activity, changes as a function of the perceived communicative significance. Thus, subjective meaning seems not only to derive from real, but crucially also from supposed interaction with others, connecting not only real but even imaginary identities of communicating partners. In the current study the ‘human sender’ was the only sender able to give meaningful feedback. It would be interesting to compare a putative ‘human sender’ with a ‘computer sender’ able to give personality feedback, to specify unique effects of ‘humanness’ in contrast to only skill attributions. In general this paradigm suggests many different possible sender manipulations which may contribute to our understanding of context influences on (emotional) language processing. Further, it may be worth to know if such very early visual modulations can be replicated in experiments not using blocked within-subject designs.

2.1.5 Conclusion

Summarizing the main results, we found an amplified N1 indicating, regardless of content, the allocation of more early attentional resources to the trait adjectives if the putative sender was another human rather than a randomly operating computer. These differences were present already in anticipation of a decision and using the identical visual input across conditions. In the EPN window, an interaction suggested that emotional adjectives in the human sender condition were processed more intensely, but post-hoc tests did not reveal clearly significant differences, precluding firm conclusions. Emotional adjectives led to a larger LPP. This interacted with sender: The LPP was particularly large when evaluations were expected from a human sender. This suggests that at early processing stages attention is allocated to all stimuli, indiscriminate of emotional content and only after (or simultaneously with) extraction of content at an evaluative processing stage selective amplification of emotional content in the human sender condition occurs. These findings indicate that imaginary social context has a large impact on language processing within the larger framework of symbolic interactionism.

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Author Disclosure Statement

The authors declared that they had no conflict of interest with respect to their authorship or the publication of this article.

Author contributions

SS and JK contributed to the study design. SS, MW and IS carried out participant testing, SS and JK performed statistical analysis, SS drafted the manuscript under the supervision of JK. MW and IS helped to draft and revise the manuscript. All authors read and approved the final manuscript. SS revised the manuscript under supervision of JK

2.2 Study II: Perceived communicative context and emotional content amplify visual word processing in the fusiform gyrus

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[2] Except for the omission of the abstract and the renumbering of the sections, tables and figures according to the overall structure of this thesis the present chapter is identical to the original paper.

2.2.1 Introduction

Language is intrinsically communicative, yet neuroscience studies typically investigate the processing of isolated words or phrases. Communication theories posit that meaning is derived from interaction with others (Blumer, 1969), implying that the perceived identity of a communicative partner should affect the way language content is processed. When emotional content is communicated, context is likely to be especially important, as emotional language is particularly relevant for humans (Barrett et al., 2007; Lieberman et al., 2007). Neuroscience research has amply demonstrated the prioritized processing of emotional language (for a review see Kissler, 2013). Brain event-related potentials (ERPs) consistently differentiate between emotional and neutral words (Kanske, Plitschka, & Kotz, 2011; Kissler et al., 2009; Ortigue et al., 2004; Schacht & Sommer, 2009a, 2009b). Although earlier effects have been reported (Kanske et al., 2011; Scott et al., 2009), emotion effects are typically reflected in a larger early posterior negativity (EPN) and a more pronounced late positive potential. The EPN arises from about 200ms, indexing mechanisms of lexical (Kissler & Herbert, 2013) and perceptual tagging and early attention (Schupp et al., 2007). The LPP occurs from about 500ms after word presentation and is implicated in stimulus evaluation and memory processing (Herbert et al., 2008; Hofmann et al., 2009; Kanske & Kotz, 2007; Schacht & Sommer, 2009a). Emotional intensity plays an important role in amplifying ERPs, but EEG data further suggest distinct functional stages with initial alerting by negative stimuli and later evaluative processing favoring positive content (W. Luo, Feng, He, Wang, & Luo, 2010; D. Zhang et al., 2014).

Source analyses revealed generators of early emotion effects in word processing in primary visual cortex (Ortigue et al., 2004), in left extra-striate visual cortex (Kissler et al., 2007), including the fusiform gyri (Hofmann et al., 2009), and left middle temporal gyrus (Keuper et al., 2014). For emotional pictures, LPP generators have been found in occipito-parietal (Moratti et al., 2011; Schupp et al., 2007) and frontal regions (Moratti et al., 2011).

Enhanced visual processing of emotional stimuli can be accounted for within the motivated attention framework, stating that emotional stimuli amplify visual cortex activity, due to their higher motivational relevance (Lang et al., 1998).

Here, we test whether a contextual manipulation can modulate word processing in a similar manner, amplifying motivational relevance and enhancing processing in the visual brain. We chose a social feedback situation as a particularly salient context (Eisenberger et al., 2011; Korn et al., 2012). Participants were either told that a human would give them personal feedback by endorsing positive, negative or neutral trait adjectives or they expected random feedback from a computer. In reality, both conditions were perceptually identical. We hypothesized that the feedback would induce larger ERP components when perceived as coming from the ‘human sender’. Content effects were expected to replicate prioritized processing of emotional words. In sum, we analyze the sequence of early (N1, P2), mid-latency (EPN) and late components (P3, LPP) in response to visually presented social feedback and determine the time course and cortical generators of context and content effects.

2.2.2 Method

Participants

18 participants were recruited at the University of Bielefeld. They gave written informed consent according to the Declaration of Helsinki and received 10 Euros for participation. The study was approved by the Ethics Committee. Due to experimentation errors, two datasets had to be excluded, leaving 16 participants for final analysis. These 16 participants (12 females) were 24.40 years on average (age range = 21-30). All participants were native German speakers, had normal or corrected-to-normal visual acuity, and were right-handed. Screenings with the German version of the Beck Depression Inventory and the State Trait Anxiety Inventory, revealed no clinically relevant depression (*M*=4.12; *SD*=4.54) or anxiety scores (*M*=35.94; *SD*=3.06).

Stimuli

Adjectives had been previously rated by 20 students in terms of valence and arousal using the Self-Assessment Manikin (Bradley & Lang, 1994). Raters had been specifically instructed to consider adjective valence and arousal in an interpersonal evaluative context. 150 adjectives (60 negative, 30 neutral, 60 positive) were selected and matched in their linguistic properties, such as word length, frequency, familiarity and regularity (see Table 2). Linguistic parameters were assessed by the dlex database, a corpus of the German language that draws on a wide variety of sources and includes more than one hundred million written words (Heister et al., 2011). Importantly, negative and positive adjectives differed only in their valence. As truly neutral trait adjectives are rare, neutral adjectives were allowed to further differ from emotional adjectives on rated abstractness. Abstractness was rated on a scale similar to the self-assessment manikin, showing a manikin with many distinct features on the left-hand side (concrete-low values) that is successively transformed into a very abstract rendering on the right-hand side. Positive and negative adjectives were somewhat more concrete than neutral ones.

Table 2: Comparisons of negative, neutral and positive adjectives by One-Way-ANOVAs

Variable	Negative adjectives (n=60)	Neutral adjectives (n=30)	Positive adjectives (n=60)	F (2,147)
Valence	3.10^{a} (0.84)	5.01^{b} (0.32)	7.01^{c} (0.90)	371.05***
Arousal	4.57^{a} (0.85)	3.30^{b} (0.66)	4.40^{a} (0.85)	25.93***
Abstractness	3.24^{a} (1.03)	5.07^{b} (1.46)	3.16^{a} (1.27)	28.10***
Word length	8.93 (2.65)	9.23 (2.94)	9.15 (2.48)	0.16
Word frequency (per million)	4.64 (8.56)	4.34 (6.26)	4.78 (8.05)	0.03
Familiarity (absolute)	21805.77 (39221.26)	18832.23 (48387.29)	19331.85 (42795.46)	0.07
Regularity (absolute)	261.58 (551.78)	165.97 (378.73)	239.06 (388.71)	0.44
Neighbors Coltheart (absolute)	3.45 (4.44)	2.53 (3.42)	3.78 (4.70)	0.83
Neighbors Levenshtein (absolute)	6.13 (6.48)	4.93 (4.14)	6.60 (6.26)	0.76

Note: *** = $p \leq 0.001$. Standard deviations appear in parentheses below means; means in the same row sharing the same superscript letter do not differ significantly from one another at $p \leq 0.05$; means that do not share subscripts differ at $p \leq 0.05$ based on LSD test post-hoc comparisons.

Procedure

Participants were told that they would be evaluated by an unknown other person or would see evaluations generated randomly by a computer program. Participants were instructed that evaluations were made by accepting or rejecting presented trait adjectives online and that these evaluations would be communicated via color changes of words on the screen. All subjects underwent both conditions. Sequence of conditions was counterbalanced across participants (see Schindler, Wegrzyn, Steppacher, & Kissler, 2014).

Upon arrival, participants were asked to describe themselves in a brief structured interview in front of a camera. They were told that their self-description would be videotaped and would be shown to a second participant next door. After the interview, participants filled out a demographic questionnaire, Beck’s Depression Inventory (Hautzinger et al., 2009), and the State Trait Anxiety Inventory (Spielberger et al., 1999) whilst the EEG was applied. To ensure face validity, a research assistant left the testing room a couple of minutes ahead of the fictitious feedback, guiding an ‘unknown person’ to a laboratory room next to the testing room. Stimuli were presented within a desktop environment of a fictitious program ‘Interactional Behavioral Systems’ allegedly allowing instant online communication (see Figure 11).

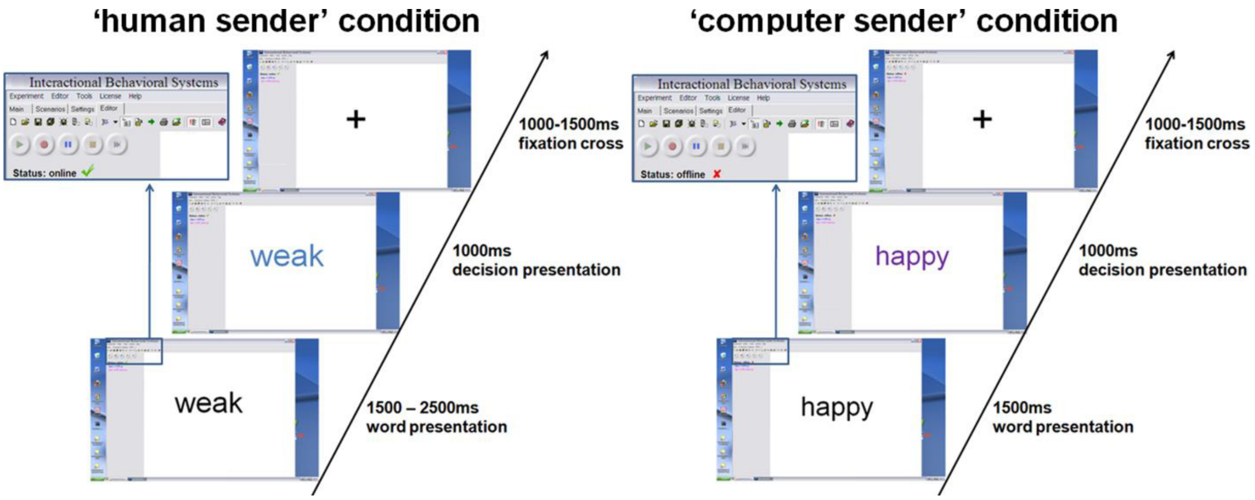

Figure 11: Trial presentation in the fictitious interactive software environment. Each trial started with a presented trait adjective. Subsequent color change indicated endorsement of a trait.

Network cables and changes of the fictitious software desktop image were made salient to ensure credibility of the situation. The presented feedback was randomly generated and half of all presented adjectives were endorsed, leading to 30 affirmative negative, 30 neutral and 30 affirmative positive decisions. Additionally, twenty highly negative adjectives were inserted and always rejected in the evaluations to further increase credibility, since it would appear very unlikely for somebody to endorse that extremely negative traits apply to a hardly known stranger. These additional trials were excluded from further analysis. The desktop environment and stimulus presentation were created using Presentation (www.neurobehavioralsystems.com). In the ‘human’ condition color changes between 1500 and 2500ms after adjective onset indicated a decision by the supposed interaction partner. This manipulation simulated variable decision latencies in humans. The decision was communicated via color change (blue or purple) of the presented adjective, indicating whether the respective adjective applied to the participant or not. Color–feedback assignments were counterbalanced. In the computer condition, corresponding color changes always occurred at 1500ms, conveying the notion of constant machine computing time. In both conditions color changes lasted for 1000ms, followed by a fixation cross for 1000 to 1500ms. After testing and debriefing, participants rated their confidence in truly being judged by another person in the ‘human’ condition, on a five point Likert-scale questionnaire.

EEG recording and analyses

EEG was recorded from 128 BioSemi active electrodes (www.biosemi.com). Recorded sampling rate was 2048Hz. During recording Cz was used as reference electrode. Four additional electrodes (EOG) measured horizontal and vertical eye-movement. These were placed at the outer canthi of the eyes and below the eyes.

Pre-processing and statistical analyses were done using SPM8 for EEG data (http://www.fil.ion.ucl.ac.uk/spm/) and EMEGS (Peyk et al., 2011). In a first step, data were re-referenced to the average reference offline. To identify artifacts caused by saccades (horizontal, HEOG) or eye blinks (vertical, VEOG) virtual HEOG and VEOG channels were created from the EOG electrodes. EEG signals that were highly correlated with HEOG or VEOG activity were subtracted from the EEG (minimum correlation of 0.5). Data were then down-sampled to 250Hz and later band-pass filtered from 0.166 to 30 Hz with a fifth-order Butterworth zero-phase filter. Filtered data were segmented from 500ms before stimulus onset until 1000ms after stimulus presentation. Because there was an immediate transition from word presentation to feedback by color change, results are presented without baseline correction so as not to introduce pre-baseline differences into the feedback phase. However, there were no apparent differences in the time segment immediately preceding the color change (see Figures 12, 14, 15) and control analyses with baseline correction lead to analogous results. Automatic artifact detection was used to eliminate remaining artifacts defined as trials exceeding a threshold of 160µV. Data were then averaged, using the robust averaging algorithm of SPM8, excluding possible further artifacts. Robust averaging down-weights outliers for each channel and each time point, thereby preserving a higher number of trials as artifacts are not supposed to distort the whole trial but most of the time corrupt only parts of the trial. We used the recommended offset of the weighting function, which preserves approximately 95% of the data points drawn from a random Gaussian distribution (Litvak et al., 2011). Overall, less than one percent of all electrodes were interpolated and on average 13.18 percent of all trials were rejected, leaving on average 26.05 trials per condition.

Statistical analyses

EEG scalp-data were statistically analyzed with EMEGS (Peyk et al., 2011). Two (sender: human versus computer) by three (content: positive, negative, neutral) repeated measure ANOVAs were set-up to investigate main effects of the communicative sender, emotion and their interaction in time windows and electrode clusters of interest. Effect sizes were calculated for main and interaction effects and post-hoc comparisons. For all post-hoc tests, mean microvolt values are presented for each condition. Time windows were segmented from 150 to 200 to investigate N1 and P2 effects, from 200 to 300ms to investigate EPN effects (Kissler et al., 2007), from 300 to 450ms to investigate P3 effects, and from 450 to 650ms and 650 to 900ms to investigate early and late portions of the LPP (Bublatzky & Schupp, 2012; Schupp, Junghöfer, et al., 2004). For the N1 time window an occipital cluster was used (twenty electrodes: PO9, PO9h, PO7, PO7h, I1, OI1, O1, POO3, Iz, OIz, Oz, POOz, I2, OI2, O2, POO4, PO10, PO10h, PO8, PO8h). For the EPN time window, two symmetrical occipital clusters of eleven electrodes each were examined (left: I1, OI1, O1, PO9, PO9h, PO7, P9, P9h, P7, TP9h, TP7; right: I2, OI2, PO10, PO10h, PO8, P10, P10h, P8, TP10h, TP8, see Kissler et al., 2007). For the P2, P3 and the LPP time windows a central cluster was investigated (twenty-six electrodes: FCC1h, FCC2h, C3h, C1, C1h, Cz, C2h, C2, C4h, CCP3h, CCP1, CCP1h, CCPz, CCP2h, CCP2, CCP4h, CPz, CPP1, CPPz, CPP2, P1h, Pz, P2h, PPO1h, PPOz, PPO2h, see Schupp et al., 2007).

Source reconstructions of the generators of significant ERP differences were generated and statistically assessed with SPM8 for EEG (Litvak & Friston, 2008; Lopez et al., 2013), following recommended procedures. First, a realistic boundary element head model (BEM) was derived from SPM´s template head model based on the Montreal Neurological Institute (MNI) brain. Electrode positions were then transformed to match the template head, which generates reasonable results even when individual subjects' heads differ from the template (Litvak et al., 2011). Average electrode positions as provided by BioSemi were co-registered with the cortical mesh template for source reconstruction. This cortical mesh was used to calculate the forward solution. The inverse solution was then calculated from 0ms to 1000 ms after feedback onset (e.g. see Campo et al., 2012). Group inversion (Litvak & Friston, 2008) was computed and the multiple sparse priors algorithm implemented in SPM8 was applied. This method allows activated sources to vary in the degree of activity, but restricts the activated sources to be the same in all subjects (Litvak & Friston, 2008). Compared to single subject matrix inversion, this has shown to result in more robust source estimations (Litvak & Friston, 2008; Sohoglu, Peelle, Carlyon, & Davis, 2012).

For each analyzed time window, three-dimensional source reconstructions were generated as NIFTI images (voxel size = 2mm*2mm*2mm). These images were smoothed using an 8mm full-width half-maximum Gaussian kernel. In line with a previous study (Campo et al., 2013), we describe statistical differences in source activity of voxels differing at least at an uncorrected threshold of $p<.005$ and a minimum of twenty-five significant voxels per cluster (Sun, Lee, & Chan, 2013). Results exceeding this threshold ($p<.001$ or FWE corrected) are marked separately to provide a transparent and comprehensive data presentation. Some previous studies show generators of surface activity only descriptively (Schupp et al., 2007), or test at more liberal significance thresholds of .05 (Sohoglu et al., 2012; Sun, Lee, & Chan, 2015). Furthermore, we extracted the significant activity from the sender effect and used it as a ROI for the emotion effect to determine the spatial overlap between the two effects. Within this ROI, FWE correction was applied. The identification of activated brain regions was performed using the AAL atlas (Tzourio-Mazoyer et al., 2002).

2.2.3 Results

Questionnaire data.

After debriefing, mean credibility ratings of the evaluative situation were 3.4 (*SD*=1.02) on a scale ranging from one to five. Two participants stated they were strongly convinced, six participants were quite convinced, four participants were somewhat convinced, and four participants said they were little convinced that they had been rated by another person in the ‘human sender’ condition.

N1 and P2

For the N1 (150-200ms), there was no main effect of sender ($F_{(1,15)} = 1.54$, p=.23, partial η^2=.09), of emotion ($F_{(2,30)} = 0.20$, p=.82, partial η^2=.01) or an interaction ($F_{(2,30)} = 1.44$, p=.25, partial η^2=.09) over occipital sensors.

For the P2, over the central sensor group, a main effect of the putative sender ($F_{(1,15)} = 11.45$, $p<.01$, partial $\eta^2 = .43$) was found (see Figure 14). Post-hoc tests showed that the ‘human sender’ (M = 1.29µV) led to an enhanced P2 compared in comparison to the ‘computer sender’ (M = 0.82µV). There was no main effect of emotion ($F_{(2,30)} = 0.31$, p=.74, partial η^2=.02), and no interaction ($F_{(2,30)} = 2.02$, p=.15, partial η^2=.12).

In source space, significant differences between the putative senders were found in the P2 time window. Decisions made by the ‘human sender’ led to more activity in the bilateral fusiform gyri and in the right inferior occipital gyrus (see Table 3). Larger activations were found only for the comparison ‘human sender’ versus computer sender. No significantly larger activity was found for the reverse comparison even using a liberal threshold (uncorrected $p<.05$).

Table 3: P2: Source estimations for the comparison between the ‘human sender’ and ‘computer sender’. Results show enhanced source activations for the ‘human sender’ in visual areas.

cluster-level	peak-level		MNI coordinates			AAL
Number of significant voxels	peak t (1, 90)	peak p-uncorrected	x (mm)	y (mm)	z (mm)	area
P2 time window (150-200ms)						
273	3.03	<.005	38	-66	-18	Fusiform R
74	2.99	<.005	44	-72	-16	Fusiform R
249	2.78	<.005	-42	-64	-18	Fusiform L
273	2.71	<.005	-36	-54	-20	Fusiform L

Notes. For each significant peak respective coordinates (x, y and z) are reported in MNI space. A cluster may exhibit more than one peak, while only the largest peak is displayed. Area = peak-level brain region as identified by the AAL atlas. R / L = laterality right or left.

EPN

Over the occipital sensor clusters a significant main effect of communicative sender was observed in the EPN time window ($F_{(1,15)}$ = 8.04, p<.05, partial η²=.35; see Figure 12 a). Here, the ‘human sender’ (M = -2.97µV) led to a larger negativity compared to the ‘computer sender’(M = -2.18µV, p<.05). Further, an interaction between sender and emotion was observed ($F_{(2,30)}$ = 3.56, p<.05 partial η²=.19). Within the ‘human sender’, negative decisions elicited the largest EPN, followed first by neutral and then by positive decisions, while for the ‘computer sender’ the opposite pattern was observed (see Figure 12b). In particular, negative decisions (M = -3.21µV) by the ‘human sender’ elicited a more negative-going EPN than negative (M = -1.89µV) $t_{(15)}$ = -3.82, p<.01, and neutral decisions(M = -2.22µV) $t_{(15)}$ = -2.59, p<.05 by the ‘computer sender’. Also, neutral decisions (M = -3.03µV) by the ‘human sender’ elicited a larger EPN than both negative $t_{(15)}$ = -2.74, p<.05, and neutral decisions by the ‘computer sender’ $t_{(15)}$ = -2.61, p<.05. All other comparisons were insignificant.

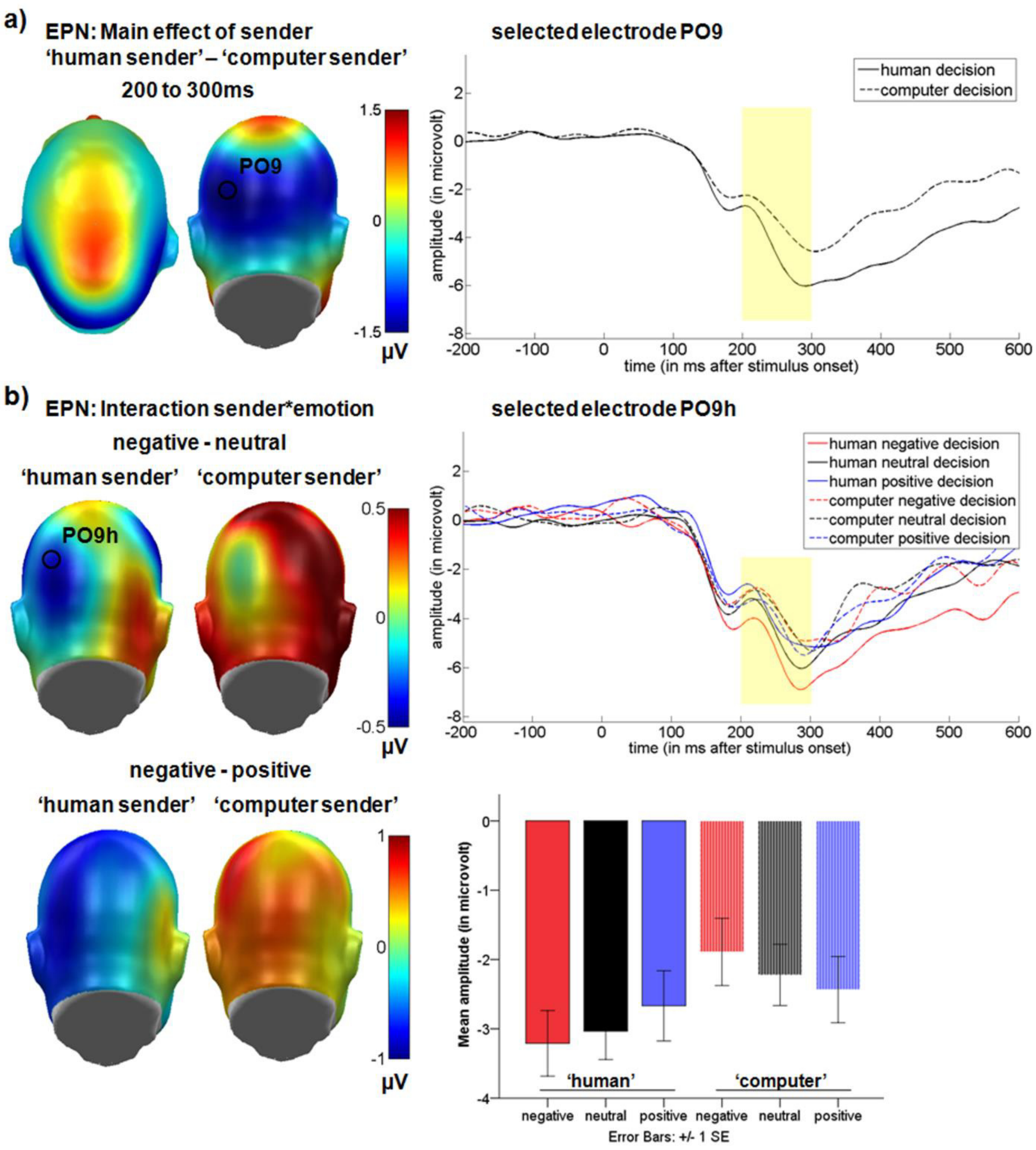

Figure 12: Results for the EPN time window displaying the significant main effect for the communicative sender and the interaction between communicative sender and emotional content. a) Left: Difference topographies for the communicative sender. Blue color indicates more negativity and red color more positivity for decisions from the 'human sender'. Right: Selected electrode PO9 displaying the time course for both senders. **b)** Left: Difference topographies for the 'human' and 'computer sender'. Right: Selected electrode PO9h displaying the time course for all decisions from both senders. Below, the mean amplitudes in microvolt for the occipital EPN cluster are shown. For display purposes electrodes were filtered using a 15Hz low-pass filter.

In source space, significant differences between the putative senders were found also in the EPN time window. Decisions made by the 'human sender' led to more activity in the bilateral fusiform gyri and in the right inferior occipital gyrus (see Figure 13 and Table 4). Larger activations were found only for the comparison 'human sender' versus computer sender. No significantly larger activity was found for the 'computer sender' even using a liberal threshold (uncorrected *p*<.05).

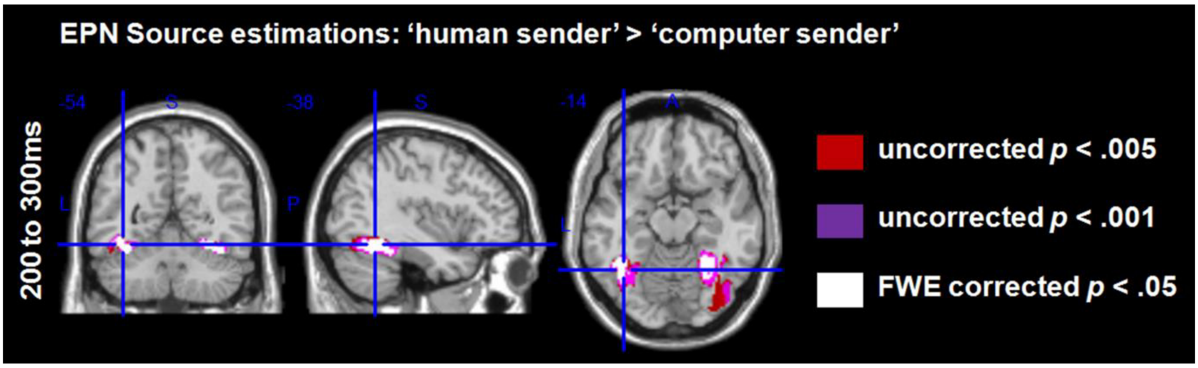

Figure 13: EPN: Source estimations for the comparison between the 'human sender' and the 'computer sender' (displayed are the FWE-corrected t-contrasts). Decisions by the 'human sender' led to enhanced activations in the bilateral fusiform gyri in the EPN time window.

Table 4: EPN: Source estimations for the comparison between the 'human sender' and 'computer sender'. Results show enhanced source activations for the 'human sender' in visual areas.

cluster-level	peak-level		MNI coordinates			AAL
Number of significant voxels	peak *t* (1, 90)	peak *p*-uncorrected	x (mm)	y (mm)	z (mm)	area
EPN time window (200-300ms)						
750 (656[a],346[b])	5.64[c]	<.001	-40	-66	-18	Fusiform L
1031 (639[a], 320[b])	5.08[c]	<.001	36	-50	-18	Fusiform R
65	3.50	<.001	44	-72	-16	Fusiform R

Notes. [a] Resulting cluster size when a threshold of *p*<.001 was used. [b] Resulting cluster size when FWE-corrected threshold of *p* < .05 was used. [c] Peak significant at *p* < .05 FWE corrected threshold. For each significant peak respective coordinates (x, y and z) are reported in MNI space. A cluster may exhibit more than one peak, while only the largest peak is displayed. Area = peak-level brain region as identified by the AAL atlas. R / L = laterality right or left.

P3

In the time window between 300 and 450ms, a significant main effect of the putative sender was found over central sensors ($F_{(1,15)} = 15.35$, $p<.001$, partial $\eta^2=.51$). Post-hoc tests show that the 'human sender' ($M = 1.85\mu V$) led to an enhanced P3 (see Figure 14). There was a trend-level effect of emotional content ($F_{(2,30)} = 3.10$, $p=.06$,

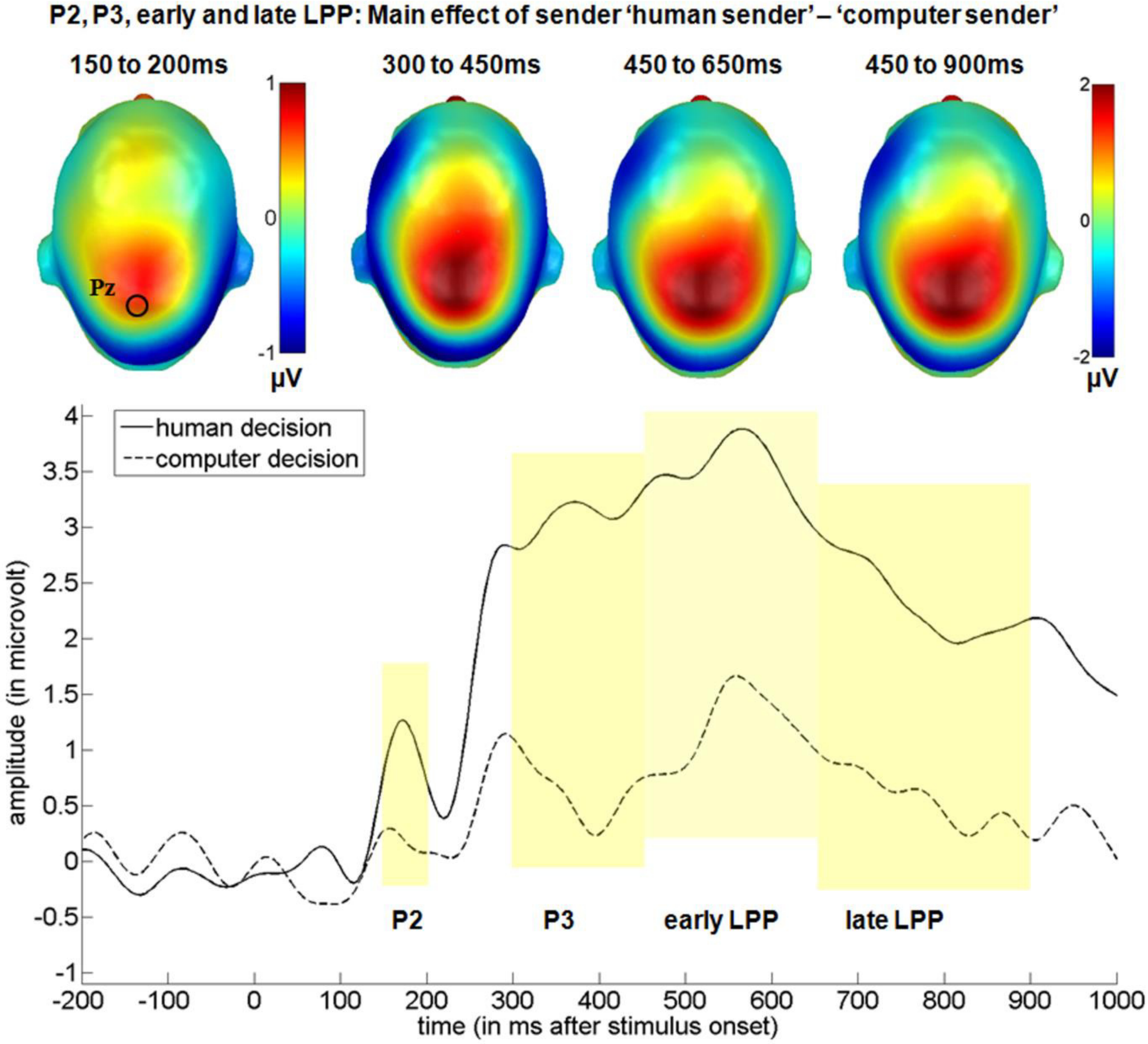

Figure 14: Main effect of the communicative sender over the central cluster in the P2, P3 and early and late LPP time windows. Top: Difference topographies for the communicative sender. Blue color indicates more negativity and red more positivity for the 'human sender'. Bottom: Selected electrode Pz displaying the time course for both senders. For display purposes data were filtered using a 15Hz low-pass filter.

partial η^2=.17). Here, negative decisions (M = 1.85µV, p<.05) and positive decisions (M = 1.97µV, p=.08) led to somewhat larger P3 amplitudes compared to neutral decisions (M = 1.25µV). Finally, no interaction between sender and emotion was found ($F_{(2,30)}$ = 0.45, p = .64, partial η^2 = .03).

In source space, significant differences were also found between the putative senders. Similar to the above reported effects, decisions made by the 'human sender' led to enhanced activity in the bilateral fusiform gyri (see Table 5), the right middle occipital gyrus and the left lingual gyrus. Again, no significantly larger activity was found for the 'computer sender' even using a liberal threshold (uncorrected p<.05).

Table 5: P3: Source estimations for the comparison between the 'human sender' and 'computer sender' in the P3 time window. Results show enhanced source activations for the 'human sender' in visual areas.

cluster-level	peak-level		MNI coordinates			AAL
Number of significant voxels	peak *t* (1, 90)	peak *p*-uncorrected	x (mm)	y (mm)	z (mm)	area
		P3 time window (300-450ms)				
807 (725[a], 549[b])	6.73[c]	<.001	-42	-64	-18	Fusiform L
795 (723[a], 553[b])	6.63[c]	<.001	36	-50	-18	Fusiform R
63	3.35	<.005	-12	-80	-12	Lingual L
81	2.90	<.005	32	-84	6	Mid Occipital R
63	2.77	<.005	40	-82	10	Mid Occipital R

Notes. [a] Resulting cluster size when a threshold of p<.001 was used. [b] Resulting cluster size when FWE-corrected threshold of p < .05 was used. [c] Peak significant at p < .05 FWE corrected threshold. For each significant peak respective coordinates (x, y and z) are reported in MNI space. A cluster may exhibit more than one peak, while only the largest peak is displayed. Area = peak-level brain region as identified by the AAL atlas. R / L = laterality right or left.

LPP

In the time window between 450 and 650ms, a significant main effect of the communicative sender was observed ($F_{(1,15)}$ = 10.45, p<.01, partial η^2=.41), where the 'human sender' (M = 2.31µV) led to a larger positivity than the computer sender (M = 0.80µV, see Figure 14). There was again a trend-like main effect of emotion

($F_{(2,30)}$ = 2.66, *p*=.09, partial η^2=.15), where negative decisions (*M* = 1.55µV, *p*=.08) and positive decisions (*M* = 1.97µV, *p*=.09) led to somewhat larger amplitudes compared to neutral decisions (*M* = 1.14µV). No interaction between sender and emotion was found ($F_{(2,30)}$ =2.20, *p*=.15, partial η^2=.12).

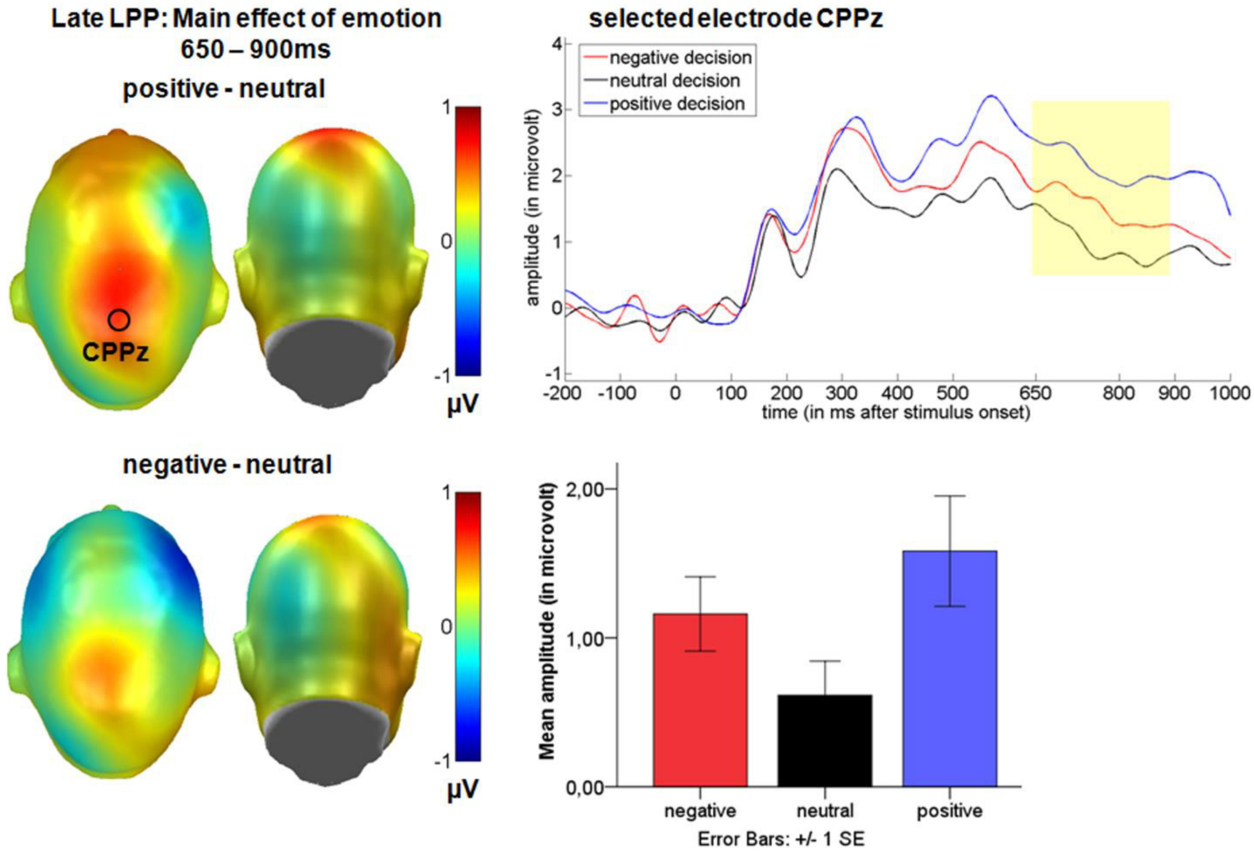

Figure 15: Main effect of emotion over the central cluster in the late LPP time window. Left: Difference topographies between emotional and neutral decisions. Blue color indicates more negativity and red more positivity for emotional decisions. Right: Selected electrode CPPz illustrates the time course for negative, neutral and positive decisions. Below, the mean amplitudes in microvolt for the central late LPP cluster are shown. For display purposes data were filtered using a 15Hz low-pass filter.

Between 650 and 900ms, during the late portion of the LPP, main effects of both the communicative sender ($F_{(1,15)}$ = 7.96, *p*<.05, partial η^2= .35), and emotion ($F_{(2,30)}$ = 3.99, *p*<.05, partial η^2= .21) were observed (see Figure 15). Again, post-hoc comparisons showed a sustained larger positivity for decisions by the ‘human sender’ (*M* = 1.75µV) compared to the ‘computer sender’ (*M* = 0.49µV, *p*<.01). Further, positive decisions (*M* = 1.58µV) elicited a larger LPP compared to neutral decisions (*M* = 0.62µV, *p*<.05), while they did not differ from negative decisions (*M* = 1.16µV, *p*=.39). There was also a trend for an enhanced LPP for negative compared to neutral decisions (*p*=.055).

In source space, significant differences between the putative senders were found in the two LPP time windows. Further, significantly larger activations were found for emotional decisions compared to neutral decisions (see Table 6).

In the early LPP time window, again enhanced activity was observed in the bilateral fusiform gyri for the ‘human sender’ as well as in the bilateral lingual, bilateral middle occipital gyri and bilateral superior occipital gyri. In the late LPP time window, more activity for the ‘human sender’ was found in the bilateral fusiform gyri, the bilateral lingual gyri and the left superior occipital gyrus. Importantly, activity induced by the ‘computer sender’ was never significantly larger than activity for the ‘human sender’, even using a liberal threshold (uncorrected *p*<.05).

Table 6: LPP: Source estimations for the comparison between the ‘human sender’ and ‘computer sender’ in the early and late LPP time windows. Results show enhanced source activations for the ‘human sender’ in visual areas.

cluster-level	**peak-level**		**MNI coordinates**			**AAL**
Number of significant voxels	peak *t* (1, 90)	peak *p*-uncorrected	x (mm)	y (mm)	z (mm)	area
early LPP time window (450-650ms)						
195 (104[a], 1[b])	4.73[c]	<.001	-12	-80	-12	Lingual L
647 (548[a])	4.37	<.001	-42	-64	-18	Fusiform L
766 (547[a])	4.31	<.001	36	-50	-18	Fusiform R
102 (47[a])	3.80	<.001	-18	-82	38	Sup Occipital L
175 (89[a])	3.59	<.001	30	-88	4	Mid Occipital R
46	3.51	<.005	24	-82	40	Sup Occipital R
156 (64[a])	3.46	<.001	-32	-80	8	Mid Occipital L
late LPP time window (650-900ms)						
105 (31[a])	3.74	<.001	-12	-80	-12	Lingual L
69	3.35	<.005	18	-74	-12	Lingual R

55	3.06	<.005	-16	-82	40	Cuneus L
321	2.87	<.005	-30	-64	-14	Fusiform L
322	2.78	<.005	26	-62	-14	Fusiform R

Notes. [a] Resulting cluster size when a threshold of p<.001 was used. [b] Resulting cluster size when FWE-corrected threshold of p < .05 was used. [c] Peak significant at p < .05 FWE corrected threshold. For each significant peak respective coordinates (x, y and z) are reported in MNI space. A cluster may exhibit more than one peak, while only the largest peak is displayed. Area = peak-level brain region as identified by the AAL atlas. R / L = laterality right or left.

To examine emotion differences in source space in the late LPP time window and to assess their overlap with the sender effect, the sender main effect was used as a region of interest within which family-wise error correction was applied. This indicated that emotional decisions led to significant larger activity in bilateral fusiform gyri compared to neutral decisions, analogous to what had been observed for the sender effect (see Figure 16, Table 7). Neutral decisions never induced more activity than emotional ones, even when applying a liberal significance threshold (uncorrected p<.05).

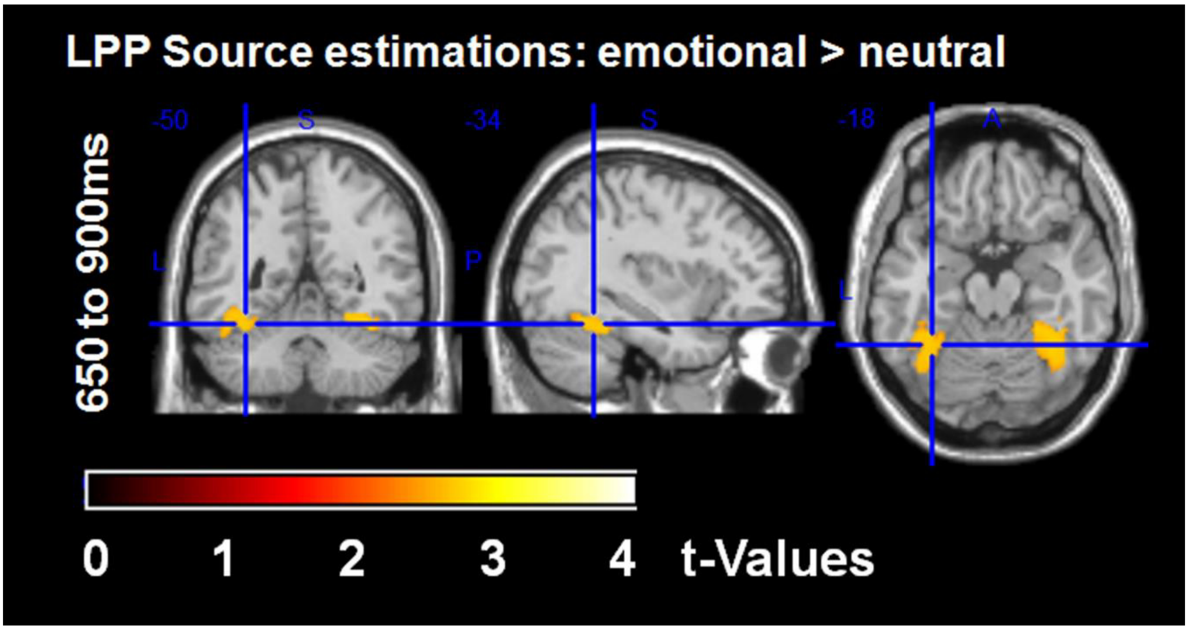

Figure 16: Late LPP: Source estimations for the comparison between emotional and neutral decisions within regions of interest derived from sender main effects (shown are the FWE-corrected *t*-contrasts). Emotional decisions led to larger activity in bilateral fusiform gyri.

Table 7: Late LPP: Source estimations for the comparison between emotional and neutral decisions. Results show enhanced source activations for the emotional decisions in visual areas.

cluster-level	**peak-level**		**MNI coordinates**			**AAL**
Number of significant voxels	peak *t* (1, 90)	peak *p*-uncorrected	x (mm)	y (mm)	z (mm)	area
		late LPP time window (650-900ms)				
248 (437a)	2.71	<.005	40	-40	-24	Fusiform R
176 (414a)	2.69	<.005	-40	-42	-20	Fusiform L

Notes. [a] Resulting cluster size when a FWE-corrected threshold of $p < .05$ was used. For each significant peak respective coordinates (x, y and z) are reported in MNI space. A cluster may exhibit more than one peak, while only the largest peak is displayed. Area = peak-level brain region as identified by the AAL atlas. R / L = laterality right or left.

2.2.4 Discussion

This study examined the impact of perceived communicative context on the processing of emotional language. We hypothesized that trait adjectives would be processed more intensely, when perceived as social feedback from another human. Indeed, in spite of physically identical stimuli, we observed large differences between the putative human and computer sender. In the ‘human sender’ condition larger ERPs were observed starting with the P2 and extending throughout the entire analysis window, encompassing EPN, P3, and LPP. Moreover, a main effect of emotion was found in the late LPP time window, where positive and in tendency also negative decisions were processed more intensely than neutral ones. Finally, on the EPN, emotion effects were found to differ between the senders, as alerting to negative content was more pronounced in the ‘human sender’ condition than in the ‘computer’ condition. Source analysis revealed the fusiform gyri as primary generators of both sender and emotion effects.

The sender effects support our main hypothesis, namely that sender information is implicitly factored into stimulus processing. This occurred, even though the communicative context was only implied and the stimulation identical across conditions. Effects started with the P2 and extended throughout the epoch, indicating phasic amplification of processing due to higher motivational relevance of the 'human sender' situation. Results fit well with the concept of motivated attention (Lang et al., 1997). Motivated attention has been suggested to account for spontaneously enhanced processing of emotional stimuli (Flaisch et al., 2011; Herbert et al., 2006; Junghöfer, Bradley, Elbert, & Lang, 2001). The concept builds on the observation that experimental effects of emotional stimuli often parallel those of explicit instructions in feature-based attention (for a review see Schupp et al., 2006). Both attention and emotion amplify stimulus processing in object-specific regions of the visual brain (Schupp et al., 2007) . Accordingly, studies with face stimuli show modulation of fusiform gyrus activity both by attended and, independent of instruction, also by emotionally relevant faces (Vuilleumier et al., 2001). In this vein, we show, for the first time, modulations of fusiform responses to words due to their implied contextual relevance.

Emotional content also affected processing. In line with other studies we found evidence for fast extraction of emotional significance (Kissler et al., 2007; Scott et al., 2009), in particular in the more relevant condition (Rohr & Rahman, 2015): An interaction between content and context occurred already on the EPN. Here, negative decisions by the 'human sender' elicited more negativity than negative or neutral decisions by the 'computer sender'. Recently, three functionally distinct stages of emotional processing have been proposed (Kissler & Herbert, 2013; W. Luo et al., 2010; D. Zhang et al., 2014): Initial alerting is supposed to accentuate negative contents whereas evaluative post-processing favors positive content. The present interaction demonstrates that contextual factors can modulate early emotion processing and that salient social contexts accentuate early alerting mechanisms.

In line with the stage model, on the late LPP primarily positive words were processed more intensely than neutral ones. The pattern was most pronounced in the ‘human sender’ condition, but also held in the ‘computer condition’, replicating previous reports of enhanced LPPs in emotion word processing (Herbert et al., 2008; Hofmann et al., 2009; Kanske & Kotz, 2007; Kissler et al., 2006, 2009; Schacht & Sommer, 2009a). A self-positivity bias may contribute to this: For instance, Tucker and colleagues (2003) had participants decide if adjectives were self-descriptive or descriptive of a close friend. Passive viewing served as the control condition. The LPP was generally larger in the active conditions. Moreover, larger LPPs were found for positive than negative traits endorsed in oneself or a close friend, the effect being larger again for the self-positive traits (Tucker et al., 2003). FMRI findings (Korn et al., 2012) and behavioral studies also support a self-positivity bias (Hepper, Hart, Gregg, & Sedikides, 2011). Positive traits seem more self-relevant for healthy subjects than negative traits and a correlation of self-positivity bias and self-esteem has been found (H. Zhang, Guan, Qi, & Yang, 2013). This might be adaptive in helping people to maintain psychological health (Blackhart, Nelson, Knowles, & Baumeister, 2009). Overall, the healthy brain appears to amplify processing of self-related positive information. Using EEG’s time resolution, the present study determines a distinct processing stage, namely the LPP window, where this occurs.

Source analyses indicate that the emotion enhancement takes place in largely the same region as the contextual enhancement, indicating that both context and content can independently amplify visual processing. Stronger activations for both the ‘human sender’ and emotional content were localized mostly in bilateral fusiform gyri, including the visual word form area (VWFA) - a region specialized in the processing of written language (e.g., Mei et al., 2010; Szwed et al., 2011; Wang, Yang, Shu, & Zevin, 2011; Yarkoni et al., 2008). For example, stronger VWFA activations are found for real words versus objects or scrambled words (Szwed et al., 2011), and can be modulated by task demands (Wang et al., 2011). VWFA activity is thought to reflect the integration of orthography, word sound and meaning (Yarkoni et al., 2008), and is also linked to memory for words (Mei et al., 2010).

Overall, our findings agree with the motivated attention model, further specify its cortical basis and extend it to contextual factors. Results confirm enhancement of visual processing by motivationally relevant stimuli in object-specific cortical areas and indicate that both stimulus and context characteristics can confer motivational relevance. Enhanced bilateral fusiform gyri activations are likely to reflect heightened attention, enhancing the stimuli's visual processing, if a supposedly 'human sender' gave feedback. Tasks such as lexical or semantic decisions compared to passive viewing (Y. Chen, Davis, Pulvermüller, & Hauk, 2013) or semantic versus perceptual tasks (Martens, Ansorge, & Kiefer, 2011) have been shown to modulate word processing in a similar manner. In the current experiment both conditions basically required passive viewing. Therefore modulations can be only explained by implicit tuning due to the context manipulation.

In face processing, stronger fusiform activity has been reported to socially and biologically relevant faces compared to non-face stimuli (Kanwisher, McDermott, & Chun, 1997). Fusiform responses are larger for emotional than neutral faces and can be tuned by attentional demands (Vuilleumier & Pourtois, 2007). Finally, social relevance manipulations, such as assigning faces to a group, also amplify fusiform activity for in-group faces (Van Bavel, Packer, & Cunningham, 2011). The present research extends these findings to word processing in social contexts. For humans, verbal feedback is socially and perhaps also biologically important, as belonging to a community reflects a motivational desire, derived from its evolutionary advantage for group-living species.

A key question for future research concerns further specification of the mechanisms behind tuning of fusiform activity by stimulus and/or context attributes. An influential model suggests that re-entrant processing from the amygdala drives fusiform responses to emotional faces (Vuilleumier, 2005) and studies with neurological patients also indicate a crucial role for the amygdala in prioritized processing of emotional words (Anderson & Phelps, 2001). The current study does not lend itself to a straightforward test of this model, as EEG does not reliably localize subcortical structures. However, future neuroimaging studies will be revealing in this regard. Attentional modulation of visual cortex has been suggested to be driven by top-down influences from parietal or prefrontal cortex (for a review see Corbetta & Shulman, 2002). However, in the present study very little activity outside visual cortex was found, even at lenient thresholds ($p<.05$) suggesting that these projections play little role in the current experimental situation. Here, we confirm reports of occipital generators of emotion-LPP enhancements (Moratti et al., 2011; Sabatinelli et al., 2007), but found no significant differences in parietal or frontal generator activity. This may be because context was manipulated between blocks, inducing phasic effects resulting in more sustained sensitization within visual cortex itself. Indeed, recent connectivity studies indicate bottom-up effects of left ventral occipito-temporal cortex, including the left fusiform gyrus in word detection (Schurz et al., 2014). Finally, emotional stimuli and social contexts manipulations may differ in their respective patterns of activity within fusiform gyrus.

In summary, we found that the perceived social context has a large impact on word processing. Our research specifies the time course of the effect and reveals involved brain structures. Sender differences started with the P2 and extended throughout the analysis window. Source estimation localized these effects primarily to the fusiform portions of the visual cortex. Early in the processing stream, negative feedback was processed more intensely when received from the 'human sender', possibly reflecting an early alerting mechanism. However, at late processing stages, positive feedback was preferentially processed supporting a self-positivity bias (Izuma et al., 2010; Korn et al., 2012; Simon et al., 2014). These results extend the concept of motivated attention from emotional stimulus content to socio-emotional context and provide a step towards studying word processing in more realistic or at least quasi-communicative scenarios. The present design will lend itself to straightforward investigations of inter-individual differences and clinical disorders. It gains further relevance in the age of virtual communication, where personally unknown communication partners often ascribe states and intentions to each other.

Acknowledgments

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2.3 Study III: People matter: Perceived sender identity modulates cerebral processing of socio-emotional language feedback

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[3] Except for the omission of the abstract and the renumbering of the sections, tables and figures according to the overall structure of this thesis the present chapter is identical to the original paper.

2.3.1 Introduction

We constantly communicate with others, exchanging facts, preferences, attitudes or gossip. Language enables us to do this. However, as Fauconnier noted (1994), in contrast to naive assumptions, the meaning of words is not fixed. Rather we need to have knowledge about the context to decode meaning (Fauconnier, 1994; p. xviii). Some communication theories even state that meaning is directly adopted from interaction with others, emphasizing the importance of social context (Blumer, 1969). However, particularly in modern-day virtual communication, such as e-mail, text messaging or twitter, the presence of interactive partners is often not physically perceived, but inferred from contextual cues, begging the question of how such socio-contextual inferences affect the processing of language content.

Recently, communicative context manipulations have been shown to modulate the processing of emotional language as reflected in brain event-related potentials (ERPs; Fields & Kuperberg, 2012; Herbert, Herbert, et al., 2011; Rohr & Rahman, 2015; Schindler, Wegrzyn, Steppacher, & Kissler, 2015; Schindler et al., 2014). For example, Rohr and Rachman (2015) presented video-clips of professional female actors, speaking single emotional or neutral words. In a non-communicative situation the speaker's eyes and mouth were closed, which resulted in drastically reduced or even absent emotion effects. Studies manipulating the self-reference of words or sentences, found enlarged processing of neutral as well as of positive words in their self-relevant conditions (Fields & Kuperberg, 2012; Herbert, Herbert, et al., 2011). Regarding the role of inferred sender identity, in a social feedback situation, which for humans is a particularly salient context (Eisenberger et al., 2011; Korn et al., 2012), the notion of interacting with a human partner has been found to amplify visual processing compared to random computer feedback, even in the absence of any physical cues (Schindler et al., 2015). In this latter study, participants supposedly received written personality feedback either from an unknown stranger or from a randomly acting computer program (Schindler et al., 2015). Although visual input was identical, word messages from the putative ‘human sender’ elicited enhanced ERPs starting with the P2 potential, sometimes characterized as an initial stage of lexical processing (e.g. Trauer, Andersen, Kotz, & Müller, 2012) and extending across the entire processing sequence, including EPN, P3 and LPP. The sources of these activities were localized in bilateral visual cortices, particularly fusiform areas. Content effects were also found in that emotional feedback magnified LPP amplitudes, largely replicating previous research on elaborative processing of emotional language (Herbert et al., 2008, 2006; Hofmann et al., 2009; Kanske & Kotz, 2007; Kissler et al., 2006, 2009; Schacht & Sommer, 2009b). Similar to the sender effects, the content effects were also mainly localized in bilateral fusiform gyri. In general, such enhanced visual activity in response to significant stimuli can be related to the framework of motivated attention, attributing enhanced visual activation in response to emotional stimuli to their higher motivational relevance (Lang et al., 1998; Schupp, Cuthbert, et al., 2004). Therefore, recent results demonstrate that next to stimulus content, stimulus context also drives motivated attention.

But isn’t there something special, qualitatively distinct, about the social context of receiving feedback from another human rather than a machine? On the one hand, computers can be perceived as social agents (Nass, Moon, Fogg, Reeves, & Dryer, 1995; Nass, Steuer, & Tauber, 1994) and participants sometimes, almost inappropriately, use social rules when interacting with them (Nass et al., 1995). In fact, computer algorithms might be superior to humans in assessing somebody’s personality (Youyou et al., 2015). On the other hand, humans often respond in a distinct manner when interacting with another human rather than a machine. For instance, when interacting with a computer partner, participants exhibit less interpersonal display than when interacting with a putative human (Aharoni & Fridlund, 2007). Also, whereas humans adapt to another human's age when talking, they hardly adapt to a robot's suggested age or cognitive status (Fischer, Foth, Rohlfing, & Wrede, 2011a, 2011b). Similarly, on the cerebral level fMRI studies indicate less activity in empathy (Rosenthal-von der Pütten et al., 2014) and mentalizing (Chaminade et al., 2012; Kircher et al., 2009) networks for human-machine compared to human-human interactions. However, when participants are given an incentive to perceive a nonhuman agent as human-like, more mentalizing is also observed, suggesting plasticity in the networks involved (Waytz et al., 2010), Finally, responses to unfair offers in the 'trust game' pardigm depend on whether the interactive partner is perceived as a human: Phan and colleagues (2010) found that brain responses towards unfair decisions by a computer partner are most similar to decisions by a neutral human partner, but different from those of an unfair human partner. Other experiments also reported that unfair offers were processed in a distinct manner only when putatively given by a human partner (Harlé et al., 2012). When participants received such putatively human-generated rather than computer-generated decisions, enhanced bilateral fusiform activity was observed next to increased activity in the left amygdala, bilateral insula, superior temporal sulcus, and reward-related areas (Singer et al., 2004). On the basis of these findings, it seems reasonable to expect a unique influence of attributions of humaness in social communicative situations.

In our previous EEG study, we showed that processing of single words was amplified from early processing stages when supposeldy generated by another human rather than by a randomly acting machine, reflecting large effects of even implied communicative contexts (Schindler et al., 2015). However, an open question is to what extent these effects were due to differences in attributed social competence or due to the notion of a human partner per se. In other words, will context-driven differences persist when perceived competence is suggested to be equal? Will quantitative effects remain, because human feedback is always more relevant, resulting in unspecific visual processing enhancement, in line with the model of motivated attention (Lang et al., 1998; Schupp, Cuthbert, et al., 2004)? Importantly, will there be also qualitative differences indicative of the recruitment of distinct social brain networks? EEG source estimation can provide cues to discriminate unspecific attention effects from specific effects of humanness. Moreover, the high temporal resolution of EEG recordings can reveal the time-course of visual and social brain activation and integration.

To address these questions in the current study participants received written emotional and neutral feedback. In one condition feedback came putatively from an unknown stranger and in the other condition from an equally competent socially intelligent computer program. To the extent that previous results were primarily due to the supposed randomness of the computer’s behavior, sender-induced differences should be reduced or even abolished. To the extent that some sender attributes are perceived as uniquely human and therefore processed in a distinct manner, differences between the implied senders should persist. We hypothesized that larger EPN and LPP amplitudes would remain in response to decisions by a putative 'human sender' and that these differences would be reflected in enhanced visual processing in source space. Further, we expected increased activity in mentalizing-related brain regions such as superior frontal regions (Chaminade et al., 2012; Kircher et al., 2009) when receiving human-generated feedback. In accordance with the model of motivated attention, enhanced processing of emotional decisions on the scalp and in source space was also predicted.

2.3.2 Method

Participants

Twenty-eight participants were recruited at the University of Bielefeld. They gave written informed consent according to the Declaration of Helsinki and received 10 Euros for participation. The study was approved by the local Ethics Committee. Due to large artifacts one participant had to be excluded, leaving twenty-seven participants for final analysis. The resulting participants (18 females) were 25.26 years on average (*SD*=2.92), all of them right-handed and had normal or corrected-to normal vision. No participant reported a previous or current neurological or psychiatric disorder.

Stimuli

Presented adjectives were rated beforehand in terms of valence and arousal using the Self-Assessment Manikin. The 20 student raters who did not participate in the actual experiment were instructed to consider the adjectives' valence and arousal in an interpersonal evaluative context. The selected 150 adjectives (60 negative, 30 neutral, 60 positive) were matched in their linguistic properties, such as word length, frequency, familiarity and regularity (see Schindler et al., 2015, 2014). Importantly, negative and positive adjectives differed in valence only. Neutral adjectives were allowed to deviate from emotional adjectives on rated concreteness since truly neutral trait adjectives are rare in an interpersonal evaluative context.

Procedure

The experimental procedure mirrored the one described previously (Schindler et al., 2015, 2014) with the critical difference that participants were told that they would be evaluated by an unknown other person or by a socially intelligent computer program, able to give personality feedback. All subjects underwent both conditions. Sequence of conditions was counterbalanced between participants.

Upon arrival, participants were instructed to briefly describe themselves in a structured interview in front of a camera. They were informed that the video of their self-description would be presented to a second participant next door as well as imported into a socially intelligent computer algorithm. Subsequently, participants filled out a demographic questionnaire. To ensure face validity, a research assistant left the testing room a couple of minutes ahead of the fictitious feedback, guiding an ‘unknown person’ to a laboratory room next to the testing room.

Stimuli were presented within a desktop environment of a fictitious program ‘Interactional Behavioral Systems’ supposedly allowing instant online communication. In order to ensure credibility of the situation, network cables and changes of the fictitious software desktop image that showed the ‘Interactional Behavioral Systems’ environment were made salient. The presented feedback was randomly generated in both conditions. Half of all adjectives were endorsed, leading to 30 affirmative negative, 30 neutral and 30 affirmative positive decisions. Additionally, twenty highly negative adjectives were defined to be always rejected in the ratings to further increase credibility, since it would appear very unlikely for somebody to endorse extremely negative traits in a hardly known stranger. These additional trials were excluded from further analysis. The desktop environment and stimulus presentation were created using Presentation software (www.neurobehavioralsystems.com). In the ‘human’ condition, color changes between 1500 and 2500ms after adjective onset indicated a decision by the supposed interaction partner. This manipulation simulated varying decision latencies in humans. The decision was indicated via color change (blue or purple) of the presented adjective, indicating whether or not the respective adjective applied to the participant. In the computer condition, color changes invariably occurred at 1500ms, conveying the notion of constant machine computing time. In both conditions color changes lasted for 1000ms, followed by a fixation cross for 1000 to 1500ms. Color–feedback assignments were counterbalanced in both conditions.

EEG recording and analyses

EEG was recorded from 128 BioSemi active electrodes (www.biosemi.com). Recorded sampling rate was 2048Hz. During recording Cz was used as reference electrode. Biosemi uses two separate electrodes as ground electrodes. First a Common Mode Sense active electrode (CMS) and second a Driven Right Leg passive electrode (DLR). The two electrodes form a feedback-loop which enables to measure the average potential close to the reference in the AD-box (see http://www.biosemi.com/faq/cms&drl.htm, where also information about extra functions of the CMS/DRL loop can be retrieved). Four additional electrodes (EOG) measured horizontal and vertical eye-movement. These were placed at the outer canthi of the eyes and below the eyes.

Pre-processing and statistical analyses were done using EMEGS (Peyk et al., 2011) and SPM8 for EEG data (http://www.fil.ion.ucl.ac.uk/spm/). Offline, data were then down-sampled to 250Hz and later band-pass filtered from 0.166 to 30 Hz with a fifth-order Butterworth zero-phase filter. Filtered data were segmented from 500ms before stimulus onset until 1000ms after stimulus presentation. There was an immediate transition from word presentation to feedback by color change. Results are presented without baseline correction therefore in order to avoid introduction of pre-baseline differences into the feedback phase. However, there were no apparent differences in the time segment immediately preceding the color change (see Figures 17, 18) and control analyses with baseline correction lead to analogous results. For trials exceeding a threshold of 160µV automatic artifact detection was used. Data were averaged, using a robust averaging algorithm, excluding possible further artifacts (Litvak et al., 2011). Robust averaging down-weights outliers for each channel and each time point, thereby preserving a higher number of trials as artifacts are not supposed to distort the whole trial but most of the time corrupt only parts of the trial. We used the recommended offset of the weighting function, which preserves approximately 95% of the data points drawn from a random Gaussian distribution (Litvak et al., 2011). Overall, 2.34 percent of all electrodes were interpolated. On average 12.43 percent of all trials were rejected, leaving on average 26.27 trials per condition.

Cortical source reconstructions of significant ERP differences were generated and statistically assessed with SPM8 for EEG (Litvak & Friston, 2008; Lopez et al., 2013), following recommended procedures. First, a realistic boundary element head model (BEM) was derived from SPM´s template head model based on the Montreal Neurological Institute (MNI) brain. Electrode positions were then transformed to match the template head, which is thought to generate reasonable results even when individual subjects' heads differ from the template (Litvak et al., 2011). Average electrode positions as provided by BioSemi were co-registered with the cortical mesh template for source reconstruction. This cortical mesh was used to calculate the forward solution. The inverse solution was calculated from 0ms to 1000 ms after feedback onset. Group inversion (Litvak & Friston, 2008) was computed and the multiple sparse priors algorithm implemented in SPM8 was applied. This method allows activated sources to vary in the degree of activity, but restricts the activated sources to be the same in all subjects (Litvak & Friston, 2008). Compared to single subject matrix inversion, this has been found to result in more robust source estimations (Litvak & Friston, 2008; Sohoglu et al., 2012).

Statistical analyses

EEG scalp-data were statistically analyzed with EMEGS. Two (sender: human versus computer) by three (content: positive, negative, neutral) repeated measure ANOVAs were set-up to investigate main effects of the communicative sender, emotion and their interaction in time windows and electrode clusters of interest. Time-windows of interest were chosen based on previous reports of attention or emotion modulations and conspicuous differences in the ERPs. Partial eta-squared (partial η^2) was estimated to describe effect sizes, where $\eta^2 = 0.02$ describes a small, $\eta^2 = 0.13$ a medium and $\eta^2 = 0.26$ a large effect (J. Cohen, 1988). When Mauchly’s test indicated a violation of sphericity, degrees of freedom were corrected according to Greenhouse-Geisser. Time windows were segmented from 150 to 200ms to investigate P2 effects, from 250 to 400ms to investigate EPN and P3 effects (Polich, 2007; Polich & Comerchero, 2003) and from 400 to 650ms to investigate early LPP effects and from 650 to 900ms to investigate late LPP effects (Schindler et al., 2015; Schupp, Junghöfer, et al., 2004). For the EPN time window, two symmetrical temporo-occipital clusters of thirteen electrodes each were examined (left: I1, OI1, O1, PO9, PO9h, PO7, P9, P9h, P7, TP9h, TP7, T7, T7h; right: I2, OI2, PO10, PO10h, PO8, P10, P10h, P8, TP10h, TP8, T8, T8h). For the P2, P3 and LPP time windows a large central cluster was investigated (twenty-six electrodes: FCC1h, FCC2h, C3h, C1, C1h, Cz, C2h, C2, C4h, CCP3h, CCP1, CCP1h, CCPz, CCP2h, CCP2, CCP4h, CPz, CPP1, CPPz, CPP2, P1h, Pz, P2h, PPO1h, PPOz, PPO2h, see Schindler, Wegrzyn et al., 2015).

For each analyzed time window in scalp space, three-dimensional source reconstructions were generated as NIFTI images (voxel size = 2mm*2mm*2mm). These images were smoothed using an 8mm full-width half-maximum. The statistical comparisons used in source space were based on significant differences on the scalp. In line with previous studies (see e.g., Campo et al., 2013; Schindler et al., 2015), we describe statistical differences in source activity of voxels starting with a difference of at least $p<.005$ and a minimum of twenty-five significant voxels per cluster. The identification of activated brain regions was performed using the AAL atlas (Tzourio-Mazoyer et al., 2002).

2.3.3 Results

P2

Over the central sensor cluster a significant main effect of the communicative sender ($F_{(1,26)} = 6.55$, $p < .05$, partial $\eta^2 = .20$) was observed. Decisions by the 'human sender' elicited a larger positivity compared to the 'computer sender' (see Figure 17a). For the P2 no main effect of emotion ($F_{(2,52)} = 0.83$, $p = .44$, partial $\eta^2 = .03$) and no interaction between sender and emotion ($F_{(2,52)} = 0.94$, $p = .40$, partial $\eta^2 = .04$) were observed.

EPN

Over the occipital sensor clusters a significant main effect of communicative sender ($F_{(1,26)} = 4.47$, $p < .05$, partial $\eta^2 = .15$), as well as a significant effect of emotional content ($F_{(2,52)} = 6.99$, $p < .01$, partial $\eta^2 = .21$) and a significant interaction between sender and emotion ($F_{(2,52)} = 3.29$, $p < .05$, partial $\eta^2 = .11$; see Figure 17) were found. Post-hoc comparisons showed that both decisions by the 'human sender' and

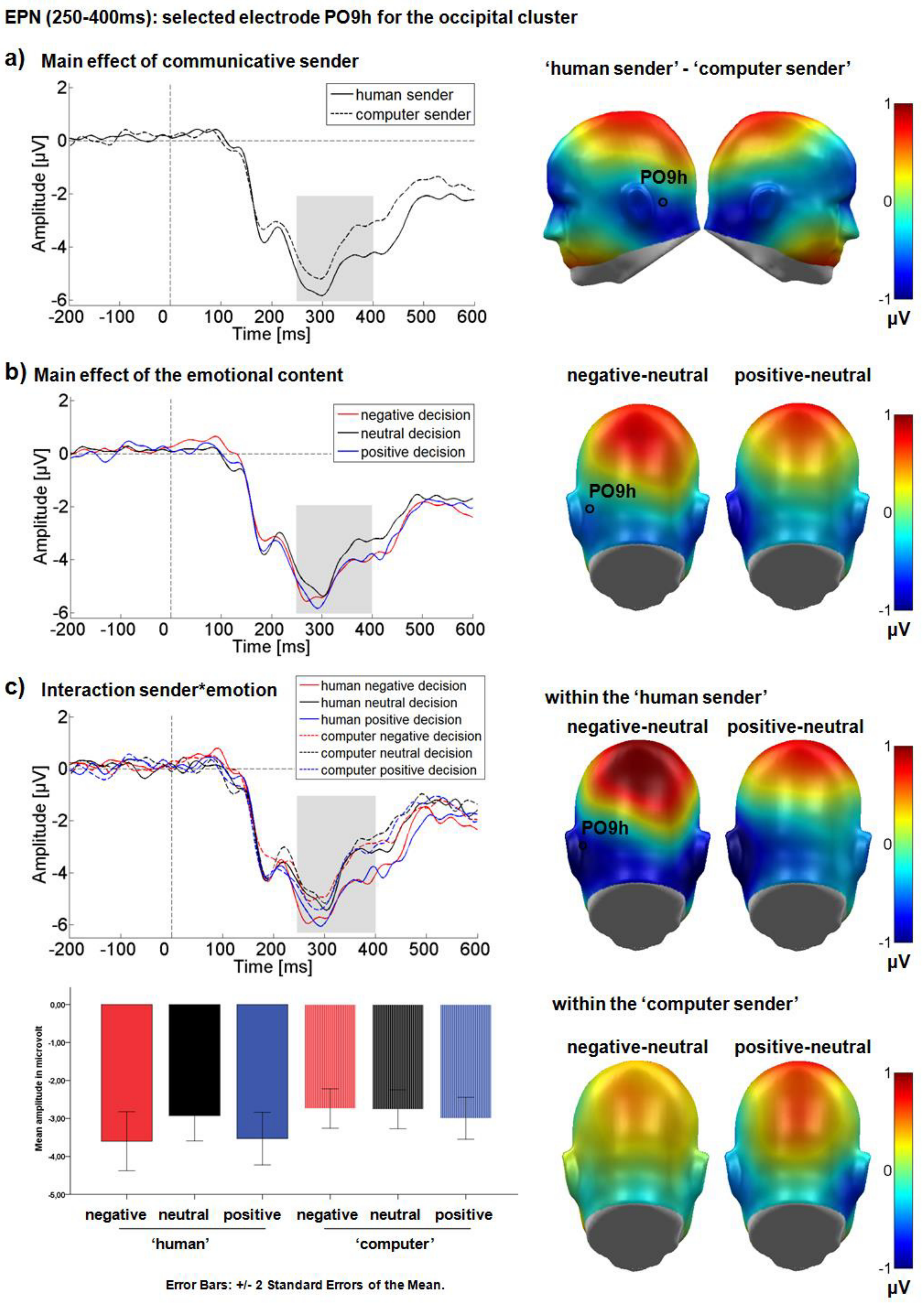


Figure 17: Results for the occipital electrode cluster for the EPN time window showing a significant main effect for the sender and emotional content and the interaction between sender and emotion. a) Main effect for the communicative

sender: Difference topographies between the ‘human’ and ‘computer’ sender. Blue color indicates more negativity and red color more positivity for the ‘human sender’. Selected electrode PO9h showing the time course for both senders. **b)** Main effect for emotional content: Difference topographies between negative, positive and neutral decisions. Blue color indicates more negativity and red color more positivity for emotional decisions. Selected electrode PO9h showing the time course for all decisions. **c)** Interaction between sender and emotion: Difference topographies for each sender between negative, positive and neutral decisions. Blue color indicates more negativity and red color more positivity emotional decisions. Selected electrode PO9h showing the time course for all decisions.

emotional decisions led to a larger EPN. Positive and negative decisions did not differ from each other (p = .47). For the significant sender by emotion interaction, post-hoc tests showed that within the 'human sender' both negative (p < .001) and positive decisions (p < .01) elicited a larger EPN compared to neutral decisions, while not differing from each other (p = .76). Within the computer sender, there were no significant differences between negative and neutral decisions (p = .90), positive and neutral decisions (p = .16) or negative and positive decisions (p = .12).

No main effect of laterality ($F_{(1,26)}$ = 0.03, p = .86, partial η² < .01) and no other interaction were observed (all *ps* >.20).

P3

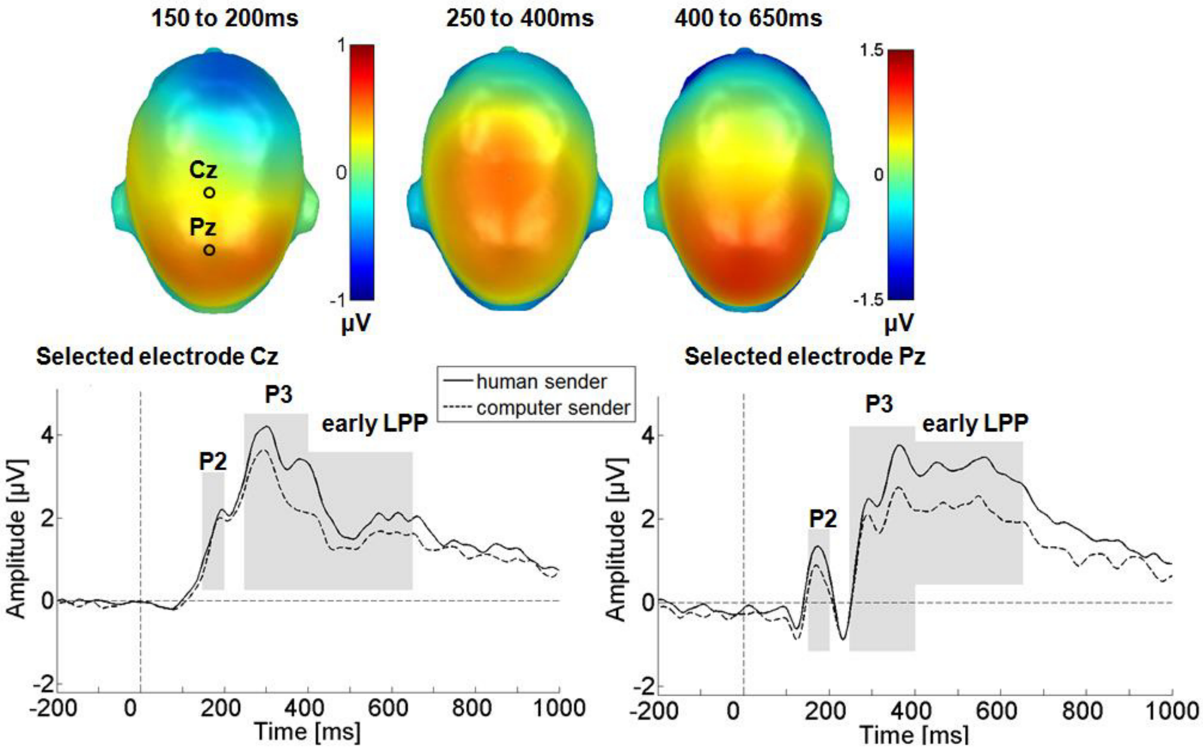
In the time window between 250 and 400ms, over the central sensor cluster significant main effects of the communicative sender ($F_{(1,26)}$ = 7.24, p < .05, partial η² = .22) and of emotional content were observed ($F_{(2,52)}$ = 28.27, p < .001, partial η² = .52; see Figure 18). A trend for an interaction between sender and emotion was also observed ($F_{(2,52)}$ = 2.45, p = .10, partial η² = .09). Descriptively, within the 'human sender' the processing enhancement of negative ($M_{\text{negative-neutral}}$ = 0.90µV) and positive decisions ($M_{\text{positive-neutral}}$ = 0.66µV) was somewhat larger than within the ‘computer sender’ ($M_{\text{negative -neutral}}$ = 0.36µV; $M_{\text{positive-neutral}}$ = 0.53µV).

LPP

Over central locations main effects of the communicative sender ($F_{(1,26)} = 8.00$, $p < .01$, partial $\eta^2 = .24$) and emotion ($F_{(2,52)} = 14.39$, $p < .001$, partial $\eta^2 = .36$) were observed in the early LPP time window (400-650ms, see Figure 18). Again, post-hoc comparisons showed a sustained larger positivity for decisions by the 'human sender' compared to the 'computer sender', as well as for positive ($p < .001$) and negative ($p < .001$) decisions compared to neutral decisions. Positive and negative decisions did not differ from each other ($p = .60$). There was no interaction between sender and emotional content ($F_{(2,52)} = 2.23$, $p = .12$, partial $\eta^2 = .08$).

In the late LPP time window (650-900ms) a trend for a main effect of the communicative sender ($F_{(1,26)} = 3.67$, $p = .07$, partial $\eta^2 = .12$) and a significant main effect of emotion ($F_{(2,52)} = 4.65$, $p < .05$, partial $\eta^2 = .15$) were found. Post-hoc comparisons showed that only positive compared to neutral decisions led to a larger LPP ($p < .01$), while for negative compared to neutral decisions a trend was observed ($p = .08$). Positive and negative decisions did not differ from each other ($p = .23$). There was no interaction between communicative sender and emotional content ($F_{(2,52)} = 1.62$, $p = .21$, partial $\eta^2 = .06$).

a) P2, P3 and early LPP: Main effect of sender, 'human sender' – 'computer sender'



b) P3, early and late LPP: Main effect of emotion, emotional decisions – neutral decisions

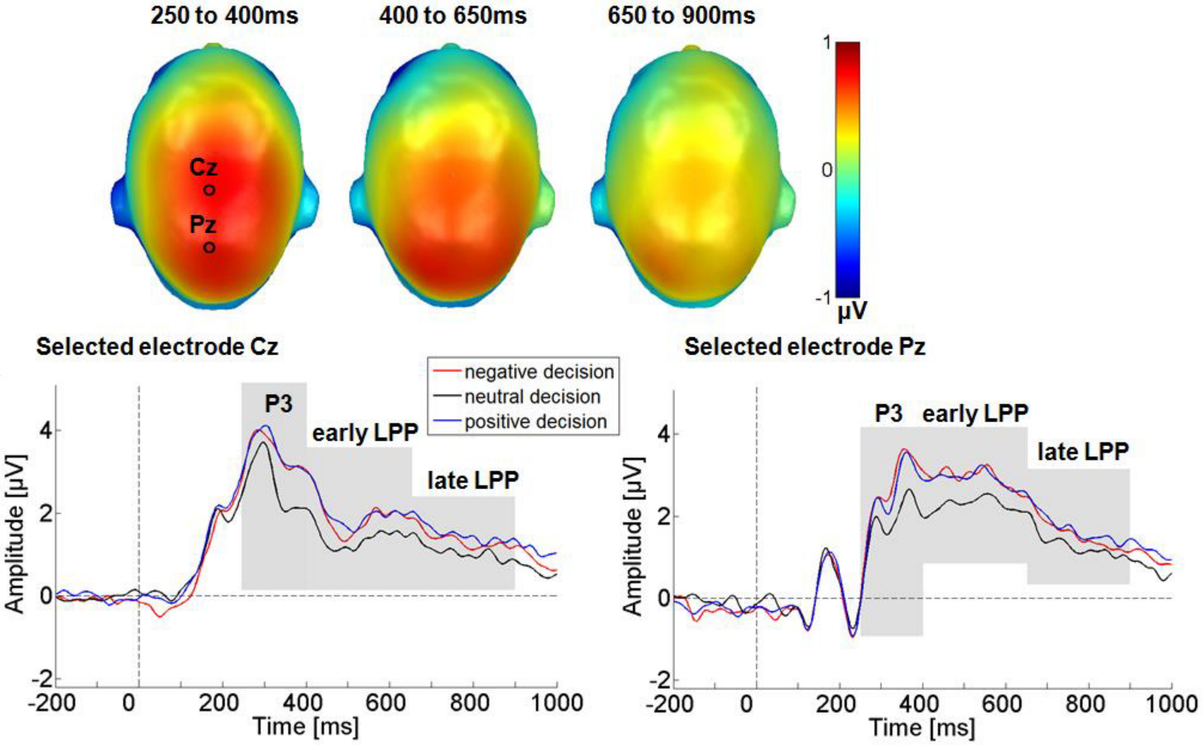


Figure 18: Results for the centro-parietal electrode cluster for the P3 and LPP time windows showing significant main effects for the communicative sender and emotional content. a) Main effect for the communicative sender: Difference topographies between the 'human' and 'computer' sender. Blue color indicates more negativity and red color more positivity for the 'human sender'. Selected electrodes

Cz and POz showing the time course for both senders. **b)** Main effect for the emotional content: Difference topographies between emotional and neutral decisions. Blue color indicates more negativity and red color more positivity for emotional decisions. Selected electrodes Cz and POz showing the time course for negative, neutral and positive decisions.

Source reconstruction

For all comparisons significantly larger activations were only found for the decisions by the ‘human sender’, for emotional decisions and emotional decisions within the 'human sender' (see Tables 8-10 and Figure 19). No differences were found for the reverse comparisons, even at lower thresholds. The EPN and P3 time window were temporally overlapping and therefore our source reconstructions included the whole topography.

For the P2 time window no significant differences in source space could be identified between the putative senders. The first significant differences between the senders in source space were found in the EPN/P3 time window. Here, decisions made by the ‘human sender’ led to enhanced activity in the bilateral fusiform, inferior occipital, superior occipital gyri, as well as in the right superior frontal gyurs (see Figure 19, Table 8). In the LPP time windows, activity remained significantly enhanced in visual areas. In addition, more activity was found in the bilateral somatosensory (postcentral) gyri.

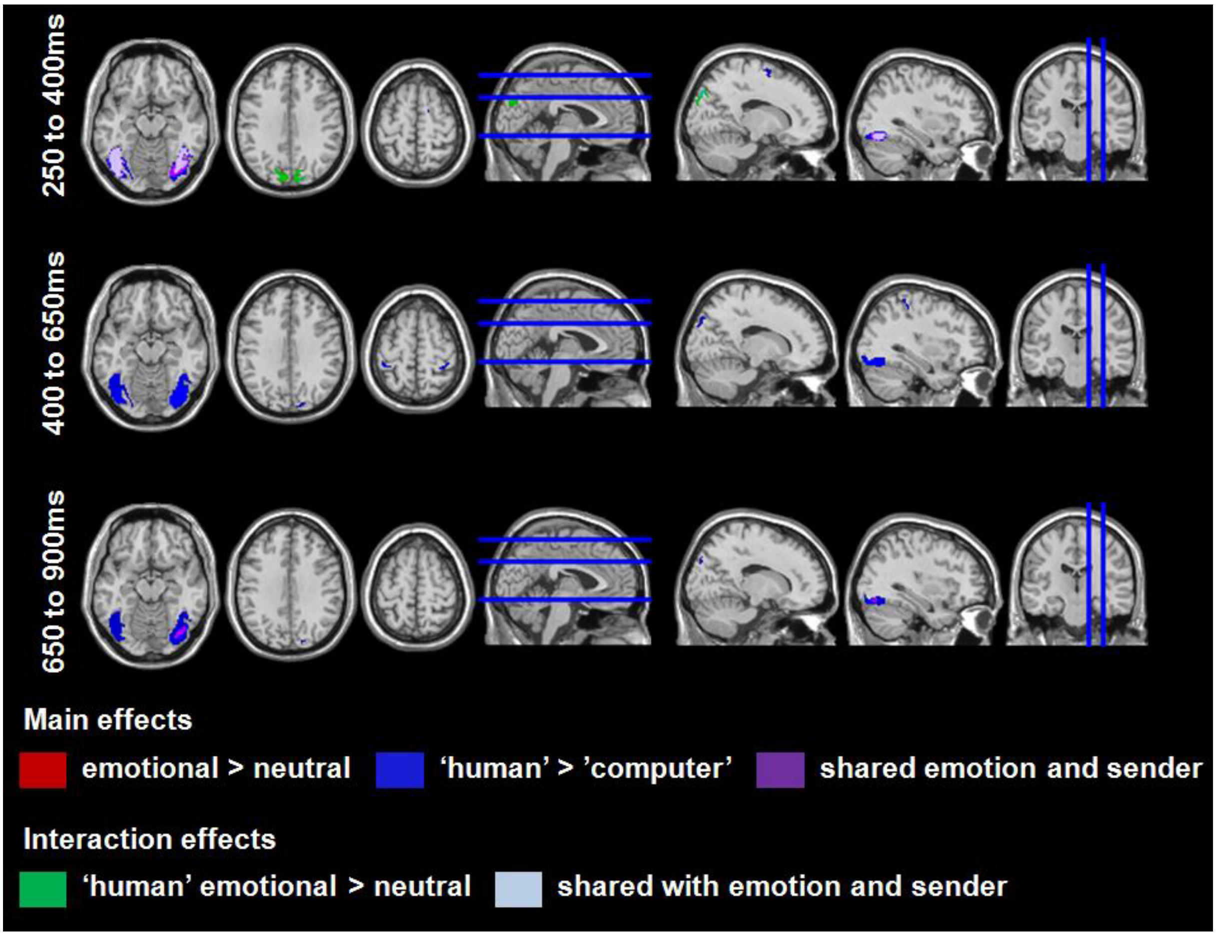


Figure 19: Source estimations the main effects of sender and emotion in the EPN and LPP time windows and their interaction in the EPN time window (displayed are the post-hoc t-contrasts, *p* < .005). In the EPN/P3, 'human-generated' decisions, emotional decisions and their interaction led to enhanced visual activity. For emotional decisions activations were also found in bilateral temporal areas, while 'human' decisions led to more activity in superior frontal regions. In the LPP time windows enhanced visual, superior frontal and somatosensory activity was found for the 'human sender'.

Table 8: Source estimations for the comparison between the 'human sender' and 'computer sender' in the EPN and LPP time windows.

cluster-level	peak-level		MNI coordinates			AAL
Number of significant voxels	peak *t* (1, 156)	peak *p*-uncorrected	x (mm)	y (mm)	z (mm)	area
		EPN/P3 time window (250-400ms)				
793 (663^{a}, 44^{b})	4.75	<.001	36	-72	-12	Fusiform R
868 (749^{a})	4.68	<.001	-38	-80	-16	Fusiform L
37	3.02	=.001	-62	-32	10	Mid temporal L
33	2.87	<.005	20	-6	68	Sup frontal R
61	2.85	<.005	24	-82	40	Sup occipital R
		early LPP time window (400-650ms)				
840 (653^{a})	4.63	<.001	32	-82	-16	Lingual R
742 (551^{a})	4.43	<.001	-32	-82	-16	Fusiform L

51	3.42	<.001	-40	-38	60	Postcentral L
61	3.28	=.001	40	-36	60	Postcentral R
105	3.05	<.005	24	-82	40	Sup occipital R
		late LPP time window (650-900ms)				
695 (457[a])	3.86	<.001	40	-76	-14	Inf occipital R
606 (127[a])	3.32	=.001	-30	-82	-18	Cerebellum L
39	3.01	<.005	22	-84	38	Sup occipital R
	2.86	<.005	30	-88	-8	Inf Occipital R
63	2.88	<.005	18	-4	68	Sup frontal R

Notes. [a] Resulting cluster size when a threshold of $p<.001$ was used. [b] Resulting cluster size when FWE-corrected threshold of $p < .05$ was used. For each significant peak respective coordinates (x, y and z) are displayed in MNI space. A cluster may exhibit more than one peak, while only the largest peak is displayed. Area = peak-level brain region as identified by the AAL atlas. R / L = laterality right or left. Inf = inferior, Mid = middle, Sup = superior.

For the emotion main effect, significant differences were found in the EPN and LPP time window. Here, emotional decisions led to larger activity in the bilateral fusiform gyri and temporal areas including the Rolandic operculum (see Figure 19, Table 9). In the late LPP time window, enhanced activations was only found in the right inferior occipital gyrus.

Table 9: Source estimations for the comparison between the emotional and neutral decisions in the EPN and LPP time windows.

cluster-level	**peak-level**		**MNI coordinates**			**AAL**
Number of significant voxels	peak $t\,(1, 156)$	peak p-uncorrected	x (mm)	y (mm)	z (mm)	area
		EPN/P3 time window (250-400ms)				
641 (384[a])	3.36	<.001	-38	-74	-18	Cerebellum L
506 (283[a])	3.34	=.001	36	-72	-18	Fusiform R
80	3.09	=.001	62	-6	14	Rolandic op R
34	2.97	<.005	-60	-4	14	Rolandic op L
		late LPP time window (650-900ms)				
72	2.66	<.005	36	-76	-12	Inf occipital R

Notes. For each significant peak respective coordinates (x, y and z) are displayed in MNI space. A cluster may exhibit more than one peak, while only the largest peak is displayed. Area = peak-level brain region as identified by the AAL atlas. R / L = laterality right or left. Inf = inferior, op = operculum.

For the interaction effect in the EPN time window, significant post-hoc tests were only found within the 'human sender'. Here, emotional decisions led to larger activity in the bilateral fusiform, superior occipital gyri and temporal areas including the Rolandic operculum (see Figure 19, Table 10).

Table 10: Interaction of sender and emotional content. Significant differences were found for the emotional compared to neutral decisions within the 'human sender'.

cluster-level	peak-level		MNI coordinates			AAL
Number of significant voxels	peak *t* (1, 156)	peak *p*-uncorrected	x (mm)	y (mm)	z (mm)	area
		EPN/P3 time window (250-400ms)				
125 (56[a])	3.53	<.001	62	-6	14	Rolandic op R
76	3.37	<.001	-60	-4	14	Rolandic op L
576	3.15	=.001	-40	-80	-14	Fusiform L
260	3.10	=.001	-6	-86	34	Cuneus L
284	3.07	=.001	20	-84	38	Sup occipital R
372	3.02	=.001	40	-54	-12	Inf temporal R

Notes. For each significant peak respective coordinates (x, y and z) are displayed in MNI space. A cluster may exhibit more than one peak, while only the largest peak is displayed. Area = peak-level brain region as identified by the AAL atlas. R / L = laterality right or left. Inf = inferior, Sup = superior, op = operculum.

2.3.4 Discussion

The key question of this experiment was whether and how putative sender humanness rather than merely ascribed sender competence modulates the processing of socio-emotional language feedback. We investigated whether there would be processing differences between supposedly equally competent senders in physically identical conditions, thus isolating the effects of attributed social context. Indeed, in spite of similar attributed competence, the notion of being evaluated by a 'human sender' led to enhanced amplitudes starting with the P2 and extending throughout all subsequent time windows. Like in a previous study, it reflected to a large extent sustained increased visual processing of words made out to be endorsed by a 'human sender' (Schindler et al., 2015). This enhancement is in line with findings of enlarged visual activity for relevant in-group faces (Van Bavel et al., 2011), putatively human-generated decisions (Singer et al., 2004) and generally accords with the model of motivated attention (Lang et al., 1998; Schupp, Cuthbert, et al., 2004; Schupp et al., 2003).

Going beyond previous findings, the present findings suggest a unique role for the “human sender”. This is partly reflected in the fact that visual processing enhancement of supposedly human-generated messages persists even when ascribed sender competence is equal. Indicative of qualitative differences, we also localized distinct activity for the ‘human sender’ in superior frontal, supplementary motor (EPN/P3) and somatosensory (LPP) areas. This fits with other previous findings of more mentalizing about human interaction partners leading to more pronounced activity in superior frontal regions (Chaminade et al., 2012; Kircher et al., 2009). In addition, this region has been found to be more active, when participants were required to silently mentalize about other people compared to physical objects (Wolf et al., 2011). Also, autistic individuals who have problems in detecting other people’s wishes and intentions have weaker functional connectivity between the superior frontal gyri and the posterior cingulate cortex (Weng et al., 2010). Finally, enhanced supplementary motor area activity can be also observed when participants watch other people commit errors (Shane, Stevens, Harenski, & Kiehl, 2008). It can therefore be assumed that the superior frontal gyrus/supplementary motor area is involved in social cognitive tasks, when for example thinking about other people’s intentions or in other words mentalizing about others (Chaminade et al., 2012; Kircher et al., 2009). Even in the absence of any physical cues, these mechanisms appear to be recruited more when supposedly receiving feedback from another human rather than a socially intelligent computer program.

On the early LPP, we also observed increased activations, which were localized in the bilateral paracentral lobe. This is interesting as it is not only known that the semantic meaning of words, including emotion words, can modulate sensorimotor activity (Moseley, 2011; Pulvermüller, 2005), supporting an embodied language account, but also that the embodiment of emotion itself can lead to activity in the sensorimotor system (Niedenthal, 2007). It can be speculated that the somatosensory activation indeed reflects an embodied processing of human-generated decisions. If so, contextual factors within a communicative situation such as implied sender identity appear to influence the degree to which embodied language processing occurs. In the present study these sensorimotor activations occurred only at secondary processing stages, more in line with the view that gradual unfolding of contextual integration activates the sensorimotor system (Papeo & Caramazza, 2014) than with an instantaneous processing view (Shtyrov, Butorina, Nikolaeva, & Stroganova, 2014). Van Dam and colleagues (2014) already suggested that the recruitment of sensorimotor activation in word processing may depend on linguistic context, although their study identified an early (P2) locus for such sensorimotor activation. However, there may be timing differences between integration of the social context of perceived sender identity that was investigated in the present study and other linguistic contexts.

Interactive effects of emotion and sender identity, which are indicative of integration of content and sender during processing, were first observed in the EPN time window from about 250 ms. Here, emotion differences within the 'human sender' were substantially larger than within the computer sender. This pattern was also observed as a trend for the central P3 amplitudes. The interaction mainly illustrates that the increased processing of human-generated feedback is even more amplified when it is about relevant, i.e. emotionally valent traits. Numerically, EPN amplitude was highest for negative content from the ‘human sender’. Within the ‘computer sender’ the data suggest an advantage for positive feedback. In this regard, the pattern is similar to previous findings (Schindler et al., 2015). In source space, next to increased visual and superior occipital activity, which is typically found in reading studies (Osipowicz et al., 2011; van der Mark et al., 2011), enhanced activity was also observed in bilateral temporal areas, around the Rolandic operculum. These regions are involved in speech production and language comprehension (Dick, Solodkin, & Small, 2010; Tremblay & Gracco, 2010). Crucially, larger emotion effects were found only within the 'human sender', which points to the selectively increased processing of emotional decision from that sender.

Regarding content effects, emotional decisions were processed more intensely in the EPN, as well as in the P3 and LPP time windows, replicating previous findings of enhanced emotion EPN (Kissler et al., 2007) and LPP in visual word processing (Herbert et al., 2008; Hofmann et al., 2009; Kanske & Kotz, 2007; Kissler et al., 2009; Schacht & Sommer, 2009b). Both positive and negative decisions elicited larger EPN, P3 and early LPP amplitudes compared to neutral decisions. On the late LPP, only positive decisions were found to differ significantly from neutral decisions. This is in line with our previous study (Schindler et al., 2015) and other EEG and fMRI reports indicating a similar pattern (Korn et al., 2012; Rohr & Rahman, 2015; Tucker et al., 2003) which has been interpreted as a self-positivity bias. Behavioral studies support this interpretation (Hepper et al., 2011).

In source space, differences between emotional and neutral decisions were also found in visual areas. First, we found increased visual activity for emotional content starting in the EPN time window, which is in line with previous reported occipito-temporal sources for emotional effects (Kissler et al., 2007). For the late LPP time window these enhanced visual activations confirm previous findings of occipital generators of emotional LPP enhancements (Moratti et al., 2011; Sabatinelli et al., 2007; Schupp et al., 2003) and are also in line with fMRI studies showing larger visual activity in reaction to positive adjectives (Herbert et al., 2009) and negative words (Compton et al., 2003), as well as with previous source reconstructions (Schindler et al., 2015). Moreover, recently emotional LPP modulations were correlated with subcortical as well as visual fMRI signals (Sabatinelli et al., 2013). In the present, as well as in previous studies, source localization produced no evidence of subcortical activity differences. This may either be due to a true lack of activity or due to a relative insensitivity of EEG source analysis to such activity. Conversely, both for the LPP sender effect and for the EPN emotion effect, significant differences were localized in the cerebellum. Although most prominently involved in motor control (Middleton & Strick, 2000; Wolpert, Miall, & Kawato, 1998), cerebellar activity is often reported also in studies of language perception and affective processing (Ritchey, Bessette-Symons, Hayes, & Cabeza, 2011; van de Meerendonk, Indefrey, Chwilla, & Kolk, 2011) , and even social preference tasks (A. C. Chen, Welsh, Liberzon, & Taylor, 2010). So far, a clear interpretation for such effects is missing but they may be in line with mechanisms of sensorimotor resonance in both these domains.

In general, it is important to note that the current source estimations may not be able to detect all relevant brain activations because we could use only a limited number of stimuli per cell to realize a credible and reasonably short within-subjects design. Thus it is not unlikely that there are other brain areas responding to the experimental manipulations. For instance, human-generated decisions also have been reported to result in additionally increased activity in the left amygdala, bilateral insula, superior temporal sulcus, and reward-related areas (Singer et al., 2004) and in fMRI or intracranial measurements sub-cortical activations for emotional words have been also reported (Fossati et al., 2003; Maddock, Garrett, & Buonocore, 2003; Naccache et al., 2005). However, we are confident about the presently reported localization results, as these are theoretically plausible, were observed only for the ‘human sender’ and not in the reverse contrast and were replicable in a follow-up study (Schindler et al., in preparation).

Summarizing the main findings, our results support the conclusion, that even the imagined social context strongly influences visual word processing and that a “people-context” is special and differs from a human-machine interaction context both quantitatively and qualitatively. Other neuroscientific studies show selective brain responses towards approval and acceptance (Izuma et al., 2010; Romero-Canyas et al., 2010; Simon et al., 2014), as well as to social rejection (Eisenberger et al., 2011; Masten et al., 2009; Somerville et al., 2006). This can be related to a motivational desire to belong to a community, as living in groups is linked to evolutionary advantages for survival and reproduction (Baumeister & Leary, 1995). Our results extend the concept of motivated attention from stimulus to contextual properties, but they also suggest more mentalizing about the 'human' communicative partner as reflected in activations in 'social brain' structures. In the age of virtual communication the findings are of particular relevance, as communication increasingly takes place between personally unknown communication partners, often ascribing states and intentions to each other.

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2.4 Study IV: 'Attending to your therapist': How perceived sender expertise amplifies cerebral processing of emotional language feedback

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2.4.1 Introduction

We are constantly receiving feedback about our performance and ourselves by our peers, supervisors and even our family. Such feedback can be very subtle in everyday interactions, e.g. showing support or agreement through smiling or nodding, but can also be explicit, e.g. in verbal performance-feedback about an exam or personal-feedback in an argument from the spouse. Such verbal feedback usually consists of emotionally charged language.

Regarding emotional language processing, a number of studies investigated the neuronal correlates of single words using ERPs (Herbert et al., 2008; Hinojosa et al., 2010; Hofmann et al., 2009; Kissler et al., 2007). Here, typically a larger Early Posterior Negativity (EPN, Kissler et al., 2007) and a larger Late Positive Potential (LPP, Herbert et al., 2008; Hinojosa et al., 2010; Hofmann et al., 2009; Kanske & Kotz, 2007) are reported in response to emotional stimuli. Recently, research expanded knowledge about neuronal correlates of emotional word processing to social communicative situations. Here, from various angles, research demonstrated enlarged emotion effects, either induced by self-referent prefixes (Herbert, Herbert, et al., 2011; Herbert, Pauli, et al., 2011), gaze-induced communicative context (Rohr & Rahman, 2015) or feedback anticipation (Schindler et al., 2014). Further, during feedback anticipation, main effects of the communicative were found to occur as early as at the N1 (Schindler et al., 2014). Such early differences are rarely reported in word studies, however combined EEG/MEG studies report an ultra-rapid differentiation between emotional compared to neutral words (Keuper et al., 2013, 2014).

Clearly, our evaluation of given feedback depends on the respective sender. We all will be less concerned about negative personality feedback when the sender is a stranger compared to a more credible source, e.g. a close friend or one's spouse. Sender credibility has been identified as a central feature, contributing to the persuasiveness of messages (McGinnies & Ward, 1980; Pornpitakpan, 2004). However, next to credibility, supposed expertise has been found to influence the acceptance of personality feedback (Collins & Stukas, 2006). In an experiment by Collins & Stukas (2006), participants filled in a short version of the Eysenck Personality Inventory and received feedback about being extraverted or introverted from either high- or low-status therapists (in terms of clinical experience, education and accomplishments). This feedback was either consistent or inconsistent with actual test results. Results showed that feedback which was inconsistent with the participants´ self-concept was more likely accepted when sent from high-status therapists. On the other hand they found a rather typical main effect: Students who received self-consistent feedback more likely accepted the test results. This is in line with accounts that people like others to evaluate them how they evaluate themselves (Swann, 1987). Next to such self-verification processes, self-enhancement is discussed as a central motive for feedback processing (Kwang & Swann, 2010). This seems to be more important in situations where the risk to be rejected is rather high (Kwang & Swann, 2010).

Neurophysiologically, social approval seem to activate reward related areas, such as the ventral striatum (Izuma et al., 2008, 2010), while social rejection seem to activates brain regions involved in pain processing such as the anterior insulae (Masten et al., 2009; Masten, Morelli, & Eisenberger, 2011), as well as the anterior cingulate cortex and the medial prefrontal cortex (Somerville et al., 2006, 2010). During such social feedback processing likely also mentalizing about the sender takes place. In mentalizing tasks the medial prefrontal cortex and the posterior cingulate cortex (PCC) are supposed to be the most important nodes of the so called cortical midline structures (Northoff & Bermpohl, 2004; Uddin et al., 2007). In addition, in the social cognition literature the PCC has been suggested to be involved in automatic self-knowledge and controlled self-reflective processes (Lieberman, 2007). A recent study tried to separate pain observation networks from mentalizing networks (Jacoby, Bruneau, Koster-Hale, & Saxe, 2016) and reported for mentalizing tasks consistent activations in the cortical midline structures, including the PCC, but for pain observation activations in the insulae and somatosensory cortices. However, somatosensory responses are also observed during emotion processing (Niedenthal, 2007), as well as towards word meaning (Pulvermüller, 2005), and recently towards social feedback based on different adjectives (Schindler & Kissler, 2016c).

In these recent studies, ERP responses to actual feedback given by different senders have been investigated, which was based on negative, neutral and positive adjectives (Schindler & Kissler, 2016c; Schindler et al., 2015). Here, participants received putatively feedback from a human or computer interactive partner, either as introduced as a random (Schindler et al., 2015) or intelligent machine (Schindler & Kissler, 2016c). Dramatically enlarged early and late amplitudes were found for 'human senders', although participants received, in fact, random and identical feedback in both conditions. Interestingly, emotional 'human-generated' feedback was further amplified as measured by EPN (Schindler & Kissler, 2016c; Schindler et al., 2015) and in tendency also P3 amplitudes (Schindler & Kissler, 2016c). Thus, humanness influences the cortical processing of language-based feedback overall, but specifically for salient content. These enlargements were mainly driven by visual generators (Schindler et al., 2015), but as mentioned also somatosensory and superior frontal differences were observed (Schindler & Kissler, 2016c). Such superior frontal activations were previously reported in response to increased mentalizing about interactions with humans compared to computers (Chaminade et al., 2012; Kircher et al., 2009). However, so far sender expertise for the putative 'human' was not manipulated independent from sender identity (human vs computer).

To this end, we manipulated the ascribed sender expertise, but controlling for humanness as an important influencing factor (Schindler & Kissler, 2016c; Schindler et al., 2015). Participants were told, that they would be evaluated either by an expert, a psychological psychotherapist, or a layperson. In a control condition, supposedly random computer feedback was shown. Participants received feedback based on color changes of written negative, neutral or positive adjectives. We investigated whether putative expertise induced differential processing on very early, ultra-rapid (cf. Keuper et al., 2014; Schindler et al., 2014) or at late stages (Schindler et al., 2015). We expected a processing advantage for „feedback given by the expert“, while overall amplitudes for 'human senders' should be amplified, namely the P2, EPN, P3 and LPP components (Schindler & Kissler, 2016c; Schindler et al., 2015). Further, by using an increased number of participants and trials, we expected to improve robustness of the source localization, replicating larger source activity for 'humans' in visual, frontal and somatosensory regions and potentially also uncovering additional generator structures (Schindler & Kissler, 2016c). We also aimed to replicate an enhanced processing of emotional decisions, based on enhanced visual activity (Schindler et al., 2015). Finally, based on previous research, we investigated possible interactions between putative sender and emotional content (Schindler & Kissler, 2016c; Schindler et al., 2015).

2.4.2 Method

Participants

Thirty-nine participants were recruited at the University of Bielefeld. They gave written informed consent according to the Declaration of Helsinki and received 14 Euros for participation. The study was approved by the Ethics Committee of the University of Bielefeld. Due to large artifacts or technical problems five participants had to be excluded. One measurement was aborted due to a fire alarm. One participant was excluded due to a reported acute neurological or psychiatric disorder and one reported to be confused from whom he received feedback. The resulting thirty participants (23 females) were 22.03 years on average (*SD*=3.73), all of them right-handed and had normal or corrected-to normal vision. None of these participants reported a previous or current neurological or psychiatric disorder.

Stimuli

The previously used stimulus set (Schindler et al., 2015, 2014) was enlarged by ten adjectives per condition. These adjectives were rated beforehand by 22 students who did not participate in the actual experiment in terms of valence and arousal using the Self-Assessment Manikin. Raters were instructed to consider the adjectives' valence and arousal in an interpersonal evaluative context. The selected 180 adjectives (70 negative, 40 neutral, 70 positive) were matched in their linguistic properties, such as word length, frequency, familiarity and regularity (see Table 11). Importantly, negative and positive adjectives differed in valence only. Neutral adjectives were allowed to deviate from emotional adjectives on rated concreteness since truly neutral trait adjectives are rare in an interpersonal evaluative context.

Table 11: Comparisons of negative, neutral and positive adjectives by One-Way-ANOVAs

Variable	Negative adjectives (n=70)	Neutral adjectives (n=40)	Positive adjectives (n=70)	F (2,147)
Valence	7.34^{a} (0.63)	4.94^{b} (0.28)	2.85^{c} (0.67)	1016.25***
Arousal	4.66^{a} (0.76)	3.2^{b} (0,82)	4.78^{a} (0.74)	60.96***
Concreteness	2.86^{a} (1.01)	5.11^{b} (1.51)	3.18^{a} (0.66)	65.70***
Word length	9.30 (2.94)	8.95 (2.43)	8.79 (2.65)	0.64
Word frequency (per million)	493.69 (780.45)	512.60 (703.15)	483.43 (769.05)	0.02
Familiarity (absolute)	39934.16 (17585.69)	23488.33 (10506.85)	30036.70 (14497.37)	0.59
Regularity (absolute)	265.70 (423.44)	103.85 (186.28)	208.61 (406.98)	2.35
Neighbors Coltheart (absolute)	4.60 (6.54)	2.38 (2.95)	3.21 (3.85)	2.88
Neighbors Levenshtein (absolute)	7.47 (8.31)	4.70 (3.73)	5.86 (6.06)	2.38

Note: *** = $p \leq 0.001$. Standard deviations appear in parentheses below means; means in the same row sharing the same superscript letter do not differ significantly from one another at $p \leq 0.05$; means that do not share subscripts differ at $p \leq 0.05$ based on LSD test post-hoc comparisons.

Procedure

The experimental procedure was comparable to the one described previously (Schindler et al., 2015, 2014). Participants were told that they would be evaluated by two unknown other persons, one putatively an expert (i.e. a psychotherapist) and one a layperson and in a third condition by a randomly operating computer algorithm. All subjects underwent the three conditions. Sequence of 'human sender' conditions was counterbalanced between participants, while the random computer feedback was always in between, putatively enabling the experimenter to switch judges in the adjacent laboratory room.

Upon arrival, participants were instructed to briefly describe themselves in a structured interview in front of a camera. They were informed that the video of their self-description would be presented to both human judges to give them an impression about the participant. Durign EEG preparations participants filled in a short reported personality inventory which was putatively handed over to the human senders. Finally, participants also completed a short demographic questionnaire. To ensure face validity, a research assistant left the testing room fifteen minutes ahead of the fictitious feedback, guiding an ‘unknown person’ to a laboratory room next to the testing room.

Stimuli were presented within a desktop environment of a fictitious program ‘Interactional Behavioral Systems’ supposedly allowing instant online communication. In order to ensure credibility of the situation, network cables and changes of the fictitious software desktop image that showed the ‘Interactional Behavioral Systems’ environment were made salient. The presented feedback was randomly generated in all conditions. Overall, 40 positive and negative adjectives were endorsed, leading to 40 affirmative negative, 40 neutral and 40 affirmative positive decisions. The desktop environment and stimulus presentation were created using Presentation (www.neurobehavioralsystems.com). In the ‘human’ condition, color changes between 1500 and 2500ms after adjective onset indicated a decision by the supposed interaction partner. This manipulation simulated varying decision latencies in humans. The decision was indicated via color change (blue or purple) of the presented adjective, indicating whether or not the respective adjective applied to the participant. In the computer condition, color changes occurred between 1400ms and 1600ms. In all conditions color changes lasted for 1000ms, followed by a fixation cross for 1000 to 1500ms. Color–feedback assignments were counterbalanced. After the experiment, participants filled in a questionnaire asking them what they thought the experiment was about. Only two out of thirty-nine participants reported spontaneously that they did not believe the presence of other participants. One of them was independently excluded due to excessive artifacts, the other is included in the analyses. This can be regarded as a rather conservative approach.

EEG recording and analyses

EEG was recorded from 128 BioSemi active electrodes (www.biosemi.com). Recorded sampling rate was 2048Hz. During recording Cz was used as reference electrode. Biosemi uses two separate electrodes as ground electrodes. First a Common Mode Sense active electrode (CMS) and second a Driven Right Leg passive electrode (DLR). The two electrodes form a feedback loop which enables to measure the average potential close to the reference in the AD-box (see http://www.biosemi.com/faq/cms&drl.htm, where also information about extra functions of the CMS/DRL loop can be retrieved). Four additional electrodes (EOG) measured horizontal and vertical eye-movement. These were placed at the outer canthi of the eyes and below the eyes.

Pre-processing and statistical analyses were done using EMEGS (Peyk et al., 2011) and SPM8 for EEG data (http://www.fil.ion.ucl.ac.uk/spm/). Offline, data were then down-sampled to 250Hz and later band-pass filtered from 0.166 to 30 Hz with a fifth-order Butterworth zero-phase filter. Filtered data were segmented from 500ms before stimulus onset until 1000ms after stimulus presentation. There was an immediate transition from word presentation to feedback by color change. Results are presented without baseline correction therefore in order to avoid introduction of pre-baseline differences into the feedback phase. However, there were no apparent differences in the time segment immediately preceding the color change (see Figures 20, 21) and control analyses with baseline correction lead to analogous results. For trials exceeding a threshold of 160µV automatic artifact detection was used. Data were averaged, using a robust averaging algorithm, excluding possible further artifacts (Litvak et al., 2011). Robust averaging down-weights outliers for each channel and each time point, thereby preserving a higher number of trials as artifacts are not supposed to distort the whole trial but most of the time corrupt only parts of the trial. We used the recommended offset of the weighting function, which preserves approximately 95% of the data points drawn from a random Gaussian distribution (Litvak et al., 2011). Overall, 6.61 percent of all electrodes were interpolated. On average 18 percent of all trials were rejected, leaving on average 32.81 trials per condition. There were no differences in the number of rejected trials between the different senders ($F_{(2,58)} = 1.30$, $p = .28$, partial $\eta^2 = .04$), nor between emotional and neutral decisions ($F_{(2,58)} = 1.75$, $p = .18$, partial $\eta^2 = .06$), and no interaction between sender and emotion ($F_{(4,116)} = 0.58$, $p = .68$, partial $\eta^2 = .02$).

Source reconstructions of the generators of significant ERP differences were generated and statistically assessed with SPM8 for EEG (Litvak & Friston, 2008), following recommended procedures. First, a realistic boundary element head model (BEM) was derived from SPM´s template head model based on the Montreal Neurological Institute (MNI) brain. Electrode positions were then transformed to match the template head, which is thought to generate reasonable results even when an individual subject's head differs from the template (Litvak et al., 2011). Average electrode positions as provided by BioSemi were co-registered with the cortical mesh template for source reconstruction. This cortical mesh was used to calculate the forward solution. The inverse solution was calculated from 0ms to 1000 ms after feedback onset. Group inversion (Litvak & Friston, 2008) was computed and the multiple sparse priors algorithm implemented in SPM8 was applied. This method allows activated sources to vary in the degree of activity, but restricts the activated sources to be the same in all subjects (Litvak & Friston, 2008). Compared to single subject matrix inversion, this has been found to result in more robust source estimations (Litvak & Friston, 2008).

Statistical analyses

EEG scalp-data were statistically analyzed with EMEGS. Three (sender: human expert, computer, layperson) by three (content: positive, negative, neutral) repeated measure ANOVAs were set-up to investigate main effects of the communicative sender, emotion and their interaction in time windows and electrode clusters of interest. For sender main effects linear trends were calculated, testing that decisions from the 'expert' should induce the largest amplitude increase, followed by the 'layperson' and finally the 'computer'. For emotion effects, quadratic trends were calculated, as an amplitude increase in response to both, positive and negative decisions, was assumed. Time-windows of interest were chosen based on previous reports of emotion modulations and conspicuous differences in the ERPs. Partial eta-squared (partial η^2) was estimated to describe effect sizes, where $\eta^2 = 0.02$ describes a small, $\eta^2 = 0.13$ a medium and $\eta^2 = 0.26$ a large effect (J. Cohen, 1988). When Mauchly’s test indicated a violation of sphericity, degrees of freedom were corrected according to Greenhouse-Geisser. Time windows were segmented from 180 to 220ms to investigate N1 effects, from 150 to 200ms to investigate P2 effects, from 250 to 350ms to investigate EPN, from 300 to 400ms to investigate P3 effects, from 400 to 650ms to investigate early LPP effects and from 650 to 900ms to investigate late LPP effects (Schindler & Kissler, 2016c; Schindler et al., 2015). For the N1 and EPN time window, two symmetrical occipital clusters of nine electrodes each were examined (left: I1, OI1, O1, PO9, PO9h, PO7, P9, P9h, P7; right: I2, OI2, PO10, PO10h, PO8, P10, P10h, P8). For the P2, P3 and LPP time windows a large central cluster was investigated (twenty-six electrodes: FCC1h, FCC2h, C3h, C1, C1h, Cz, C2h, C2, C4h, CCP3h, CCP1, CCP1h, CCPz, CCP2h, CCP2, CCP4h, CPz, CPP1, CPPz, CPP2, P1h, Pz, P2h, PPO1h, PPOz, PPO2h, see Schindler et al., 2015; Schindler & Kissler, 2016c).

For source analyses, for each analyzed time window in scalp space, three-dimensional source reconstructions were generated as NIFTI images (voxel size = 2mm*2mm*2mm). These images were smoothed using an 8mm full-width half-maximum. The statistical comparisons used in source space were restricted to time-windows that revealed significant differences on the scalp. Similar to previous studies (Campo et al., 2013; Schindler et al., 2015), we describe statistical differences in source activity of voxels differing at least at an uncorrected threshold of p<.001 (for main effects) or p<.005 (for interactions) and a minimum of twenty-five significant voxels per cluster. In addition, results using a familywise error (FWE) corrected threshold of p<.05 and a minimum of twenty-five significant voxels per cluster are reported in all tables. The identification of activated brain regions was performed using the LONI atlas (Shattuck et al., 2008).

2.4.3 Results

N1

Over the occipital sensor cluster a significant main effect of the communicative sender ($F_{(2,58)} = 3.27$, $p < .05$, partial $\eta^2 = .10$) was observed. Significant linear trends ($F_{(1,29)} = 6.01$, $p < .05$, partial $\eta^2 = .17$) showed, that decisions by the 'expert' elicited the largest negativity ($M_{\text{expert}} = -3.01\mu V$), followed by the 'layperson' ($M_{\text{layperson}} = -2.78\mu V$) and finally by the 'computer sender' ($M_{\text{computer}} = -2.60\mu V$; see Figure 20). No main effect of emotion ($F_{(2,58)} = 0.13$, $p = .88$, partial $\eta^2 < .01$) and no effect of laterality was found($F_{(1,29)} = 0.02$, $p = .89$, partial $\eta^2 < .01$). Further, there were no significant interactions between sender, emotion and laterality (*ps* >.50).

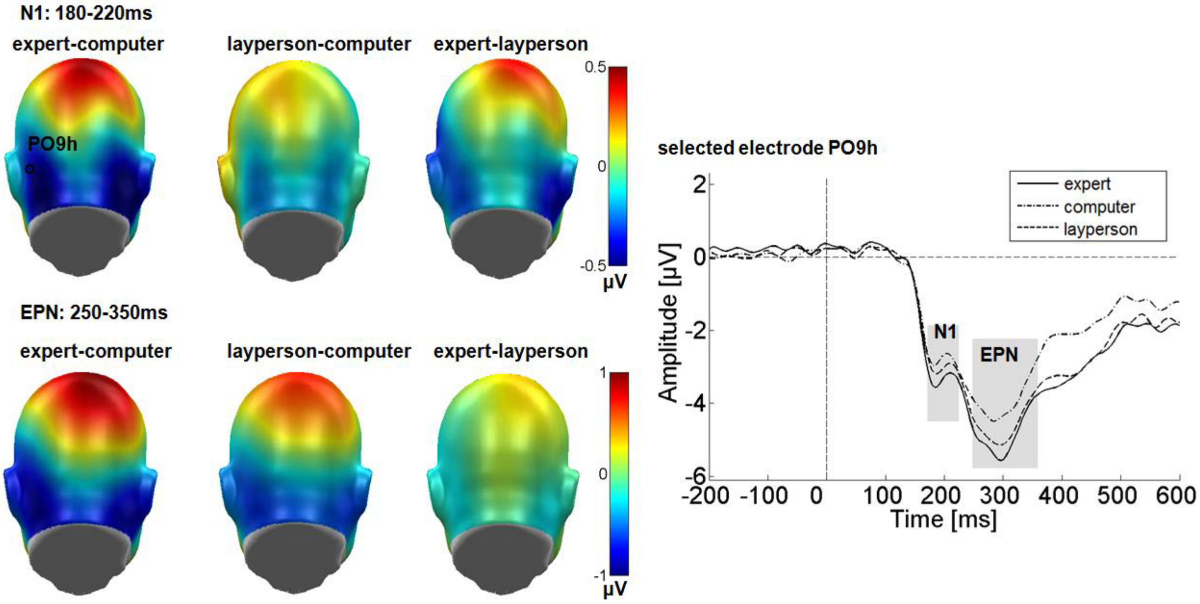

Figure 20: Results for the occipital electrode cluster for the N1 (top left) and EPN (bottom left) time window showing significant main effects for the communicative sender. Difference topographies: Blue color indicates more negativity and red color more positivity for the respective comparison. A significantly larger N1 was found for the 'expert' compared to the 'computer' sender and a significantly larger EPN was found for both 'human senders' compared to the 'computer'. Selected electrode PO9h shows the time course for all senders over left-occipital areas.

P2

Over the central sensor cluster a significant main effect of the communicative sender ($F_{(2,58)} = 3.23$, $p < .05$, partial $\eta^2 = .10$) was observed. Linear trends ($F_{(1,29)} = 6.00$, $p < .05$, partial $\eta^2 = .17$) found, that the 'expert' ($M_{\text{expert}} = 1.09\mu V$) elicited a larger positivity compared to the 'layperson' ($M_{\text{layperson}} = 0.98\mu V$), followed by the 'computer sender' ($M_{\text{computer}} = 0.85\mu V$; see Figure 21a). For the P2 no main effect of emotion ($F_{(2,58)} = 0.50$, $p = .44$, partial $\eta^2 = .03$) and no interaction between sender and emotion ($F_{(4,116)} = 1.48$, $p = .21$, partial $\eta^2 = .05$) were observed.

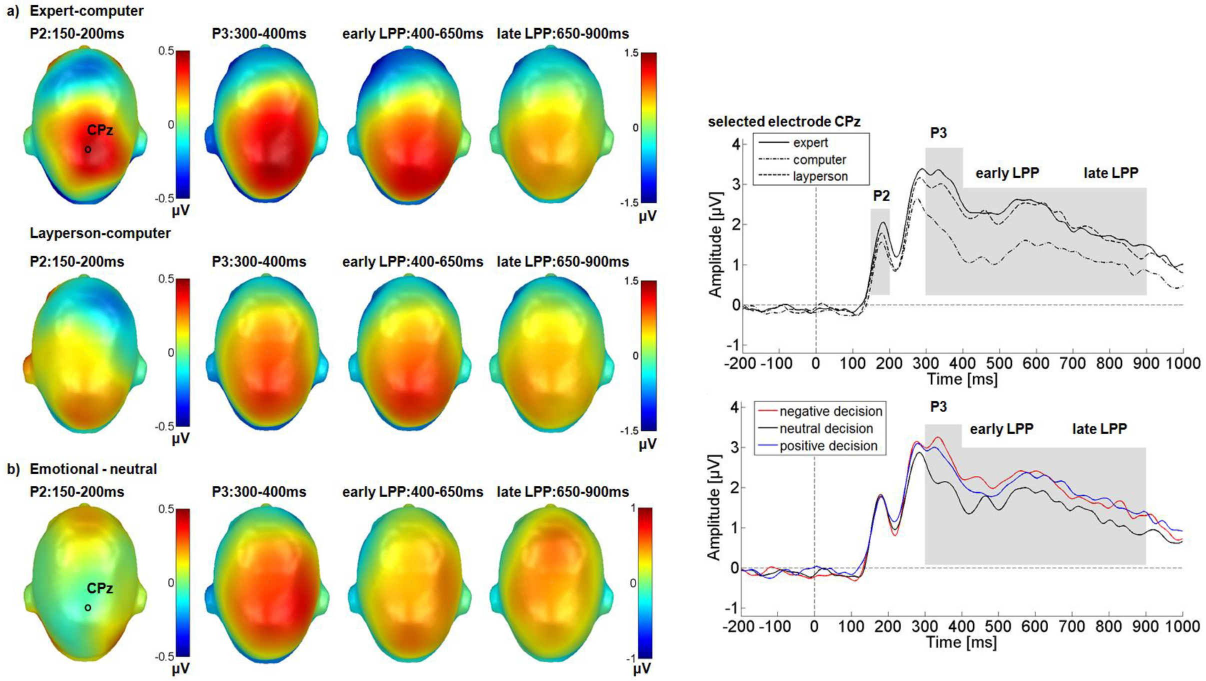

Figure 21: Centro-parietal main effects of sender and emotion. Displayed results for the centro-parietal electrode cluster. **a)** Main effect for the communicative sender. Difference topographies: Blue color indicates more negativity and red color more positivity for the respective ‘human sender’. **b)** Main effect for the emotional content. Difference topographies: Blue color indicates more negativity and red color more positivity for emotional decisions. Selected electrode CPz showing the time course all conditions.

EPN

Over the occipital sensor cluster (250-350ms) a significant main effect of the communicative sender ($F_{(2,58)}$ = 7.62, p < .001, partial η² = .21; see Figure 20) was observed. Decisions by the 'expert' (M_{expert} = -3.62µV) induced the largest EPN, followed by the 'layperson' ($M_{\text{layperson}}$ = -3.49µV) and the 'computer' (M_{computer} = -2.89µV; $F_{(1,29)}$ = 9.43, p < .01, partial η² = .25). In contrast, there was no main effect of emotion ($F_{(2,58)}$ = 1.73, p = .19, partial η² =.06) and no effect of laterality ($F_{(1,29)}$ = 1.31, p = .26, partial η² = .04). There was a trend for a significant interaction between communicative sender and laterality ($F_{(2,58)}$ = 2.72, p = .07, partial η² = .09). Descriptively, the EPN over the left sensor cluster was most pronounced for the 'expert' ($M_{\text{left-right}}$ = -0.42µV), compared to the 'layperson' ($M_{\text{left-right}}$ = -0.27µV) and the 'computer' ($M_{\text{left-right}}$ = -0.15µV). No other interactions were found to be significant, not even on a trend-level (*ps* >.40).

P3

In the time window between 300 and 400ms, over the central sensor cluster significant main effects of the communicative sender ($F_{(1.58,45.71)} = 12.87$, $p < .001$, partial η² = .31) and of emotional content were observed ($F_{(2,58)} = 12.87$, $p < .001$, partial η² = .31; see Figure 21). Again, the largest P3 was found for the 'expert' (M_{expert} = 2.51µV) followed by the 'layperson' ($M_{\text{layperson}}$= 2.26µV) and the 'computer' (M_{computer} = 1.50µV; $F_{(1,29)} = 15.64$, $p < .001$, partial η² = .35). Further, quadratic trends showed that both negative (M_{negative}= 2.33µV) as well as positive decisions (M_{positive}= 2.21µV) led to a larger P3 amplitude compared to neutral decisions (M_{neutral}= 1.72µV; $F_{(1,29)} = 25.99$, $p < .001$, partial η² = .47). Interestingly, an interaction between sender and emotion was found at the P3 ($F_{(4,116)} = 2.51$, $p < .05$, partial η² = .08; see Figure 22). While for the 'expert' amplitudes in response to all decisions seem to be

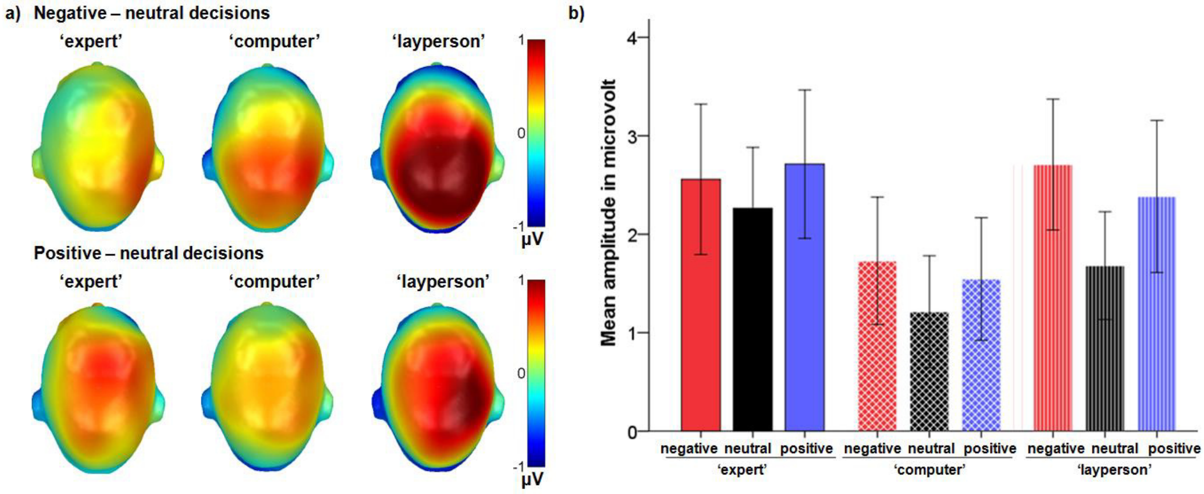

Figure 22: Interaction between sender and emotion in the P3 time window. a) Difference topographies: Blue color indicates more negativity and red color more positivity for emotional decisions within each sender. **b)** Mean amplitudes in microvolt over the centro-parietal sensor cluster are displayed for all decisions. Error Bars are +/- 2 standard error of the mean.

increased, for the 'laymen' only emotional feedback was more intensely processed. This assumption was tested by comparing neutral decisions between the senders. Here, neutral decisions by the 'expert' were more positive compared to neutral decisions by the 'layperson' ($p < .05$), which in turn were more positive compared to neutral decisions by the 'computer' ($p < .05$).

LPP

In the early LPP time window between (400-650ms), significant main effects of the communicative sender ($F_{(2,58)} = 12.60$, $p < .001$, partial $\eta^2 = .30$) and of emotional content were observed centrally ($F_{(2,58)} = 10.81$, $p < .001$, partial $\eta^2 = .27$; see Figure 21). Again, LPP amplitudes showed a linear trend from 'expert' ($M_{\text{expert}} = 2.00\mu V$), followed by the 'layperson' ($M_{\text{layperson}} = 1.90\mu V$) and the 'computer' ($M_{\text{computer}} = 1.12\mu V$; $F_{(1,29)} = 15.40$, $p < .001$, partial $\eta^2 = .35$). Further, quadratic trends again showed that emotional decisions ($M_{\text{negative}}= 1.84\mu V$; $M_{\text{positive}}= 1.77\mu V$) elicited a larger LPP compared to neutral decisions ($M_{\text{neutral}}= 1.41\mu V$; $F_{(1,29)} = 27.42$, $p < .001$, partial $\eta^2 = .49$). In the LPP, there was no interaction between sender and emotion in the LPP time window ($F_{(4,116)} = 0.64$, $p = .63$, partial $\eta^2 = .02$).

For the late LPP time window (650-900ms) again significant main effects of the communicative sender ($F_{(2,58)} = 7.27$, $p < .01$, partial $\eta^2 = .20$) and of emotional content were observed centrally ($F_{(2,58)} = 14.77$, $p < .001$, partial $\eta^2 = .34$). A significant linear trend was confirmed ($F_{(1,29)} = 10.13$, $p < .01$, partial $\eta^2 = .26$). However, in this time window LPP amplitudes of the 'expert' ($M_{\text{expert}} = 1.39\mu V$) and 'layperson' ($M_{\text{layperson}} = 1.39\mu V$) were comparable, both larger compared to the 'computer' ($M_{\text{computer}}= 0.86\mu V$). Further, emotional decisions ($M_{\text{negative}}= 1.30\mu V$; $M_{\text{positive}}= 1.38\mu V$) elicited a larger LPP compared to neutral decisions ($M_{\text{neutral}}= 0.97\mu V$; $F_{(1,29)} = 26.45$, $p < .001$, partial $\eta^2 = .48$). In the late LPP time window, there was again no interaction between sender and emotion ($F_{(4,116)} = 0.25$, $p = .98$, partial $\eta^2 = .01$).

Source reconstruction

Corresponding to significant effects on the scalp, main effects of the sender were investigated in the P2, EPN/P3 and LPP time windows, main effects of emotion in the P3 and LPP time windows and for the significant interaction in the P3 time window. The N1 and P2 as well as the EPN and P3 time window were temporally partly overlapping. Therefore source estimations were performed between 150 and 200ms for the P2 and between 300 and 400ms for the P3 time window.

In the P2 time window, for main effect of the communicative sender, the 'expert' was found to elicit larger activity compared to the 'computer' in left middle frontal areas (see Figure 23, Table 12). Later in the EPN/P3 and LPP time windows

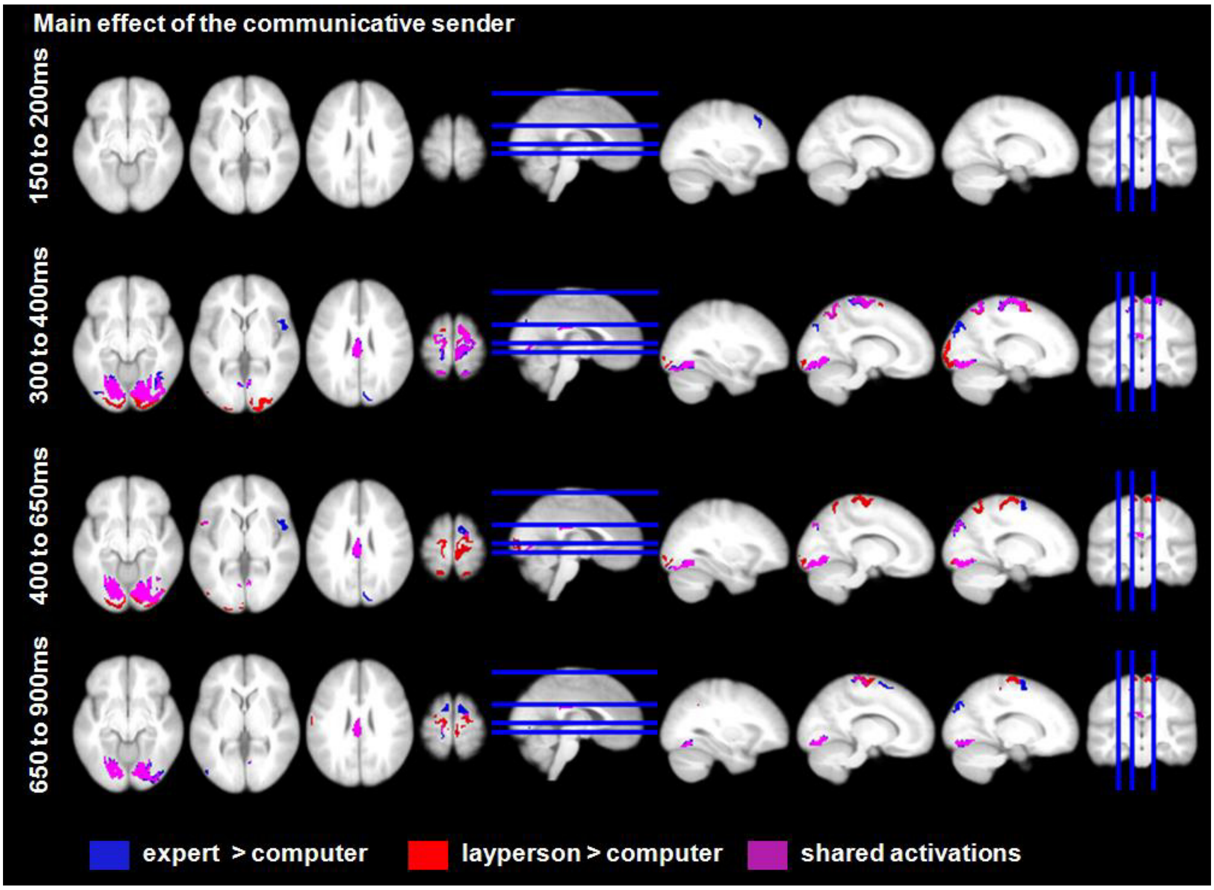

Figure 23: Source estimations for the main effects of the communicative sender (displayed are the post-hoc *t*-contrasts, $p < .001$). Larger activity is found

in broad visual, frontal, somatosensory and posterior cingulate areas for both 'human senders' compared to the 'computer'.

both human senders led to larger activity in broad visual, parietal, frontal and somatosensory regions as well as in the posterior part of the cingulum. However, compared to the 'computer' the 'expert' elicited larger and more sustained activity in broad frontal regions, including the bilateral insulae, while on the other hand the 'layperson' elicited more sustained activity in postcentral/central areas.

Table 12: Source estimations for the comparison between the two ‘human senders’ and the ‘computer sender’. Results show enhanced source activations for both ‘human sender’ in visual, somatosensory, cingulate and frontal areas.

cluster-level	**peak-level**		**MNI coordinates**			**LONI**
Number of significant voxels	peak *t* (1, 261)	peak *p*-unc	x (mm)	y (mm)	z (mm)	area
			P2 time window (150-200ms)			
			'expert' > 'computer'			
54	3.32	<.001	-28	26	48	Mid frontal G L
			EPN/P3 time window (300-400ms)			
			'expert' > 'computer'			
1361 (561^a)	6.38	<.001	10	-72	-4	Lingual G R
1036 (506^a)	6.20	<.001	-20	-72	-12	Inf occipital G L
204 (147^a)	5.34	<.001	0	-34	22	Cingulate G R
806 (325^a)	4.59	<.001	20	-8	66	Sup frontal G R
389	4.54	<.001	18	-82	42	Sup occipital G R
261	3.96	<.001	16	-56	68	Sup parietal G R
79	3.93	<.001	-6	-86	34	Cuneus L
365	3.90	<.001	-20	-14	70	Precentral G L
180	3.63	<.001	-18	-54	68	Sup parietal G L
109	3.62	<.001	54	6	2	Precentral G R
			'layperson' > 'computer'			
1900 (459^a)	5.50	<.001	6	-80	-8	Lingual G R
1112 (312^a)	4.95	<.001	-14	-76	-12	Inf occipital G L
767	4.58	<.001	20	-6	66	Sup frontal G R
177 (60^a)	4.49	<.001	0	-32	24	Cingulate G L
263	3.83	<.001	16	-56	58	Sup parietal G R
366	3.78	<.001	-24	-8	68	Sup frontal G L

281	3.75	<.001	-18	-60	64	Sup parietal G L
40	3.43	<.001	-42	-66	44	Angular G L
36	3.20	<.001	58	-42	10	Sup temporal G R
84	3.16	<.001	48	-62	42	Angular G R
early LPP time window (400-650ms)						
'expert' > 'computer'						
1119 (525[a])	6.31	<.001	8	-76	-6	Lingual G R
767 (449[a])	6.24	<.001	-12	-78	-12	Lingual G L
182 (84[a])	4.67	<.001	0	-32	24	Cingulate G L
406	4.51	<.001	14	-86	38	Sup occipital G R
114	3.93	<.001	-6	-86	34	Cuneus L
98	3.56	<.001	-44	-80	14	Mid occipital G L
96	3.55	<.001	52	4	2	Precentral G R
94	3.42	<.001	-50	10	2	Inf frontal G L
82	3.38	<.001	18	-2	68	Sup frontal G R
'layperson' > 'computer'						
1291 (539[a])	6.31	<.001	8	-80	-8	Lingual G R
1120 (414[a])	5.92	<.001	-12	-78	-12	Lingual G L
164	4.20	<.001	0	-34	22	Cingulate G R
451	3.89	<.001	24	-28	56	Postcentral G R
229	3.80	<.001	-12	-14	66	Sup frontal G L
202	3.76	<.001	20	-82	40	Sup occipital G R
110	3.61	<.001	-44	-82	14	Mid occipital G L
196	3.57	<.001	20	-56	56	Sup parietal G R
85	3.51	<.001	-12	-84	40	Sup occipital G L
95	3.48	<.001	-50	10	2	Inf frontal G L
153	3.46	<.001	-20	-60	64	Sup parietal G L
late LPP time window (650-900ms)						
'expert' > 'computer'						
785 (252[a])	5.19	<.001	12	-80	-12	Lingual G R
431 (139[a])	5.06	<.001	-18	-76	-14	Inf occipital G L
200	3.93	<.001	20	-82	40	Mid occipital G R
146	3.80	<.001	0	-32	24	Cingulate G L
156	3.61	<.001	-46	-80	12	Mid occipital G L
155	3.61	<.001	-18	8	62	Sup frontal G L
124	3.49	<.001	12	6	66	Sup frontal G R
76	3.30	<.001	-14	-24	66	Precentral G L
'layperson' > 'computer'						
580 (72[a])	4.82	<.001	10	-80	-8	Lingual G R
405 (60[a])	4.72	<.001	-12	-78	-12	Lingual G L
265	3.85	<.001	18	-16	72	Precentral G R

50	3.83	<.001	26	-28	58	Postcentral G R
146	3.83	<.001	0	-34	22	Cingulate G R
239	3.77	<.001	-12	-12	68	Sup frontal G L
42	3.64	<.001	-42	-56	40	Angular G L
104	3.41	<.001	-56	6	6	Precentral G L

Notes. [a]Resulting cluster size when FWE-corrected threshold of *p* < .05 (≥25 significant voxels) was used. No. of sig. voxel = the number of voxel which differ significantly between both conditions. Peak *p*-unc = uncorrected *p* Value. For each significant peak respective coordinates (x, y and z) are displayed in MNI space. A cluster may exhibit more than one peak, while only the largest peak is reported. Area = peak-level brain region as identified by the LONI atlas. R / L = laterality right or left. G = Gyrus; Inf = inferior, Mid = middle, Sup = superior.

For the emotion main effect, significant differences were found in the P3 and LPP time window (see Figure 24b, Table 13). Here, stronger visual processing was found for emotional decisions. Emotional decisions led also to larger activity in parietal, posterior cingulate and left superior frontal areas.

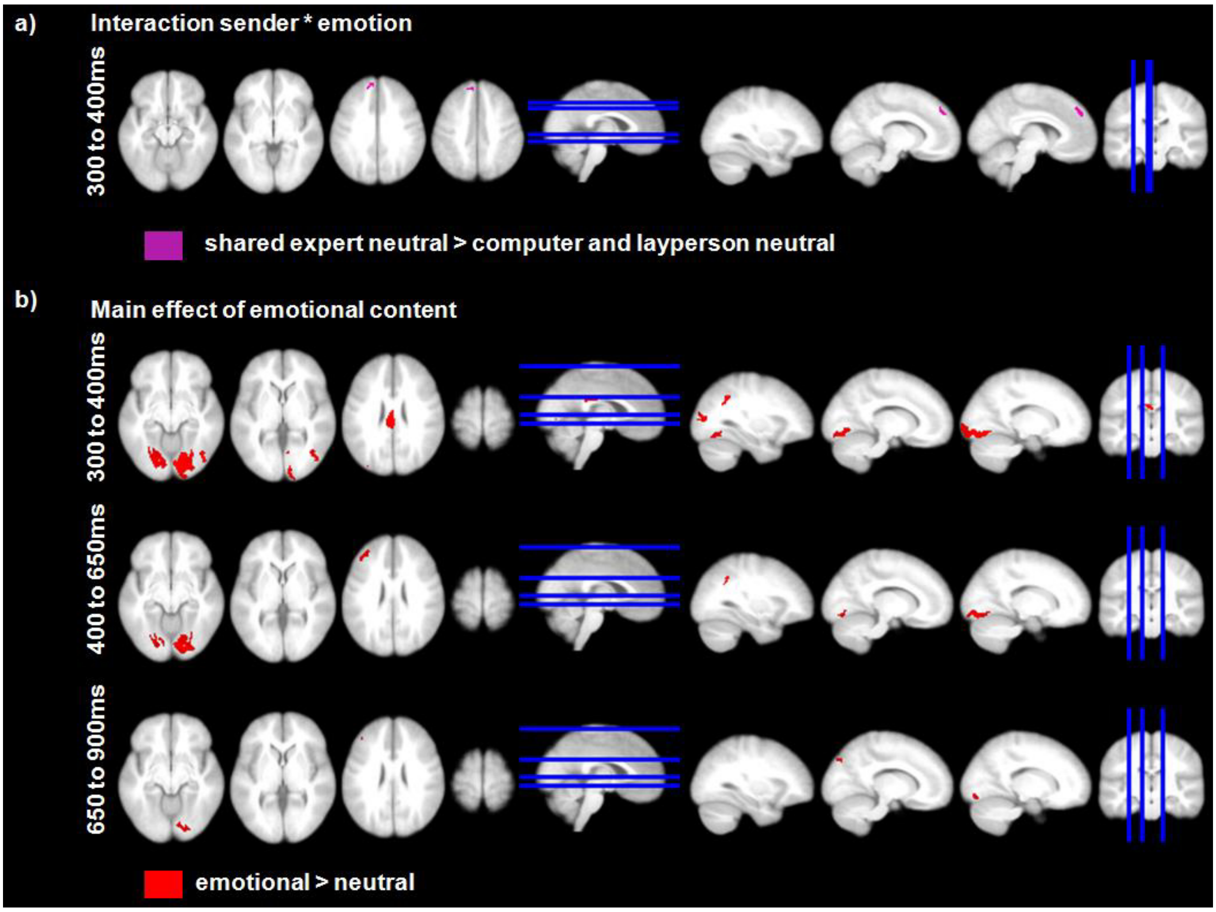

Figure 24: Source estimations for the interaction between sender and emotion and the main effect of emotional content (displayed are the post-hoc *t*-contrasts, *p* < .001). a) Enhanced activations for neutral decisions from the 'expert'.

b) Larger activity is found in broad visual and posterior cingulate areas, as well as a left-lateralized frontal effect for emotional compared to neutral decisions.

Table 13: Source estimations for the comparison between the emotional and neutral decisions in the P3 and LPP time windows. Results show enhanced source activations for emotional decisions in visual, cingulate and frontal areas.

cluster-level	**peak-level**		**MNI coordinates**			**LONI**
Number of significant voxels	peak *t* (1, 261)	Peak *p*-unc	x (mm)	y (mm)	z (mm)	area
		P3 time window (300-400ms)				
238 (60[a])	4.91	<.001	-32	-52	40	Sup parietal G L
213(47[a])	4.85	<.001	-36	-50	36	Angular G L
977 (43[a])	4.80	<.001	6	-82	-8	Lingual G R
209	4.53	<.001	48	-78	-6	Mid occipital G R
171	4.32	<.001	0	-32	24	Cingulate G R
328	3.92	<.001	-28	-84	10	Mid occipital G L
446	3.84	<.001	-12	-78	-12	Lingual G L
36	3.30	<.001	-22	2	64	Sup frontal G L
		early LPP time window (400-650ms)				
483	4.22	<.001	12	-84	-8	Lingual G R
108	4.09	<.001	-30	-52	38	Sup parietal G L
89	4.03	<.001	30	-50	38	Sup parietal G R
186	3.62	<.001	-42	36	14	Inf frontal G L
145	3.33	<.001	-12	-80	-12	Inf occipital G L
		late LPP time window (650-900ms)				
102	3.63	<.001	18	-88	-12	Inf occipital G R
75	3.42	<.001	-10	-84	40	Sup occipital G L
60	3.27	<.001	-38	34	14	Inf frontal G L

Notes. [a]Resulting cluster size when FWE-corrected threshold of $p < .05$ (≥25 significant voxels) was used. No. of sig. voxel = the number of voxel which differ significantly between both conditions. Peak *p*-unc = uncorrected *p* Value. For each significant peak respective coordinates (x, y and z) are displayed in MNI space. A cluster may exhibit more than one peak, while only the largest peak is reported. Area = peak-level brain region as identified by the LONI atlas. R / L = laterality right or left. G = Gyrus; Inf = inferior, Mid = middle, Sup = superior.

For the interaction effect in the P3 time window, neutral decisions were compared between the senders. Within significant interaction effects, neutral decisions by the 'expert', neutral led to larger 'expert' led to larger left medial superior frontal gyrus activity compared to both the 'layperson' and the 'computer'. No differences were observed for the 'layperson' compared to the 'computer' (see Figure 24a, Table 14).

Table 14: Interaction effects of sender by emotion. Enhanced left superior frontal activity can be found for neutral decisions from the ‘expert’.

cluster-level	**peak-level**		**MNI coordinates**			**LONI**
Number of significant voxels	peak *t* (1, 261)	peak *p*-unc	x (mm)	y (mm)	z (mm)	area
			P3 time window (300-400ms)			
			'expert' neutral > ‘layperson’ neutral			
62	3.85	<.001	-6	52	32	Sup frontal G L
			'expert' neutral > ‘computer’ neutral			
62	2.97	<.005	-8	48	38	Sup frontal G L

Notes. Peak *p*-unc = uncorrected *p* Value. For each significant peak respective coordinates (x, y and z) are displayed in MNI space. A cluster may is reported. Area = peak-level brain region as identified by the LONI atlas. R / L = laterality right or left. G = Gyrus; Sup = superior.

2.4.4 Discussion

We investigated the effect of putative sender expertise on feedback processing of socio-emotional words. We expected to find clear advantage for supposedly meaningful feedback from both 'human senders' compared to random feedback, as well as for emotional compared to neutral feedback. Indeed, we replicated substantially larger EPN, P3 and LPP amplitudes for the two 'human senders', as well as in the P3 and LPP an advantage for emotional feedback. Further, we also replicated visual generators of both sender and emotion main effects.

Crucially, we investigated differences between the two 'human senders'. Derived from social psychology experiments (e.g. Collins & Stukas, 2006), we expected an effect of expertise. Indeed, we found consistently significant linear trends, showing that 'expert' decisions led to largest amplitudes on all components, starting already on early stages, namely the N1 and P2. Here, the 'expert' sender led to a larger N1 and P2 compared to the 'layperson' and the 'computer'. For the P2 time window, the 'expert' induced already enhanced visual, parietal but also middle frontal activations in source space compared to the 'computer'. Such early differentiations are rarely found in ERP studies towards, in fact, identical stimuli. For example, such early differences in ERPs and their (prefrontal) cortical generators are reported from conditioning studies (Hintze et al., 2014; Rehbein et al., 2015). However, in this experiment, participants had no prior experience of this setting or associative learning possibilities. Nevertheless, when investigating emotional words, combined EEG/MEG studies also reported such ultra-rapid differentiation in scalp and source space (Keuper et al., 2013, 2014). This might be due to the highly specialized ability of humans to rapidly decode emotional meaning based on language stimuli. Emotional content has for example been shown to accelerate lexical access to words (Kissler & Herbert, 2013). Social context might similarly speed up this significance decoding. Finally, regarding the P2, we also previously found enlargement for 'human-generated' decisions (Schindler & Kissler, 2016c; Schindler et al., 2015), while during the feedback-anticipation even N1 modulations were observed (Schindler et al., 2014). However, such early modulations need to be replicated by a trial-wise feedback presentation. So far, unspecific anticipatory effects might have contributed to these early differences.

Later in the P3 time window an interaction occurred: All decisions by the 'expert' were amplified, while strongest emotion to neutral differences were observed on the scalp within the layperson. This replicates previous trend-like interactions on the P3 for a stranger (not further specified but roughly comparable to the 'layperson' in this experiment) compared to a computer (Schindler & Kissler, 2016c). We tested differences between the senders for neutral decisions and found again a familiar pattern: Neutral decisions by the 'expert' elicited a stronger P3 amplitude compared to the 'layperson', which in turn showed a larger P3 compared to the 'computer'. This interaction was further investigated in source space, where neutral decisions from the 'expert' led to larger left medial superior frontal gyrus activity compared to both the 'layperson' and the 'computer'. The medial prefrontal cortex is considered to be a highly important structure in social cognition (Eisenberger & Cole, 2012; Lieberman, 2007). This enhanced activity could reflect more mentalizing about neutral decisions only when given by an 'expert', which would point to an unique contribution of human expertise.

Interestingly, for the 'expert' the differences compared to the 'computer' were more sustained in frontal regions, whereas for the 'layperson' differences were found to be more pronounced in somatosensory regions. Feedback by both 'human senders' could have led to simultaneously occurring processes: Mentalizing about the sender, as well as an emotional evaluation of the sender feedback. This might have amplified emotional feedback from a potential peer and all decisions from an expert. This is insofar interesting as word meaning has shown to elicit sensorimotor activity (Moseley, 2011; Pulvermüller, 2005), supporting an embodied language account. Further, embodied emotion processing itself was concluded from activity in the sensorimotor system (Niedenthal, 2007). Lately, pain matrixes for both verbal and nonverbal material have been related to the bilateral insulae and secondary somatosensory cortices (Jacoby et al., 2016). Here, it can be speculated that the somatosensory activation reflects an embodied processing of human-generated decisions as previously reported (Schindler & Kissler, 2016c). The communicative context as implied by sender identity appears to modulate the degree to which embodied language processing occurs. We avoided characterizing the 'layperson' in any way to avoid confounding the cortical response due to social group biases.

However, the lack of any information about the 'layperson' might not prevented participants to infer that this person would be more likely a peer than the 'expert'.

On the other hand, the sustained frontal activations in the early and late LPP for the 'expert' as well as the overall amplified processing, even of neutral decisions, might be seen as an attempt to understand the 'experts' decisions. This is in line with reported increased mentalizing about interactions with humans compared to computers (Chaminade et al., 2012; Kircher et al., 2009) and increased superior frontal activity when participants silently mentalize about people compared to objects (Wolf et al., 2011). Processing of communicative intentions also leads to enhanced frontal, supplementary motor (precentral) and parietal activity enhancements (Ciaramidaro et al., 2013; Enrici, Adenzato, Cappa, Bara, & Tettamanti, 2010). Further, in a social working memory paradigm, the increase of social information load led to increased activity in medial fronto-parietal networks (Meyer, Spunt, Berkman, Taylor, & Lieberman, 2012), including the here found superior frontal, supplementary motor area and parietal activity enhancements. Thus, it might be that participants tracked decisions and intentions for both senders but more carefully for the supposed 'expert'.

Although previously similar visual, parietal, frontal and somatosensory activations were reported (Schindler & Kissler, 2016c), the current results show much stronger and temporally more sustained sources for both 'human senders'. This might be explained by increases in trials, increased number of participants and finally also both 'human senders' were compared to a 'random computer' and not to an 'intelligent machine' (cf. Schindler & Kissler, 2016c). Furthermore, posterior cingulate regions were found to be activated by 'human' feedback. The PCC shows reliable intersubject activation in response to written narratives, next to visual and lingual areas (Regev, Honey, Simony, & Hasson, 2013). Moreover, it has been suggested that this region is involved in both automatic self-knowledge and controlled self-reflective processes take place (Lieberman, 2007). Such an interpretation self-reference or mentalizing is also reported from social preference tasks (A. C. Chen et al., 2010) or evaluative feedback compared to performance feedback (Pan, Hu, Li, & Li, 2009), where enhanced PCC activity was found. Specifically, the PCC and medial prefrontal cortex are seen as integral nodes of the metalizing network (Northoff & Bermpohl, 2004; Schilbach et al., 2012; Uddin et al., 2007). A recent study showed overlapping activity for mentalizing tasks and emotional content processing in the PCC (Jacoby et al., 2016). Hence, the PCC is involved in mentalizing but also in emotional content decoding: In a study where participants had to relate personal memories or attitudes to emotional and neutral words, words which were rated to be extremely emotional were found to be correlated with PCC activity (Posner et al., 2009). Interestingly, under social stress, large increases in the functional connectivity were found between the amygdala and the posterior cingulate cortex (Veer et al., 2011). Hence, social stress would in our study explain both sender but also emotion enhancements in this area. This idea could be tested by peripheral and cortisol measurements in future experiments.

We finally confirmed enlarged late ERPs for emotional compared to neutral content (Hinojosa et al., 2010; Kissler et al., 2009; Schacht & Sommer, 2009a). Interestingly, we did not replicate a strong positivity preferences (M_{negative}= 1.30µV; M_{positive}= 1.38µV) at late LPP stages (Schindler & Kissler, 2016c; Schindler et al., 2015). This might be due to changes in the experimental paradigm. In contrast to previous studies we did not include highly negative filler items which were always rejected. Thus, there was an exact balance in the numbers between positive and negative feedback, controlling for possible frequency effects. Of course, this comes with problems on its own: In every-day interactions positive exchanges typically outnumber negative feedback. One might debate if an odd-ball effect is induced by the unequal number of positive and negative feedback in one experiment or by the violation of expectations from every-day life. However, other studies manipulating communicative context or self-reference show pronounced positive processing at late stages, while using equal numbers of positive and negative words (Herbert, Herbert, et al., 2011; Rohr & Rahman, 2015). Still, other experiments, which are quite similar to the cited ones, show a preference for negative words (Herbert, Pauli, et al., 2011) or even neutral enhancements at late stages (Fields & Kuperberg, 2012). This points to highly variable modulations by social context. Future studies should closely investigate the contextual factors leading to positively- or negatively-biased processing, ideally also investigating different patient groups along the socio-emotional disorder spectrum. Finally, in source space we found increased visual activity for main effects of emotion and communicative sender. Such increased visual and superior occipital activity are typically found in reading studies (Osipowicz et al., 2011; van der Mark et al., 2011).

There are some limitations to be mentioned. Linear trends show significant effects on all components, starting with the 'expert', followed by the 'layperson', and ending with the 'computer'. However, between the 'human senders', the amplitude differences seem to be larger on early components, while being in the late LPP time window rather comparable. This might be partly explained by the changes in the experimental paradigm: The experiment was extended in the number of used stimuli and in the number of conditions, possibly reducing the credibility of the experimental manipulation. However, only one out of the thirty included participants did not believe the experimental manipulation, as documented by post-hoc questionnaires. Further, substantial amplitude differences between the 'human senders' and the 'computer' exist even in the late LPP. Another explanation for less pronounced 'human sender' differences might be the extremely subtle manipulation: Participants were only ***informed*** that two human senders with putatively different expertise would evaluate them. An actual interaction with an 'expert' and a 'layperson' might increase perceived differences, but comes at the cost of a loss of experimental control. A fully standardized interaction protocol is unlikely to be accomplished in actual personal interactions. However, future studies should aim to increase the expertise manipulation strength, as these differences are possibly underestimated from this experiment. Further, although source estimations revealed strong and broad sources, these are not able to replace fMRI experiments. Source estimations are not able to detect some structures deep in the brain, like e.g. the amygdalae or the ventral striatum. They are further not as sensitive and as precise in their spatial resolution as fMRI. However, these source estimations helped us to interpret scalp effects with the advantage of the extremely high temporal resolution. Nevertheless, future studies should investigate such social communicative manipulations in the scanner. Whilst this experiment revealed an effect of expertise, future studies might try to separate effects of self-verification compared to self-enhancement as two central motives for feedback processing (Kwang & Swann, 2010; Swann, 1987). This could be implemented by assessing participants' self reports on the same adjectives prior to the experiment.

Summarizing the main findings, we found evidence that sender expertise contributes to amplified processing, starting on very early cortical components. Moreover, expertise seems to amplify feedback, (almost) regardless of its emotional content. Even neutral decisions led to characteristic responses in the brain when an putatively given by an expert. Finally, global content (emotion) and context (sender) effects were replicated in scalp and even extended in source space. We think that these findings contribute to the developing field of neurophysiological language processing in seemingly realistic situations. The results point to the need for such paradigms, as sender-dependent changes in language processing seem to be drastic and systematic, starting to modulate cortical processing already at very early stages. If we want to understand the neural bases of natural language processing, we need to mimic real world settings.

Acknowledgments

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3 Chapter III: General discussion - The social brain

This series of experiments was dedicated to (a) showing the impact of the social communicative context on emotional language processing and (b) investigate two important contributing factors by using a very simple but powerful scenario. These supposed factors were ascribed humanness and expertise, which were thought to amplify responses to the presented feedback. The used manipulation was however only descriptive, only affecting participant’s attributions about the given sender.

Nevertheless, we found in all experiments a sustained amplified processing of 'human-generated' feedback. In addition, we found that emotional feedback was selectively amplified when anticipated or given from a 'human sender' (studies I, III, IV), or differently processed (study II). Humanness seems to play the most important role. Compared to a putatively equally competent computer, the 'human sender' still showed substantially increased amplitudes (study III). These amplifications could be related to enhanced sensory processing (studies II-IV), but also to enhanced mentalizing (studies III-IV), and somatosensory processing (studies III-IV) of 'human' feedback. However, expertise showed also effects in addition to the 'human factor': An 'expert' led to continously larger amplitudes compared to a 'layperson' (study IV). To which extent expertise might play a role within machines, as in the studies no direct tests were conducted (see page 157 for further comparisons). But one could think that for computers, expertise matters less. Lastly, we found in all studies main effects of emotional content, showing that emotional feedback was amplified processed. However, this constantly occurred after initial sender modulations, but showed a similar topography in late time windows. Finally, as we could differentiate between anticipation of feedback (Schindler & Kissler, 2016b; Schindler et al., 2014) and actual feedback presentation (Schindler & Kissler, 2016a, 2016c; Schindler et al., 2015), we found smaller modulations, in terms of microvolt and statistical values, during feedback anticipation. It might be that cognitive processing resources were attracted to feedback, leaving fewer capacities for feedback anticipation.

3.1. Overall comparison and combined analyses across all studies

Overall, it is fair to say that the communicative context established in these experiments shows dramatically altered brain responses. We found replicable main effects of the communicative sender, which started at the P2, encompassing the EPN and P3 and extending to the early and late LPP. As the experimental designs were highly similar, I could conduct an overall comparison on sender effects. Thus, I calculated main effects by using the total number of 73 investigated participants from the three feedback studies (studies II-IV). Here, for this overall comparison data for the 'layperson' in Study IV was used as the 'human sender', as thought to be most similar to the 'unknown stranger' in studies II and III. The same occipital and central sensor groups were used to calculate effects on all investigated components (Schindler et al., 2015). For this large sample, main effects of the 'human sender' start even at the N1, while pronounced differences are found at the P2 (see Table 15, Figure 25). From the P3 onwards, it should be noted that for the main effects of sender and emotion, even the lower bounds of the 95% confidence intervals for the effect sizes still suggest large effects ($\eta^2 > .12$). These overall comparisons are skewed towards Study III and IV, due to the increased number of participants.

Table 15: Overall comparison of main effects for the 'human sender' and for emotional content (*N* = 73).

ERP component	**Main effect of sender $F_{(1, 72)}$**	**Main effect of emotion $F_{(2, 144)}$**
N1 (170-210ms)	**4.12*, $\eta^2 = .05$**	0.28, $\eta^2 < .01$
P2 (150-200ms)	**17.41***, $\eta^2 = .20$**	0.02, $\eta^2 < .01$

EPN (210-270ms)	**9.04***, $\eta^2 = .11$**	1.02, $\eta^2 = .01$
P3 (300-400ms)	**35.41***, $\eta^2 = .33$**	**34.00***, $\eta^2 = .32$**
early LPP (400-650ms)	**34.72***, $\eta^2 = .33$**	**18.31***, $\eta^2 = .20$**
late LPP (650-900ms)	**19.60***, $\eta^2 = .21$**	**15.02***, $\eta^2 = .17$**

Note: * = $p \leq 0.05$, ** = $p \leq 0.01$ *** = $p \leq 0.001$. Depicted values are mean amplitudes in microvolt, averaged over the occipital sensor cluster (N1, EPN) or the central sensor cluster (P2, P3, LPP) from (Schindler et al., 2015).

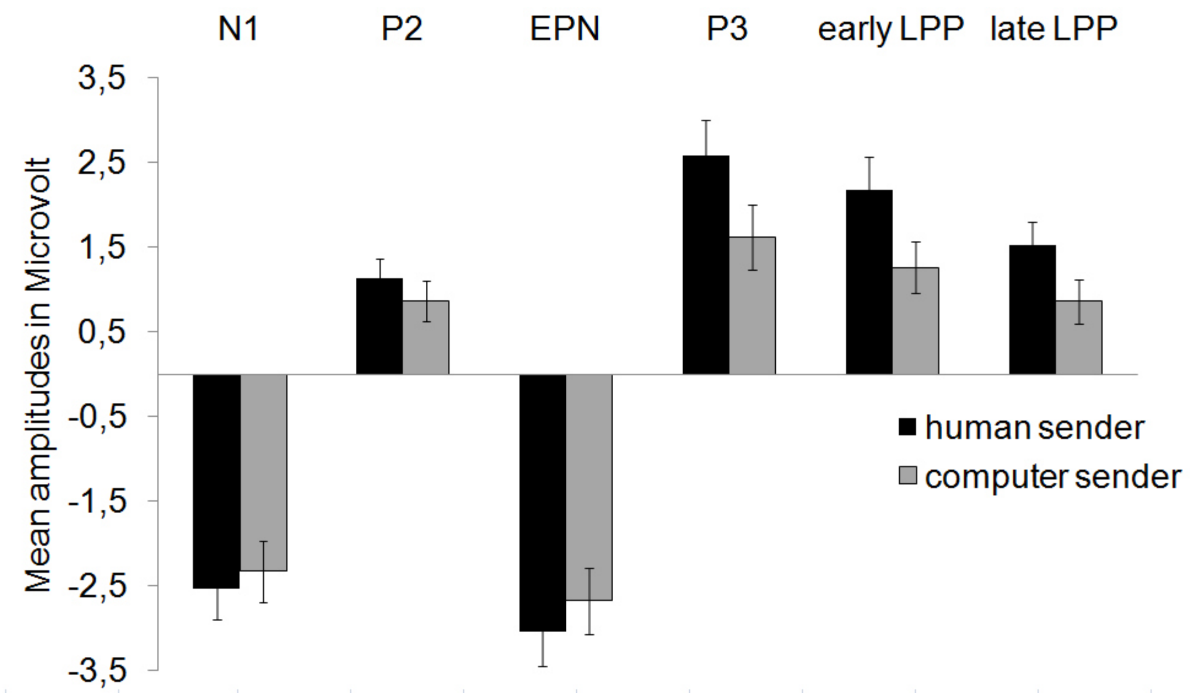

Figure 25: Overall comparison of main effects for the 'human sender' (*N* = 73). Error Bars represent +/-2 Std errors of the mean, representing the 95% confidence interval of the mean.

Sender effects seem to start prior to emotion effects, which showed comparable effects at the late processing stages (see Table 15). This might be partly due to the circumstance, that there are no 'neutral' adjectives, which can adequately describe a person. These neutral adjectives could be regarded to be somewhat strange and thus might induce unspecific oddball effects, underestimating the emotion effects. However, we have found and replicated substantially increased amplitudes starting at the P3 (where oddball effects should play a role), showing that an amplified processing for emotional content is present by the used adjectives. Another idea would be that the emotional information is given before the actual feedback is delivered. However, we also found during feedback anticipation that main effects of the 'human sender' preceded emotion main effects (Schindler & Kissler, 2016b; Schindler et al., 2014). More likely, a competition between attentional resources takes place, where the sender information seem to be more relevant compared to the emotional information. Interactions between sender and emotion might also contribute to explain temporal issues.

So, what about interactions between sender and emotion at the feedback stage? In three studies we found different interactions of sender and emotion, but these were much more variable than the main effects. They occurred in time windows of mid-latency, the EPN and the P3. When calculating across this sample of 73 participants we found a slightly significant interaction at the EPN, but not at the P3 (see Table 16). This points to a highly variable social influence and possibly also different cortical generators of these scalp differences. We found in two studies interactions in the EPN time window (Schindler & Kissler, 2016c; Schindler et al., 2015), and in two studies an interaction for the P3 (Schindler & Kissler, 2016a) or a trend for such an interaction (Schindler & Kissler, 2016c). However, the identification of the exact EPN window varied between studies (210 to 270ms, 250 to 400ms, 250 to 350ms) as well as for the P3 (300-450ms, 250-400ms, 300-400ms). Possibly, this is due to the rather small sample size given in the first study and the decision on temporally partly overlapping or fully overlapping time windows (EPN/P3) for identified components and for source estimation. However, even taking this variability into account, there are at least amplifications visible for human-generated negative feedback in the EPN and for human-generated emotional feedback in the P3 (see

Table 16, Figure 26). And interestingly, when conducting an overall analysis I found an unexpected, trend-like interaction at the N1 (see Table 16, Figure 26).

Table 16: Overall interaction effects of sender by emotion (*N* = 73).

ERP compo-nent	**'human sender' decisions**			**'computer sender' decisions**			**Interaction sender by emotion $F_{(2, 144)}$**
	negative	neutral	positive	negative	neutral	positive	
N1 (170-210ms)	-2.63	-2.59	-2.41	-2.16	-2.43	-2.40	2.71, *p* = .07
P2 (150-200ms)	1.10	1.10	1.20	0.88	0.85	0.86	0.40, *p* = .67
EPN (210-270ms)	**-3.22**	**-2.97**	**-2.98**	**-2.61**	**-2.57**	**-2.85**	**3.18, *p* < .05**
P3 (300-400ms)	2.95	1.99	2.80	1.83	1.28	1.76	2.20, *p* = .12
early LPP (400-650ms)	2.31	1.81	2.41	1.42	0.94	1.42	0.26, *p* = .77
late LPP (650-900ms)	1.55	1.13	1.86	0.94	0.66	0.99	2.02, *p* = .14

Note. Depicted values are mean amplitudes in microvolt, averaged over the occipital sensor cluster (N1, EPN) or the central sensor cluster (P2, P3, LPP) from (Schindler et al., 2015).

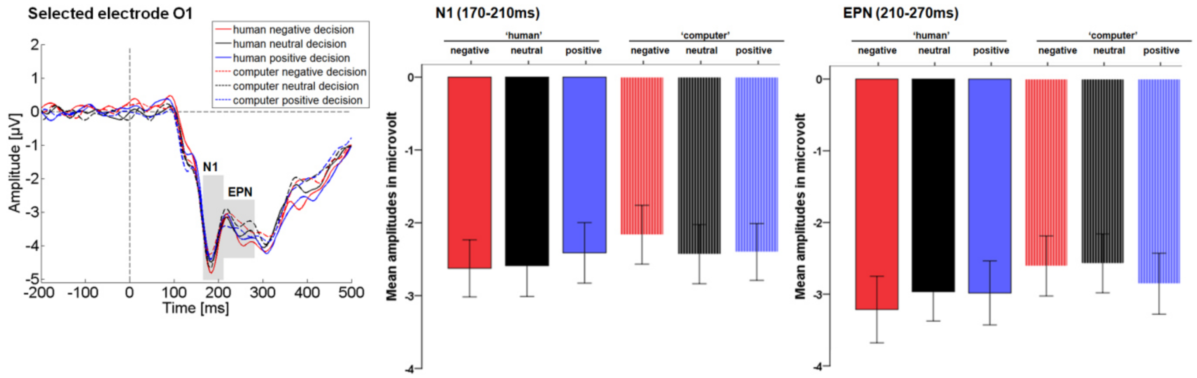

Figure 26: Interaction effects for the overall sample analysis (*N* = 73). Time course over occipital locations and mean amplitudes for the N1 and EPN. Error Bars represent +/-2 Std errors of the mean, representing the 95% confidence interval of the mean.

This is quite unusual, as at this stage, primary visual processing takes place (Friederici, 2011; Sereno & Rayner, 2003), possibly influenced by visual attention (Hillyard et al., 1998; E. K. Vogel & Luck, 2000). However, neither in auditory (Friederici, 2011) nor in visual (Sereno & Rayner, 2003) models of language processing the N1 is thought to be sensitive towards complex sender by emotion variations. Nevertheless, very early context modulations are found in various experiments, affecting processing of faces, pictures and also of words (Baess & Prinz, 2014; Bublatzky et al., 2010; Bublatzky & Schupp, 2012; Fields & Kuperberg, 2012; Klein et al., 2015; Shestyuk & Deldin, 2010; Suess et al., 2014; Trautmann-Lengsfeld & Herrmann, 2013; Wieser et al., 2010). Regarding language, P1 and N1 enlargements were found for the critical final word in sentences under self-reference (Fields & Kuperberg, 2012). However, more typically self-reference effects start from 200ms onwards, while interactions of emotional content with self-reference are found in the LPP (Fields & Kuperberg, 2012; Herbert, Herbert, et al., 2011; Herbert, Pauli, et al., 2011). But even an interaction might occur quite early: When depressive patients and healthy controls judged the self-descriptiveness of emotional words, an interaction of self-reference and emotion was found for the P2, where depressives had a strong P2 enlargement for negative self-descriptive words, while healthy controls exhibited a positivity bias (Shestyuk & Deldin, 2010). Since emotion has found to accelerate the word-pseudoword differentiation (Kissler & Herbert, 2013) and emotion effects itself have been found to be earlier and more pronounced in more realistic communicative situations (Rohr & Rahman, 2015), it can be speculated that in our social feedback studies, the social context accelerated access to emotional information.

It is really interesting that the N1 difference between positive and negative feedback for both senders are similiar compared to the reported EPN interaction of study I (Schindler et al., 2015) and also compared to the EPN interaction in this overall analysis (see Figure 26). This slight negative preference for human-generated feedback is present until the P3, but changes into a descriptively enhanced processing of positive feedback in the late LPP (see Table 16). This could be related to the proposed three stage model of emotion processing (W. Luo et al., 2010; D.

Zhang et al., 2014), suggesting an initial processing advantage for negative and late preference for positive content. These data also show that emotional information is taken into account prior to the relatively late emerging main effects of emotion at the P3 time window. However, this overall comparison should be interpreted very cautiously, as there are differences in the cover story or even stimulus selection across these three studies. These differences might affect the huge main effects to a lesser extent.

For the combined source estimation across all participants I found a large overlap in visual regions for decisions from the 'human sender' (see Figure 27a). Study II mainly found visual differences, possibly due to the limited power by the smaller number of participants. In addition, study III found parietal, somatosensory and frontal differences. These were fully overlapping with effects found in Study IV. In this fourth study we found also much broader differences in frontal, somatosensory, parietal and posterior cingulate areas. The combined analyses of the overall sample hence show strong (familywise error corrected) differences in visual, parietal, frontal and posterior cingulate regions (see Figure 27a). These results show an extensive neuronal network involved in social feedback processing. One major finding is, that a part of this network is the primary sensory analysis, interpreted to reflect motivated attention in response to the social context (Schindler & Kissler, 2016c; Schindler et al., 2015). Possibly, some integrative analyses of the written information happens here as well: Although we do not see a lateralization to the left hemisphere, an involvement of the Visual Word Form Area (VWFA) is likely to be responsible for part of these visual activations (Dehaene & Cohen, 2011; McCandliss et al., 2003; Yarkoni et al., 2008).

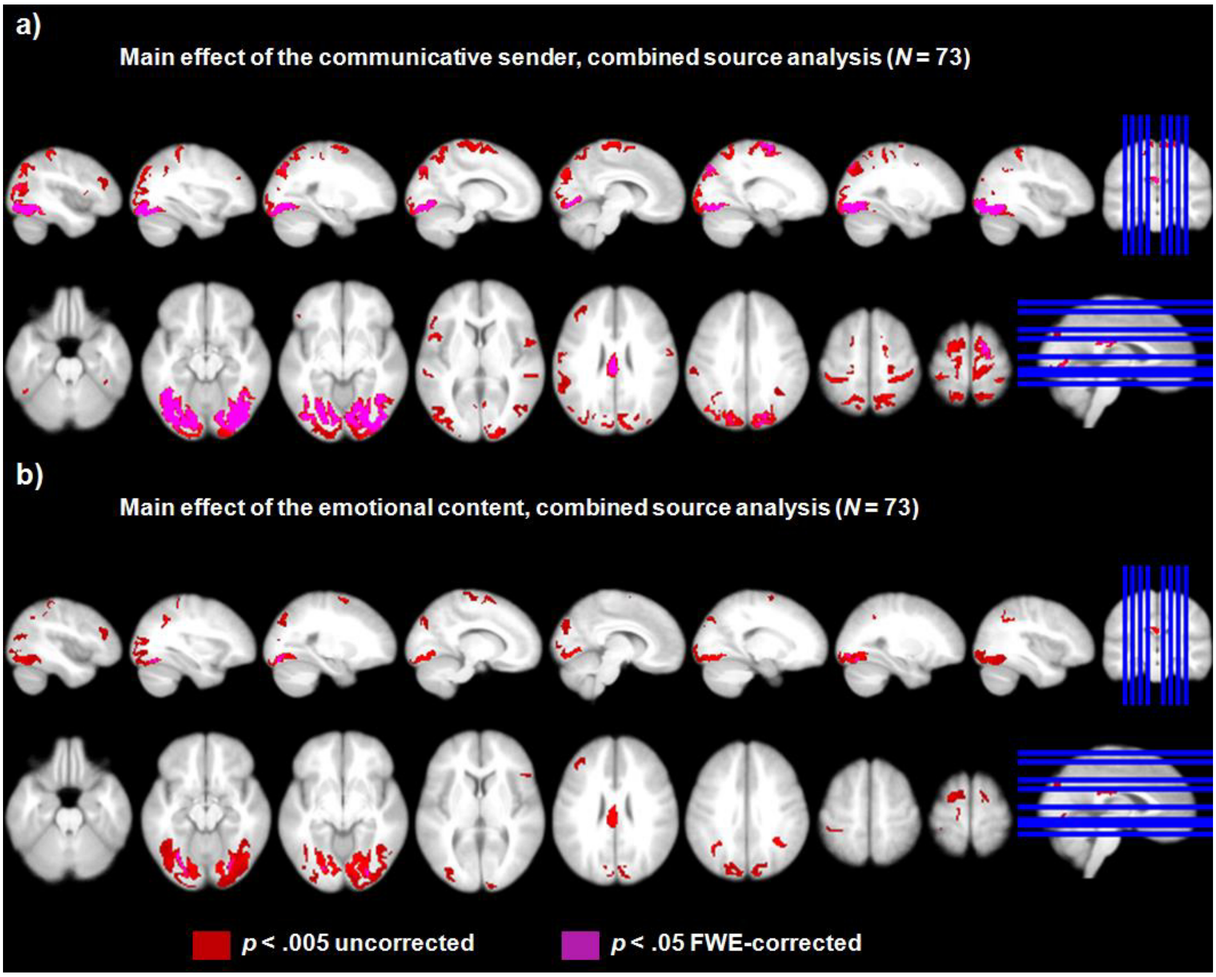

Figure 27: Combined source estimation results (*N* = 73). a) Main effect for the communicative sender, using different statistical thresholds. Displayed is the post-hoc t-contrast for 'human sender' > 'computer sender' **b)** Main effect for the emotional, using different statistical thresholds. Displayed is the post-hoc t-contrast for emotional > neutral.

Further, it is likely that the prefrontal and posterior cingulate cortex (PCC) activations found for the 'human sender' reflects enhanced mentalizing. As pointed out above, enhanced frontal activity, related to increased mentalizing, can be observed in response to interactions with human but not with computer partners (Chaminade et al., 2012; Kircher et al., 2009). Meta-analyses identified the medial prefrontal cortex and the posterior cingulate cortex to be crucial nodes of the mentalizing network (Northoff & Bermpohl, 2004; Schilbach et al., 2012; Uddin et al., 2007). Further, the PCC activity was recently shown to be activated in response to mentalizing tasks and emotion content, but not in other social cognitive tasks, namely pain observation (Jacoby et al., 2016). In an overview on automatic and controlled processes, Lieberman suggests that in this region both, highly automatic self-knowledge and controlled self-reflective processes take place (Lieberman, 2007). This might be the case in these experiments. Next to the understanding of the action of others, likely processes of self-reflection and matching of the evaluation with one´s own evaluation is executed.

Finally, we also have strong somatosensory activations, first appearing in study III and replicated in study IV. A mapping of action words with the respective somatotopic brain area has been reported some time ago (Pulvermüller, 2005), showing an engagement of somatosensory regions in language processing. Recently, enhanced somatosensory activity was reported in response to action words also for non-native speakers (De Grauwe, Willems, Rueschemeyer, Lemhöfer, & Schriefers, 2014) and for action words in metaphors (Desai, Conant, Binder, Park, & Seidenberg, 2013; Lacey, Stilla, & Sathian, 2012). However, in our studies we included only adjectives which had no motor-related meaning. Thus, we previously discussed this activity to be evidence for an embodied processing of human-generated decisions. This is corroborated by a study showing overlapping effects of pain observation in bilateral somatosensory regions and the bialteral insulae (Jacoby et al., 2016). This does not necessarily mean that decisions by 'humans' elicited stronger somatic feelings, but this activity might contribute to the integration and decoding. An alternative explanation would be, that 'human' decisions induced a stronger motivation to approach to or withdraw from the socially relevant communicative partner. Recently, an fMRI study claimed by enhanced insula activation towards conflicting positive and negative word stimuli evidence for such an approach / withdrawal framework (Citron, Gray, Critchley, Weekes, & Ferstl, 2014).

An withdrawal account would be in line with robust stronger activations in the PCC from our source estimations. Here, a study report that under social stress, large increases in the functional connectivity were found between the amygdala and the PCC (Veer et al., 2011). This is not contrary to the idea that an embodied (pain) processing takes place. Moreover, it is in line with some old dual approach/avoidance system ideas (Schneirla, 1959), or two dimensional emotion models (Bradley et al., 2001; Lang et al., 1993), and therefore could be interpreted as preparation for action. Social evaluation can be regarded as a severe threat. This points to our first reaction towards threat: Activation of the sympathetic nervous system for a fight or flight response (Sapolsky, 2004). This idea could be tested by peripheral and cortisol measurements in future experiments, while increased connectivity between the PCC and the amygdalae could be tested in fMRI paradimgs.

On the other hand, I confirmed visual generators of the emotional enhancements in the EPN and LPP time windows (see for example Liu et al., 2012; Sabatinelli et al., 2013) by the combined source estimation (see Figure 27b). However, in the third study we also found temporal and in the fourth study parietal, posterior cingulate and (left lateralized) superior frontal generators of the emotion effects. Simultaneously EEG and fMRI recordings relate temporal and frontal activity to LPP amplitudes (Liu et al., 2012). Further, the PCC responds stronger to emotional compared to neutral words (Demirakca et al., 2009; Nakic et al., 2006; Posner et al., 2009). Finally, likely also other subcortical structures like the amygdala respond to the emotional content (e.g. Hamann & Mao, 2002; Herbert et al., 2009), but the present source estimations are not able to detect such differences.

Social context and emotion share some characteristics, as both factors should increase stimulus salience. However, despite the interesting overlap visual areas, we can see crucial differences between both effects. I found only some small, left-lateralized frontal, small parietal and no pre- or postcentral emotion enhancements. In contrast, I found some anterior temporal activations for emotion effects (cf. Lindquist et al., 2012). Generally, also in source space, significant emotion effects occurred at later time points and were less pronounced.

3.2. Integration: Language is social and social is emotional

The social context modulates brain responses to language. Why is this interesting at all? And why is the social context different from emotion effects? First, before acquiring fundamental language abilities, humans and apes perform comparably on cognitive tasks. However, even at this stage, humans outperform apes in social tasks (Herrmann et al., 2007). Our social cognition skill seems to be particularly sophisticated. However, not only our cognitive abilities (cf. Herrmann et al., 2007), but also social cognition is tightly linked to language. One idea of the origin of language is that it has a inherently social function, when social groups became larger and communication about people not present was necessary (Aiello & Dunbar, 1993). Note that communication about others can be also interpreted as a prerequisite for empathy, theory of mind and mentalizing. And attributed mental states not only influence our cognition or interpretation about others, but even our conscious perception (Teufel, Fletcher, & Davis, 2010). We often infer mental states of others through language: Surprised faces can be perceived as happy or afraid, depending on the preceding descriptive sentence (Kim et al., 2004). Interestingly, our brains' anatomy does not differ as much as commonly assumed from those of apes or monkeys, even the morphological asymmetry of language related brain structures can be found in apes (Sherwood et al., 2008). Yet, despite some apes having the capability to learn small communicative sets, to our knowledge we are the only species which uses abstract and symbolic language (Sherwood et al., 2008) to communicate about other people, express preferences and exchange evaluations. In short, language is used in most social situations, and this social context is in nearly all cases highly emotional, while not all emotional stimuli are social (e.g. threatening snakes, tasty food).

So it might be totally reasonable to expect increased stimulus salience in an social context, and therefore the amplified language processing is in its essence not very surprising. However, first, there was no actual other human present. It was all reduced to an attributed interaction. Such indirect interactions based on modern media services will likely increase over the next years. And in these experiments it has been shown that the ascribed presence indeed affects our processing strongly. Secondly, the found increased sensory processing in response to color changes of single words might be surprising at first. This gave rise to the idea to extend the model of Motivated Attention from content to context. And indeed, the similarity of social and emotional processes is very interesting. But the time course is even more interesting, showing an earlier access to social context compared to emotional content. One might, argue that in our feedback experiments, the emotional information is given prior to the sender feedback, but earlier effects for the sender are also found during feedback anticipation (Schindler & Kissler, 2016b; Schindler et al., 2014). Still, so far a lot of research on language processing focuses on controllable linguistic parameters like word frequency or word length (Hauk et al., 2006), or even on font size (Bayer, Sommer, & Schacht, 2012b). I propose that these factors are important, but of highest interest seems to be the given social context. This is based on our everyday life experiences. In our daily routines, we are constantly confronted with social information and this information is in most cases expressed through language. We react to expectations and evaluations by others and a substantial impact on our behavior is socially motivated. The most important reward we receive for our work is socially based - for example the acceptance and distinction by a given community. Even if we consider monetary rewards, these act as social amplifiers as they can express one´s value in a social hierarchy. In line with this, surprisingly overlapping reward structures were found for both monetary and social rewards in the ventral striatum (Izuma et al., 2008, 2010). And we know that social interactions are long lasting: A single social encounter can have long-lasting and measurable effects in prefrontal regions (Izuma & Adolphs, 2013). And we have a selectively improved memory for social events after episodes of social rejection (Gardner et al., 2000).

But not every interaction partner is treated in the same manner. We certaintly have a tendency to anthropomorphism, stating human-like abilities to non-human agents (Epley et al., 2007). This has been suggested to be advantagous in the implementation and use of social robots (Duffy, 2003). On the other hand, in certain domains machines are not perceived to matter that much. We respond strongly to unfair behaviors from interaction partners, but not when they are computers (Harlé et al., 2012; Phan et al., 2010). This might be partly explained by ascribed human intentionality compared to disimpassioned computers (Singer et al., 2004). However, it seems to be stronger the more personal it gets. For instance, participants show less interpersonal display to computers during interaction (Aharoni & Fridlund, 2007) and empathy (Rosenthal-von der Pütten et al., 2014) and mentalizing (Chaminade et al., 2012; Kircher et al., 2009) in response to computers. In our experiments, we did not found strong effects of computer expertise across the studies. Here, computers with putative different abilities were not directly compared, making it hard to judge. However, when comparing between the experiments, I could not find strong effects. For example the decisions by the intelligent computer seem to descriptively amplified P2 (study III: $M = 0.91$ µV) compared to those from the random computer (study IV: $M = 0.84$ µV), but these differences are not even close to statistical significance ($F_{(1,55)} = 0.55$, $p = .82$). In contrast, human expertise affected these early components already. Here, it can be speculated that humaness and expertise might interact with each other, creating a much stronger impact. Although experts must not be subordinates, this could even be a reminiscence of social hierarchy, since living in hierarchic groups was dominant in the last five thousand years for humans (Boehm & Boehm, 2009; p. 4) and is typically also observed for other primates (Sapolsky, 2005). More research is needed to disentangle effects of expertise, status, authority, age and other likely influencing factors from each other.

Social cognition is sensitive to the given context (Adolphs, 2009). Although there is no common definition of 'social' context, human presence appears to influence our cognition in many ways. I think that we added one interesting finding: Social is inherently emotional, but even more important for us. Most neutral-rated adjectives in our databases (these were rated without context) became emotional-laden when rated in a social context (Schindler et al., 2015, 2014), suggesting that anything which gets social value gets emotional quality. Further, overlapping effects in source and scalp space of social context and emotional content were present in all studies (Schindler & Kissler, 2016a, 2016b, 2016c; Schindler et al., 2015, 2014). But we observed already occipital N1 modulations in our paradigms for 'human senders' which are likely generated in visual cortices. Crucially, our studies suggest that in visual paradigms the primary sensory cortices seem to take the social context into account, at least in the form of salience detection. This is an ultra-rapid and highly automatic response. It would be interesting to see if cognitive load could influence this ultra-rapid processing, as for example an fMRI study show reduced mentalizing activity in an observation task under high cognitive load (Spunt & Lieberman, 2013).

Finally, based on source estimations across all studies and time series of the emerging sources, I can draw a very preliminary picture on social evaluative feedback processing (see Figure 28). Here, I can separate fast and highly automatic from more controlled and elaborative processes. Such a distinction is for example assumed in the domain of attitudes or evaluations towards someone/something (Cunningham & Zelazo, 2007), and also generally proposed in the social cognition literature (Lieberman, 2007). After initial sensory processing, which possibly includes some meaning decoding already in the VWFA, information is processed to multiple

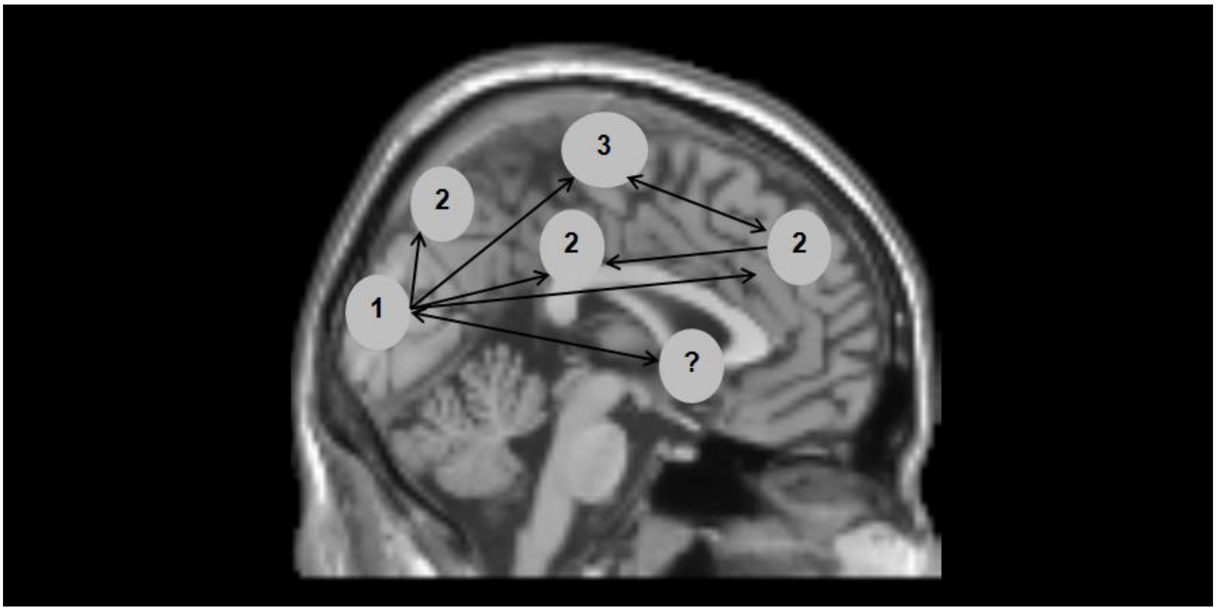

Figure 28: Schematic time course of social information processing. First visual information processing and salience detection starts in visual areas (1). From here, multiple projections to frontal (2), parietal (2) and likely subcortical regions (?) initate different processing circuits. Elaborative mentalizing processes start (2), which start from frontal but target posterior cingulate (self-referential processing) and pre- and postcentral areas (response preparation, fight-or-flight; 3). There seems to be a co-activation of frontal and central areas, possibly also a bidirectional signaling between these brain regions.

frontal, parietal and posterior cingulate regions. Interestingly, multiple regions seem to be target from visual areas in parallel. Likely, in parallel, or even earlier, bi-directional projections to the amygdalae begin, possibly overlapping with emotional content processing. Although, the amygdala is crucial in social behavior regulation (Terzian & Dalle Ore, 1955; Weiskrantz, 1956) it has been suggested that the amygdala does not have a specific role in social cognition (Adolphs, 2009). However, as source estimations are not able to detect activity in these deep structures, I cannot test this hypothesized emotion/salience activation. Thus, after initial access in fronto-parietal regions, elaborative mentalizing starts in PCC and medial prefrontal areas. Likely, the assumed intentionality of interactive partners plays at this stage a role in feedback processing (Harlé et al., 2012; Singer et al., 2004). In parallel, pre- and postcentral regions are activated for emotional evaluation and processing as well as for a behavioral response preparation. This preparation of a behavioral response is likely also engaging the sympathetic nervous system.

Is this proposed processing stream the same for all reviewed context modulations? This seems unlikely. There are various findings on context modulations for language stimuli (Fields & Kuperberg, 2012; Herbert, Pauli, et al., 2011; Rohr & Rahman, 2015), and other stimulus modalities. For example, as reviewed above, it has been shown that emotional descriptions change the processing of identical neutral faces (Klein et al., 2015; Rahman & Sommer, 2012; Suess et al., 2014). These findings likely influence the processing in other ways. Here, the participant is not under an evaluative threat. Thus, I would assume less activity in medial prefrontal, somatosensory and PCC areas. Enhanced processing of faces can also be found for angry faces when participants are instructed to prepare themselves for a public speech (Wieser et al., 2010). This finding seems to be more comparable to our design, as some social evaluative threat is likely induced by the context information. Our paradigm might be more engaging, as it is not the anticipation of a possible evaluation but an actual evaluation. However, our findings do not overestimate responses to social encounters. For example oral exams are likely to induce a similarly strong threat and motivation to decode (social) evaluative information. Even artificial oral exams show a reliable strong activation of the sympathetic nervous system (e.g. by the Trierer Social Stress Test; Kirschbaum, Pirke, & Hellhammer, 1993).

3.3. Language constructs emotion, but what constitutes language?

I earlier discussed that some theorists argue that meaning is generated from interactions with others (Blumer, 1969). In line with theories why language evolved at all (Aiello & Dunbar, 1993; Dunbar, 1992, 1998), social interactions might shape the emotional meaning of the given words. This idea is, that the (social) contextual information always influences word meaning, including the emotional quality and intensity. Repeated occurrence of words in a given context forms an inherent emotional content. When the adjective 'stupid' often co-occurs in a context of punishment and negative evaluation, then this word meaning gets its negative socio-emotional valence information. An example how the word meaning can rapidly change can be observed when considering persons with mental disorders. Labeling a person to suffer from a mental disorder leads to social distance and exclusion (Link, Phelan, Bresnahan, Stueve, & Pescosolido, 1999). When patients are described differently (e.g. they have a need for help), the perceived social distance decreases (Link et al., 1999). So, in Germany, the wording has changed from mental illness to mental disorder, in an attempt to reduce prejudices and stigmatization. However, changes of the label seem not to prevent stereotyping and stigmatization on the long run. The stereotypes likely emerge not from the language itself but from the interactions with others. These are not necessarily interactions with the persons concerned, but for example from interactions of people *talking about these people* with mental disorders. Interestingly, a rather common mental disorder such as depression seems to be unaffected by changing the labeling (Angermeyer & Matschinger, 2003).

This can be seen as evidence in contrast to the famous Saphir-Whorf hypothesis, which suggested a direct influence of language concepts on the way people think and react towards their environment (Caroll, 1956; Whorf, 1950). The Saphir-Whorf hypotheses had been widely criticized and a lot of their initial accounts have been proven to be exaggerated or wrong. However, this hypothesis still has a large influence also on public opinion and policy. It is not surprising that in the scientific field some people react rather harsh to reoccurring Whorfian ideas. For example Steven Pinker points wrote (1995; p.57):

> 'And supposedly there is a scientific basis for these assumptions: the famous Sapir-Whorf hypothesis of linguistic determinism [...]
>
> But it is wrong, all wrong. The idea that thought is the same thing as language is an example of what can be called a conventional absurdity [...]'

However, Casasanto argued recently, that accumulating evidence show an influence of language on cognition (Casasanto, 2008). Although this of course neither states that language determines thinking, nor that we actually think in language (Casasanto, 2008), but it can be connected to neuroscientific models which propose an influence of language on emotional processing. Here, language is seen as a basis to create emotional classification and subsequently experience distinct and namable emotional states (Barrett et al., 2007; Lindquist & Barrett, 2012; Lindquist & Gendron, 2013; Lindquist et al., 2012). I argue that the social context, the communication with and about others, constructs meanings for words and shapes our cognition and experiences by generating namable classifiers. Such classifications (by words) are much more efficient and easier to use than to draw from a large array of social interactions. In a way, compared to the public view on the Saphir-Whorf hypotheses, this is exactly the opposite point of view: Not language is determining our cognition but social interactions. The social context and -history determines what language labels we are using and what are we can differentiate and what not. Thus, when tribes have no words for right and left, it is due to the fact that in their social development it was never necessary to find labels for such a distinction.

Nevertheless, such speculations are difficult to test. However, one way to corroborate such an assumption would be to show that social usage and not linguistic content determines our perception of a given (emotional) word. Although language is the typical way for social exchange, we have multiple ways to communicate approval and disapproval. So, symbolic cues, for example ‘thumbs up’ or ‘thumbs down’, already produces distinct cerebral activities (Kohls et al., 2013). And we can rapidly learn to respond to new symbolic forms of communication, for example use emoticons in text messages, and decode that :-) has a positive meaning but :-(is rather negative. Here, the learned social usage shapes our perception. And this is also true for shifts in natural language, where the meaning of words change over decades. So, it would be at least possible to test if emotional word meaning changes after massive relearning sessions induced by social interactions.

3.4. Limitations and implications for further research

Where should we go from now on? We have learned a lot about the time course and cortical generators of emotional langauge processing in a social setting. But some information is missing or need confirmation. Future experiments should extend the current findings both in a theoretical as well as a methodological fashion.

With the current design different disorders along the socio-emotional spectrum, for example autistic, depressive or social anxious participants should be tested. For these disorders we have certain hypotheses how they deal with social information, some of these information is even implicated in their diagnostic criteria (American Psychiatric Association, 2003). However, when these patients report their reactions towards social events or interactions, this information is based on self-reports with the given cognitive biases. Moreover, when such events are assessed by a therapist, these situations can be quite long ago, and memory biases might further weaken the accuracy of the information. Studying the temporal processing of negative and positive information might contribute to a better understanding of the physiological basis of socio-emotional disorders. Further, it has been recently proposed that actual interactions will be the ultimate goal to understand the mechanisms of our social brains (Schilbach et al., 2013). Measuring real interactions are indeed of highest interest and might extend our knowledge about underlying brain processes. But other authors warned that the loss of experimental control makes data non-analyzable - as we have no possibility to detect when something is actually happening (L. Moore & Iacoboni, 2013). On the other hand it is also questioned if this can really contribute to our understanding of intentionality (C. Moore & Paulus, 2013). To overcome these problems, researchers have suggested to induce the social component in advance of the actual measurement (e.g. by interactions with confederates) to have experimental control but observe social modulations in response to this 'social immersion' (Krach et al., 2011; Krach, Müller-Pinzler, Westermann, & Paulus, 2013). This is exactly what we have done here so far. And indeed it has given us the best of both worlds: Full experimental control, but also a window to the social communicative brain. However, I do think that this design can be modified to investigate actual interactions without losing too much experimental control. By restricted functionality, for example by enabling participants to send each other single word messages and approve or deny statements, one would still be able trigger these events but give participants the sense of an actual interaction. In such a design we could record the brain activity of both the *sender* and the *receiver* simultaneously.

Methodologically, some experiments might be needed to add confidence to the temporal order of sender and emotion effects. So far the 'human sender' effects and their interaction with emotional content were tested only in blocked designs. Thus, the estimation of the time course may be biased: Participants knew in a given block what was about to come and might have 'accelerated' their brains to deal with social information. I need to prove that differences as early as at the N1 stage can be found in a trial-wise presentation. Here, participants should receive sender information as late as with the decision itself. This question will be resolved in the near future. However, preliminary data suggest no differences between such a trial-wise compared to a blocked design. Another issue would be to improve the spatial resolution and acquire more detailed information about involved brain regions. Source estimations are not as sensitive as fMRI, and are also not able to detect activations in some regions deep in the brain (e.g. the amygdalae, insulae, ventral striatum). So I need to perform such an experiment in the scanner to get a full picture of the involved brain structures. This is of high interest as in subcortical regions I might find as well show some overlapping processes in response to emotional content and social context. Further, I could study the coupling between the amygdalae and the PCC, testing increased connectivity in social situations. Finally, peripheral measures (heart rate, skin conductance), but also metabolic parameters such as cortisol could be included to show an activation of the sympathetic nervous system for 'human-generated' feedback.

3.5. Final remarks

Human presence influences our cortical responses in a profound and systematic way. This can be induced by a merely attribution of a sender presence. It is not necessary for us the see the actual presence of another human to change our perception fundamentally. Nowadays communication often involves exchange of mails or short text messages where the presence of another human has to be inferred from the context. The work to understand social cognition and the brain bases of this unique human skill has just started. It is tightly related to language and this work has tried to show this interdependence and generate some new insights on how our brains react to emotional language in a social communicative context.

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Record of achievement / Abgrenzung der Eigenleistung

Study I:

Sebastian Schindler and Johanna Kissler contributed to the study design. Sebastian Schindler, Martin Wegrzyn, and Inga Steppacher carried out participant testing, Sebastian Schindler and Johanna Kissler performed statistical analysis, Sebastian Schindler drafted the manuscript under the supervision of Johanna Kissler. Martin Wegrzyn and Inga Steppacher helped to draft and revise the manuscript. All authors read and approved the final manuscript. Sebastian Schindler revised the manuscript under supervision ofJohanna Kissler.

Study II:

Sebastian Schindler and Johanna Kissler contributed to the study design. Sebastian Schindler, Martin Wegrzyn, and Inga Steppacher carried out participant testing, Sebastian Schindler and Johanna Kissler performed statistical analysis, Sebastian Schindler drafted the manuscript under the supervision of Johanna Kissler. Martin Wegrzyn and Inga Steppacher helped to draft and revise the manuscript. All authors read and approved the final manuscript. Sebastian Schindler revised the manuscript under supervision ofJohanna Kissler.

Study III:

Sebastian Schindler and Johanna Kissler contributed to the study design. Sebastian Schindler carried out participant testing; Sebastian Schindler performed statistical analysis and drafted the manuscript under the supervision of Johanna Kissler. Sebastian Schindler revised the manuscript under supervision ofJohanna Kissler.

Study IV:

Sebastian Schindler and Johanna Kissler contributed to the study design. Sebastian Schindler carried out participant testing; Sebastian Schindler performed statistical analysis and drafted the manuscript under the supervision of Johanna Kissler. Sebastian Schindler revised the manuscript under supervision ofJohanna Kissler.

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