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Electrophysiological Evidence on the Processing of Emotional Prosody: Insights from Healthy and Patient Populations

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Contents

Part I

Introduction

Chapter 1

Introduction and Thoughts on the Current Topic

Even though the possibility to speak and understand is unique to us humans, we often take our verbal capacity for granted. Furthermore, we do not seem to appreciate this capacity until we encounter a loss of it. It is usually at this point when we realize how important speech has become in our lives. One feature of speech in particular, namely emotional prosody, has a high impact on our life. Disorders of emotional prosody - be it on the level of perception or production - influence social interactions and very often restrict daily-life communication of affected patients. Still, neither the perception of emotional prosody, nor the disorders (and their underlying mechanisms) of it are very well understood. Therefore, the present work investigates the perception of emotional prosody in healthy students and in a patient population suffering from lesions in the basal ganglia. This patient population was of special interest because it is assumed that emotions are processed via a complex brain network which is thought to include cortical as well as subcortical brain structures. For instance, Cancelliere and Kertesz (1990) carried out a study with brain damaged patients and found that impaired prosody recognition was often associated with damage to the basal ganglia in addition to cortical damage. The role for the basal ganglia in emotional prosody processing has also been suggested by two studies of Breitenstein and colleagues and by Kotz and colleagues (Breitenstein, Daum, & Ackermann, 1998; Breitenstein, Lancker, Daum, & Waters, 2001; Kotz et al., 2003).

Over the last decade or so, researchers have become more and more interested in how we perceive and produce emotional prosody. To this aim, investigations with healthy and patient populations have been carried out to provide us with a better understanding of emotional prosody. Communicating emotion is a multidimensional process and we are usually using different modes or so called channels of expression to communicate our emotion. These different channels (e.g. facial, prosodic, lexic, gestural, postural) need to interact with each other. Due to the fact that communication of emotions is a complex phenomena, it can be approached from a variety of different perspectives: For example, from a cognitive perspective it is of interest if an emotion is driven by cognition (e.g. Lazarus, 1991), or if emotions are separate from cognition (e.g. Izard, 1993), or maybe emotion and cognition are interactive (e.g. Scherer, 2000)? From a physiological and biological perspective it is of interest to define certain structures, systems, and mechanisms that underly emotions (e.g. LeDoux, 1996). And from a neuropsychological perspective, the brain-behavior relationships are of interest, keeping both, psychological models of emotion and the underlying neural mechanisms of emotions in mind (Borod, 1993).

However, in order to understand the full process of emotional communication, we need a better understanding of the subprocesses that are involved first. Thus, the main focus of the present work lies on emotional prosody perception, only. Emotional prosody helps us to evaluate the inner state of a speaker, it helps us to understand how other people feel. As mentioned above, the communication of emotions is crucial to social relationships, from the very first moment of our life we start expressing our feelings (e.g. babies scream when feeling pain, hunger, fear, or even when feeling happy). Some researchers even claim that emotional communication is crucial for our survival (e.g. Ekman, 1992) and it has also been shown that the way we express our emotions has implications on our physical health (e.g. Booth & Pennebaker, 2000).

The present study aims to contribute to the discussion about emotional prosody perception by investigating the potential relatedness between emotional prosody and emotional-semantics. Several points are of central concern for this thesis. The first main question pursued is in how far the temporal integration of emotional-semantics and emotional prosody can be specified, i.e. at which point in time do these two channels interact and can they be isolated? The second question is in how far different emotion specific intonation patterns can elicit different brain responses, i.e. can we differentiate different emotional prosodies in the ERP? And if so, at which point in time does this differentiation occur first? The third concern aims to contribute to the discussion about the emotional network in the brain. As mentioned previously, it is assumed that emotions are processed via a complex brain network. This network is thought to include the orbito-frontal cortex, the amygdala, the anterior cingulate cortex, and temporal and subcortical structures (e.g., Davidson, 2000). To this aim, patients with lesions in the basal ganglia were of interest, i.e. the question raised was in how far do the basal ganglia contribute to the emotional network. Do patients show any particular disorder related to emotional prosody processing?

Whereas the first part of this thesis adresses theoretical, methodological and empirical issues related to emotional prosody processing, the second part presents a series of electrophysiological experiments. Chapter 2 deals with emotions and prosody in general. In the first part of this chapter several influencial theories on emotion will be presented. Secondly, emotional valence and the lateralization of emotion will be discussed. Furthermore, there will be a section that attends to the emotional network in the brain and to emotions and the basal ganglia in particular. The second part of the chapter is concerned with prosody and emotional prosody particularly. Here, the focus is on the lateralization of emotional prosody and brain regions involved in the recognition of emotional prosody. As a last point, auditory language comprehension will be briefly discussed.

Chapter 3 is concerned with event-related brain potentials (ERPs). An introduction to the basic terminology, language related ERP components and ERP components related to emotional processing in general will be given. Also, the methodological advantages of the ERP method when investigating emotional pro-sody will be discussed briefly.

Chapter 4 opens the experimental study section. Within this and the proceeding four chapters, five ERP experiments and one behavioural experiment will be discussed separately. Each chapter includes an introduction to the following experiment, as well as a result and discussion section. The first two ERP experiments are mainly concerned with the interaction between emotional prosody and emotional-semantics under two different task instructions, i.e. under implicit (Chapter 4 - ERP Experiment 1) and explicit (Chapter 5 - ERP Experiment 2) emotional prosody processing. The experiments were designed to specify the (temporal) integration of emotional prosody and emotional semantics. So far, it is yet not fully understood in which way and at which point in time emotional prosody and emotional-semantics interact at the sentence level. However, previous evidence (Kotz, Alter, Besson, Schirmer, & Friederici, 2000) showed that the time course of emotional prosody and semantics differ. The aim of the studies to be presented was to investigate the two channels by isolating the emotional prosody channel from the emotional semantic channel using a cross-splicing method in which an emotional prosodic specific expectation was violated. Chapter 6 presents a rating study exploring possible speaker differences in the production of emotional prosodic utterances in two age cohorts. The third and fourth ERP experiments attempt to gain insights into more differentiated emotional prosody processing. In particular, the influence of different emotional prosodies and of different speaker voices are of central importance. Thus, in ERP Experiment 3 it is of special interest to investigate in how far different emotional intonation patterns elicit different ERPs. Also, to explore possible speaker differences, material of two speakers (female, male) are presented. ERP Experiment 4 continues with this line of research. Within the experiment it is of special interest to investigate in how far different emotional intonation patterns can elicit different ERPs and if this differentiation is independent from the semantic content by introducing pseudosentences. Last, in Chapter 9, the fifth ERP experiment addresses the question of emotional prosody processing in a patient population suffering from lesions in the basal ganglia. The experiment was designed to test emotional prosody perception of five emotional prosodies: anger, fear, disgust, happy, and neutral utterances. In addition to exploring implicit emotional prosody perception in basal ganglia patients by means of ERPs, explicit emotional prosody recognition is investigated with the help of a behavioural experiment. This experimental design allows to investigates implicit and explicit emotional prosody processing in the same patient group.

The last chapter, Chapter 10, summarizes all important results, includes a general discussion, and will close will conclusions gained from this empirical work. In addition, implications for future research will be defined.

Part II

Theoretical and Empirical Background

Chapter 2

Emotions and Prosody

2.1 Emotion

Conducting research on emotion is at once a fascinating and difficult endeavor. It is fascinating because emotions are of central importance to our daily-life, and it is difficult because even though there has been extensive research on emotions, there is not yet one unified and generally accepted theory on emotion. Rather, various different approaches on and multiple aspects of emotions have been studied. The following chapter will give a brief overview of the major research traditions in emotion theory. Also, there will be a short introduction to the emotional network in the brain and the basal ganglia in particular. Furthermore, emotional valence per se will be discussed. In the second part of the chapter, an introduction to prosody and emotional prosody in particular, as well as a definition of relevant terms, will be given. Special emphasis will be put on existing hypotheses of where and how emotional prosody is processed. To this aim, there will also be an introduction to the existing guiding hypotheses on emotional prosody. There will also be a section summarizing the brain regions that are thought to be involved in the recogntion of emotional prosody. Last, a brief introduction to auditory language comprehension in general will be provided.

2.1.1 Theories on Emotion

Theories on emotion can be classified by the underlying question that is central to the theory, i.e. which question the theory tries to answer. Following this line, one can classify emotion theories into 1) theories with an evolutionary perspective, 2) theories with a cognitive perspective, and 3) neuro-psychophysiological theories (e.g. Ulich & Mayring, 1992). The next paragraphs will briefly discuss each perspective.

2.1.1.1 The Evolutionary Perspective

Within this line of research, the central question is related to the phylogenetic development of emotions, i.e. how emotions evolved in the first place. A second question that is central to this area of research is the biological function of an emotion.

Charles Darwin's (1872) work laid the foundation for the view that emotions are reaction patterns shaped through evolution and that humans should, more or less, show and experience the same set of basic emotions. Within the Darwian perspective, emotions are seen as phenomena that are important for survival, i.e. they evolved because humans as a species faced particular problems. In addition to the assumption that humans share basic, or fundamental emotions, it is also assumed that due to our evolutionary past, related species should share at least similar emotions.

Among many modern researchers following Darwin's ideas are Ekman and Plutchik, for example. Plutchik's theory of emotions (1980) proposed that there is an innate basic set of emotions that all humans experience. These innate emotions are directly related to adaptive behavior that is supposed to ensure human survival, similar to the "fight" or "flight" responses that enhance survival. For example, when feeling angry because you cannot do something you want, the adaptive behavior might be to destroy the barrier that stops you (example taken from Grivas, Down, & Carter, 1996). Plutchik based his model on an emotion wheel with eight basic emotions, including four pairs of opposites, i.e., joy and sadness, fear and anger, disgust and acceptance, surprise and anticipation. According to the theory, it is impossible to experience opposite emotions at the same time, i.e. one cannot, for example, feel fearful and angry in the same moment. Despite the fact that this model leaves little room for cognitive aspects of emotions, the notion of basic emotions has been very appealing to many researchers (e.g. Ekman, 1972; Plutchik, 1980). Even though the number of basic emotions varies from researcher to researcher, the emotions of happiness, anger, fear, sadness, disgust, and surprise are usually among them (c.f. Cornelius, 1996). The following experiments will take up the notion of basic emotions, thereby explicitely testing whether a processing difference exists between these six emotions with regard to emotional prosody.

2.1.1.2 Cognitive Perspective

One of the more dominant perspectives is the cognitive approach to emotion. Often, the beginning of the modern cognitive approach is traced back to the work of Magda Arnold (1960) (c.f. Schröder, 2003; Cornelius, 2000), even though one could say that initially, this line of research was influenced by the debate between defenders of the sensory-feedback theory of emotion (e.g. James, 1884) and Cannon and Bard's approach to emotion theory (Cannon, 1927; Bard, 1928). Whereas the James-Lange theory assumed sensory processing to elicit bodily changes (e.g., increase in heart rate, sweating), the Cannon-Bard theory argued against this idea when stating that bodily changes were not specific enough to account for all different emotions (e.g., fear and anger might both elicit an increased heart rate, but are nevertheless two distinct emotions). Instead, Cannon and Bard proposed that subjective experience and physiological changes occur simultaneously and that all emotions are underlied by the same pattern of response. According to their beliefs, the thalamus played a key role by sending sensory information to the cortex for interpretation and at the same time sending activation signals via the hypothalamus to the rest of the body. Because neither approach served to be sufficient as a general theory of emotion, cognitive theories on emotion became more popular.

Cognitive theories on emotion build their work on a notion called "appraisal", the process by which events, objects, or persons are judged as being either positive or negative, and it is this process that triggers the correct emotional response within us. According to this approach, a specific pattern of appraisal is associated with one particular emotion. In the words of Cornelius (2000):

> These patterns provide the link between particular characteristics of the person or organism, his or her learning history, temperament, personality, physiological state and particular characteristics of the situation in which the person or organism finds him or herself. The notion of appraisal, (...), goes hand in hand with the idea that emotions are "action tendencies".

Taken together, the cognitive theories on emotion assume that the cognitive state of a person has to interact with appraisal in order to elicit an emotion. A famous theory within this line of research is the Schachter-Singer theory of emotion (Schachter & Singer, 1962). According to this theory, physical arousal occurs first in an emotion and is then followed by a cognitive interpretation of the environment and an appropriate label for the emotion felt. The authors tested this arousal-cognition theory in an experiment where subjects were injected with epinephrine. A control group was injected with a placebo. Some participants were told that the injection would have no side effects, while the others were told thruthfully or misleading of its effects. Participants told misleadingly of the effects were manipulated to feel either angry or euphoric. Those participants who were misinformed felt euphoric when they had been manipulated to feel euphoric and felt angry when they had been manipulated to feel angry. None of the participants from the control group or the correctly informed participants reacted in the same way. The authors concluded that the emotions felt by the misinformed experimental group were elicited by a combination of physical arousal that was neutral and a cognitive evaluation that transformed the arousal into either happiness or anger. Many concerns were raised regarding the soundness of the research method, and the results have been difficult to replicate (e.g. Marshall & Zimbardo, 1979; Reisenzein, 1983). Nevertheless, the cognitive approach per se is still appealing to researchers. Among the modern defenders of this approach are, for example, Lazarus (1991), Ortony and colleagues (1988), and particularly important for research on speech and emotion Scherer (1984). Scherer developed the component process model. With the help of this model, he was able to hypothesize various detailed physiological predictions that can be associated with certain emotions. For example, the emotion of anger is usually conveyed with high pitch speech and a fast speech rate (for more detailed examples of his hypotheses, see Table 2.1 in Section 2.3)

2.1.1.3 Neuro- and Psychophysiological Perspective

Neurophysiological and psychophysiological theories on emotion try to answer which physical central-nervous and peripheral-psychological processes and structures correlate with an emotion. Whereas neurophysiological theories try to explain which central nervous system brain processes and brain structures are involved in the origin of a particular emotion, psychophysiological theories are more interested in the question of whether different emotions correlate with specific peripheral-physiological patterns.

In short, neuropsychological theories of emotions aim to clarify the relationships between emotions and the brain. For example, early theories focused on subcortical structures that might be involved in emotional functions. A pioneer in this area was Bard (1928, 1929). While Bard assumed that the hypothalamus plays a crucial role in emotional processing, Papez proposed a much more complex anatomical model of emotions (Papez, 1937). According to Papez's view, different brain structures might "mediate" different emotion components. Within Papez's model, he postulated that the mechanism that "embosses" the function of central emotions is comprised of the hypothalamus, the anterior thalamic nuclei, the cingulate gyrus, the hippocampus, and interconnections between these structures. Furthermore, he assumed that functions of emotional evaluation and expression are mediated mainly by the hypothalamic component of the circuit, whereas the elaboration of emotional experience is mediated mainly by the cingulate gyrus, which is the cortical component of the circuit.

One of the most frequently cited neurological theories that builds on Papez's model is the limbic system hypothesis by MacLean (1949, 1952). MacLean proposed the idea of a triune brain, which is composed of the reptilian brain (brainstem), the limbic system (paleomammalian brain) and the neocortex (neomammalian brain). According to him, a group of phylogenetically old structures (e.g., the hypothalamus and related parts of the paleostriatum) mediates drive-related forms of behavior (e.g., "fight" or "flight" reactions) while what Gainotti (2000) calls family-related patterns of emotional behavior (e.g., nursing) are mediated by the cingulate gyrus, a phylogenetically younger part of the limbic system. Despite the influence the limbic system hypothesis had and still has, however, it has also been seriously criticized (LeDoux, 1996). For example, MacLean believed that there are few anatomical connections between the limbic system and the neocortex. This would be the reason why humans find it difficult to control emotion rationally. However, Roth (1994) discusses extensive connections between the neocortex and the limbic system. Furthermore, the disctinction between phylogenetically older and newer brain regions has been questioned on an anatomical basis when anatomists found that so-called primitive creatures have brain regions that are similar in structure and function to the neocortex. Also, there is an ongoing debate about the definition of the limbic system, i.e. which structures are actually part of the system (Kötter & Meyer, 1992).

Today, neuropsychological theories still try to map specific components of emotions to specific brain structures. To this aim, both animal and human studies have been carried out. One structure that has been found to be very influential in emotional processing is the amygdala (e.g. Adolphs, Tranel, Damasio, & Damasio, 1994, 1995; LeDoux, 1986, 1987, 1993). Several authors (LeDoux, 1996; Adolphs et al., 1995; Calder et al., 1996) have suggested that the amygdala is the brain structure where an external stimulus is evaluated according to its emotional significance. For example, the focus of research conducted in the LeDoux Laboratory (Center for Neural Science, New York University) has been on the neural system underlying the experience of fear. With experimental studies, he and his co-workers have tried to map out how the fear system of the brain works. One of their findings includes the results that led to the conclusion that the experience of fear involves neural pathways leading to the amygdala. For example, it has been shown that stimulation of the amygdala in anaethetized animals elicits stiffness, flight reactions, and defensive fight-reactions. In epileptic patients, stimulation of the amygdala has been carried out during brain operations. Because patients were awake during the stimulation, one could not only observe the expressions elicited, but patients were also able to describe their feelings. Most often, the feeling described was fear (LeDoux, 1998).

Damasio (1999) has tried to summarize existing results on the basis of the neurophysiological perspective. He states that the brain elicits emotions mainly in subcortical brain regions, i.e. the brainstem, the hypothalamus, the basal frontal brain, and in the amygdala. These brain regions are involved in different emotions. Imaging investigations have shown that sadness, anger, fear, and happiness can activate different brain regions. For example, sadness activates parts of frontal lobe, the hypothalamus, and the brainstem, while anger or fear do not activate the first two regions. Furthermore, Damasio (1999) proposed that some brain regions are also involved in the stimulus recognition that accompanies certain emotions. For instance, he discusses a patient with a disfunction of the amygdala who is not able to recognize fear in the facial expressions of others (Damasio, 1999).

Obviously, it is not yet possible to map out each component of one particular emotion to a specific brain region. More research has to be carried out. Furthermore, it should be noted that the emotion theories briefly summarized above are not mutually exclusive. Rather, depending on the question asked, i.e. whether we want to investigate the perception or the expression of emotions, we get different answers that speak in favor of or against each particular theory of emotion. The experiments that will be discussed next cannot say anything about emotion perception in general, but they can help to specify which brain structures might underly the processing of emotional prosody, i.e. to which extend the basal ganglia in particular might be part of the emotional system underlying emotional prosody. There will be sections on both the emotional brain network and the basal ganglia.

2.1.2 Emotional Valence and the Lateralization of Emotion

Directly related to the section on theories of emotion is the assumption that different emotional valences influence our behavior. For instance, a negative emotion like sadness might cause us to cry. Rolls (1999) classified emotions according to their different reinforcement contingencies and according to whether the reinforcer is positive or negative. According to Rolls (1999), "some stimuli are unlearned (or 'primary') reinforcers (e.g., the taste of food if the animal is hungry, or in pain); while others may become reinforcing by learning, because of their association with such primary reinforcers, thereby becoming 'secondary reinforcers'" (Rolls, 1999, pg. 62). Emotions associated with the presentation of a positive reinforcer include pleasure and ecstacy (where ecstacy can be differentiated from pleasure with respect to its intensity, i.e., emotions can also be classified according to their intensity). Negative reinforcer presentation is associated with emotions like terror and fear. In Rolls's classification model, he also includes emotions associated with the omission or termination of a reinforcer. His theory partly serves as an example for a dimensional account on emotion, i.e. an emotion can be explained on a valence dimension (positive versus negative) and emotional intensity (high versus low). Although dimensional theories differ regarding particular details from theory to theory, they have helped to shape the assumption that negative and positive emotions might be processed by neural systems that at least partially differ.

The valence lateralization hypothesis conceptualizes that both brain hemispheres are involved in emotion processing but that each hemisphere is specialized for one valence. Several authors (e.g. Davidson, 1992; Gur, Skolnick, & Gur, 1994; Robinson & Starkstein, 1989) have proposed that the left hemisphere is dominant for positive emotions, while the right hemisphere is dominant for negative emotions. Many authors (e.g. Sackheim et al., 1982; Morris et al., 1996; Paradiso, Chemerinski, Yazici, Tartaro, & Robinson, 1999) have noted that sometimes, patients with lesions in the left frontal lobe, particularly in the basal ganglia or prefrontal cortex, become depressed. In contrast, patients with dysfunctions in the right frontal lobe often suffer from mania or show signs of "inappropriate" cheerfulness (Starkstein et al., 1989). Davidson and colleagues (Davidson, Ekman, Saron, Senulis, & Friesen, 1990; Davidson, 1992) found evidence in an EEG-study that negative emotional episodes elicited more activation in the right hemisphere, whereas positive emotional episodes activated predominantly the left hemisphere. Fox and Davidson (1984) proposed that positive emotions can be related to approach behaviors and that these behaviors are mediated by the left hemisphere. In contrast, they further proposed that negative emotions are related to avoidance behaviors. However, Crucian and colleagues (1997) investigated approach-avoidance behavior and emotions and observed that both approach and avoidance behaviors can be associated with negative emotions.

In contrast to the valence hypothesis, the right hemisphere lateralization hypothesis posits that the right hemisphere is dominant over the left hemisphere for all emotions. Early behavioral studies suggest that the left side of the face is emotionally more expressive than the right side of the face (Sackheim, Gur, & Saucy, 1978). Some patient studies suggest that lesions in the left hemisphere are more likely to influence language processing, while lesions in the right hemisphere are more likely to affect different aspects of emotional processing. Gazzaniga (1988) reports that split brain patients could react to an emotional stimulus but could not verbally explain what they saw. Strauss and Moscovitch (1981) reported better performance of participants in identifying the expression of faces that were rapidly flashed on a screen when these faces were presented to the right hemisphere as opposed to the left hemisphere. However, as with the valence lateralization hypothesis, the right hemisphere hypothesis has also been challenged by studies that have failed to find lateralization of emotion (Caltagirone et al., 1989; Kowner, 1995). Furthermore, it should be noted that several variants of the right hemisphere hypothesis have emerged. For instance, some authors postulate that the right hemisphere is activated in the perception and expression of emotion, but not when experiencing an emotion (Adolphs, Russel, & Tranel, 1999). Others have proposed that highly arousing and unpleasant emotions specifically activate the right hemisphere (Adolphs et al., 1999).

As Murphy, Nimmo-Smith, and Lawrence (2003) note, several researchers have started to think in terms of individual neural systems coding distinct dimensions of emotions rather than thinking in terms of an integrated neural system that is activated in all emotional processes. Furthermore, it seems obvious that the differentiation between positive and negative emotions may serve as a good starting point; however, it seems to be insufficient for a deeper exploration on individual emotions. Imagine the emotions "fear" and "anger". Even though both emotions are negative when feeling frightened you might feel like running away from the frightening stimulus, but when feeling angry you might run towards the stimulus that makes you feel angry. Therefore, the following experiments will start out using positive and negative emotional stimuli but will later draw upon the notion of basic emotions and will make use of seven basic emotions as stimuli.

2.1.3 Emotional Network in the Brain

Despite the fact that researchers have long been interested in the neurobiology of emotion perception, there is only a limited understanding of the underlying processes of emotion up until today. The following section attempts to summarize the function of the most important brain areas involved in emotional processing. It should be noted that a detailed discussion of all brain regions involved in the processing of emotion is beyond the scope of this thesis. Thus, please refer to e.g., Rolls (1999) or Davidson and Irwin (1999) for a more detailed review on this topic. Last, it should also be kept in mind that this thesis investigates patients with lesions in the basal ganglia, so special emphasis is put on the role of the basal ganglia in emotional processing in an extra section.

2.1.3.1 Complexity in Studying Human Emotion - Some Remarks

Before reviewing the literature on emotional processing, some remarks regarding the complexity of studying human emotion should be made. One of the central questions in emotional processing is the question of lateralization of emotional processing (c.f. previous section). Unfortunately, there is no universally agreed upon model regarding the lateralization of emotional prosody processing. To account for the differences found, the hypothesis that lateralization can be influenced by the task used in a given experiment has been put forward. However, different results could not only be due to the various tasks used in different experiments, but also due to the lack of a precise definition of what aspect of emotional processing is actually investigated. Throughout the literature, one can find divergent results of brain activation in emotional processing. It is assumed that emotions are processed via a complex brain network. This network is thought to include the orbito-frontal cortex, the amygdala, the anterior cingulate cortex, and temporal and subcortical structures (e.g., Davidson, 2000). However, not every study of emotional processing reports activation of (all) these brain regions. Again, the reason for this lack of activation seems manifold: for instance, it is often not explicitly stated whether the perception or the production of emotion is studied. Another principally unsolved question in the literature is whether the perception of an emotional stimulus elicits the same emotional reaction in the participant. Another aspect that might have led to divergent activation patterns is that the importance of a control condition is often underestimated. In many studies, a neutral baseline has been omitted. Furthermore, many studies failed to investigate more than one or two emotions whithin one experiment. These single investigations can partially help us to draw conclusions about the one emotion investigated, but they prevent us from drawing conclusions about an interactive emotional network. One last general problem of many studies is that stimuli material are often not controlled for regarding arousal or intensity, i.e. two studies investigating the same emotion might get different activation patterns due to the different arousal levels of the participants. This problem goes hand in hand with the fact that often stimuli are not controlled for their physical attributes (e.g. pitch, intensity, duration in the vocal realization of emotional stimuli) and thus, stimuli can seldom be compared across studies. Taken together, one can conclude that divergent results in emotional processing studies are due to conceptual and methodological differences (Davidson & Irwin, 1999). Nevertheless, the

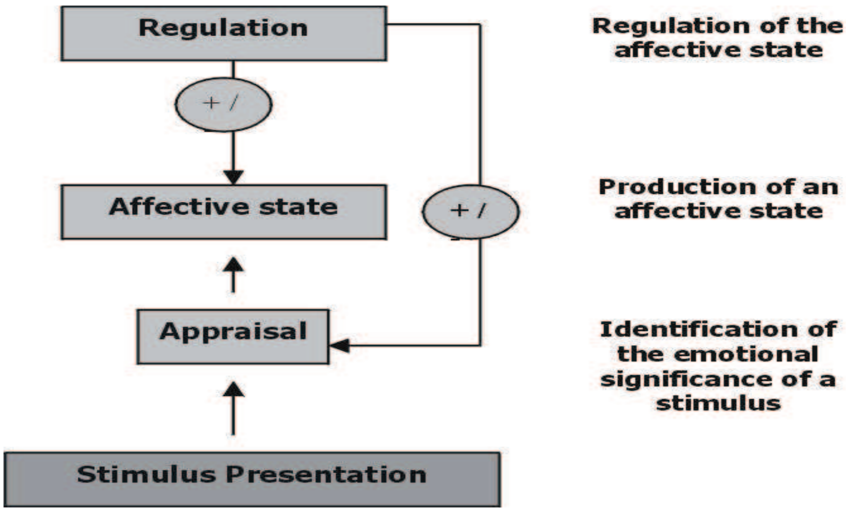

Figure 2.1: The illustration shows the main processes involved in emotion perception according to Phillips et al. (2003). Figure taken from Phillips et al. (2003).

following section will try to sketch out an emotional network. This thesis will address processing differences obtained so far by introducing an explicit prosody processing and an implicit prosody processing task (c.f. experimental study section).

2.1.3.2 Emotional Network

It has been proposed that emotional perception can be divided up into the following subprocesses after the first encounter with an emotionally laden stimulus: First, the emotional significance of an emotional stimulus has to be identified, i.e. a fast and early perceptual processing of the stimulus has to occur. Second, in response to the stimuli, autonomic, neuroendocrine, and somamotor processes have to be carried out, i.e., the detailed perception of the stimuli causes an emotional reaction in the body. Furthermore, it can be assumed that it is at this stageconceptual knowledge about the emotional stimulus comes into play. As a last subprocess, Phillips, Drevets, Rauch, and Lane (2003) have proposed the regulation of an emotional behavior, and this might "involve an inhibition or modulation of process 1 and 2, so that the affective state and behavior produced are contextually appropriate" (Phillips et al., 2003, pg.1; see also Figure 2.1). In the following section, brain structures that have been identified to play a key role in emotion processing will be listed.

2.1.3.3 Amygdala

Probably one of the most studied brain structures in emotion processing is the amygdala. Over the last few years, many studies concerned with various aspects of emotional processing have provided converging evidence that the amygdala plays an important role in the emotional network (e.g. LeDoux, 1996; Ochsner & Feldman Barett, 2001). As was mentioned previously, LeDoux and colleagues suggested that the amygdala is necessary for conditioned fear. Whether the almond-shaped brain structure is also necessary for the expression of fear is still under debate (Davidson, 2000). Even though there are few studies that were able to test patients with discrete lesions of the amygdala, the small number of existing studies have very much helped to provide researchers with important information about the amygdala's function in emotional processing. Several studies of patients with restricted amygdala lesions have demonstrated impaired recognition of fearful facial expression (Young et al., 1995; Adolphs et al., 1995; Adolphs, Damasio, Tranel, & Damasio, 1996; Calder et al., 1996). For instance, Calder et al. (1996) investigated facial emotion recognition in two patients with bilateral amygdala damage, and their results showed severe deficits in the recognition of fear. Activation of the amygdala in response to facial expressions of fear compared with happy, disgust, neutral, or control faces have also been reported in the literature of patient lesion data (e.g. Morris et al., 1996; Phillips et al., 1997). Furthermore, in studies by Adolphs and colleagues (1995, 1996), the recognition of facial signs of fear was impaired in patients with bilateral damage to the amygdala. Interestingly, the recognition of other emotions in facial expressions was not impaired. A number of neuroimaging studies have also reported activation and increased blood flow within the amygdala in response to the presentation of fearful (Breiter et al., 1996; Morris et al., 1996; Phillips et al., 1997), happy (Breiter et al., 1996), and sad (Blair, Morris, Frith, Perrett, & Dolan, 1999) facial expressions. For instance, in a PET study, Morris and colleagues (1996) compared the blood flow within the amygdala after presenting fearful and happy faces. Fearful faces elicited significantly greater blood flow compared to the reaction to happy facial expressions. Breiter et al. (1996) investigated temporal changes during activation of the amygdala and reported rapid habituation in the response to fearful faces. One year later, Phillips et al. (1997) were able to replicate this finding and went on to report that the amygdala is not activated by facial expressions of disgust. Amygdala activation by fearful facial expressions has even been found in masked presentations, i.e. when participants were unaware of the fearful face presentations (e.g. Whalen et al., 1998). However, amygdala activation has not only been found for fear, but also in response to unpleasant pictures in general (Irwin et al., 1996).

In addition to activations during the presentation of visual stimuli, the amygdala has also been reported to be activated in fearful emotional expression (Phillips et al., 1998). Scott et al. (1997) report a single case study in which impaired perception for fearful and angry vocal expressions has been found to activate the amygdala. They therefore concluded that the amygdala is not limited to processing visual aspects of emotional stimuli (see also Section 2.3.2).

Ochsner and Feldman Barett (2001) have tried to define the role of the amygdala in emotional processing more precisely. They suggest that the amygdala is a pre-attentive analyzer of an incoming stimulus, i.e. the amygdala "looks for" significant information that need to be "encoded" into memory. They further assume that this pre-attentive analysis is carried out for both threatening or rewarding stimuli. However, if the stimulus is found to be rewarding after all, other brain areas might play a more important role in subsequent processing, i.e., the amygdala is important for the initial encoding of the emotional significant stimulus, but plays a different role in the production of an emotional response when the stimuli is rewarding or positive and not threatening. The authors further conclude that the anatomy of the amygdala is consistent with this view, i.e. identification of the emotional significance of a stimulus can "reach" the amygdala via two possible routes. One route is through cortically based systems, while the other rout is through connections that bypass the cortical route, i.e. through a subcortical route with connections to sensory organs via the thalamus (c.f. also Aggleton, 1992).

2.1.3.4 Anterior Cingulate Cortex

In his review on the emotional brain, Dalgleish (2004) notes that several researchers assume the anterior cingulate cortex (ACC) to be a point that integrates attentional, visceral, and emotional information which might be involved in affect regulation (Bush, Luu, & Posner, 2000; Davidson, Lewis, et al., 2002). Others have suggested that the ACC serves a key function in the central representation of autonomic arousal (Critchley, Elliot, Mathias, & Dolan, 2000) or might be important for conscious emotional experience (Lane et al., 1998). In a study by Lane, Fink, Chau, and Dolan (1997) it has been found that the ACC is especially activated in a condition in which participants had to attend to their own subjective emotional responses after being exposed to emotional pictures. The authors also introduced a second condition in the experiment where subjects had to attend to the stimulus context (e.g. whether the scene on the picture occurs outdoors, indoors, etc.). When comparing the two conditions, significantly more activation of the ACC was found for the first condition involving attention to their emotions. Thus, it was also suggested that the ACC plays a key role in attentional aspects of emotional processing.

Staying with the assumption that the ACC plays a dominant role in integrating attentional, visceral, and emotional information in affect regulation (i.e., a key function in the regulation of emotional responses), Ochsner and Feldman Barett (2001) claim that this regulation can only be carried out if one knows that this procedure might be of importance. In their view, the ACC's role is to evaluate if there is a need for response regulation. They and others (Posner & DiGirolamo, 1998; Shallice, 1994; Stuss, Eskes, & Foster, 1994) further proposed that the ACC is part of an executive system that controls behavior in general, i.e. the system is not specifically bound to emotional behavior. This assumption might be true if one considers the anatomy of the ACC. Different parts of the brain have projections into different subregions of the ACC, the large area of cortex on the medial surface of each cerebral hemisphere just dorsal to the corpus callosum. Furthermore, this brain region has several connections to motor systems. While the more posterior parts of the ACC have projections into frontal, parietal, and subcortical parts of the brain thought to be involved in attention, the more anterior areas of the ACC have extensive connections to frontal parts of the brain and subcortical areas such as the amygdala, hypothalamus, and striatum, all thought to be involved in emotion processing (c.f. Ochsner & Feldman Barett, 2001).

An example for the role of the ACC in monitoring the regulation of behavior comes from an event-related fMRI study by Carter and colleafues (Carter et al., 1998). While the authors confirmed hypotheses that the ACC is activated while detecting errors, they also report the same kind of activity in the ACC when responses of subjects were correct but elicited under conditions of increased response competition. Therefore, the authors concluded from their study that the ACC is not activated due to an error per se, but rather because it was likely that an error would occur.

In summary, following Ochsner and Feldman Barett's (2001) discussion, it is concluded that the ACC's numerous subregions are involved in comparable functions but carry out these functions in various domains. These subregions collectively assist the ACC in appraising the suitability of feelings that one might be involved in by indicating conflict, uncertainty, or pain. Furthermore, the authors suggest that the ACC also plays a dominant role in evaluating whether an emotional stimulus will cause danger or discomfort and distress in the future. According to them, this estimation is embodied in consciousness, and other parts of an executive system concerned with regulation and self-monitoring can then use the ACC's evaluation.

2.1.3.5 Prefrontal Cortex

From an anatomical perspective, it has to be noted that the prefrontal cortex (PFC) is a heterogenous zone of brain tissue and is often divided into three subregions: the dorsolateral PFC (DLPFC), which is on the lateral surface of the prefrontal lobes; the ventral medial PFC (vmPFC), which is on the medial surface of the prefrontal lobes; and the orbito frontal cortex (OFC), which is the large area of the PFC on the anterior pole and interior surface of the prefrontal lobes right next to the eye sockets. Today, numerous studies of both animal and humans indicate that the various regions of the PFC are involved in emotion processing. However, there is no consensus as to what exact function the PFC is responsible for. Fol-

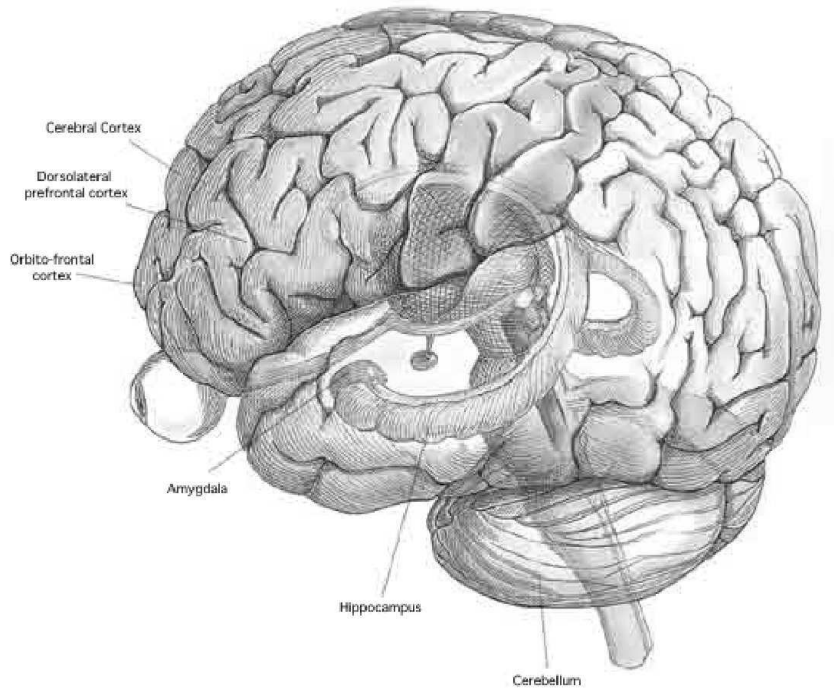

Figure 2.2: The figure above illustrates the prefrontal cortex, displaying the dorsolateral and orbitofrontal cortices, in particular. (Figure taken from www.psypress.co.uk/brainscans-etc/images/dehaan04.jpg; 11/08/2005).

lowing the discussion by Dalgleish (2004), three views of the PFC functioning are presented below. Figure 2.2 displays brain regions belonging to the prefrontal cortex.

Edmund Rolls proposed that the orbito frontal region of the PFC is engaged in learning the affective and motivational value of stimuli (Rolls, 1996, 1999). Together with the amygdala, PFC sectors collaboratively work to acquire and represent connections between primary and secondary reinforcers. Again, according to Rolls (1999), primary reinforcers are innate, such as food, drink, and sex, while secondary reinforcers are previously neutral stimuli that can, by association, come to be learned reinforcers.

Damasio and colleagues have proposed that the PFC plays a dominant role in bodily feedback in emotion. According to their somatic marker hypothesis (Damasio, Tranel, & Damasio, 1991; Damasio, 1994, 1996, 1997), they believe that the vmPFC processes are so-called somatic markers (physiological reactions) that enable us to get through "situations of uncertainty where decisions need to be made on the basis of the emotional properties of the present stimulus array. In particular, somatic markers allow decisions to be made in situations where a logical analysis of the available choices proves insufficient." (Dalgleish, 2004, pg.586).

Support for these assumptions comes from a study where Saver and Damasio (1991) tested a patient who suffered from a bilateral ventromedial frontal injury. The authors report that the patient showed intact cognitive functions as well as intact emotional knowledge, but he encountered great problems in social situations of uncertainty. Saver and Damasio proposed that the patient, due to his PFC damage, could not make use of somatic markers and so when using logical reasoning alone, he encountered problems in situations of uncertainty.

Davidson and colleagues (e.g. 2002) proposd that the PFC sectors send signals to different brain regions in order to guide action and organize behavior towards an appropriate adaptive goal, i.e. to carry out affect-guided planning and anticipation. According to Davidson and colleagues, the affect-guided anticipation is most often realized under circumstances of competition "from potentially stronger alternatives" (Davidson, Pizzagalli, et al., 2002) and they would expect the PFC to be activated in these cases. They also propose an asymmetry in PFC functions. In their valence-asymmetry model, right-sided PFC regions are believed to play a key function "in the maintenance of goals that require behavioral inhibition and withdrawal in situations that involve strong alternative response options to approach". Alternatively, left-sided PFC regions are first and foremost "involved in approach-related appetitive goals" (Davidson, Pizzagalli, et al., 2002).

Taken together, it can be concluded that emotional processing draws on multiple brain structures distributed between left and right hemispheres. It is not yet clear which exact role each of these structures play, but there seems to be convincing evidence that the structures need to interact in order to fully process emotional stimuli. The following section will deal with the role of the basal ganglia in emotional processing. Since most studies reviewed previously dealt with visual stimuli, there will also be a short summary of the findings directly related to brain regions involved in the recognition of emotional prosody.

2.1.4 Emotions and the Basal Ganglia

Before exploring the emotional function of the basal ganglia (referred to throughout as BG), a brief structural description of the BG and functionally associated areas will be given. Figure 2.3 displays the BG system.

The BG is composed of a grey matter subcortical structure located in the diencephalon and the mesencephalon. They include several nuclei such as the striatum (compromised of nucleus caudate and putamen), the globus pallidus, the subthalamic nucleus, and the substantia nigra (Tisch, Silberstein, Limousin-Dowsey, & Jahanshahi, 2004; Poeck & Hacke, 2001). The BG are part of an interconnected system of circuits that link the BG to other brain areas such as the cortex and the thalamus, and these circuits convey information con-

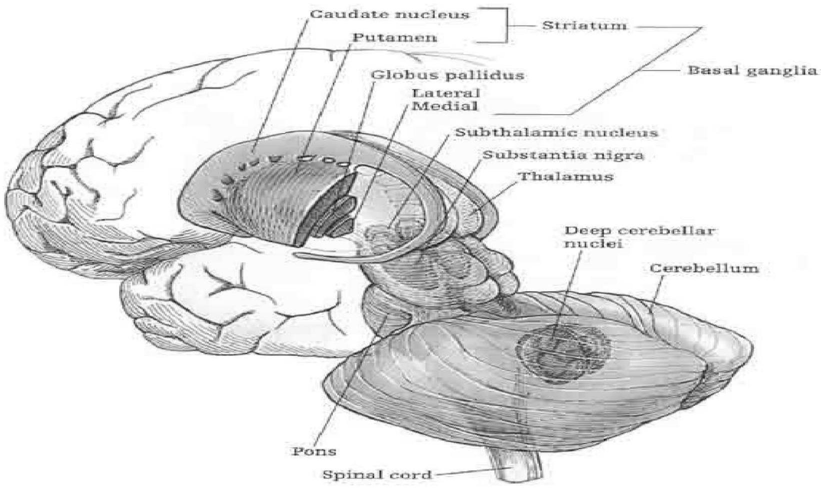

Figure 2.3: The illustration above shows the basal ganglia system. (Picture taken from www.psypress.co.uk/brainscans-etc/images/dehaan05.jpg; 11/08/2005).

cerning movement, cognition, and of special interest to this thesis, emotion. The striatum receives many afferents from the cortex and is thought to be the main input structure, while the globus pallidus and the subthalamic nucleus project mainly to the thalamus and the brainstem and are believed to be the main output structures. In the following, each nucleus is discussed separately.

2.1.4.1 *Corpus Striatum:*

The caudate nucleus and putamen form the corpus striatum. The caudate nucleus is a tail-like nucleus that extends in each cerebral hemisphere from the amygdala in a backwards direction, and it almost completely encircles the other nuclei of the BG. It can be divided into head (caput), body (corpus), and tail (cauda). The frontal part of the caudate nucleus is connected to the putamen by a series of fiber bridges. The putamen is situated in each cerebral hemisphere lateral to the globus pallidus. Between the putamen and the thalamus lies the globus pallidus. Ninety five percent of the neuronal population of the striatum are made up of efferent neurons, the so-called spiny neurons (named after the spikes on their dendrites). The spiny neurons consist of GABA, taurine, neuropeptides, and aspiny neurons (Tisch et al., 2004; Houk, 1995). There are two types of aspiny neurons, small and large ones. While the small aspiny neurons contain GABA, the large ones contain acetylcholine. The striatum is divided into weakly reactive patches (striosomes) and scattered with strongly reactive patches (matrix). The two patch types have different inputs, outputs, neurotransmitters, second messengers, neuropeptides, and receptors. This suggests a different role for each patch type (see Tisch et al., 2004).

2.1.4.2 *Globus Pallidus:*

As was mentioned above, the globus pallidus is located in each hemisphere between the thalamus and the putamen. The globus pallidus is made up of internal (GPi) and external (GPe) segments. The globus pallidus and the putamen are anatomically close, but considered functionally different (e.g Wise, Murray, & Gerfen, 1996; Haber, 2003). Whereas the putamen and the caudate nucleus are believed to be input nuclei, the globus pallidus is assumed to be an output nucleus. The three nuclei are located below the insula and are separated from the insulas grey matter by the claustrum, the extreme capsula, and the external capsula.

2.1.4.3 *Substantia Nigra (SN):*

The SN is a nucleus of the tegmentum. The SN is a component of the brainstem and due to its reciprocal connections with the BG, it is considered to be part of the BG system. The SN can functionally and neurochemically be differentiated into the pars reticulata and the pars compacta. Substantia nigra reticula efferents are GABAeric and inhibitory and project primarily to the thalamus (ventral anterior, ventral lateral, and dorsomedial nuclei) and the brainstem (superior colliculus, pedunculopontine nucleus). The pars compactas efferents are dopaminergic and project primarily to the neostriatum.

2.1.4.4 *Subthalamic Nucleus:*

Almost all cortical areas project to the subthalamic nucleus. The projections are glutamageric and excitatory from these several cortical areas, the primary motor cortex, the somatosensory cortex, the premotor cortex, the prefrontal cortex, and cingulum.

2.1.4.5 Functional approach to the Basal Ganglia:

As has become apparent in the previous paragraphs, the BG are composed of various subcortical brain regions. As manifold as the "morphology" of the BG is the proposed language function of the BG. However, whereas the language functions of cortical structures have been well explored by means of neuroimaging studies (ERPs, fMRI, PET) and lesion studies, the role of subcortical structures has been less extensively investigated. Furthermore, the role of subcortical structures in language processing has been discussed rather controversially in the literature.

Nevertheless, recent patient and imaging results have proposed that parts of the BG may be engaged during language perception. For example, an fMRI study by Friederici, Rüschemeyer, Hahne, and Fiebach (2003) reported activation of the left striatal complex during syntactic processing. A similar result was reported by Moro et al. (2001). But the BG have not only been shown to be activated during syntactic processing but also during lexical-semantic processing. Increased activation (or decreased activation in the case of Parkinson Disease patients, Huntington Disease patients, and patients with BG lesions) has been reported in several studies investigating lexical-semantic processing. For example, an activation increase has been found in studies exploring semantic judgement and categorization (Abdullaev, Bechtereva, & Melnichuk, 1998; Binder et al., 1997; Mummery, Patterson, Hodges, & Price, 1998; Pilgrim, Fadili, Fletcher, & Tyler, 2002; Price, Moore, Humphreys, & Wise, 1997), semantic working memory (Crosson, 1999), lexical decision (Abdullaev et al., 1998; Fiebach, Friederici, Müller, & Cramon, 2002), and semantic priming (Kotz, Cappa, Cramon, & Friederici, 2002).

However, more important for this thesis is the potential role of the BG in emotional prosody processing. For instance, lesions to the caudate nucleus have been reported to impair the perception of emotion conveyed through facial expression and prosody (e.g. Cohen, Riccio, & Flannery, 1994; Speedie, Wertman, Ta'ir, & Heilman, 1993). Interestingly, A. K. Anderson and Phelps (1998) have shown that the perception of prosody, which implies the integration of acoustic changes over time, is impaired by damage to the BG but not to the amygdala. Furthermore, Van Lancker and Pachana (1995) have shown that the production of nonverbal behavior (including emotional intonation as well as production of voluntary facial expressions) is impaired when there is damage to the putamen. Also, BG activation has been reported during positive, but not negative, emotional experiences after emotion induction with films, personal recalls, or personal experiences (Lane, Reiman, et al., 1997) and during the subconscious registration of positive faces (Morris et al., 1996). In addition, BG activation has also been found for sad recall memories (George et al., 1995; Lane, Reiman, et al., 1997), and the presentation of emotional words has elicited selective caudate activation (Beauregard et al., 1997).

Last, a number of neuroimaging and lesion studies on the perception of emotional prosody have suggested a highly distributed network involving cortical as well as subcortical brain structures (Adolphs, Damasio, & Tranel, 2002; Baum & Pell, 1999; Buchanan et al., 2000; George et al., 1996; Kotz et al., 2003; Wildgruber, Pihan, Ackermann, Erb, & Grodd, 2002; Wildgruber et al., 2004). However, it should be noted though that not all imaging studies described BG activation (Buchanan et al., 2000; George et al., 1996). The brain regions known to be involved in the recognition of emotional prosody will be summarized and discussed separately in Section 2.3.2. Thus, in summary, it seems obvious that the BG play a functional role in various processes during language and non-language functions. For example, Ochsner and Feldman Barett (2001) have suggested that the BG might be "important for coding the temporally patterned stimulus-stimulus and stimulus-response relationships that underlie implicit cognitive and motor skills. These implicit skills are essential because they allow us to make automatic the sequence of thought and action that lead to the attainment of goals and receipt of rewards of various kinds."

2.2 Prosody

The German saying "Der Ton macht die Musik" often serves as an explanation when introducing the term prosody to a non-linguist. Interestingly, the saying suits this purpose very well since it points to the importance of prosody in our daily communication. While we speak, we use a variety of emotional tones that give the correct meaning to what we are saying. A simple example is the difference between the statement: "Tim drives" and the question "Tim drives?". Depending on the way we rise, or do not rise, our voice when articulating these words, the interpretation of the utterance changes.

Speech relies on psychoacoustic parameters such as fundamental frequency (F0) and intensity, or loudness. Together with the speech rate, or duration, and rhythm, these parameters (and others not listed here) combine to form what we call suprasegmental parameters of speech, or prosody (see Figure 2.4). In Crystal's (1995) discussion on prosody, he claims that the most important suprasegmental feature is pitch (also called F0, measured in Hz). As mentioned in the example above, pitch variation can be used to convey non-lexical information, i.e. in a question, pitch is usually raised near the end of a sentence, but in a declarative statement intonation in English is most often marked by a falling ending.

The second important prosodic feature is loudness (usually measured in dB). For example, a raised voice is typically associated with an angry utterance, whereas a lowered voice could indicate a feeling of sadness or fear felt by the speaker.

Speech rate (usually measured in ms or s) is the last of the three basic parameters that are most often subsumed under the term prosody (e.g. Van Lancker & Sidtis, 1992). Duration refers to the time structure, or tempo of speech units such as syllables, words, or pauses.

Shih and Kochanski (2002) list four functions of prosody: 1) Prosody is used to convey lexical meanings, e.g. in tone languages such as Chinese-Mandarin; 2) Prosody is used to convey non-lexical information through intonation (as in questions versus declarative sentences as in the example above); 3) Prosody is used to convey discourse functions, e.g. new information in a discourse is often accented while old information is deaccented; and 4) Prosody is used to convey emotion, e.g. excitement is expressed with high pitch and fast speed (see Table 2.1 below). Taken together, one can conclude that prosody serves a linguistic function and an emotional function. One of the linguistic functions of prosody that has been extensively studied with the help of event-related brain potentials (ERPs)

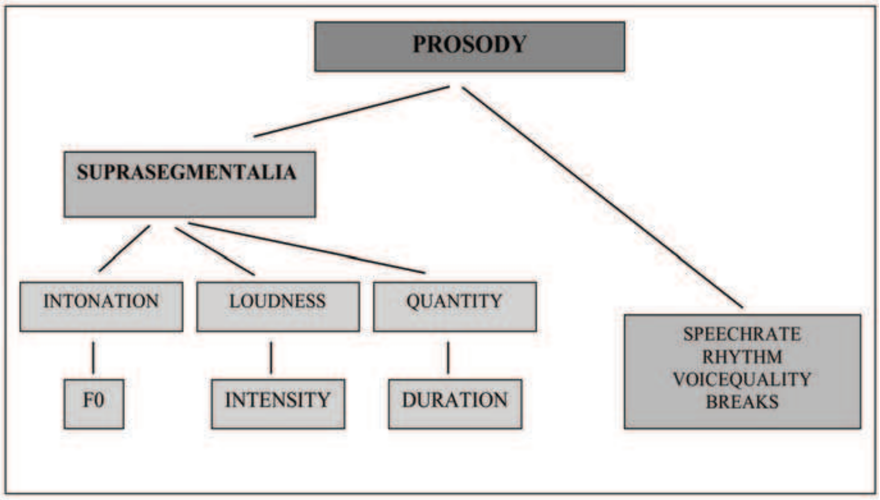

Figure 2.4: The illustration shows prosodic criteria after Moebius (1993). Figure adapted from Alter (2002).

over the last few years is prosodic phrasing. For example, Steinhauer, Alter, and Friederici (1999) found the so-called closure positive shift (CPS) to be an ERP correlate of the processing of prosodic phrasing. The CPS has since been found in studies using normal speech (Steinhauer et al., 1999), filtered-delexicalized speech (Steinhauer & Friederici, 2001), and hummed speech (Pannekamp, Toepel, Alter, Hahne, & Friederici, 2005). Because the second function of prosody, namely to convey emotion, is of particular importance for the following experiments, it is discussed in more detail in the next subsection.

2.3 Emotional Prosody

As was mentioned previously, humans start communicating their feelings from the very first day on. In order to get a better idea of this emotional vocalization, this section will start out with a brief introduction to the voice production system and how its different realizations might influence emotional prosody processing.

To vocalize (emotions), our lungs have to produce energy required for vocalization by filling the trachea below the closed glottal folds with air. Together with motor commands to the laryngeal musculator, this subglottal air pressure brings about phonation, i.e., vibration of vocal folds release air pulses into the supraglottal vocal tract. In order to articulate, the series of pulses which are released in the supraglottal vocal tract are varied by tongue, lips, or jaw movements (c.f. Scherer, 1989). In short, vocalization of speech therefore involves three physiological processes, i.e. respiration that provides flow of air, phonation

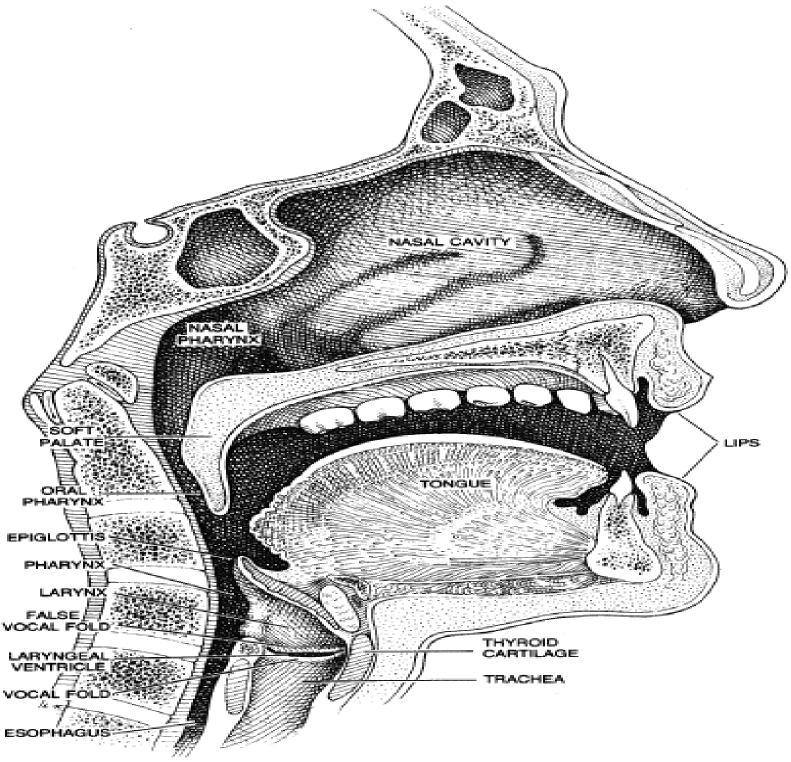

Figure 2.5: The illustration shows the human vocal tract. (Illustration taken from www.columbia.edu/itc/psychology/rmk/T1/VTract; 11/08/2005).

that transfers flow of air from lungs into sounds, and articulation that modulates speech sounds. Figure 2.5 gives an overview of the speech production system.

Following Scherer's (1989) review of the physiological and neurological systems that control the production mechanisms of vocalization, linguistic speech production and emotional vocalization can be distinguished. Scherer suggests that linguistic speech production is primarily controlled by the neocortex since speech production is mainly modulated by motor movements, whereas the emotional vocalization is, first and foremost, controlled by the limbic system. He proposes that effects of emotional arousal on the speech production process are primarily produced by the tonic activation of the autonomic and somatic nervous system. Their effects, such as respiration, phonation, and articulation influence the nature of the vocal output (e.g Scherer, 1986).

As Scherer (1986) notes, the vocalization of (emotional) expressions can very easily be influenced by e.g., slight changes in physical regulation. Nevertheless, Banse and Scherer (1996) have tried to define acoustical profiles in vocal emotion expression with the help

	Emotions				
Acoustic Parameter	ANGER	DISGUST	FEAR	HAPPINESS	SADNESS
F0	>	< >	>	>	<
Intensity	>	>	>	>	<
Speech Rate	>	?	>	>	<

Table 2.1: Predicted emotion effects for selected acoustic parameters according to the component process theory by Scherer (1986). Note: F0 = fundamental frequency; < = decrease; > = increase; ? no prediction made. All predictions were made in comparison to "normal" speech. No general predictions for the emotion of pleasant surprise have been made.

of several acoustic parameters. One of their main findings is that each emotion seems to have its own acoustic profile. For example, the vocalization of anger revealed a higher fundamental frequency than did the vocalization of sadness. Furthermore, intensity measurements revealed louder vocalizations for happy utterances than for sad ones. Within their study, Banse & Scherer (1996) also supposed that vocal parameters can often be good indicators of physiological arousal, i.e., high-stress conditions such as anger were found to be expressed by greater intensity and/or higher speech rate in the vocal expressions. A summary of their findings is given in Table 2.1 and will be referred to again in the experimental study section when introducing the stimulus material used in this thesis.

2.3.1 Lateralization of Emotional Prosody

One aspect that has been of particular importance in the study of emotional prosody is the question of lateralization in perception. A second concern has been the extent to which lateralization can be functionally influenced by specific emotional tones. Regarding the first question, there has been no commonly agreed upon model developed throughout the last 30 years. In the broadest sense, this controversial issue is a consequence of several manipulations and techniques that have been used experimentally, mainly in clinical groups. Ross and colleagues (1997) first criticized the fact that in many patient studies, there has been no conscious effort made by researchers to define the size or the place of the lesion in the patient precisely. According to the authors, this is one reason for the very heterogeneous results obtained, so it would be impossible to define the lateralization of emotional prosody precisely. A second concern has been raised by Pell (1998), who noted that in most of the existing clinical studies, the influence of linguistic and prosodic factors were not adequately controlled for. The following subsections will give a short overview of the existing guiding hypotheses.

2.3.1.1 Right Hemisphere Hypothesis

Primarily receptive, but also expressive, clinical studies support a hypothesis of right hemispheric lateralization of emotional prosody. In comparison to the processing of purely linguistic prosody, which also helps to structure and emphasize syntactical phrases within the speech signal, some authors claim that both linguistic and emotional prosody are processed in the right hemisphere (e.g. Bryan, 1989; Dykstra, Gandour, & Stark, 1995). However, other studies, in which both prosody types were investigated show that only emotional prosody (e.g. Blonder, Bowers, & Heilman, 1991; Borod, 1993; Starkstein, Federoff, Price, Leiguarda, & Robinson, 1994) or only linguistic prosody (e.g. Weintraub, Mesulam, & Kramer, 1981; Brådvik et al., 1991) is processed in the right hemisphere.

Heilman, Scholes, and Watson (1975) investigated a group of patients with left and right tempo-parietal lesions. Participants were presented with sentences of neutral semantics but vocalized with four different emotional prosodies. Subjects were asked to identify the meaning of the utterance. Patients with lesions in the right hemisphere performed worse than patients with left hemisphere lesions. The authors interpreted their results in terms of the right hemisphere hypothesis for emotional prosody processing. Tucker, Watson, and Heilman (1977) replicated this study, but they also included a second task where two utterances had to be judged as being the same or different with regard to their emotional meaning. Again, patients with lesions in the left hemisphere outperformed patients with lesions in the right hemisphere. A study by Bowers, Coslett, et al. (1987) also showed better performance for left hemisphere lesion patients than for right hemisphere lesion patients in an emotional prosody recognition task. Still, it should also be noted that considerable data have challenged the solely right hemisphere hypothesis in emotional prosody processing (e.g. Darby, 1993; Van Lancker & Sidtis, 1992).

2.3.1.2 Functional Hypothesis

Furthermore, other research on linguistic prosody processing at the sentence-level show a selective influence of the left hemisphere (Van Lancker, 1980; Emmorey, 1987). Van Lancker (1980) argued that depending on the linguistic load, the processing of prosody is either left or right hemispheric orientated (functional lateralization-hypothesis). Thus, the relation of lateralization and processing of prosody forms a continuum. The more linguistically emphasized the task, the more the left hemisphere is involved. Theoretically, one could also expect that the smaller the linguistic load, the stronger the right hemisphere would involved.

An alternative to a strong right hemispheric lateralization hypothesis, and a more detailed functional lateralization hypothesis was postulated by Van Lancker and Sidtis (1992) as well as by Zatorre and colleagues (2002). The so-called parameter dependence lateralization hypothesis states that prosody perception is ruled by acoustic parameters such as pitch, duration, and intensity. In the above studies, it was found that pitch is processed preferably in the right hemisphere, whereas duration and intensity are primarily processed in the left hemisphere. In studies by Ouellette and colleagues (1993) and earlier works by

Zatorre (e.g., 1988) it is noted that prosody perception occurs independently of emotional or linguistic input of the speech signal.

In the experiment by Van Lancker and Sidtis (1992), results suggested that left hemisphere- and right hemisphere-damaged patients, when judging affective meaning, used acoustic cues to prosody differently, i.e. left hemisphere-damaged patients based their decisions primarily on F0 variability, whereas right hemisphere-damaged patients relied on durational cues when identifying the affective meaning of the stimulus. The notion of a more basic disorder in analyzing the acoustic properties of prosody in brain damaged patients received further support from studies using non-linguistic tasks in which patients also showed deficits in using auditory cues. Whereas left hemisphere superiority has been suggested for the processing of time structure cues in non-linguistic tasks (Carmon & Nachshon, 1971; Robinson & Starkstein, 1990), the right hemisphere has been shown to be involved in pitch processing (Robin, Tranel, & Damasio, 1990; Sidtis & Feldmann, 1990; R. Zatorre, Evans, & Meyer, 1994). Taken together, these data speak in favor of a functional lateralization hypothesis. It should be noted, though, that this view is not without challenge, as rather recently, Pell and Baum (1997) found no evidence for functional lateralization of emotional prosody (but see Section 2.3.1.4 below).

2.3.1.3 Valence Hypothesis

With regard to the second concern that is of relevance for the processing of emotional prosody (i.e. the extent to which lateralization of emotional prosody can be influenced by specific emotional tones), the valence hypothesis needs to be briefly mentioned again. A possible valence-specific processing of emotional prosody is discussed in relation with depression. Davidson, Abercrombie, Nitschke, and Putnam (1999) reported that patients in a depressive mood (who are often preferred in hemispheric field research) process positive emotions in the left hemisphere, but negative emotions in the right hemisphere. In contrast, Ross and colleagues (1981; 1997), as well as work by Pell and Baum (1997) speak against the valence-dependent lateralization of emotional prosody, because, according to the authors, there is no evidence that supports this hypothesis.

2.3.1.4 Summary and Concluding Remarks

The short survey above clearly shows that research (especially patient studies) dealing with the processing of emotional prosody, and linguistic prosody in particular, has given very little convergent evidence that prosody is solely processed in the right hemisphere (also see Baum & Pell, 1999, for similar conclusions). As mentioned above, plausible factors for this divergence are the selection of patients and imprecise lesion description, and aspects such as times of the investigation (i.e., how much time has passed since the first diagnosis) that may cause possible compensation strategies and/or reorganization leading to functional as well as structural changes. Another reason for varying results can be lesion accompanying deficits (e.g., depression, neglect). Furthermore, stimuli characteristics play an important role. A study by Van Lancker (1980) successfully showed that receptive investigations regarding prosody on sentence-level (and thus communication-bound aspects) can lead to less obvious lateralization effects than investigations on prosody at the word-level only. In addition, Tompkins and Flowers (1985) showed that the degree of task complexity when judging emotional prosody correlates with the degree of lateralization, i.e. the more complex the task, the less left hemispheric involvement when processing emotional prosody in language.

Thus, the following remains to be solved: 1) the extent to which the right hemisphere plays a dominant, potentially prosodically unspecified (linguistic and emotional) role (Blumstein & Cooper, 1974; Heilman, Bowers, Speedie, & Coslett, 1984; Starkstein et al., 1994) and 2) whether linguistic as well as emotional prosody is processed functionally within a bilateral network (Bryan, 1989; Cancelliere & Kertesz, 1990; Dykstra et al., 1995; Pell & Baum, 1997; Van Lancker & Sidtis, 1992). According to several authors, this bilateral network also includes sub-cortical areas such as the BG (Brådvik et al., 1991; Blonder, Gur, & Gur, 1989; Cancelliere & Kertesz, 1990; Pell, 1998). In studies about the perception of non-verbal vocalization of emotions (sad, happy, frightened, and neutral), Morris, Scott, and Dolan (1999) identified bilateral activation in the nucleus caudatus, the anterior insula, the anterior temporal lobes and in the ventral prefrontal cortex. The right amygdala was especially activated during the perception of vocalization of fear, but not with other emotions. This last finding confirms data from a patient study by Scott et al. (1997) in which a selective deficit for the perception of fear-emphasized vocalization was found for a patient with bilateral amygdala lesions (but see also Section 2.3.2 for a more detailed review on brain regions involved in emotional prosody recognition).

Potential problems of clinical models of processing emotional prosody can be addressed with the help of imaging techniques in "healthy" subjects. Event-related brain potential (ERP) and behavioral research shows that linguistic prosodic features and language-specific sub-processes like semantics and syntax interact (Cutler, Dahan, & Donselaar, 1997; Steinhauer et al., 1999; Warren, Grabe, & Nolan, 1995). Also, there are imaging technique investigations of processing emotional prosody that show that the emotional prosody of language comprehension is processed in the right hemisphere (Buchanan et al., 2000; George et al., 1996; Pihan, Altenmüller, & Ackermann, 1997; Meyer, Alter, Friederici, Lohmann, & Cramon, 2002). However, this claim can be put into perspective if one looks at results from Pihan and colleagues (2000) and Kotz et al. (2003), who have shown that emotional prosody may also lead to bilateral activation patterns.

2.3.2 Brain Regions involved in the Recognition of Emotional Prosody

Apart from the question of the lateralization of emotional prosody, it is also of special interest to specify which brain regions might be most critical to the recognition of emotional prosody. The following paragraphs will briefly summarize the most important findings.

As has been mentioned previously, it is assumed that cortical as well as subcortical brain structures are part of a highly distributed network involved in the perception of emotional prosody. For instance, Starkstein et al. (1994) have suggested the involvement of, among other areas, right fronto-parietal regions in the recognition of emotional prosody. Hornak, Rolls, and Wade (1996) reported predominantly right orbito-frontal regions, and Breitenstein et al. (1998) reported right frontal brain involvement when recognizing emotional prosody. During the perception of emotional prosody, significant blood flow changes have been reported in the right dorsal and ventral prefrontal cortex and also in the right insula and right amygdala by functional imaging studies (George et al., 1996; Morris et al., 1999). Buchanan et al. (2000) have reported right prefrontal cortex, right anterior parietal cortex, and left frontal lobe activation in an fMRI study of emotional prosody. Other imaging studies have found activations in right inferior frontal regions (Buchanan et al., 2000). As has been mentioned before, subcortical structures also seem to be involved in processing emotional prosody. Cancelliere and Kertesz (1990) carried out a study with brain damaged patients and found that impaired prosody recognition was often associated with damage to the BG in addition to cortical damage. The role of the BG in emotional prosody processing has also been suggested by two studies of Breitenstein and colleagues (Breitenstein et al., 1998, 2001). In their 1998 study, patients with focal cortical lesions as well as Parkinson patients were tested in both facial expression and emotional prosody recognition. The authors report that only patients with focal damage to the right frontal lobe and patients in advanced stages of Parkinson's Disease were found to be impaired in both modalities. In a fMRI study carried out by Morris et al. (1999), healthy participants listened to fearful, sad, happy, and neutral non-verbal vocalizations, and the authors suggested a bilaterally distributed network of brain regions that are involved in the processing of verbal emotions. Whereas enhanced activity to all emotional vocalizations was found in the caudate nucleus, the anterior insula, and in both temporal and prefrontal cortices, decreased activation was found in the right amygdala after presentation of fearful vocalizations. Kotz et al. (2003) compared brain activation patterns in healthy participants in response to normal speech and PURR-filtered speech (in this case, the semantic and syntactic context was filtered out, leaving only the prosodic characteristics of the stimulus). The authors found a bilaterally distributed BG activation pattern. However, in response to normal speech, a temporo-putaminal network was found, but in response to filtered speech, a fronto-caudate activation was obtained. Last, in a recent study by Pell and Leonard (2003), Parkinson patients and controls were tested on various tasks involving the processing of emotional prosody (discrimination, identification, and emotional feature rating). Parkinson patients showed difficulties in a range of contexts, so the authors argued that the BG play a critical role in emotional processing.

In summary, it is proposed that in addition to left- and right-lateralized cortical structures, subcortical structures such as the BG play a key role in emotional prosody processing. However, it seems that these structures of the bilateral network do not play equal roles, but rather, their contribution may rely on task and stimulus type.

2.4 Auditory Language Comprehension

Within the psycholinguistic literature, there is agreement that auditory language comprehension relies on various sub-processes that involve interaction and integration between one another. Various linguistic theories and psychological models attempt to explain the processes of language comprehension. However, there is less agreement on how these different sub-processes are represented and how they interact over time. Even though existing models differ greatly in detail, most models agree that the following sub-processes have to be part of the language comprehension process (c.f. Schreuder & Weltens, 1993); First of all, an "input system" has to process the auditory language input or phonological information. Second, information about semantic and morphological aspects of words have to be processed, and third information about the grammatical rules of a language or the syntactical aspects have to be processed. This information has to be accessible with milliseconds. Moreover, the different information levels have to interact within milliseconds if normal language comprehension is to be guaranteed (Friederici, 2002).

The psycholinguistic models vary in how and when these different sub-processes occur and interact. So-called serial models with autonomous search processes (e.g. Forster, 1981) can be distinguished from parallel and interactive models (e.g. Marslen-Wilson, 1984; MacWhinney & Bates, 1989), while some models combine autonomous and interactive processes as in the cohort model of word recognition (Marslen-Wilson, 1987). Many behavioral off-line experiments in which participants react after they heart a stimulus and on-line experiments in which ERPs are measured neuropsychological have been carried out to explore the different processes involved in spoken word recognition (for a review, see e.g., Lively, Pisoni, & Goldinger, 1994; Tannenhaus & Trueswell, 1995).

Even though various models exist, few models have suggested how suprasegmental information can be integrated. However, there is empirical evidence that suggests that prosodic information is in fact used during language comprehension processes. For example, investigations with different paradigms have shown that prosody can modulate spoken word recognition. It has been proposed that the various suprasegmental information such as pitch accent (Cutler & Otake, 1999) or stress (Cutler & Donselaar, 2001) are encoded at the lexical level. For example, words that equal each other in their segmental onset can be distinguished by their prosodic information and word recognition is speeded up with the help of this prosodic information, in segmentally ambiguous words onsets. Furthermore, tone languages like Mandarin or Cantonese rely on prosodic information to distinguish between words that share segmental structure but differ in meaning. Also, it has been shown that prosody can help listeners to establish a syntactic structure (Steinhauer et al., 1999). In addition to verbal information, prosody also provides an emotional context.

One model that has taken the role of prosody into account is the dynamic dual-pathway model by Friederici and Alter (2004). Friederici and Alter propose that sentence-level prosody is processed in a right-lateralized temporo-frontal network, while the verbal content of an utterance is processed in a left-lateralized temporo-frontal network. This network includes separate circuits for syntactic and semantic information needed to decode the auditory signal. In order to convert sounds into words, analyze them grammatically, and put them into a meaningful sentence, continuous feedback between syntactic and semantic sources is required. The authors proposed a right-hemispheric temporo-frontal pathway for sentence-level prosodic processing, but they did not specify if their model also applies to the processing of emotional prosody.

In summary, various models of auditory language comprehension exist, but unfortunately, none really integrates the influence of affective prosody. The following study aims to help specify when emotional prosody and emotional semantics interact in time. With help of the BG-lesion patient study, it will also be possible to evaluate the possible role of the BG in emotional prosody processing.

Chapter 3

Event Related Brain Potentials and Emotional Prosody

3.1 Event Related Brain Potentials

This introductory chapter will explain the definitions and the vocabulary of an ERP-researcher by introducing how an ERP signal is obtained and analyzed. Second, a brief review of components of special interest to psycholinguists will be provided. Third, there will be a brief review of studies of emotional prosody processing of relevance to this thesis, and a section discussing the methodological advantages of the ERP method that will serve as an explanation of why the method was chosen for the following study. Please note that the given discussion is largely based on Osterhout (1995).

3.1.1 Basic Terminology

As mentioned in the introduction, the use of language is a value that is specific to human beings. Language enables us to communicate our thoughts and feelings. Therefore, the importance of language cannot be valued highly enough. However, despite the importance of language, whether we deal with language comprehension or production, most of the underlying processes seem to remain a mystery. Both comprehension and production of language occur very rapidly and a satisfying model that describes the processes as they unfold over time including features of language like prosody has yet to be developed. One reason why the underlying processes of language comprehension remains not entirely understood is the lack of adequate methodologies that allow for on-line measurement of psychological processes. Often researchers measure at discrete points of time (usually after the task) which means that the underlying process(es) cannot be observed.

Therefore, an imaging technique measuring brain activity, namely electroencephalography (EEG), is used more and more often as an investigative tool by researchers. In the application of this technique, electrodes are attached to the head surface and connected to amplifiers. The electrical activity which is produced when brain cells are activated can be recorded. Small electrical signals are detected by the scalp electrodes and are amplified thousands of times and then displayed. This derivation procedure does not cause any kind of penetration, the method is completely non-invasive, can be applied repeatedly to subjects, and can be used to study language-related processing. The most useful application of EEG recording for this purpose is the ERP technique, which will be further explained below.

As mentioned above, electrodes are used to record voltage fluctuation between two electrode sites. The question of where those electrodes should be placed has been resolved, as most researchers employ a procedure which is known as common reference. The system is based on the relationship between the placement of an electrode and the underlying area of the cerebral cortex. It assumes four standard points of the head, namely the nasion (point between the forehead and nose), inion (bump at back of skull), and two points close to the auricular (ears). As can be noted in Illustration 3.1, each electrode has a descriptor, which refers to a particular brain area (i.e. frontal, temporal, central, parietal and occipital). Odd (1,3,5,7) numbers stand for the left, even (2,4,6,8) numbers for the right hemisphere and the letter "z" refers to an electrode placed on the midline. It should be noted that the smaller the number, the closer the position is to the midline. However, it should also be noted that the activity measured at a certain electrode does not necessarily reflect the activity from the particular brain region of that electrode. (I.e., activity measured at F3 does not mean that the information was processed in the frontal lobe).

A brain wave which is evoked through a presented stimulus is called ERP. This ERP is to be distinguished from neural brain activity which is always present in a brain of a living human being. It appears that these brain waves, or components, first reflect the features/properties of the stimuli, i.e., its intensity, but then begin to reflect cognitive processes, as for example the evaluation of the stimuli by the subject. To make it a bit clearer: a subject is presented a stimulus while recording the EEG, one can then define an epoch, or time period, of the EEG which is time-locked to the stimulus (i.e., the time period may begin 100 ms before the onset of the stimulus and end 700 ms later). As there is possible voltage variation within this time period, one can assume that these changes are specifically due to the presented stimulus. Thus, ERPs are small voltage variations resulting from the brains response to the stimulus. The series of voltage peaks and valleys caused by a stimulus, are called components (the issue of several language related components will be dealt with in more detail later in this section). Even though it is generally accepted that ERPs reflect brain activity, the relationship between the scalp recording and the brain activity is not yet completely understood. Furthermore, there should be an awareness that there are numerous processes which can neither be explained nor detected with the help of the ERP technique.

Clearly, not only brain activity evoked through the stimulus, but also other activity is measured with an EEG. Therefore, special artifacts, such as eye-movements or any other

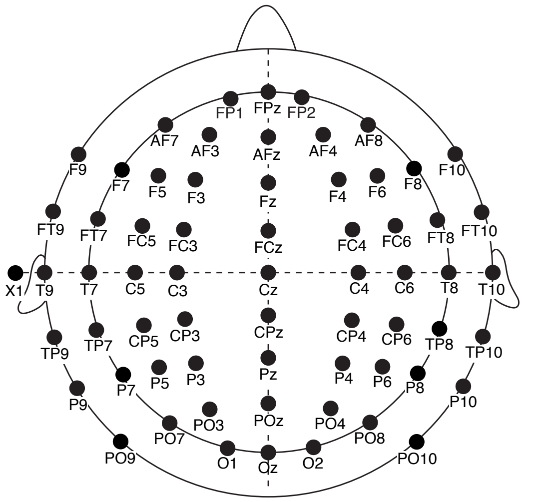

Figure 3.1: The illustration shows the electrode distribution according to the 'common reference'. Each electrode has a descriptor that refers to a particular brain area (for a detailed explanation refer to the text).

muscle movements have to be filtered out. Furthermore, and as noted above, each epoch of an EEG is time-locked to the onset of a particular presented stimulus. The voltage fluctuations, which constitute the ERP, are rather small in relation to the EEG waveform. Therefore, it is necessary to extract the time-locked ERP, or signal, from the background EEG, also called "noise". One of the most commonly used techniques for this elimination is averaging. In this procedure the average ERP originates when for each time point in the epoch the digital EEG values are averaged to display a single vector of values representing the average activity at each time point. (Assuming that not to the event-time-locked EEG-activity will unspecifically vary across epochs, the "noise" will tend to average to zero). Therefore, the residual waveform after the process of averaging should massively represent activity that conveys a fixed temporal relationship to the event across epochs. The procedure of averaging is also done over all participants of a study, resulting in a more reliable result. Usually, for an EEG study 12 to 32 subjects and usually 30 trials for each condition are needed to obtain a reliable result. Please see Illustration 3.2 for a depiction.

As previously stated, the ERP component mainly reflects the peaks and valleys of an EEG which are evoked through the stimulus. Although the EEG itself is not interpretable, when averaged over subjects and over trials, the ERP can be calculated. One problem that researchers are confronted with is the so called 'component overlap'. This term refers to the problem that one particular waveform observed, i.e. a peak or valley, might result from different electrical activity generated from different brain locations. This means, that be-

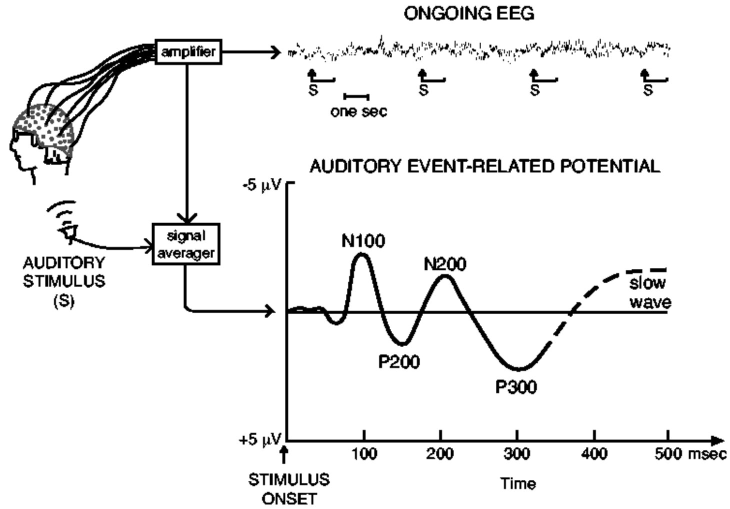

Figure 3.2: The picture illustrates how an EEG-signal is obtained and how an ERP-component is extracted from the background EEG (adapted from Coles and Rugg, 1995).

cause an electrode does not necessarily measure the activity from the place it is located, the voltage fluctuation might result from different generators in different locations. Therefore, it is not only helpful but also necessary to define an ERP component as accurately as possible. There are two approaches currently adopted: the 'physiological' and the 'functional' approach. Within the physiological approach researchers try to define an ERP component according to its anatomical source within the brain. In this case it is important to disambiguate sources that might contribute to the component but are not of interest. The second approach tries to define an ERP component more in terms of the information with which it correlates, and in terms of the cognitive processes to which it is related. This means, that researchers have to isolate the component by defining its waveform and then subtracting it from waveforms obtained under other conditions. Nevertheless, the problem of identification of components still remains to be solved. There is yet not one technique that is able to handle all possible occurring problems. However, even though the techniques being used now are far from perfect, certain ERP components have been identified and their definition is generally well accepted.

3.1.2 Language-related ERP Components

As mentioned in the previous section, components are evoked through a stimulus. They are marked according to their polarity, where P stands for positive and N for negative, their latency (e.g., N400 is a negative peak occurring 400 ms after the onset of a stimulus), or their waveform (e.g., N1 stands for the first negative peak). It can be distinguished between early or late components. An early component, sometimes referred to as an exogenous component, is influenced by the physical features of a stimulus and is almost completely unaffected by the changes in the cognitive state of a subject (Hillyard & Picton, 1987). In contrast, the later, or endogenous, components are believed to reflect the cognitive state of the participant. Therefore, these late components are of special interest to researchers, as it might be possible to get an insight of human cognitive processing through them.

3.1.3 The N100/P200 Components

Two ERP components that are most often elicited by auditory stimuli, are the N1, a negativity occurring between approxiametly 75-150 ms post-stimulus onset, and the P2, a positivity with a latency of approxiametely 150-250 ms. These early components are elicited by attended and unattended stimuli, leading to the assumption that they are exogenous components (Crowley & Colrain, 2004). It should be noted that even though the P200 component is typically thought of as an exogenous component, there is some evidence suggesting it is an endogenous ERP-component reflecting higher cognitive processes (e.g. Dunn, Dunn, Languis, & Andrews, 1998). Both, the N100 and the P200 component are thought to reflect physical stimulus features (Luck & Hillyard, 1994a).

Even though the two components co-vary along many stimulus dimensions, the P200 component can be dissociated topographically (Vaughan, Ritter, & R., 1980), experimentally and developmentally (Oades, Dittmann-Balcar, & Zerbin, 1997). Particularly interesting for the following studies is the fact that the P200 is known to be influenced by stimulus pitch (Pantev, Elbert, Ross, Eulitz, & Terhardt, 1996) and intensity (Picton, Woods, Baribeau-Braun, & Healey, 1977). Also, several studies suggest that the P200 varies with age (Crowley & Colrain, 2004). Functionally speaking, it has been shown that the P200 ERP component increases when participants are asked to attend to a particular stimulus characteristic, as e.g. color or size (Hillyard & Münte, 1984), and is therefore often assumed to reflect selective attention processes. For example, in a visual-search-task study by Luck and Hillyard (1994a), increased P200 amplitudes have been observed for several features of targets such as orientation, size, and color of the stimulus. Thus, the authors interpreted the P200 component to mirror a "transdimensional feature detection process" (Luck & Hillyard, 1994b, pg.,305). Furthermore, it has been suggested that the P200 amplitude increases with increasing (subjective) relevance of a stimulus (e.g. Carretié & Iglesias, 1995). Also, the P200 has been reported to be elicited in semantic contexts (Boddy & Weinberg, 1981; Vartanov & Pasechnik, 2005). For example, in a semantic priming study by Boddy and Weinberg (1981), P200 amplitudes were larger for positive compared to negative instances of primed categories. Vartanov and Pasechnik (2005) report the P200 to correlate with complexity of semantic analysis, i.e. with increasing complexity of semantic analysis the P200 amplitude decreases. Last, the P200 has also been reported to be modulated by emotional stimuli (Carretié & Iglesias, 1995; Ashley, Vuilleumier, & Swick, 2004). For instance, Ashley et al. (2004) presented upright and inverted pictures of emotional facial expressions. The authors report enlarged P200 amplitudes for upright fearful faces.

Taken together, there is evidence that exogenous as well as endogenous process affect the P200 ERP component (for a detailed review of the two components see Crowley & Colrain, 2004). Illustration 3.3 depicts typical N100/P200 waveforms.

3.1.4 The P300 Component

A component that was discovered more than 30 years ago and which has usually been correlated with detection/discrimination processes is the P300. This positivity is elicited 300-500 ms post-stimulus onset. The P300 is often differentiated as the P3a or "novelty" P300 (Courchesne, Hillyard, & Galambos, 1975) and the P3b (Courchesne et al., 1975) component. Whereas the P3a is large over frontal/central electrodes, the P3b has its maximum over central/parietal electrode sites. As in the original study by Sutton et al. (1965) the component is usually elicited in a so called "oddball" paradigm. Within this paradigm, there is the presentation of two different stimuli at a random order and participants have to discriminate the infrequent target stimulus from the standard stimulus. This discrimination occurs either actively (via button press) or passively (silent counting). The target stimuli then elicits the P300. This component can be elicited with auditory, visual and somatosensory stimuli (Courchesne, Kilman, Galambos, & Lincoln, 1984; Knight, 1984; Yamaguchi & Knight, 1991). Whereas the P3a has been interpreted in terms of an orienting response towards novel events (Yamaguchi & Knight, 1991), the P3b component seems to be correlated with inhibition processes during processing of expected targets (e.g. Heit, Smith, & Halgren, 1990). Illustration 3.3 depicts a typical P300 waveform.

3.1.5 The N400 Component

One of the most frequently described language related ERP components in the literature is the so called N400, a negativity between 250ms and 600ms, with a peak at around 400ms post-stimulus onset. The classical N400 has a posterior, right lateralized distribution. This special component is believed to be very sensitive to meaning. It was first observed by Kutas & Hillyard (1980) in a study of sentence processing. In their study subjects had to read sentences with the final word either being semantically inappropriate to the sentence but syntactically correct, larger in letter size, or appropriate in semantics, syntax, and letter size (control condition). The N400 was elicited under the first condition, a classical P300 under the second condition, but none of the components were elicited under the last condition. This result led Kutas & Hillyard to the conclusion that the N400 component is especially

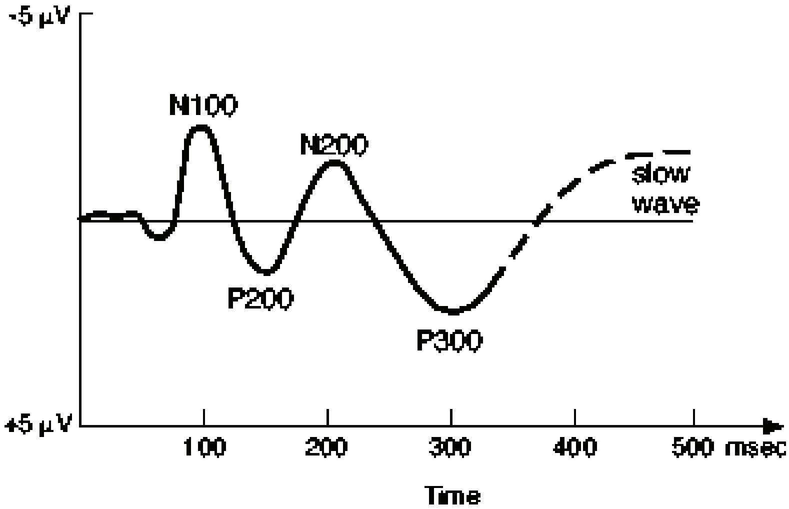

Figure 3.3: The picture illustrates an ideal waveform of the N1, P2, and P3 ERP-component.

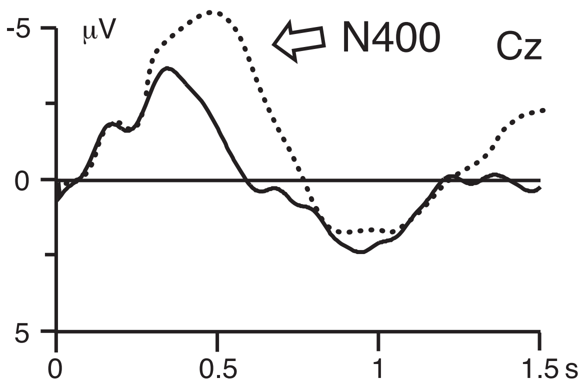

Figure 3.4: The illustration shows an ideal waveform of an N400.

sensitive to semantic manipulations, thus identifying the N400 as being a language-specific component. Illustration 3.4 depicts an ideal waveform of an N400.

Measurements of the N400 have sometimes shown a latency onset as early as 50 ms (Holcomb & Neville, 1990), in addition, it has been shown that the N400 amplitude can be influenced by the abstract-concrete word distinction, word frequency, repetition and different forms of priming (phonological, morphological, orthographical and semantic) (Kutas & Federmeier, 2000). Furthermore, a reduction of the N400 amplitude across the course of a sentence has been found. This reduction has often been interpreted as reflecting a decreased difficulty of sentential integration (Van Petten & Kutas, 1990).

In general, the N400 is assumed to reflect post lexical integration (e.g. Holcomb, 1993); however, research has also shown that an N400 effect was elicited under short and long stimulus onset asynchronies during semantic priming (e.g. J. E. Anderson & Holcomb, 1995). It is assumed that post-lexical integration can not have taken place at short stimulus onset asynchronies and thus it was proposed that the N400 might reflect both automatic spreading of activation and post-lexical integration (e.g. Holcomb, 1988; Besson, Kutas, & Van Petten, 1992). Nevertheless, today it is generally agreed upon the fact that the N400 reflects lexical integration rather than lexical access (Brown & Hagoort, 1993; Van Petten, Coulson, Rubin, Plante, & Parks, 1999; Friederici, Steinhauer, & Frisch, 1999)

It should be noted that the N400 effect has been found in the visual as well as in the auditory domain. However, the N400 in the auditory modality has an onset about 100ms earlier than in the visual domain and the component is more bilaterally distributed (Osterhout & Holcomb, 1995). In a study by Holcomb and Neville (1991) naturally spoken sentences were presented to participants, and even though the last word of the sentence was approxiametely 561ms long, contextually appropriate words distinguished as early as 50ms post word onset from contextually anamolous words. This effect led to the conclusion that that the hypothesis that contextual information can have an influence on lexical integration prior to the point when all acoustical information of the stimulus is available can be supported. Thus, it appears that beside the factors that were mentioned above, the N400 amplitude can be influenced by a complex interaction between lexical and contextual factors (Van Petten & Kutas, 1991). The question with regard to the studies to follow is whether such a contextual factor can also be given by the emotional prosody of a sentence.

3.1.6 The P600 Component

The processing of syntactic information can also be measured with the help of ERPs. Two components have been identified as being sensitive to correlate with syntactic processing. The first is the left early anterior negativity, which, depending on the experimental studies, can be seen between either 100 and 200 ms (early left anterior negativity, or ELAN) or between 300 and 500 ms (left anterior negativity, or LAN) after the onset of the stimulus. The second syntax-related component, the P600, is a slow, positice shift, typically described with a peak at around 600 ms. This late positivity was found for the processing of infrequent sentence structures (Osterhout & Holcomb, 1992, 1993; Hagoort, Brown, & Groothusen, 1993; Osterhout, Holcomb, & Swinney, 1994; Mecklinger, Schriefers, Steinhauer, & Friederici, 1995) as well as for the processing of syntactically incorrect sentences (Neville, Nicol, Barss, Forster, & Garrett, 1991; Friederici, Pfeifer, & Hahne, 1993; Osterhout & Mobley, 1995). It is also reported to reflect various syntactic manipulations,

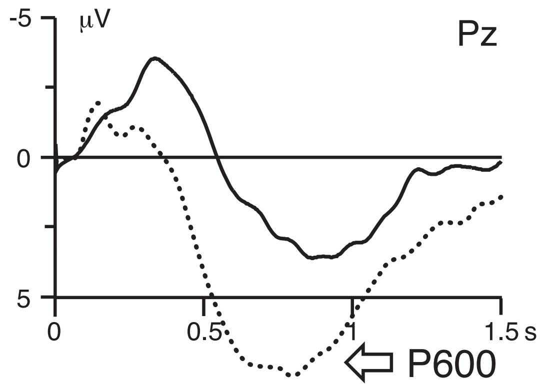

Figure 3.5: The illustration shows an ideal waveform of a P600.

including manipulations on phrase structure, agreement, and sub-categorization (Neville et al., 1991; Osterhout & Holcomb, 1992; Hagoort et al., 1993; Münte, Matzke, & Johannes, 1997; Coulson, King, & Kutas, 1998). Even though the nature of the P600 has not been entirely consistent over studies, resulting in different interpretations, there is evidence that the P600 can be seen as a marker for the "garden-path-effect" (Osterhout & Holcomb, 1992, 1993; Osterhout et al., 1994). Friederici and Mecklinger (1996) also explain the function of the P600 in terms of reanalysis for difficult syntactic structure. In a recent study by Eckstein and Friederici (2005), this interpretation was extended: it is suggested that the P600 correlates with integrative processes in general but which take the prosodic level into account. However, what is generally agreed upon is the fact that the P600 reflects syntactic manipulations of various kinds in contrast to the semantics-sensitive N400. Illustration 3.5 depicts an ideal waveform of a P600.

3.2 ERP components related to Emotional Processing

Even though the literature on emotional processing has grown over the last years, it is far from being "elusive". Especially, the literature on emotional prosody processing and its electrophysiological correlates is sparse. It should also be noted that the literature on emotional processing compromises studies which differ with respect to participant populations (sex, age, health), task (implicit or explicit processing of the emotion), and stimulus modality (auditory or visual processing, perception or production). Also, there are very few studies that take more than one or two emotions into account. The experiments to follow take up this "missing link" by 1) testing male and female participants to explore possible sex differences and in the behavioral study testing two age cohort to explore possible age differences,

2) by testing healthy students and a patient population 3) by testing implicit and explicit processing, and 4) by testing seven basic emotions to explore possible valence differences.

3.2.1 ERPs and Emotional Processing in the Visual Domain

As mentioned above, there is much diversity in the literature on emotional processing; however, one general finding in the literature is the fact that emotional stimuli seem to be processed differently from neutral stimuli. Several oddball-paradigm experiments have shown a larger P300 in response to emotional as compared to neutral stimuli (e.g. Johnston, Miller, & Burleson, 1986; Johnston, Burleson, & Miller, 1987; Naumann, Bartussek, Diedrich, & Laufer, 1992; Kayser, Bruder, Tenke, Stewart, & Quitkin, 2000). For example, Johnston et al. (1986) carried out an ERP experiment and found that emotional pictures (positive and negative) elicited a greater P300 amplitude than neutral pictures. In a second study by Naumann et al. (1992) emotionally negative, positive or neutral adjectives were visually presented. Their results indicate that the P300 component was more positive going for the emotional adjectives compared to neutral adjectives. It has been suggested that the P300 amplitude increases when participants consider the stimuli relevant for the task (Bashore & Molen, 1991; Johnson, 1988), i.e., as Carretié (1996) has pointed out, larger P300 amplitudes could have occurred due to the emotional categorization participants had to carry out in some experiments rather than being results of real emotional reactions from participants. Indeed, there is a study by Carrettié and colleagues, which shows that emotional stimuli did not elicit larger P300 amplitudes when participants believed they were engaged in a study that deals about "artistic preferences" (Carretié, Iglesias, & Garcia, 1997).

Still, the assumption that the P300 amplitude could be a reflection of the significance an emotional stimuli has for the subjects remains to be found throughout the literature (e.g. Kayser et al., 2000). From an evolutionary perspective it has also been suggested that emotional significant stimuli (or cues) have a "privileged" processing. For example, Schupp et al (2003), observed an early posterior negativity (or so called EPN) which is thought to reflect facilitated processing of emotional images. Furthermore, this EPN was largest for stimuli with so called high evolutionary significance (e.g for erotic images). Another study with visual emotional stimuli (i.e. with still images of faces), was carried out by Sato and co-workers (2000). Within their study, fearful, happy or neutral faces were randomly presented. Participants were engaged in a gender discrimination task. Results revealed that emotional faces evoked a larger negative peak after 270ms (N270) than neutral faces. The authors concluded that the emotional cue boosts the early visual processing of the stimuli.

Whereas the studies listed above suggest no differences between valences, two studies carried out by Carretié and colleagues suggest that valence of the stimuli might play a role during processing. Within the first study (Carretié, Mercado, Tapia, & Hinojosa, 2001), they used positive, negative and neutral pictures as stimuli. They found that the P200 component showed higher amplitudes and shorter latencies in response to negative pictures but not in response to positive ones. Recently, in a second study where they investigated automatic attention to emotional stimuli in a passive oddball paradigm, their results revealed that attention is captured earlier by negative pictures than by positive or neutral ones (Carretié, Hinojosa, Martín-Loeches, Mercado, & Tapia, 2004). Furthermore, results revealed a different timing for automatic attention to positive and neutral pictures. Whereas their results imply that the P1 component (peak at 105 ms) was influenced by negative pictures, the P2 (peak at 180 ms) component was influenced by negative and positive pictures and the N2 (peak at 240 ms) component was modulated by positive and neutral stimuli but not by negative stimuli. The authors concluded from their results that automatic attention depends on the emotional content of the stimulus.

3.2.2 ERPs and Emotional Processing in the Auditory Domain

Studies dealing with emotional prosody processing reveal similar divergent results. Bostanov and Kotchoubey (2004) investigated the recognition of affective prosody using emotional exclamations as stimuli (e.g. "Wow", "Oooh", etc.) in a passive oddball paradigm. They found an N300 to contextually incongruous exclamations. They assumed the N300 to be similar to the well-known N400 as an indicator of semantically inappropriate words. A recent study by Wambacq and co-workers (2004) investigated the non-voluntary and voluntary processing of emotional prosody. In the voluntary condition, participants had to evaluate emotional characteristics of a stimulus whereas in the non-voluntary condition they were asked to evaluate the semantic characteristics of a stimulus. Their results revealed a timing difference between the two conditions, i.e., emotional prosody was processed 360 ms post-stimulus onset in the voluntary processing condition (revealed by a P360), but already 200 ms earlier (revealed by a P160 ms post-stimulus) in the non-voluntary condition. The authors take their results as evidence for non-voluntary processing of emotional prosody in sentence comprehension. As in the visual domain, there have been studies in the auditory domain investigating valence differences in emotional prosody processing. Results from a study by Kotz et al. (2000) revealed differences in the P200 component for the different valences tested in the experiment. The P200 amplitude was largest for positive stimuli. In addition to the early component they also found a difference between the valences at a later stage of processing (largest negativity for neutral stimuli 400ms after stimulus onset).

As can be inferred from the selective review of ERP studies on emotional processing, various components have been reported in the literature that are thought to reflect (at least partial) emotional processing. Again, this divergence is amongst others, probably due to the lack of coherence with regard to emotional valence and arousal investigated, processing modality, and task used. It should thus be kept in mind that there is great need to be as precise as possible with the vocabulary used and to explicitely state what aspects of emotional processing will be investigated.

Part III

Experiments

Chapter 4

Experiment 1

4.1 Introduction

As has been mentioned previously, the influence of emotional prosody on speech perception has seldom been investigated, even though the importance of (emotional) prosody in speech perception has been acknowledged more and more (Astésano, Besson, & Alter, 2004; Wambacq & Jerger, 2004). This lack of research on such an important aspect of language is, among other reasons, probably due to the fact that it has been proven difficult to investigate emotional prosody processing in isolation. Thus, it is of special interest to investigate which processes constitute an emotional utterance, i.e. to investigate the emotional prosodic aspect in addition to the emotional semantic aspect of an emotionally-driven vocalization. The following experiment took up this task by investigating the potential relatedness between emotional prosody and emotional-semantics information channel. As has become clear in the previous chapter, ERPs are useful in studying language processes as they unfold in time, i.e. with their high temporal resolution, ERPs are an excellent tool to address the issue of temporal interaction versus independence.

The first question pursued in the following experiment was the extent to which the temporal integration of emotional-semantics and emotional prosody can be specified, i.e., at which point of time these two channels of information interact and whether the respective underlying mechanisms are isolated by differentiating ERP correlates. The second question is related to the extent to which different emotion specific intonation patterns might elicit different or varying degrees of these respective brain responses. Previous evidence suggests that different valences (i.e. positive and negative) can be differentiated in the ERP at an early and a later point of time (Kotz et al., 2000). This investigation was further pursued in the following experiment by exploring whether violations of an emotional prosodic specific expectation would elicit different or varying brain responses when the emotional prosodic expectations were of different valences. Thus, it was of relevance to investigate first whether different valences of emotional prosodies could be differentiated in the ERP, and furthermore if these valences could elicit different brain responses when implemented in an expectancy violation paradigm.

As for the first question, regarding whether the underlying mechanisms of emotional prosody and emotional-semantics can be isolated, a cross-splicing method was applied to create an emotional prosodic violation. With this method, incongruities of emotional prosodic intonation contours were created by cross-splicing a semantically and emotional prosodically neutral start of a sentence to an semantically neutral but prosodically emotional (positive or negative) end of a sentence. To further investigate if emotional prosodic and emotional-semantic aspects of language are processed independently or are interactive, a joint semantic-prosodic violation was created. Here, incongruities of emotional prosodic and emotional-semantic information channels were created by cross-splicing a semantically and emotional prosodically neutral start of a sentence to an semantically *and* prosodically emotional (positive or negative) end of a sentence. This violation paradigm was thought to be promising, as it is able to specify at which point of time the expectation of an emotional prosodic contour and/or an emotional prosodic contour and emotional-semantic information contour is violated. If emotional prosody and semantics are processed differently, the different conditions should elicit varying brain responses. Based on previous evidence (e.g. Astésano et al., 2004), it was hypothesized that the combined semantic-prosodic violation should elicit a negativity comparable to the well-known N400 component. If emotional prosody processing is a different process, the pure emotional prosody violation should elicit a different brain response. These effects should not be influenced by valence if they are a pure brain response to emotional prosodic and emotional prosodic/semantic contour violations.

As for the valence effect, it was hypothesized that the different emotional prosodies, i.e. positive and negative, could be differentiated in the ERP, especiallay in the early P200 component. For example, in a study by Kotz et al. (2000), different ERP traces were found for different emotional valences. Whereas a difference between neutral and positive emotional prosody as well as a difference between positive and negative emotional prosody was reflected in the P200 component, a differentiation between neutral and positive as well as neutral and negative emotional prosody was shown to be reflected in a later component starting at around 400 ms post-stimulus onset. Since the P200 is believed to reflect intensity/loudness effects of a stimulus (c.f. ERP chapter), the early ERP effect was believed to reflect acoustical differences of the stimuli, while the later effect was interpreted to reflect interaction between emotional prosody and emotional semantics.

4.2 Methods

4.2.1 Participants

Thirty-four volunteers were invited to participate in the experiment. Two participants had to be excluded from the data analysis due to extensive eye and muscle movement artifacts. Eighteen of the subjects were women with a mean age of 24.7 (SD 2.6). The sixteen male subjects had a mean age of 25.6 (SD 2.06). All participants were native speakers of German, right-handed, had normal or corrected to normal vision and no hearing impairment. Participants were paid seven Euro per hour as compensation.

4.2.2 Stimulus Material

The stimulus material consisted of 30 semantically and prosodically positive, 27 semantically and prosodically negative, and 30 semantically and prosodically neutral sentences. Furthermore, the same sentences were spliced in two ways. For the combined semantic/prosodic violation condition: a semantically and prosodically neutral start of the sentence was spliced to a semantically and prosodically positive or negative end of the sentence. For the prosodic violation condition, a semantically and prosodically neutral start of the sentence was spliced to a semantically neutral but prosodically positive or negative end of the sentence. This splicing procedure resulted in another 30 spliced semantically and prosodically positive sentences and 27 spliced semantically and prosodically negative sentences for the combined violation. Furthermore, 30 semantically neutral but spliced prosodically positive sentences and 30 semantically neutral but spliced prosodically negative sentences for the prosodic violation were presented in the experiment (for an illustration of this procedure see Figure 4.1). To balance spliced and unspliced sentences, 30 unspliced sentences (20 neutral, 5 positive, 5 negative) were added. This made a total of 117 spliced and 117 unspliced sentences. In total, 234 sentences were presented to each subject. Trials were pseudo-randomized and distributed over six blocks each containing 39 trials. In order to specify the splicing point, the mean duration (measured in ms) of the neutral start of the sentences that were used as splicing templates ("Er hat" / "Sie hat") was calculated revealing a mean splicing point at 260 ms after sentence onset. Emotional valence was obtained in an earlier rating study. Fifteen subjects (eight female) rated all words on a 5-point scale that ranged from -2 to +2 for emotional valence (where -2 equaled "very negative" and +2 equaled "very positive"). If at least 42% of the participants had rated the sentence as being either positive (+2 or +1), negative (-2 or -1), or neutral (0), the sentence was included in the respective emotion category. Sentences with less then 42% agreement were not included in the ERP experiment. Additionally, nouns and verbs from the sentences were controlled for word frequency (Baayen, Piepenbrock, & Rijn, 1995) so that there was no difference between the conditions. A female native speaker of German produced all sentences. Words

Condition	mean FO	max F0	min F0	mean dB	max dB	min dB	dur (s)
NEG	191.46	285.70	132.24	69.96	84.07	35.40	1.67
POS	226.56	358.18	129.86	67.30	83.03	36.01	1.81
NEU	156.95	265.81	126.87	68.52	82.10	40.13	1.61
SNN	189.72	266.25	132.19	70.45	84.19	36.01	1.74
SNP	212.95	365.26	129.99	66.77	82.82	35.67	1.80
CSNN	189.33	298.64	132.35	70.01	83.83	36.37	1.68
CSNP	213.78	357.11	129.70	66.92	82.90	36.26	1.75

Table 4.1: Acoustical analyses for sentences in each experimental condition, i.e. for spliced prosodically positive (CSNP), spliced prosodically negative (CSNN), spliced semantically and prosodically positive (SNP) and spliced semantically and prosodically negative (SNN). Analyses were carried out for the parameters F0 (Hz), intensity (dB), and duration (s).

start of sentence		end of sentence	
Prosody neutral / Semantic neutral	Sie hat	die Augen geschlossen.	Prosody positive / Semantic neutral
Prosody neutral / Semantic neutral	Sie hat	die Augen geschlossen.	Prosody negative / Semantic neutral
Prosody neutral / Semantic neutral	Sie hat	den Schatz gefunden.	Prosody positive / Semantic positive
Prosody neutral / Semantic neutral	Sie hat	das Vertrauen missbraucht.	Prosody negative / Semantic negative

Figure 4.1: The illustration explains the splicing procedure. A prosodically and semantically neutral start of the sentence is spliced either to a a) prosodically positive/negative but semantically neutral end of sentence, or to b) a prosodically and semantically positive/negative end of sentence.

were taped with a DAT recorder and digitized at a 16-bit/44.1 kHz sampling rate. The stimulus material was prosodically analyzed (i.e. pitch, intensity and duration of the sentences were extracted) using *Praat*. Results of the acoustical analyses can be found in Table 4.1.

4.2.3 Procedure

Each subject was tested individually and was seated at a computer with a three-button panel placed before him/her in a sound-attenuating room. Half of the subjects pressed the yes-button with their right hand and the no-button with their left hand. The other half proceeded vice versa. Participants were seated in a comfortable chair at a distance of 115 cm from the computer monitor. The sentences were presented via loudspeaker. The Experimental Run Time System (ERTS) (Beringer, 1993) was used to carry out the experimental task. Directions, with examples, asked subjects to listen to the presented sentence, read the following word (flashed on the screen for 300 ms) and to make a decision on the probe as accurately and as quickly as possible. Participants were asked to avoid eye movements during sentence presentation. The intertrial interval was 2000 ms. See Figure 4.2 for a schematic illustration of this procedure.

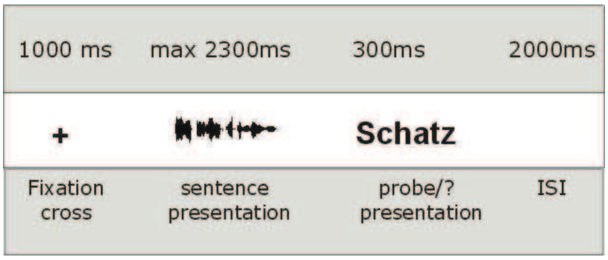

Figure 4.2: The figure above show a schematic illustration of an example trial.

4.2.4 ERP Recording and Data Analysis

The electroencephalogram (EEG) was recorded with 59 Ag-AgCl electrodes mounted in an elastic cap (*Electro-Cap International*, n.d.) from FP1, FPZ, FP2, AF7, AF3, AFZ, AF4, AF8, F9, F7, F5, F3, FZ, F4, F6, F8, F10, FT9, FT7, FC5, FC3, FCZ, FC4, FC6, FT8, FT10, T7, C5, C3, CZ, C4, C6, T8, TP9, TP7, CP5, CP3, CPZ, CP4, CP6, TP8, TP10, P9, P7, P5, P3, PZ, P4, P6, P8, P10, PO7, PO3, POZ, PO4, PO8, O1, OZ, O2, A1 and A2, each referred to the nose (NZ). The nomenclature above is that proposed by the American Electroencephalographic Society (1991). Bipolar horizontal and vertical EOGs were recorded for artifact rejection purposes. Electrode resistance was kept under 5 K-ohm. Data was rereferenced offline to linked mastoids. The signals were recorded continuously with a band pass between DC and 70 Hz and digitized at a rate of 250 Hz. ERPs were filtered off-line with a 7 Hz low pass for graphical display, but all statistical analyses were computed on non-filtered data.

ERP components of interest were determined by visual inspection. For statistical analysis, ANOVAs with *Sex* as a between-subject factor were conducted [1]. For each condition (i.e. no violation, combined prosodic/semantic violation, and pure prosodic violation), separate analyses were conducted. In addition, for ERP analyses, the repeated factor *Scalp Regions of Interest* (*SROI*) was included. Each following *SROI* defined a critical region of four scalp sites: left frontal (LF): FP1 AF7 AF3 F9 F7 F5 F3 FT9 FT7 FC5 FC3; right frontal (RF): FP2 AF4 AF8 F4 F6 F8 F10 FT10 FT8 FC6 FC4; left posterior (LP): TP9 TP7 CP5 CP3 P9 P7 P5 P3 PO7 PO3 O1; and right posterior (RP): CP4 CP6 CP6 TP8 TP10 P4 P6 P8 P10 PO4 PO8 O2. To keep the number of electrodes constant for each *SROI*, midline electrodes were excluded from the analysis. ERPs measured at frontal and posterior *SROI*s created the factor *REG* (Frontal vs. Parietal Region) in the statistical analysis, and ERPs measured at right and left hemisphere *SROI*s established the factor *HEMI* (Right vs. Left

[1]The present study investigates the interaction between emotional prosody and emotional-semantics. Some previous research (e.g Schirmer & Kotz, 2003) has suggested participant's sex to influence emotional prosody processing. Therefore, even though no hypotheses were clear with regard to if and to which extent the participants sex could possibly modulate this interaction *Sex* was included as a between-subject factor.

Hemisphere). As separate analyses were conducted for the two violation types (combined prosodic/semantic violation and pure emotional prosodic violation), each analysis had additional repeated measurement factors. For the combined violation, the factors *P* (Positive vs. Negative prosody) and *M* (Match vs. Mismatch condition, i.e. Unspliced vs. Spliced items) were included. For the pure emotional prosodic violation, the repeated factor *P* was present in each analysis (Positive and/or Negative vs. Neutral Prosody). The null-hypothesis was rejected for *p*-values smaller than 0.05. The Geissser-Greenhouse correction (Geisser & Greenhouse, 1959) was applied to all repeated measures with greater than one degree of freedom in the numerator. If a higher number of post-hoc comparisons than the degrees of freedom would permit were required, and because of the increased likehood of Type I errors associated with the large number of comparisons, *p* Values of post hoc single comparisons were corrected using a modified Bonferroni procedure (see Keppel, 1991). For all statistical analyses, the SAS 8.2 software package (*SAS 8.2*, 2001) was used.

4.3 Results

4.3.1 Behavioral Results

Mean percentage correct (PCs) were calculated for each subject. Accuracy data for the two different violation types (combined semantically and prosodically spliced material vs. prosodically spliced material) were calculated with separate ANOVAs, treating *M* (Match: positive/negative and Mismatch: positive-spliced/negative-spliced) and *P* (positive and negative for the combined semantic/prosodic violation and positive/negative/neutral for the emotional prosodic violation) as within-subject repeated-measures factors and *Sex* (male/female) as between-subject factors. See Table 4.2 for an overview of percentage correct values. For the ease of reading, each violation type is discussed separately.

Combined Semantic/Prosodic Violation: Statistical analysis of the PCs over both sex groups revealed no statistically significant effects (all $p>.05$).

Prosodic Violation: Statistical analysis of the PCs over both groups yielded a significant *P* effect ($F(2,64)=30.61$, $p<.0001$). Post-hoc comparisons revealed higher error rates for spliced prosodically negative sentences when compared to neutral sentences ($F(1,32)=38.49$, $p<.0001$).

4.3.2 ERP results

After visual inspection, the critical ERP data analyses were quantified for correct responses by calculating amplitudes relative to a 200 ms prestimulus baseline in two latency windows (170 to 230 ms and 600 to 1200 ms). ERP data in the P200 time win-

Mean PC Values in both Violation Types		
Condition	*PC*	*SD*
Neutral	98.43 %	3.09
Positive	98.82 %	1.62
Negative	99.23 %	1.99
CSNP	98.03 %	3.19
CSNN	94.11 %	2.60
SNP	98.91 %	1.94
SNN	98.72 %	2.01

Table 4.2: Mean percentage correct values for neutral, positive, negative, prosodically spliced positive (CSNP), prosodically spliced negative (CSNN), semantically and prosodically spliced positive (SNP), and semantically and prosodically spliced negative sentences (SNN).

dow (170 to 230 ms) was analyzed with an ANOVA with the factors *P* (Prosody: Positive/Negative/Neutral), *HEMI* (Left/Right Hemisphere), *REG* (Frontal/Parietal Region) as repeated factors and *Sex* (Female/Male) as a between-subject factor. For the late component, ERP data were analyzed with separated ANOVAS with the factors *M* (Match: Positive/Negative vs. Mismatch: positive-spliced/negative-spliced; this factor was included for the combined prosodic/ semantic violation only), *P* (Prosody: Positive and Negative for the combined semantic/prosodic violation and Positive/Negative/ Neutral for the prosodic violation), *HEMI* (Left/Right Hemisphere), *REG* (Frontal/Parietal Region) as within-subject repeated-measures factors and *Sex* (Female/Male) as a between-subject factor. Statistical analyses are reported for effects that relate to the possible dissociation between emotional prosody and semantics only. Again, for the ease of reading, each condition is discussed separately.

Visual inspection of ERPs across both sexes showed that the overall morphology of the waveforms in both groups was comparable. Statistical analyses were conducted in the time window of 170 to 230 ms (P200) for all match conditions (i.e. no violation type included) in order to explore possible valence effects and in a time window of 600 to 1200 ms for both violation types.

***P200:* Valence Effects:** Within the classical P200 time window of 170 to 230 ms a significant main effect of *P* was found ($F(2,64)=3.73$, $p<.05$). Break-down comparisons revealed significant differences between positive and neutral ($F(1,32)= 3.99$, $p=.05$) and between positive and negative sentences ($F(1,32)=6.56$, $p=.01$). Also, the interaction between *P* x *REG* x *Sex* was significant ($F(2,64)=5.60$, $p<.01$). Further analyses by *Sex* revealed a significant *P* x *REG* interaction in male participants ($F(2,34)=3.70$, $p<.05$). The analysis by *REG* for the male participants revealed a significant *P* effect in the frontal region ($F(2,34)=11.24$, $p<.001$). Taken together, the results suggest that there is a significant valence effect in the P200 time window for all participants, but, this P200 effect is especially pronounced for

Time Window: 170 ms - 230 ms			
Effect	*df*	*F value*	*p value*
P	2,64	3.73	<0.05
HEMI	1,32	15.36	<0.001
REG	1,32	66.91	<.0001
P x *REG* x *Sex*	2,64	5.60	<0.01
HEMI x *REG* x *Sex*	1,32	4.53	<0.05

Table 4.3: Significant/borderline results from ANOVAs on mean amplitudes in the match condition for the early time window of 170 to 230 ms for all participants.

Time Window: 600 ms - 1200 ms			
Effect	*df*	*F value*	*p value*
HEMI	1,32	30.79	<.0001
M x *P* x *Sex*	1,32	4.73	<0.05
M x *HEMI*	1,32	4.14	<0.08

Table 4.4: Significant/borderline results from ANOVAs on mean amplitudes for the emotional semantic/prosodic violation for all participants.

male participants in the frontal region. Table 4.3 shows all significant effects found in the omnibus analysis and Illustration 4.3 shows P200 ERP component results for all participants, female participants, and male participants.

***Late component: Combined Semantic/Prosodic Violation*:** Within the time window of 600 to 1200 ms no significant main effect of P was found (*p*>.05). However, the interaction between *M* x *P* x *Sex* reached significance (F(1,32)=4.73, *p*<.05). A further analysis by *Sex* yielded a significant interaction between *M* x *P* for the male participants (F(1,15)=5.50, *p*<.05). The step-down analysis for the male participants by *P* revealed a significant *M* effect (F(1,15)=8.53, *p*<.05), revealing waveform differences for prosodically negative sentences, with the spliced sentences more negative than the unspliced sentences. In addition, the interaction *M* x *HEMI* (F(1,32)=4.14, *p*=.05) was found to be significant. The analysis by *HEMI* revealed an *M* effect in the right hemisphere (F(1,33)=3.93, *p*=.05), showing a more negative waveform for the spliced sentences than for unspliced sentences. Overall, these results reveal a right lateralized negative component for the combined semantically/prosodically violated sentences. Furthermore, results revealed that male participants showed this effect in a more pronounced way for prosodically negative spliced sentences. See Table 4.4 for a list of all significant effects and Figure 4.4 for a graphical display of effects.

Prosodic Violation: The analysis in the time window of 600 to 1200 ms revealed a significant main effect of *P* (F(2,64)=5.93, *p*<.01). Follow-up analyses revealed waveform differences between the spliced sentences and the neutral sentences, with the waveforms for pos-

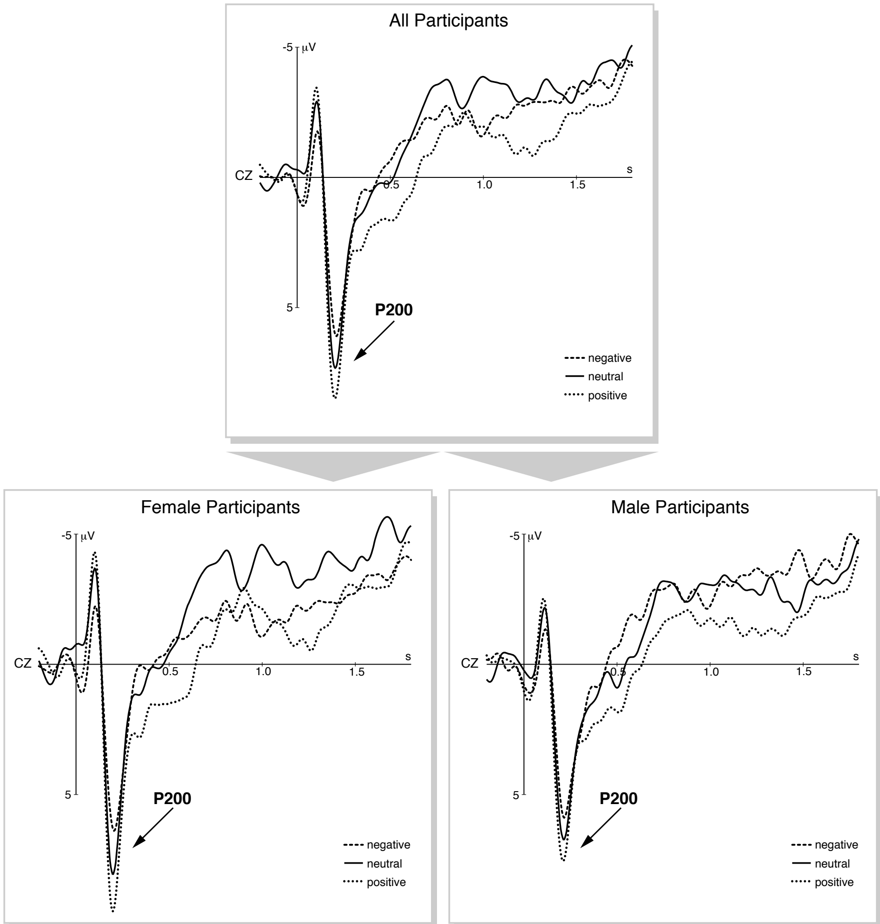

Figure 4.3: The illustration shows ERPs measured at a central electrode (CZ) in response to different emotional prosodies for all participants, and for female and male participants separately.

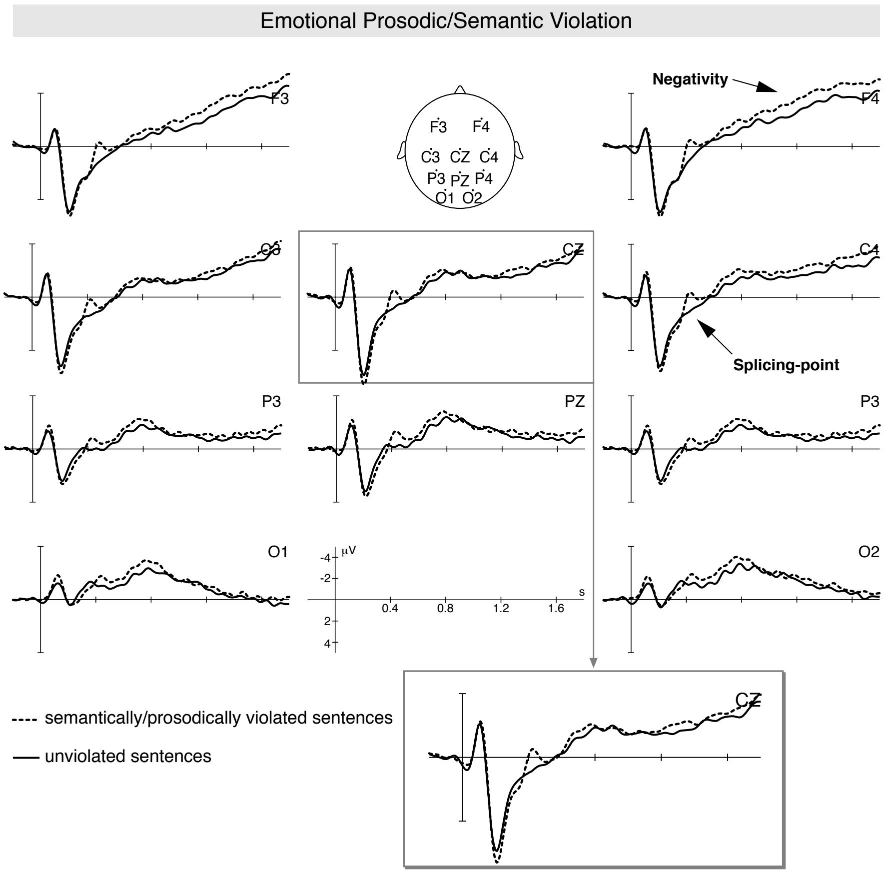

Figure 4.4: Global ERPs averaged from sentence onset for the emotional semantic and prosodic violation condition.

Time Window: 600 ms - 1200 ms			
Effect	*df*	*F value*	*p value*
P	2,64	5.93	<0.01
HEMI	1,32	19.69	<.0001
P x *HEMI* x *Sex*	2,64	4.52	<0.05
P x *HEMI* x *REG* x *Sex*	2,64	4.17	<0.05

Table 4.5: Significant/borderline results from ANOVAs on mean amplitudes for the emotional prosodic violation for all participants.

itive spliced (*P* effect: F(1,32)=9.48, *p*<.001) and negative spliced (*P* effect: F(1,32)=5.94, *p*<.01) sentences more positive-going than for the neutral sentences.

There was also a significant interaction between *P* x *HEMI* x *Sex* (F(2,64)=4.52, *p*<.05) as well as a significant interaction between *P* x *HEMI* x *REG* x *Sex* (F(2,64)= 4.17, *p*<.05). Step-down analyses by *Sex* revealed a significant interaction *P* x *HEMI* (F(2,34)=4.29, *p*<.05) for female subjects and a trend for the same interaction for the male subjects (F(2,30)=2.73, *p*<.1). In a further break-down analysis by *Sex* and *HEMI*, a trend towards a significant *P* effect was found for female participants in the right hemisphere (F(2,34)=3.03, *p*<.08) and a significant *P* effect was found in the left hemisphere (F(2,34)=5.46, *p*<.01) and only approaching significance in the right hemisphere for male participants (F(2,30)=3.04, p<.08). Post-hoc comparisons revealed a left-lateralized, positive-going waveform in female participants for both the negative (*P* effect: F(1,17)=5.61, *p*<0.05) and positive (*P* effect: F(1,17)=9.78, *p*<0.01) spliced sentences when compared to neutral sentences, and a right lateralized positivity for negative spliced sentences (*P* effect: F(1,17)=5.25, *p*<0.05). For the male participants, post-hoc comparisons revealed a positivity for positive (*P* effect: F(1,15)=4.41, *p*=0.05) spliced sentences and a trend towards significance for negative (*P* effect: F(1,15)=3.72, *p*=0.07) spliced sentences when compared to neutral sentences.

In the step-down analyses by *Sex* for the four-way interaction *P* x *HEMI* x *REG* x *Sex*, no effects reached significance.

Taken together, these results reveal a bilaterally distributed positivity for all participants for the prosodically violated sentences. Furthermore, the results are qualified by sex, i.e. women showed a left lateralized positivity for all spliced items and a right lateralized positivity for negative-spliced items. In comparison men showed a positivity for all spliced items in the right hemisphere only. Tables 4.5 and 4.6 display all significant effects from the omnibus analysis including post-hoc comparisons. See Figures 4.5 and 4.6 for a graphical display of ERP-effects.

Post-hoc comparisons			
Effect	*df*	*F value*	*p value*
P	2,64	5.93	<.01
Neu vs. CSNP	1,32	9.48	<0.01
Neu vs. CSNN	1,32	5.94	<0.05

Table 4.6: Post-hoc comparisons in the prosodic violation.

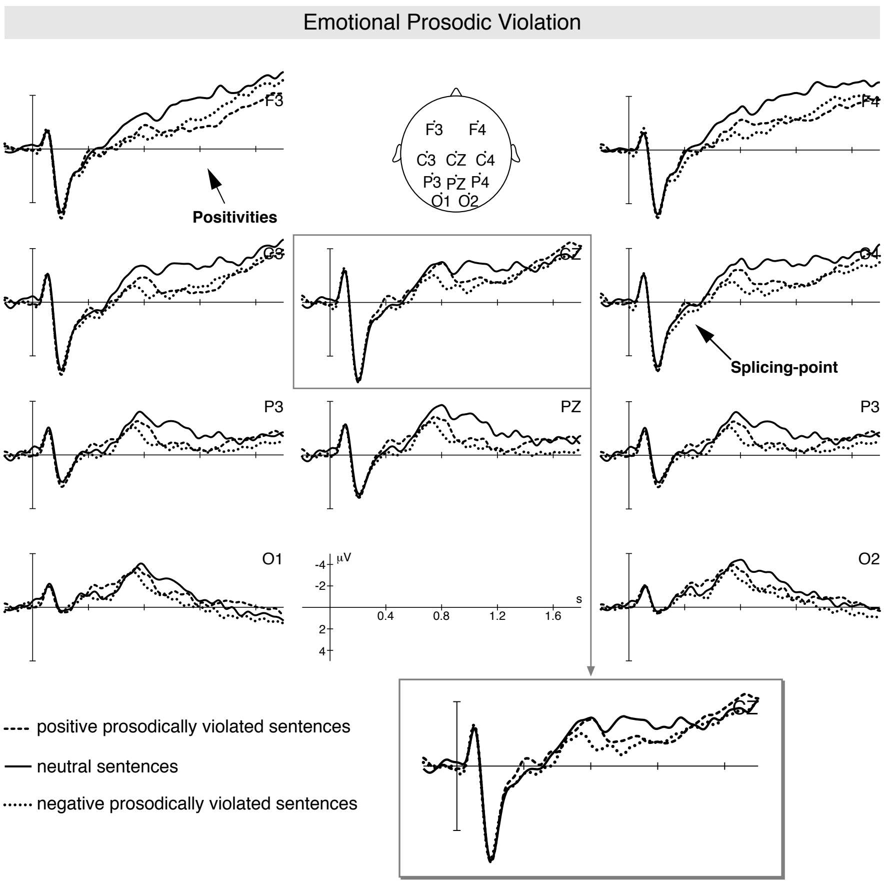

Figure 4.5: Global ERPs averaged from sentence onset for the emotional prosodic violation condition.

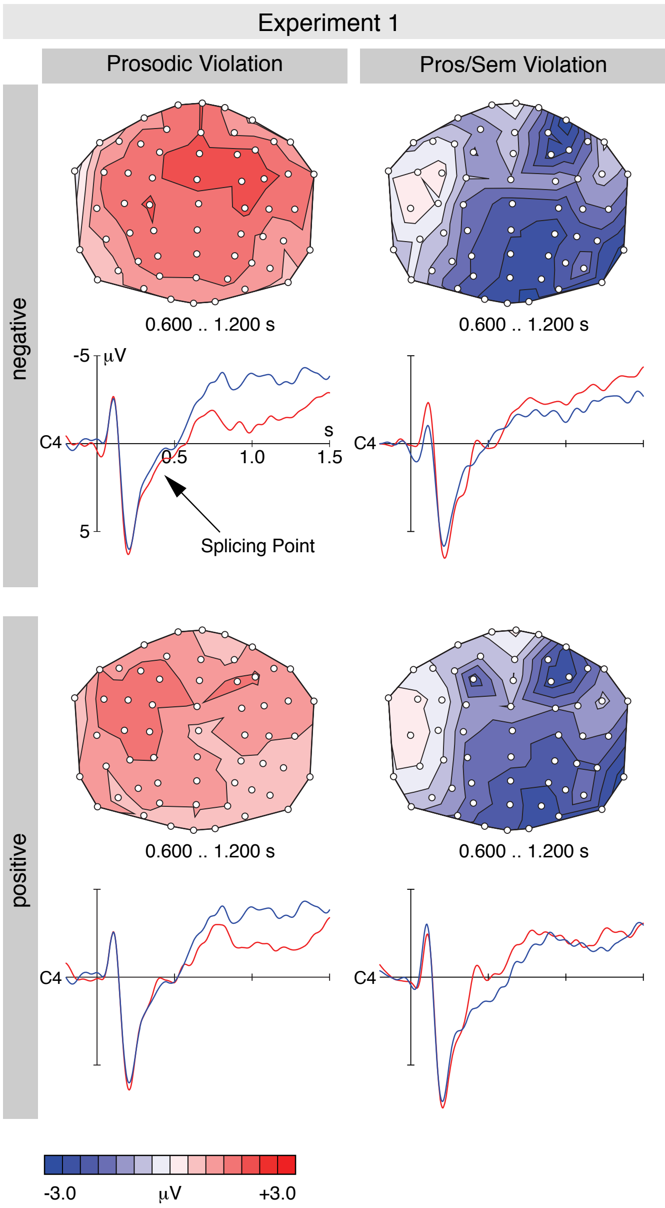

Figure 4.6: The illustration shows ERP difference maps comparing the correct and violated sentences and ERP effects at one selected electrode (C4). Waveforms show the average for correct (blue) and violated (red) sentences from 200 ms prior to stimulus onset up to 1500 ms post stimulus onset.

4.4 Discussion

In sum, the experiment was effective in showing that ERPs can help to specify the underlying mechanisms of emotional prosody and emotional-semantics. These results clearly show that different brain responses are elicited when sentences are a) semantically and prosodically violated, or b) prosodically violated only. As the main aim of this study was to investigate the two emotional channels (i.e. emotional-semantics and the emotional prosody channel) by violating an expectation with regard to emotional prosodic and semantics, it can be concluded that the proposed paradigm served its purpose. Furthermore, it can be concluded that ERPs can contribute to the discussion on the relationship between emotional prosody and emotional semantics. Within the next paragraphs, each ERP effect is discussed separately with regard to its proposed underlying function.

P200: Within the early time window of 170 to 230 ms, a significant difference between ERP waveforms for positive and neutral stimuli as well as for positive and negative sentences was found. This finding replicates results from earlier studies (Kotz et al., 2000; Alter et al., 2003). Kotz et al. (2000) discussed this difference as being related to the intensity/loudness of the stimuli. However, as has been mentioned in the chapter on ERPs, there are studies that suggest that the P200 component can be modulated by pitch variation as well (e.g. Pantev et al., 1996). Therefore, the view that the P200 component is modulated by pitch and intensity variations of the stimuli is presumed here. However, whether acoustical differences alone modulated the P200, or whether lexical information also influences the different P200 waveforms found here, remains an open question. This aspect will be tested explicitly in Experiment 4, in which the on-line processing of lexical and non-lexical sentences of different emotional categories will be investigated. For now, it can only be assumed that the modulation of the P200 is manifold, i.e. the component is influenced by a combination of pitch modulation, intensity modulation, and probably different lexical information. Also, it will be interesting to find out if this early emotional prosody processing effect is dependent on task, i.e. whether task influences the P200 component for the different emotional valences. Does early emotional prosody processing differ between explicit and implicit processing situations? Experiment 2 will take up this question and will investigate whether the same P200 pattern will be found under an explicit prosody processing situation.

In sum, it can be said that different valences can indeed be differentiated in the ERP in an early ERP component. However, which aspects of emotional processing contribute in which way to the results obtained remains to be clarified. That is further research needs to be carried out to investigate whether lexical information already influences emotional prosody processing during an early stage of processing.

Emotional Prosodic Violation: The violation of an emotional prosodic intonation contour, i.e. when a neutral start of a sentence was cross-spliced to a semantically neutral but prosodically emotional end of a sentence, elicited a positivity between 600 and 1200 ms after sentence onset. The fact that the emotional prosody and emotional semantic violation condition elicited a negativity in the same time window points to the interpretation that the positive ERP component is closely related to the emotional prosodic contour violation and not an acoustical artifact produced by the splicing procedure. To better understand this positivity and its underlying function, it is helpful to take other language-related ERP components into account. For example, Astésano et al. (2004) have reported a P800 as a response to linguistic prosody contour violations. In a similar cross-splicing study, the authors manipulated the intonation contour of statements and questions. The authors suggested that the P800 found was closely linked to F0 contour violations due to three reasons: 1) pretesting of their material ensured that no acoustical artifacts were produced during the splicing procedure that could be attributed to be responsible for the ERP effect; 2) their acoustic analyses showed that the spliced and unspliced material differed only in F0 and not in intensity or duration; and 3) the authors suggest that the latency of the ERP effect was too long to represent sensory analyses. Similar conclusions can be drawn from the present study. As has been mentioned above, acoustical artifacts created during the splicing procedure (if any) should be the same for the prosodic violation condition and the combined prosodic/semantic violation condition. As two different ERP components were elicited for the two conditions, it seems very unlikely that an acoustic artifact is responsible for the ERP effects. Second, durational and intensity measurement means do not significantly differ between the spliced and unspliced sentences. Last, the latency of the ERP effect is even 300 ms longer in the current study than in the Astésano et al. (2004) study, which in turn also suggests that the ERP effect is unlikely to reflect sensory analysis. However, the positive component in the Astésano et al. (2004) experiment was elicited only under an explicit prosody processing condition, i.e. when subjects had to focus their attention on the intonation contour of an utterance. The positivity in this experiment, in contrast, was found under an implicit emotional prosody processing situation. This suggests that the two components might be related but are unlikely to reflect the same process(es). A second positive ERP component that has been linked to prosodic processing is the CPS (c.f. ERP chapter). However, whereas the CPS has been shown to be elicited by prosodic phrase boundaries, i.e. during/after segmentation processes of long and syntactically complex sentences, the current material did not require linguistic phrase segmentation due to its syntactically simple construction. Also, the CPS has been reported to be of rather short latency (less than 300 ms), which makes it differ significantly from positive ERP component obtained here, which shows a rather long latency. Aside from the components both having a positive polarity, another aspect that the two components have in common is their morphological distribution, i.e. both components are rather bilaterally distributed. Last, as was mentioned previously, the third well-known positive component, namely the P600, has been argued to reflect not only syntactic reanalysis processes, but also more general reanalyses and integration processes of linguistic and non-linguistic information (e.g. Friederici, 1998; Hagoort et al., 1993; Osterhout & Holcomb, 1992; Steinhauer & Friederici, 2001). However, an important difference between the P600 and the component reported here is that the P600 is always elicited by syntactic errors, whereas the current positive ERP component was elicited by a violation of the emotional prosody contour of emotional prosodic expectancy. However, this could still suggest similar functions. For example, the P600 is thought to be a reanalysis component of syntactic information, and a combination of syntactic and linguistic prosodic aspects. In addition, Astésano et al. (2004) suggested a similar interpretation for the P800, namely a reflection of reanalysis of F0 violations. Following this line of argumentation, the positivity elicited by emotional prosodic intonation contour violations could reflect reanalysis of emotional prosodic aspects of the stimulus based on an F0 manipulation.

Taken together, it is suggested that the positivity obtained in this experiment occurring between 600 and 1200 ms after sentence onset might be closely related functionally to the P600, the P800, and to the CPS found in various studies. However, due to the reasons elaborated above, i.e., e.g. different task situations and different linguistic aspects of manipulation, it is also proposed that none of the components precisely match the component found here.

Combined Emotional Prosody and Emotional Semantic Violation:

The present study aimed to specify how and when emotional prosody and emotional-semantics interact during sentence-level processing. Furthermore, we aimed to specify whether this interaction is dependent on emotional valence, i.e. if there is a processing difference between violations of emotional positive and emotional negative sentences. As for the latter question, the current results suggest that this is not the case. Neither in the prosodic violation condition nor in the combined emotional prosodic and emotional semantic violation condition did the ERP responses differ with respect to valence of the stimuli. As for the former question, i.e. how and when emotional prosody and emotional semantics interact at the sentence level, the answer seems to be more complex. First, it should be noted again that the two experimental conditions tested here elicited two different ERP responses, namely a positive and a negative ERP component. This result implies that it is possible to isolate the emotional prosody information channel from the emotional-semantic information channel. Furthermore, it can be assumed that the respective underlying mechanisms of these two processes are different. However, even though this paradigm helped to isolate the respective emotional channel, it should also be noted that when the two processes interact, i.e. in the combined emotional prosody and semantics violation condition, the semantic information channel seems to predominate the emotional prosody channel. By cross-splicing a semantically and prosodically neutral start of a sentence to a semantically and prosodically emotional end of a sentence, an integration between emotional prosody and emotional semantics was reinforced. This enables us to shed more light on the temporal integration of the two processes, since it was possible to specify the moment when this renewed interaction had to occur (i.e. after the splicing point). The negativity obtained suggests that the interaction is predominantly driven by semantic information; otherwise, the positivity found for the pure prosodic violation condition should have also been found for this violation condition. Functionally speaking, it is assumed that the combined violation of emotional prosody and semantics elicited an N400-like negativity. Within the literature, it has been shown that the N400 is larger for semantically incongruent items than for congruent ones. Within the violation paradigm used here, though, the semantic violation did not occur independently of the emotional prosodic violation. Thus, it remains speculative to suggest that the brain response was triggered by the emotional semantic violation alone. But since the pure emotional prosodic intonation contour violation elicited a positive ERP component, it can be assumed that different language processing mechanisms seem to underlie both processes, and moreover, it seems as if semantic processing can override emotional prosodic processing. One last point should be considered, though. The task of the current study might have led participants to pay more attention to the semantic content of the sentence than to the emotional prosodic content (since emotional prosody is not helpful when deciding if a probe word has occurred in the preceding sentence or not). Therefore, it could be argued that semantic processing predominates emotional prosody processing only because of the task applied here.

4.4.1 Further Questions

The question raised above was taken as a starting point for further explorations regarding the interaction and independence of emotional prosody and emotional semantics. The next experiment reported in this thesis will investigate if on-line processing differences exist between implicit and explicit emotional prosody processing situations. It will thereby enable us to specify whether the negativity found for the combined violation was only elicited due to the fact that semantic processing was mandatory during the present task. If this were really the case, it could be concluded that the experimental task can profoundly influence the processing hierarchy of emotional prosody and emotional semantics and that their interaction is highly dependent on the processing situation.

Chapter 5

Experiment 2

5.1 Introduction

Many behavioral studies that have investigated emotional prosody processing have made use of explicit prosody processing tasks, e.g. tasks in which participants categorize emotional prosody or recognize emotional prosody. However, there is evidence that suggests that implicit and explicit processing of emotional prosody may accentuate different brain areas in a functional network supporting emotional prosody processing (Kotz et al., 2003, in prep). In fMRI studies by Kotz et al. (2003, in prep), implicit processing of emotional prosody activated a fronto-temporo-striatal network with right claustrum activation, whereas an explicit task resulted in a bilateral temporo-striatal activation (Kotz et al., in prep). Thus, only in the implicit task did emotional prosody engage a right subcortical structure. Therefore, it seems important to specify whether on-line processing of emotional prosody differs as a function of task demands. Whereas Experiment 1 applied an implicit emotional prosody processing task, Experiment 2 makes use of an explicit emotional prosody processing task. In order to specify if the obtained results from Experiment 1 were due only to the task applied, the same experiment was carried out with a different explicit task, i.e. emotional prosody categorization. Results from Experiment 1 have suggested that the time-course of emotional prosodic processing and emotional semantics differ. While the violation of the emotional prosodic contour (independent of emotional semantics) elicited a positivity, the violation of both emotional prosody and emotional semantics elicited a negativity in the ERP. It was hypothesized that this pattern should hold true independent of task, i.e. the same pattern of ERP components should be elicited in Experiment 2 if indeed emotional prosody processing is confirmed as an automatic process in Experiment 1.

A second question pursued in Experiment 2 is whether the combined emotional prosodic and emotional semantic violation still elicits an N400-like negativity related to the predominant processing of emotional-semantic information, or whether this predominance is dependent on task. With the explicit emotional prosody processing task (as opposed to the implicit emotional prosody processing task, namely probe verification in Experiment 1) applied in Experiment 2, emotional prosody processing as opposed to emotional-semantic processing was tapped. In Experiment 2, it was of interest to specify if the time-course of emotional prosody processing differs when an explicit prosody processing task is applied. More particularly, it was hypothesized that the positive ERP effect elicited by the emotional prosodic violation found in Experiment 1 might evolve at a slightly earlier point of time due to the focus of attention on the emotional prosody in Experiment 2.

Last, it was possible to investigate if the emotional valence effect reflected in the P200 could also be influenced by the task. However, there is previous evidence that suggests that this might not be the case (Kotz et al., 2000), i.e. Kotz et al. (2000) found P200 effects comparable to the effects found in Experiment 1 but under an explicit task situation.

5.2 Methods

The stimulus material, ERP recording and data analysis, and the procedure were comparable to Experiment 1, with the exception that the task was now a prosody categorizations task (cf. Section 5.2.2).

5.2.1 Participants

Thirty-two participants performed the experiment. In this experiment, sixteen of the subjects were women with a mean age of 26.1 (SD 3.1). The remaining sixteen male subjects had a mean age of 25.7 (SD 3.0) years.

5.2.2 Procedure

In Experiment 2, half of the subjects pressed the positive-button with their right index finger and the negative-button with their left index finger. The remaining subjects had the reverse button assignment. Neutral responses were always assigned to the middle-button. Participants were asked to listen to the sentence prosody and then press the button for the corresponding valence as accurately and quickly as possible.

5.3 Results

5.3.1 Behavioral Results

Combined Emotional Semantic/Prosodic Violation: Statistical analysis of the PCs over both sex groups revealed no statistically significant effects (all $p>.05$).

Mean PC Values in both Violation Types		
Condition	*PC*	*SD*
Neutral	87.93 %	24.30
Positive	95.31 %	8.62
Negative	96.29 %	6.71
CSNP	93.12 %	11.38
CSNN	93.95 %	15.03
SNP	96.75 %	7.08
SNN	95.31 %	6.97

Table 5.1: Mean percentage correct values for neutral, positive, negative, spliced prosodically positive (CSNP), spliced prosodically negative (CSNN), spliced semantically and prosodically positive (SNP), and spliced semantically and prosodically negative sentences (SNN).

Emotional Prosodic Violation: As in the combined semantic/prosodic violation, no statistically significant effects were found for PC analyses over both sexes in the emotional prosodic violation condition(all p>.05). See Table 5.1 for percentage correct values.

5.3.2 ERP results

Again, after visual inspection, the critical ERP data analyses were quantified for correct responses by calculating amplitudes relative to a 200 ms prestimulus baseline but in Experiment 2, three latency windows (400 to 650 ms, 900 to 1125 ms, and 550 to 750 ms) were analyzed. ERP data were analyzed with separated ANOVAS with the same factors as in Experiment 1. Again, statistical analyses are reported for effects that relate to the possible dissociation between emotional prosody and semantics only, but see Tables 5.2, 5.3 and 5.4 for an overview of all significant effects from the respective omnibus analyses.

Visual inspection of ERPs across both sexes showed that the overall morphology of the waveforms in both groups was comparable and characterized by two different late components for the two different violation types. Therefore, statistical analyses were conducted in the time window of 400 to 650 ms and 900 to 1125 ms in the combined semantic/prosodic violation condition and in the time window of 550 to750 ms in the prosodic violation condition. In addition, a P200 time window (150 to 300 ms) was also analyzed to explore possible valence effects.

P200: Valence Effects: In the P200 time window of 150 to 300 ms, there was a trend towards a significant interaction between *P* x *REG* (F(2,60)=2.92, p=.06). The step-down analysis by *REG* revealed a significant *P* effect in the parietal region (F(2,60)=3.48, p=.06). Post-hoc comparisons in the parietal region showed a significant difference between neutral and negative sentences (*P* effect: F(1,30)= 5.56, p<.05) with the negative sentences more negative-going than the neutral sentences.

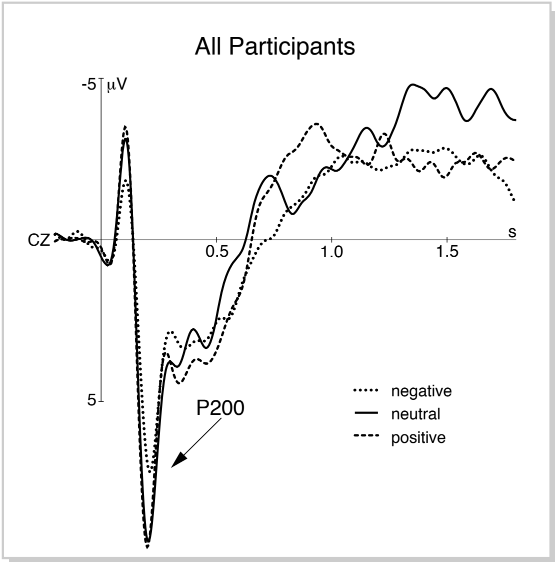

Figure 5.1: The illustration shows ERPs measured at a central electrode (CZ) in response to different emotional prosodies for all participants. Waveforms show the average for neutral (black), negative (dotted), and positive (dashed) sentences from 100 ms prior to stimulus onset up to 1800 ms post stimulus onset.

Furthermore, there was a second marginal significant interaction between *P* x *HEMI* x *REG* (F(2,60)=2.99, *p*=.06). The by-*REG* analysis revealed a significant interaction between *P* and *HEMI* (F(2,60)=3.24, *p*<.05) in the frontal region. Further step-down analyses showed no further significant effects.

Taken together, the results revealed a significant difference between ERP amplitudes of neutral and negative sentences at parietal electrode sites whereby the neutral sentences showed a more positive-going waveform than the negative sentences. Illustration 5.1 displays the ERP-effect at a selected electrode.

Late components: Combined Emotional Semantic/Prosodic Violation:

In the time window of 400 ms to 650 ms, a significant main effect of *M* was found (F(1,30)=9.21, *p*<.01), indicating a more negative-going component for the spliced sentences irrespective of valence.

Also, the interaction between *M* x *REG* reached significance (F(1,30)= 24.57, *p*<.0001). A further analysis by *REG* yielded a significant *M* effect in parietal regions (F(1,31)= 25.64, *p*<.0001) with the spliced sentences showing a more negative-going component than the unspliced sentences.

Time Window: 400 ms - 650 ms			
Effect	*df*	*F value*	*p value*
M	1,30	9.21	<0.01
M x *REG*	1,30	24.57	<.0001

Table 5.2: ANOVAs on mean amplitudes in the time window of 400 to 650 ms in the emotional semantic/prosodic violation for all participants.

In sum, the analysis revealed a broadly distributed negativity between 400 and 650 ms for all spliced sentences; however, this negativity was more pronounced over parietal regions.

In the second time window of 900 ms to 1125 ms, there was also a significant main effect of *M* (F(1,30)=5.89, $p<.05$), indicating a more positive-going component for the spliced sentences irrespective of valence. Second, there was a highly significant *P* effect (F(1,30)=21.61, $p<.0001$), indicating a valence difference with a more negative-going waveform for both positive sentence types, i.e. for the spliced and unspliced sentences.

Furthermore, the interaction between *P* and *HEMI* was marginally significant (F(1,30)=3.66, $p=.07$). The step-down analysis by *HEMI* revealed a significant *P* effect in the left hemisphere (F(1,31)=10.55, $p<.01$), again with the positive sentences showing a more negative-going wave for the positive sentences irrespective of type. Within the right hemisphere, there was also a significant *P* effect (F(1,31)=30.39, $p<.0001$), showing the same kind of effect.

Also, the interaction between *M* and *REG* turned out to be significant (F(1,30)= 8.99, $p<.01$). The step-down analysis by *REG* revealed a significant *M* effect in parietal regions (F(1,31)=14.00, $p<.001$), again showing a more positive-going component for spliced sentences irrespective of valence.

Taken together, results revealed a positive-going ERP waveform for spliced sentences, that was more pronounced at parietal electrode sites. Also, a bilaterally distributed valence difference between the positive and negative sentences irrespective of sentence type (i.e. spliced and unspliced) was found. See Table 5.3 for a list of all significant effects in the omnibus analysis. In Figure 5.2 ERP effects for the emotional semantic and prosodic violation condition are graphically displayed.

Emotional Prosodic Violation: In the time window of 550 ms to 750 ms, no main effect of *P* was significant, but the interactions *P* x *HEMI* (F(2,60)=9.16, $p<.001$), *P* x *REG* (F(2,60)=4.93, $p=.01$), and the three-way interaction *P* x *REG* x *Sex* (F(2,60)=3.37, $p<.05$) reached significance. As for the first interaction, step-down analyses by *HEMI* showed a significant *P* effect in the right hemisphere (F(2,62)=3.63, $p<.05$). Post-hoc comparisons revealed a positivity for both the negative (*P* effect: F(1,31)=5.17, $p<0.05$) and positive (*P* effect: F(1,31)=4.28, $p<0.05$) spliced sentences.

Time Window: 900 ms - 1125 ms			
Effect	*df*	*F value*	*p value*
M	1,30	5.89	<0.05
P	1,30	21.61	<.0001
HEMI	1,30	15.38	<0.001
REG	1,30	10.21	<0.001
P x *HEMI*	1,30	3.66	<0.07
M x *REG*	1,30	8.99	<0.001

Table 5.3: Significant/borderline results from ANOVAs on mean amplitudes for the time window 900 ms to 1125 ms in the emotional semantic/prosodic violation for all participants.

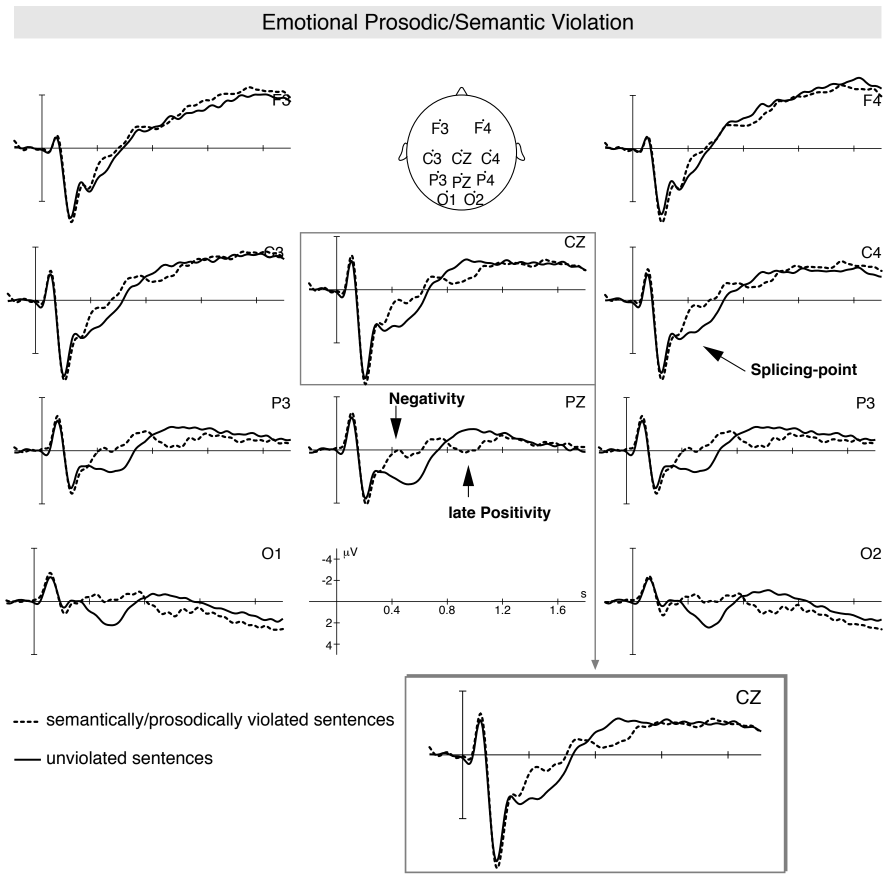

Figure 5.2: The illustration shows ERPs measured at selected electrodes. Waveforms show the average for semantically and prosodically violated (dashed) and unviolated (black) sentences from 200 ms prior to stimulus onset up to 1800 ms post stimulus onset.

Time Window: 550 ms - 750 ms			
Effect	*df*	*F value*	*p value*
HEMI	1,30	3.89	<0.06
P x *HEMI*	2,60	9.16	<0.001
P x *REG*	2,60	4.93	<0.05
P x *REG* x *Sex*	2,60	3.37	<0.05
HEMI x *REG*	1,30	9.41	<0.01

Table 5.4: Significant/borderline results from ANOVAs on mean amplitudes for the emotional prosodic violation for all participants.

Also, for the second interaction, the by-*REG* analysis revealed a frontally distributed *P* effect (F(2,62)=3.69, *p*<.05) with the post-hoc comparisons revealing a positivity for the negative spliced sentences (*P* effect: F(1,31)=7.14, *p*<0.05).

Last, the step-down analysis by-*Sex* for the third significant interaction revealed a significant interaction between *P* and *REG* for male participants (F(2,30)= 6.25, *p*<.01). For the male participants, there was a significant *P* effect in the frontal regions (F(2,30)=5.92, *p*<.05), with post-hoc comparisons revealing a significant positive-going component for the negative spliced sentences (*P* effect: F(1,15)= 20.14, *p*<.001) for males in the frontal regions. See Table 5.4 for a list with all significant effects.

Overall, results suggest that both female and male participants showed a positivity for spliced sentences over right hemispheric electrode sites. However, the effect was found to be more pronounced over frontal regions for negative spliced items and even more pronounced over frontal regions for male participants for negative spliced items. In Figure 5.3 ERP effects for the emotional prosodic violation condition are graphically displayed. See Figure 5.4 for a graphical display of distributional effects in the emotional prosodic violation as well as in the combined violation condition.

5.4 Discussion

The present study examined whether the on-line processing of emotional prosody processing differs with varying task demands. Taken together, the results suggest that the violation of an emotional prosodic intonation contour elicited a similar positivity as found in Experiment 1. However, the positive ERP component observed in this experiment is lateralized to the right hemisphere and its latency is not as long as the latency from the positivity reported in Experiment 1. The same holds true for the violation of an emotional prosodic and semantic violation, i.e. the negativity is distributed similarly but the latency of the two components differs for the two tasks. Also, the onset of the negative ERP component is slightly earlier than the onset of the negativity in Experiment 1. In addition to the early negative ERP component, a later positive-going ERP waveform was observed in the combined

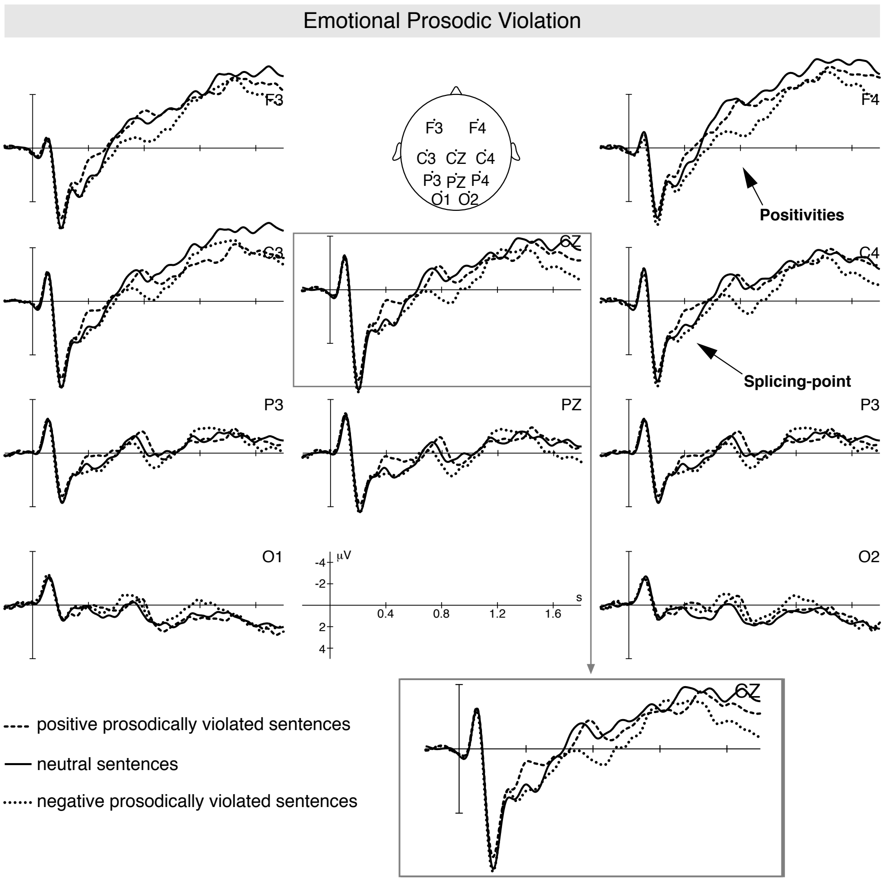

Figure 5.3: The illustration shows ERPs measured at selected electrodes. Waveforms show the average for emotional prosodically violated (dashed/dotted) and unviolated (black) sentences from 200 ms prior to stimulus onset up to 1800 ms post stimulus onset.

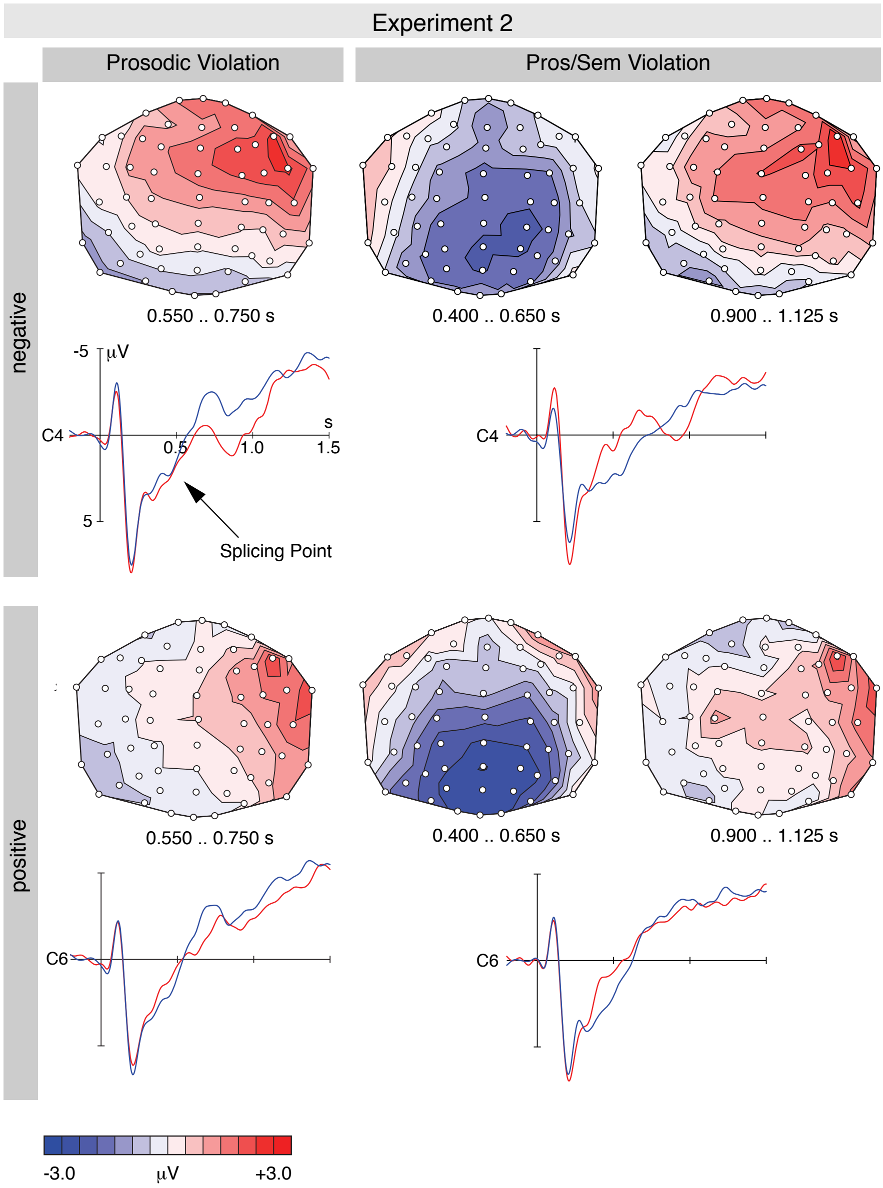

Figure 5.4: The illustration shows ERP difference maps comparing the correct and violated sentences and ERP effects at selected electrodes (C4 and C6). Waveforms show the average for correct (blue) and violated (red) sentences from 200 ms prior to stimulus onset up to 1500 ms post stimulus onset.

violation condition. Furthermore, as in Experiment 1, a significant valence effect was found in the early P200 time window during an explicit emotional prosody processing situation. In the following, results for each condition will be discussed separately.

P200: Within the clinical literature, there is plentiful evidence that emotional prosody processing might differ as a function of valence. However, studies using on-line measurements of emotional prosody investigating this issue in healthy participants are scarce. Still, there are findings that suggest that valence can be differentiated in the ERP (Kotz et al., 2000; Pihan et al., 1997). The current results replicated findings from other studies and further suggest that the early valence distinction in the P200 ERP component is not task dependent, i.e. differences between neutral and negative valences can also be found when asking the participant to focus his/her attention on the emotional prosody. Nevertheless, as was the case in Experiment 1, the P200 components for neutral and positive sentences did not differ significantly.

Valence effects per se (i.e. emotional stimuli in general) have been investigated frequently. For example, early studies by Johnston and colleagues (1986, 1987) revealed larger P300 amplitudes for positive and negative stimuli than for neutral stimuli. Also, a recent study by Carretié and co-workers (2001) suggests that valence can be differentiated in early ERP components. However, the authors suggest that automatic attention to negative pictures is reflected in an earlier ERP component than for positive pictures (P1 vs. P2 ERP components). Interestingly, the current study did not replicate this emotional "time-line" processing with auditory stimuli, but nevertheless, found a difference between the processing of positive emotional prosodic and negative emotional prosodic stimuli. First of all, the P200 component was larger for negative stimuli than for positive or neutral stimuli; however, a difference between positive emotional prosodic stimuli and neutral stimuli was not found. This result might suggest that the negative stimuli were of more evolutionary relevance for participants than the positive stimuli. Within the literature, a so-called negative bias has been discussed, i.e. negative events or stimuli in general lead to faster and more distinguishable responses than non-negative stimuli. This effect has been related to cognitive and emotional behavior (e.g. Carretié et al., 2001; Cacioppo & Gardner, 1999; Mogg & Bradley, 1998). Unfortunately, there are few electrophysiological studies that have explicitly investigated the negativity bias, so the assumption that the current P200 effect is modulated by acoustical parameters and also possibly lexical information (c.f. Experiment 1 discussion) may not be the only interpretation. The present P200 might also be elicited due to evolutionary advantages of attending in a more pronounced way to negative stimuli, though this remains highly speculative. Also, as in Experiment 1, it cannot be specified how and to which extent lexical information has an influence on the P200. For now, it can only be concluded that the current experiment replicated results of valence differentiation in the ERP under an explicit emotional prosody processing task.

Emotional Prosodic Violation: Due to the fact that in humans, emotional prosody is potentially visceral and cognitively controlled, the response to an emotional prosodic violation was investigated not only under an implicit processing situation but also under an explicit emotional prosody processing situation. This procedure allowed for the exploration of implicit and explicit processing and their influence on the emotional prosody channel. Again, by controlling the direction of attention to the emotional prosodic contour, we could specify if emotional prosodic processing relies on automatic or controlled processes.

First and foremost, it needs to be mentioned that the positive ERP component elicited by the emotional prosodic violation found in Experiment 1 was replicated in the current experiment, leading to the conclusion that the positivity cannot solely be an expectancy response, or a response to novel events, with its electrophysiological correlate being the P300. Furthermore, the current experiment provides evidence that the positivity evoked by the emotional prosodic contour violation is very unlikely to be a P600 since the current positive component is shifted rightwards with an explicit emotional prosody processing task. The P600, in contrast, has not been reported to be lateralized with varying task demands. The CPS discussed in the first experiment, however, has been reported to be lateralized (e.g. Pannekamp, Toepel, Hahne, & Friederici, 2003). This similarity makes it even more probable that the two components belong to the same family of ERP components. However, the current experiment was not aimed to further specify the functionality of the positive ERP component, but rather to investigate if responses to violations of emotional prosodic contours might be task-dependent. The results of the current experiment suggest that this is not the case. This result is in contrast to results obtained in the study by Astésano and colleagues, in which the response to F0 manipulations indeed depended on task, i.e. the P800 only evolved under explicit prosodic processing circumstances. This makes it plausible to conclude that the current response evoked is not solely due to a violation of the F0 contour, but is very likely a response to the conjoint influences of acoustical parameters making up emotional prosody. A further study that has investigated emotional prosody processing under two task situations was carried out by Wambacq, Shea-Miller, and Abubakr (2004). In their study, voluntary and non-voluntary processing of emotional prosody was investigated. Their so-called non-voluntary task involved evaluating semantic stimulus characteristics, while their voluntary task required the evaluation of emotional characteristics of the stimulus. Interestingly, as is the case in the current experiment, the authors also found timing differences, in their case between processing emotional prosody under voluntary and non-voluntary situations. Their results imply that emotional prosody is processed earlier when not attending to the emotional tone of voice, whereas the current results suggest that this is not necessarily the case because an earlier onset of the effect was observed when attending to the emotional tone of voice. Thus, it should be noted that the current experiment found an earlier onset to both the emotional prosodic and the combined emotional semantic and emotional prosodic violations, though, the onset of the ERP elicited by the violation for the combination of emotional prosody and emotional semantics was even 150 ms earlier than the onset of the pure prosodic violation. In short, whereas the combination violation elicited a negative ERP component about 150 ms earlier than in the first experiment, the onset of the ERP response for the pure prosodic violation was only about 50 ms earlier. Furthermore, the latency of the ERP effects in both violation conditions was also shorter.

Taken together, the current experiment leads to similar conclusions as were proposed by Wambacq et al. (2004). First, during language comprehension, emotional prosody is processed implicitly. Second, it can also be assumed that emotional prosodic characteristics of a spoken utterance are extracted long before the production of the utterance is complete, i.e. while the average duration of the presented sentences were about 2.5 seconds long, the response to the emotional prosodic contour violation was shortly after the splicing point. Last, it should also be noted that while both the onset and the latency of the ERP component were different under explicit emotional prosody processing circumstances, the distribution of the positivity was also shifted to the right hemisphere. Even though ERPs are not as usefool a tool when trying to localize processing as are other imaging techniques (e.g. fMRI, PET), this rightward shift of the ERP effect under an explicit emotional prosody processing situation nevertheless fits nicely into the proposal that the more emotional a task, the more the right hemisphere might be involved (c.f. Chapter on Emotions and Prosody).

In sum, it is assumed that emotional prosody processing is a highly automatic process that does not seem to be influenced by valence differences, i.e. when encountering violations to an emotional prosodic contour, the valence of this contour does not influence subsequent processing steps. Second, it can be concluded that with attention on the emotional prosodic contour, the ERP effects are shifted rightwards, leading to the assumption that emotional prosody might be processed primarily in the right hemisphere if processed explicitly.

Combined Emotional Prosody and Emotional Semantic Violation: One aim of the current experiment was to investigate whether processing of semantic information predominates the processing of emotional prosody even when the task forces participants to focus their attention on the emotional prosody and not on the semantic content of the stimulus. Since a similar, if not identical, N400-like negativity was found under the explicit prosody processing situation, it can be safely concluded that the semantic information channel still predominates the emotional prosodic channel, at least an an early stage of processing, i.e. this "predominance-effect" is reflected in the negativity occurring 450 ms after sentence onset. Similar results have been reported by Besson and co-workers (Besson, Magne, & Schön, 2002), who have proposed that semantics cannot be ignored, even if participants were asked to focus their attention on linguistic prosody. Interestingly, the authors report that subjects were able to focus their attention on the semantic content of the stimulus, thereby ignoring the prosody. Taken together, these and the current results again lead to the proposal that semantics predominates emotional prosody.

Furthermore, the current experiment was able to show that the influence of semantic context might be influenced by task. Whereas at an early stage of processing (i.e. 450 ms after sentence onset), emotional semantics seems to override emotional prosody, this pattern seems to be reversed at a later stage of processing (i.e. 925 ms after sentence onset). During the current explicit emotional prosody processing situation, a late positive ERP component evolved in addition to the semantically related early negativity. It has been reported that ERP components' amplitudes (e.g. of the P300 component) increase when subjects consider the stimuli to be more relevant for the task (e.g. Bashore & Molen, 1991; Johnson, 1988; Picton & Hillyard, 1988). Up until now, this "relevance-for-task-effect" has been mainly discussed in terms of valence effects reflected in the P300, i.e. the P300 amplitude of emotional stimuli increase when compared to neutral stimuli because participants believed the emotional stimuli to be more relevant for the task. Here, however, a different approach is suggested. Following the line of assumption that the "relevance-for-task-effect" influences language comprehension, it could well be that the later positive ERP component found in the combined violation condition was only elicited because emotional prosody evaluation was mandatory to complete the emotional prosody categorization task and thus the emotional prosody was the more relevant parameter of the stimulus. Surprisingly, the violation of the semantic contour seemed to be processed first, even though emotional prosody was of prior importance for the task. This seems to be even stronger evidence for the fact that semantic information cannot be ignored even if the task requires participants to do so, but that this channel of emotional information might loose its strong influence at a later stage of processing when the emotional stimulus is processed with the focus of attention on the emotional prosodic contour.

As was the case in the prosodic violation condition, the combined violation condition also elicited a negativity with an earlier onset and a shorter latency in the second experiment. It should be noted that this effect does not imply that the negativity is no longer comparable to the N400. As previously mentioned, the N400 has been reported to occur with an onset as early as 200 ms after a stimulus violation during auditory presentation (c.f. ERP chapter). Also, within the literature, there has been an extensive debate on whether emotional information is stored in addition to lexical information in the mental lexicon (c.f. Wurm, Vakoch, Strasse, Calin-Jageman, & Ross, 2001). If the N400 reflects semantic integration problems, then it is plausible to assume that the current negativity reflects integration problems of emotional semantics and emotional prosody. If it is further considered that emotions can be identified during auditory stimulus presentation as short as 100 ms and shorter (e.g. Pollack, Rubenstein, & Horowitz, 1960), then the early onset of the current negativity is not really that surprising.

In sum, it can be concluded that semantic information processing is predominant over emotional prosody processing irrespective of the task applied, i.e. for both implicit and explicit emotional prosody processing tasks. Second, it seems as if emotional prosody gains relevance during processing at a later point of time, i.e. after the first realization of the combined emotional prosody and emotional prosodic violation.

5.4.1 Further Questions

The current results suggest that emotional prosody processing can be somewhat influenced by task, implied in the rightward shift of the ERP component. However, at the same time, results suggest that semantic information always predominates emotional prosody processing. Both Experiment 1 and Experiment 2 made use of a female speaker, which raises the question if results are due solely to the voice used in the experiments. Also, both experiments explored valence effects in a rather over-simplified way if one considers that individuals can experience more than two emotions. Thus, the following ERP experiments are extended in stimuli, make use of both female and a male speakers, and test seven basic emotions (i.e. angry, fearful, disgust, happy, neutral, pleasant surprise, and sad). This approach allows for the further exploration of whether different emotional prosodies elicit different ERP responses and whether the results obtained so far were dependent on the speaker. Before reporting the third ERP experiment, however, a behavioral rating study used to define Experiment 3 stimuli is reported.

Chapter 6

Rating Study

6.1 Introduction

In social interaction, understanding the mood and attitude of the meaning of a spoken utterance is crucial. The emotional expression of a message is usually conveyed by various channels, i.e. through body language, facial expression, and tone of voice. Thus, in order to achieve effective affective interpersonal communication, individuals need to accurately encode the emotional expressions of others. If this accuracy is not guaranteed, and the emotional expression is misinterpreted, the interpersonal communication process is disturbed. It is therefore of social relevance to understand how emotional meaning is encoded and decoded. The following rating study will take up this task by investigating emotional prosody recognition.

Emotional prosody recognition has been studied extensively over the last few years, but there are still several questions that need to be answered. For example, it is still under debate to what extent emotional prosody recognition differs between sexes. There are studies that have reported gender differences when processing emotional prosody (e.g. Schirmer, Kotz, & Friederici, 2002; Hall, 1978). Most often, women are thought to be better than men at identifying or discriminating emotional prosody; however, not all existing studies have reported this gender difference (Raithel & Hielscher-Fastabend, 2004). In addition, it has been suggested that emotional prosody perception does not only differ between female and male, but also that the recognition of emotional prosody declines with age (e.g. Kiss & Ennis, 2001). For example, Kiss and Ennis (2001) carried out a behavioral study which made use of the Emotional Perception Test-Revisited to investigate the perception of emotional prosody in older adults. Their results indicate that older participants were significantly outperformed by their IQ-matched younger controls (e.g. Kiss & Ennis, 2001). Last, it has also been suggested that the perception or recognition of emotional prosody differs between basic emotions. For instance, Banse and Scherer (1996) have reported significant different emotional prosody recognition accuracy rates for different emotional categories. Whereas an emotion like hot anger was recognized with an accuracy rate of 78%, recognition rates for panic fear, shame, or disgust were all below 40%.

The following rating study investigated these issues in a behavioral experiment. Within this experiment, male and female participants of two age cohorts were asked to identify as fast and accurately as possible the emotional prosody of an auditorily presented sentence belonging to one of the seven emotional categories. However, since this experiment was primarily designed to evaluate which sentences might be best suited to be presented in a follow-up ERP experiment, i.e. to present only sentences in the ERP study that were rated consistently, only PCs will be presented and RTs will not be discussed here (see Appendix for a Table with RTs).

6.2 Methods

6.2.1 Participants

Sixty-four participants between the ages of twenty and forty-nine years participated in the experiment. Participants were grouped according to two criteria, age and sex. Thus, two participant groups were analyzed. In the first division, the results of sixteen younger women (mean age 22.88 years, SD=1.89) and sixteen older women (mean age 43.44 years, SD=2.5) were contrasted against results of sixteen younger men (mean age 24.0 years, SD=2.13) and sixteen older men (mean age 41.81 years, SD=3.35). The mean age of all women was 33.16 years (SD=10.67) and the mean age of all men was 32.19 years (SD=9.46). Within the second division, the emotional prosody recognition performance of the sixteen younger women and the sixteen younger men (mean age 23.44 years, SD=2.06) was compared to the performance of the sixteen older women and the sixteen older men (mean age 42.63 years, SD=3.02). All participants had normal or corrected to normal vision and no hearing impairment. The native language of all participants was German.

6.2.2 Stimulus Material

The stimulus material consisted of 350 syntactically similar (SVO) sentences. The verbs and nouns of the sentences were controlled for word letter length, syllable length, word frequency, initial sounds, and plosive consonants. There were no repetitions of the critical material. Prior to testing, sentences were grouped according to whether they belonged to one of the six basic emotion categories (anger, disgust, fear, happy, pleasant surprise, sadness) or to a semantically neutral category (50 sentences in each category). Four German actors (two female, two male) of two age cohorts (young/middle-aged) were then asked to produce each sentence with the respective emotional prosody. This made a total of 1400 sentences. Sentences were taped with a video camcorder (SONY Digital Videocamera Recorder MiniDV DCR-TRV60E). The video-material was digitized and the voice-track was separated from

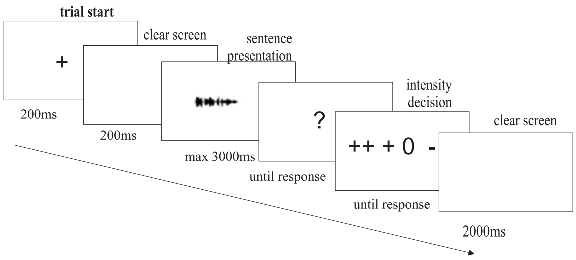

Figure 6.1: The figure above shows a schematic illustration of a trial presentation with all sequences of events occurring in one trial.

the visual-track. Within the experiment, only the voice material was presented. The voice material was digitized at 16-bit/44.1 kHz sampling rate and the amplitudes were normalized (with *CoolEdit Version 2000*). The stimulus material was prosodically analyzed (i.e. pitch, intensity, and duration of the sentences were extracted) using *Praat*. Results of the acoustical analyses can be found in Table 6.1 below. In order to control the length of the experiment for the participants, the material was divided into four lists (350 sentences each). In each of the lists, all 50 sentences of each emotional category were presented; however, lists differed with respect to which speaker articulated the sentence. Each list was pseudo-randomized. Each participant was presented with one of the four lists.

6.2.3 Procedure

Each participant was tested individually and was seated at a computer with a seven-button panel placed before him/her. Participants were seated in a chair at a distance of approximately 60 cm from the computer monitor. The sentences were presented via loudspeaker with a distance of about 70 cm from participants. ERTS (Beringer, 1993) was used to carry out the experimental task. Directions, with examples, asked subjects to listen to the sentence presented and to first make a decision on emotional prosody as accurately and as quickly as possible and second, to make a decision on the stimulus intensity as quickly and accurately as possible. The trial sequence was thus as follows: 1) presentation of fixation cross for 200 ms, 2) clear screen for 100 ms, 3) acoustical presentation of sentence with simultaneous presentation of a question mark on the screen that indicated that the emotional prosody categorization decision was now applicable, 4) clear screen for 500 ms, 5) presentation of picture (++ + 0 - –) which indicated that the intensity categorization decision was now applicable, 6) intertrial interval of 2000 ms. Answers had to be given within a time frame of 8000 ms measured. See Figure 6.1 for a schematic illustration of this procedure.

Acoustical Analyses: Stimulus Material Rating Study, and folow-up Experiments 3, 4, and 5

ACTOR	EMOTION	MEAN/SD	meanF0	sdF0	maxF0	minF0	rangeF0	udur	meandB	sddB	maxdB	mindB	rangedB
FEMALE OLD	ANGER	mean	276.57	46.65	393.86	176.60	217.26	2.90	64.57	16.32	83.64	28.08	55.56
		sd	31.52	10.96	59.65	26.73	59.11	0.25	1.65	0.63	0.95	3.34	3.38
MALE OLD			174.59	43.48	264.33	101.45	162.88	3.18	63.73	15.63	82.46	28.40	54.06
			22.37	9.24	32.37	18.28	34.30	0.40	2.18	0.69	0.97	3.12	3.39
MALE YOUNG			256.36	46.41	346.88	138.56	208.32	3.01	68.13	16.99	85.62	29.49	56.14
			25.44	5.22	28.35	20.65	28.81	0.24	1.72	0.74	0.95	3.22	3.08
FEMALE, YOUNG			279.16	36.99	359.87	194.48	165.40	2.46	66.91	15.53	83.52	32.60	50.92
			14.33	8.59	31.59	17.05	36.94	0.14	2.79	0.65	0.92	3.07	3.09
MEAN			246.67	43.38	341.24	152.77	188.46	2.89	65.83	16.12	83.81	29.64	54.17
SD			49.12	4.50	54.97	41.41	28.35	0.30	2.04	0.68	1.32	2.06	2.34
FEMALE OLD	DISGUST	mean	247.53	39.25	356.41	171.22	185.18	3.86	67.92	15.47	83.91	30.58	53.33
		sd	33.03	10.08	57.67	18.81	51.92	0.51	2.12	0.81	0.83	0.71	1.02
MALE OLD			136.10	24.07	205.90	95.15	110.76	3.32	62.44	15.79	82.22	28.52	53.71
			15.68	6.53	46.99	13.24	43.65	0.40	1.89	0.59	0.64	0.37	0.54
MALE YOUNG			130.92	19.27	177.99	95.36	82.63	2.90	65.55	15.26	82.38	31.67	50.71
			31.60	7.48	48.88	17.58	38.14	0.29	2.86	0.71	1.05	0.44	1.12
FEMALE YOUNG			222.72	27.46	331.55	171.57	159.98	2.70	62.60	15.96	82.27	28.18	54.09
			10.55	12.23	81.32	18.14	79.62	0.25	5.28	0.58	5.12	4.98	0.84
MEAN			184.32	27.51	267.96	133.33	134.64	3.20	64.63	15.62	82.70	29.74	52.96
SD			59.57	8.52	89.09	43.96	46.45	0.51	2.62	0.31	0.81	1.67	1.53
FEMALE, old	FEAR	mean	240.43	25.35	316.17	182.13	134.05	3.30	65.61	14.78	82.40	30.81	51.59
		sd	26.76	8.41	57.40	25.43	46.10	0.52	2.32	0.70	1.15	1.22	1.46
MALE, old			202.34	32.72	276.85	137.59	139.26	2.86	64.01	16.61	82.96	28.60	54.36
			17.60	5.89	36.49	17.88	32.77	0.29	1.83	0.75	0.75	0.98	0.95
MALE, YOUNG			120.34	12.18	159.92	96.15	63.77	4.34	65.89	14.54	83.11	29.79	53.31
			10.23	2.48	18.40	10.22	18.83	1.11	3.01	0.81	0.96	2.63	2.28
FEMALE, YOUNG			247.04	15.42	301.19	216.20	84.99	2.54	62.77	14.05	83.06	32.07	51.00
			10.12	8.25	53.03	19.07	55.50	0.18	2.05	0.84	1.27	1.02	1.48
MEAN			202.54	21.42	263.53	158.02	105.51	3.26	64.57	14.99	82.88	30.32	52.56
SD			58.23	9.39	70.95	52.32	37.04	0.78	1.46	1.12	0.33	1.48	1.55
FEMALE, old	HAPPY	mean	263.28	66.63	434.35	156.02	278.34	2.81	65.93	15.90	83.23	30.42	52.81

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ACTOR	EMOTION	MEAN/SD	meanF0	sdF0	maxF0	minF0	rangeF0	udur	meandB	sddB	maxdB	mindB	rangedB
		sd	34.75	15.26	64.75	17.34	63.20	0.25	2.48	0.68	1.02	0.67	1.10
MALE, old			190.10	42.08	276.51	111.94	164.57	2.77	62.72	17.06	82.82	28.34	54.48
			24.42	9.62	38.20	17.51	35.06	0.32	1.89	0.62	0.58	1.01	0.95
MALE, YOUNG			139.65	36.65	230.15	92.79	137.36	2.79	64.58	16.58	82.40	28.58	53.82
			13.31	8.19	42.52	5.26	41.24	0.25	2.61	0.64	0.87	0.39	0.84
FEMALE, YOUNG			273.45	40.75	361.06	196.90	164.17	2.29	65.37	16.40	83.37	32.04	51.32
			15.56	6.84	23.74	13.63	25.40	0.17	2.35	0.52	1.04	1.00	0.99
MEAN			216.62	46.53	325.52	139.41	186.11	2.66	64.65	16.49	82.96	29.84	53.11
SD			63.34	13.60	90.56	46.58	62.79	0.25	1.40	0.48	0.44	1.73	1.38
FEMALE, old	NEUTRAL	mean	196.13	32.78	284.92	141.64	143.28	3.43	65.67	14.77	82.79	30.56	52.23
		sd	9.13	10.58	56.40	7.51	54.22	0.33	1.88	0.44	0.81	0.74	0.65
MALE, old			109.60	17.67	148.79	78.71	70.08	2.91	62.36	15.63	82.30	28.33	53.97
			7.72	3.27	15.51	2.97	14.44	0.34	1.80	0.48	0.60	0.04	0.61
MALE, YOUNG			118.84	18.89	180.86	91.21	89.65	2.80	66.16	16.12	82.59	28.41	54.18
			7.81	4.24	28.77	5.07	28.27	0.26	2.97	0.54	0.97	0.27	1.06
FEMALE, YOUNG			223.00	20.13	276.82	182.95	93.87	2.35	65.18	15.98	83.29	31.87	51.42
			9.74	5.82	27.82	13.05	28.66	0.20	2.51	0.55	0.75	0.62	0.66
MEAN			161.89	22.36	222.85	123.63	99.22	2.87	64.84	15.62	82.74	29.79	52.95
SD			56.26	7.02	68.34	48.00	31.15	0.45	1.70	0.61	0.42	1.73	1.34
FEMALE, old	PLS SURP	mean	358.10	84.69	541.98	192.02	349.95	2.99	65.90	16.29	84.03	30.02	54.01
		sd	37.96	16.79	45.59	27.53	48.25	0.35	2.54	0.77	0.88	1.66	1.72
MALE, old			229.32	49.19	314.03	129.99	184.04	2.71	64.56	17.06	83.68	28.71	54.97
			25.97	8.00	26.63	26.16	27.66	0.27	1.95	0.72	0.96	1.68	1.50
MALE, YOUNG			224.87	52.26	332.06	121.43	210.62	2.77	67.12	17.36	83.83	27.98	55.85
			19.31	7.68	28.15	15.29	33.17	0.19	3.32	0.89	0.68	1.83	1.80
FEMALE, YOUNG			331.54	64.90	480.34	205.10	275.24	2.70	66.24	16.42	83.75	31.41	52.34
			19.90	11.62	48.40	17.47	52.48	0.23	3.08	0.67	0.90	1.43	1.37
MEAN			285.96	62.76	417.10	162.14	254.96	2.79	65.96	16.78	83.82	29.53	54.29
SD			68.85	16.12	111.73	42.54	74.01	0.14	1.06	0.51	0.15	1.51	1.51
FEMALE, old	SADNESS	mean	190.53	14.21	233.81	156.56	77.25	3.43	64.56	13.96	82.58	32.08	50.50
		sd	10.02	4.29	34.25	11.48	33.91	0.43	2.14	0.91	1.08	1.93	2.18
MALE, old			120.04	11.69	152.40	97.03	55.37	2.74	63.65	15.83	82.76	28.56	54.20

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ACTOR	EMOTION	MEAN/SD	meanF0	sdF0	maxF0	minF0	rangeF0	udur	meandB	sddB	maxdB	mindB	rangedB
			7.55	2.28	19.82	7.72	18.19	0.27	1.86	0.55	0.64	0.53	0.41
MALE, YOUNG			128.32	13.70	164.48	97.83	66.65	2.85	67.20	15.25	82.38	29.25	53.13
			16.53	4.76	27.62	10.62	25.73	0.24	1.72	0.60	0.90	0.79	0.98
FEMALE, YOUNG			266.38	16.63	316.29	234.94	81.34	2.49	64.63	15.26	83.41	32.17	51.23
			32.56	4.98	29.21	18.42	24.38	0.22	2.08	0.48	1.05	0.94	0.77
MEAN			176.32	14.06	216.74	146.59	70.15	2.88	65.01	15.08	82.78	30.51	52.27
SD			67.78	2.03	75.43	65.16	11.64	0.40	1.53	0.79	0.44	1.88	1.70

Table 6.1: The Table lists results from acoustical analyses of the 350 sentences that were included in the Rating Study. The top-30 categorized sentences from each emotion were included in the follow-up ERP-Experiments 3, 4, and 5. Listed are mean, min, max, and range of F0 (measured in Hz), mean, min, max, and range of intensity (measured in dB), as well as mean duration of utterances (udur).

6.3 Results

As was mentioned in the introductory part of this experiment, only PC values are reported here (for a graphical illustration of mean intensity ratings see Appendix). For more information on RTs, see Appendix. In general, emotional prosody recognition was above chance level, since chance level was at 14%. In Illustration 6.2, mean PC values for each emotion are illustrated. The mean PC over all actors for the emotional prosody of anger was 87.69% (SD 9.5). Together with neutral vocalizations (mean PC 88.65%, SD 5.88), anger was the best recognized emotional prosody. Followed by disgust vocalizations (mean PC 76.19%, SD 25.09), sad (mean PC 63.96%, SD 19.67), and happy utterances (mean PC 62.09%, SD 14.4), it becomes obvious that the emotional prosody of fearful sentences (mean PC 58.16%, SD 15.41) and pleasant surprise vocalizations (mean PC 43.48%, SD 11.52) were recognized least accurately. In Illustration 6.3, mean PC values for each speaker and emotion are illustrated.

Accuracy data over all seven basic emotional categories were also calculated with an ANOVA, treating *Affect* (angry/disgust/fear/happy/neutral/pleasant surprise/sadness), *Speaker-age* (young/old), and *Speaker-sex* (female/male) as repeated-measures factors and participant *Sex* (male/female) and participant *Age* (young/old) as between-subject factors.

No overall *Sex* effect for participants was found to be significant (p>.05); however, the *Age* effect for participants turned out to be highly significant (F(1,57)= 21.48, p<.0001), indicating better recognition rates for younger participants than for older participants (72.83% vs. 62.51%). Also, an overall effect of *Affect* turned out to be higly significant (F(6,342)=77.17, p<.0001). However, since no prior hypotheses were clear with regard to which emotional category might be recognized best and which might be categorized worst, no post-hoc comparisons were carried out. It is believed that listing the mean PC values for each emotion (as done above) suits the purpose of stating which emotion was categorized best (anger) and which was categorized worst (pleasant surprise). However, of importance for this rating study was that there was a significant main effect of *Speaker-age* (F(1,57)=67.60, p<.0001), revealing better recognition rates for vocalizations produced by the older actors (mean of approx. 70%) than for the younger actors (mean of approx. 65%). In addition, *Affect* interacted with *Speaker-age* (F(6,342)=11.45, p<.0001). Step-down analyses by *Affect* revealed significant *Speaker-age* effects in the emotional categories of fear (F(1,60)=24.65, p<.0001), of neutral (F(1,60)=19.92, p<.0001), and of pleasant surprise sentences (F(1,59)=65.28, p<.0001), all showing that the emotional vocalizations of the older actors were better recognized than the ones of the younger actors. (Note that observations with missing values, i.e. when no button-press was registered, or no correct answer was registered, were not included in these analyses, so for the emotional category of pleasant surprise only 63 participants were analyzed instead of 64).

Furthermore, an interaction between *Affect* and *Speaker-sex* turned out to be significant ($F(6,342)=9.62$, $p<.0001$). Step-down analyses by *Affect* revealed significant *Speaker-sex* effects in the emotional categories of disgust, ($F(1,60)=10.88$, $p<.01$), pleasant surprise ($F(1,59)=5.32$, $p<.05$), and sad sentences ($F(1,59)=22.04$, $p<.0001$), revealing that the female actresses were better recognized than the male actors for the emotional category of sadness (70% vs. 56%), but not for the emotional categories of disgust (72% vs. 77%), or pleasant surprise (41% vs. 45%) (again, note that no observations with missing values were included in these analyses).

Last, there was a significant interaction between *Affect* and *Speaker-sex* and *Speaker-age* ($F(6,342)=12.47$, $p<.0001$). First step-down analyses by *Affect* revealed significant interactions between *Speaker-sex* and *Speaker-age* for the emotional categories of anger ($F(1,60)=6.01$, $p<.05$), fear ($F(1,60)=8.29$, $p<.01$), and pleasant surprise ($F(1,59)=61.85$, $p<.0001$). This allowed for further step-down analyses in these emotional categories by *Speaker-age*. For the emotional category of anger, a significant *Speaker-sex* effect was found for the older actors ($F(1,60)=5.86$, $p<.05$), indicating better recognition rates for the older female speaker than for the older male speaker (89% vs. 85%). No such effect was found for the younger actors. In contrast, for the emotional category of fear, this same *Speaker-sex* effect was found for the younger actors ($F(1,60)=7.11$, $p<.01$), indicating better recognition rates for the younger female speaker than for the younger male speaker (54% vs. 47%). For the emotional category of pleasant surprise, the *Speaker-sex* effect was found for the older actors ($F(1,60)=36.41$, $p<.0001$) as well as for the younger actors ($F(1,59)=15.54$, $p<.001$). While for the older actors, it was found that the male speaker was better recognized than the female speaker (58% vs. 43%), the opposite was true for the younger actors, where it was found that the female speaker was better recognized than the male speaker (39% vs. 32%). Last, for the emotional category of sadness, the *Speaker-sex* effect was found again, for both, the older actors ($F(1,60)=29.06$, $p<.0001$) as well as for the younger actors ($F(1,59)=7.10$, $p<.01$), this time indicating better recognition rates for both female actresses compared to their age-matched male actors.

No other interactions that were of any relevance for the aim of the study turned out to be significant. Please see Table 6.2, and Tables A.5, A.6, A.7, A.8, A.9, A.10, and A.11 in the Appendix for a list with all significant interactions (also split by emotional category), including those that were of no theoretical importance to the research question of which actors might be best suited to for the follow-up ERP experiments.

6.4 Discussion

Taking all emotions portrayed here together, an average accuracy percentage of approx. 70% was obtained, i.e., the accuracy percentage of emotional prosody recognition was five times higher than what one would expect by chance alone. This result is in line with the

Omnibus Analysis			
Effect	*df*	*F value*	*p value*
SEX	1.57	3.24	<0.08
AGE	1.57	21.48	<.0001
EMOTION	6.342	77.17	<.0001
Actor-age	1.57	67.60	<.0001
Actor-age x *AGE*	1.57	7.46	<0.01
EMOTION x *Actor-age*	6.342	11.45	<.0001
EMOTION x *Actor-age* x *AGE*	6.342	2.46	<0.08
EMOTION x *Actor-sex*	6.342	9.62	<.0001
Actor-age x *Actor-sex*	1.57	8.45	<0.01
EMOTION x *Actor-age* x *Actor-sex*	6.342	12.47	<.0001

Table 6.2: Significant/borderline results from ANOVAs on percentage correct as revealed in the Rating Study for all participants for all tested emotional categories.

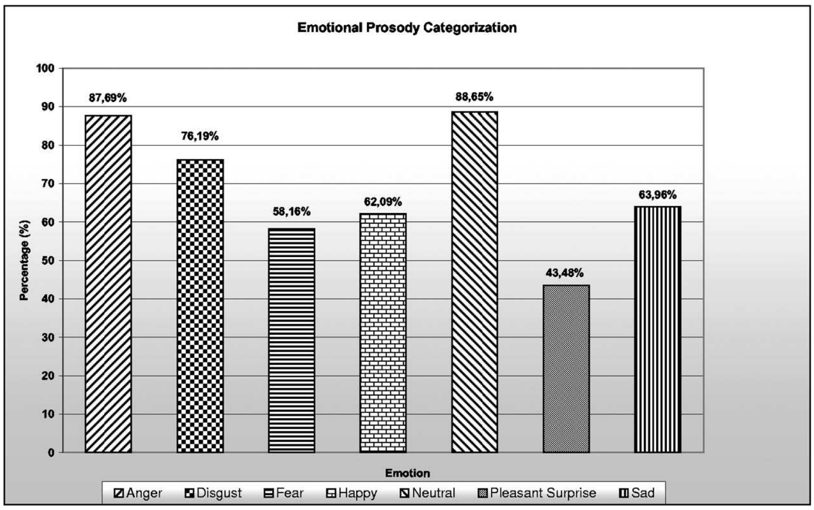


Figure 6.2: The illustration shows percentage correct (in %) for emotional prosody categorization as revealed from results of the Rating Study.

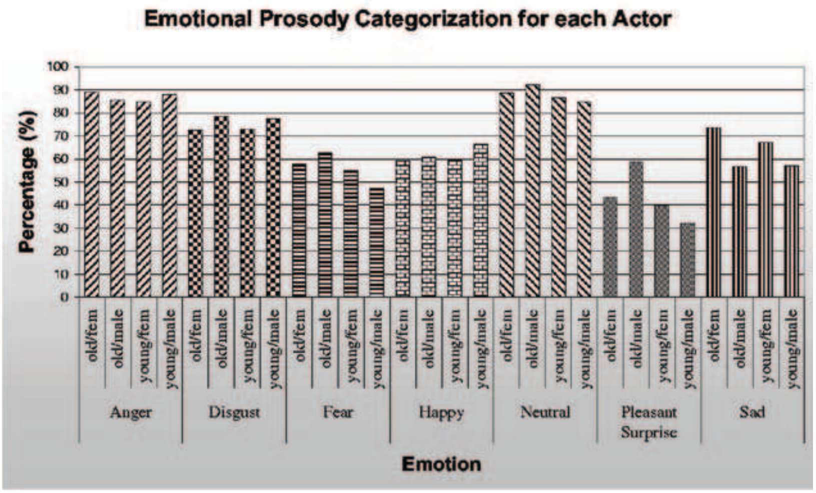


Figure 6.3: The illustration shows percentage correct (in %) for emotional prosody categorization for each speaker as revealed from results of the Rating Study.

literature (e.g. Scherer, Johnstone, & Klasmeyer, 2003) where similar results have been reported. In an early study by Bezooijen (1984), an accuracy rate of 65% was reported for the emotional vocalizations of anger, disgust, fear, inburst, joy, sadness, shame, and surprise. In a study by Scherer, Banse, Wallbott, and Goldbeck (1991), the mean accuracy rate was a bit lower, namely 56% for the emotional vocalizations of anger, disgust, fear, joy, and sadness.

As for the hierarchy of the ease of identification of different emotional categories, results reported in the literature are a bit more mixed. The emotional category recognized best varies from study to study; however, according to Banse and Scherer (1996), anger and sadness are often best recognized. Interestingly, sadness is not as well recognized as anger in the current study. This raises the question of why this might have been the case and if emotional categories might have been confused as is also reported to occur in the literature. In particular, it has been argued that emotions which may be acoustically similar, such as anger and enthusiasm, are often misidentified despite semantic differences. Furthermore, misinterpretation is also said to occur between emotions that are similar in terms of their emotional valence (e.g. happiness and pleasant surprise) and their emotional arousal, i.e. anger and sadness are less often confused than anger and fear due to the similarly high arousal level of anger and fear (c.f. Scherer, 1981). This would also explain why emotions such as happiness and pleasant surprise are often misinterpreted when occurring in isolation, i.e. without a situational context. Both emotions of happiness and pleasant surprise belong to the same valence category and are also similar with regard to their physical arousal that they might elicit in the listener, or decoder. Taken together though, the current results suggest that the hierarchy of recognizability of emotional prosody which often varies from study to study is due to the acoustical data presented rather than being a universally applicable hierarchy.

This conclusion leads to a difficulty which needs further discussion. All emotional expressions presented here were portrayed by professional actors and were not samples from real-life situations. As has been mentioned by others (e.g. Scherer et al., 1991; Banse & Scherer, 1996), actors might not be equally well in portraying all emotional categories very well, e.g. one speaker might be very good at portraying anger but not at disgust, whereas another speaker's performance might be vice versa. Furthermore, it has been suggested that listeners might be better at recognizing emotions from particular voices (c.f. Bachorowski, 1999). In general, it can therefore be said that it is easier and/or more difficult to recognize an emotion from one voice or another, but also that the speakers or actors might differ in the quality of their emotional portrayals. The current results revealed an overall Speaker-age effect, which suggests that the emotional prosodies produced by the older actors were generally better recognized ($\sim$70% vs. $\sim$65%). In this case, one could assume that the longer working and life experience of the two older actors might have contributed to this effect. It should be noted, though, that the interaction between *Speaker-age* and *Affect* revealed only portrayal differences in emotional prosody recognition of fearful, neutral, and pleasant surprise vocalizations, but not in e.g., angry or sad utterances. This effect nicely reflects the observation by Banse and Scherer (1996) where it has been stated that anger and sadness are two emotions that are often best recognized. Even though this was not the case in the current study, it can be assumed that there is no *Speaker-age* difference in emotional prosody recognition of the two emotions of sadness and anger because they are easy to recognize, but also easy to portray. In addition to the *Speaker-age* effect, there were also significant *Speaker-sex* effects in the different emotional categories, revealing different recognition rates, i.e. no universal pattern for emotional recognition for sentences made by female actresses or by male actors. This is rather surprising, because it is often suggested in the literature that women are more emotionally expressive than men (e.g. Polce-Lynch, Myers, Kilmartin, Forssmann-Falck, & Kliewer, 1998). However, as has been noted elsewhere, only two actors of each sex were included in the current experiment and their individual performance in portraying emotional prosody differed, so gender differences should be replicated in studies making use of more than two actors of each gender. Nevertheless, the current study helps to shape a growing awareness of how important the gender of the speakers might be when investigating emotional prosody.

As for the gender and age differences in the population tested in the current experiment, it can be concluded that no *Sex* effect has been found, i.e. women did not outperform men as might have been assumed by some existing studies. However, there was a significant decline of emotional prosody recognition with increasing age of participants. This results is again in line with the literature, where it has been suggested that emotional prosody recognition declines with increasing age (e.g. Orbelo, Testa, & Ross, 2003). Interestingly, the two age cohorts were rather close in age, i.e. the older adults were still not as old as populations reported in the literature. Thus, it would be interesting to clarify, if emotional prosody recognition further declines with even older participants. It could also be interesting to experimentally test, if a critical period exists for emotional prosody recognition. This could be done, e.g., by testing more than two age cohorts to specify a point of time of when emotional prosody recognition might start to decline with age.

Before summarizing the results, one point should be critically mentioned with regard to the current study. It has been criticized by Banse and Scherer (1996) that many emotional prosody recognition studies make use of limited emotional categories, and due to the limited number of categories and the task applied, it cannot be determined whether recognition or discrimination processes have been studied. The current experiment is no exception to this problem. Given that there are only two positive emotions, it could well be that in cases of doubt, a discrimination process was involved rather than a recognition process. Obviously, real-life situations seldom lead to emotional discrimination but require emotional prosody recognition. Also, the use of portrayed emotional expressions does not reflect real-life situations. However, it is believed that acted or posed emotional prosodies will engage the same emotional prosody processing as used in real-life situations. Also, even though the limitations of the current experiment are recognized, it is assumed that the experiment served its real purpose, namely to find out which sentences of an emotional category are best suited for the following ERP-experiments.

In sum, it can be said that emotional prosody recognition was above chance level, a result which is often interpreted as evidence that listeners relate particular patterns of acoustic cues with different emotional categories. As there are studies that report cross-cultural similarities (Scherer, Banse, & Wallbott, 2001) in accuracy rates for particular emotional categories, it is thus assumed that individuals are able to recognize an emotion from speech (c.f. Bachorowski, 1999). The current experiment failed to find gender differences between participants. This result is not to imply that these differences do not exist but rather that more systematic research beyond the present scope needs to be carried out in this field. However, results imply that more extensive acting and/or life experience of actors might lead to better performance in emotional prosody portrayal. Whether this factor has an effect on on-line emotional prosody processing will be tested explicitly in the following ERP experiments.

Chapter 7

Experiment 3

7.1 Introduction

As was made clear in Chapter 2, not only is linguistic information conveyed through speech sounds, but also speaker information, i.e. speaker identity (e.g. female/male; young/old) as well as the speaker's emotional state (e.g. happy/sad). It was also mentioned that speaker information is typically thought to be conveyed through pitch, intensity, and duration (or tempo). However, little is known about the underlying processing mechanisms of speaker information. Thus, whereas the first two experiments were designed to investigate the dissociation between emotional prosody and emotional semantics and thus to explore their joint influences on an emotional vocalization, the aim of the third ERP experiment was slightly differently orientated and investigated emotional prosody in general and the influence of speaker information on emotional prosody in particular. Its aim was twofold. First of all, the experiment was designed to explore if different emotional prosodies, i.e., prosodies from six basic emotions (anger, disgust, fear, happiness, pleasant surprise, sadness) and a neutral baseline could be differentiated in the ERP. If so, at which point in time does this differentiation occur first? Evidence from the first two ERP experiments reported previously as well as evidence from other studies investigating the processing of emotional prosody (Kotz et al., 2000) suggest that the P200 component might be the electrophysiological correlate to differentiate the different emotional prosodies. However, as has been mentioned previously, it is not yet clear to what extent the P200 may reflect only acoustical stimulus differences, e.g., intensity or pitch variations in particular. The experiment to be reported here tested this influence by introducing emotional stimulus that differed in intensity and/or pitch variation as well as in the emotional content of the utterance. If the P200 effect found in e.g. Kotz et al. (2000) was solely related to intensity or pitch differences, then the different emotional prosodies included in the current stimulus material should be reflected in the P200 component systematically. To clarify, if intensity or pitch alone modulate the P200, i.e., the louder the utterance/the higher the pitch, the larger the P200, then we should find a systematic hierarchy of emotional prosodies in the P200 according to their intensity/pitch level. If, however, intensity or pitch variation are not solely responsible for the P200 modulation, this should be reflected in varying P200 amplitudes. Thus, if, as hypothesized and previously proposed, an interaction of intensity, pitch, and possibly lexical information is primarily responsible for the P200 effect, we expect no systematic variation in the P200.

It will also be possible to explore if female and male speakers of emotional prosody will lead to different ERP responses. Behavioral studies suggest that voice identity (e.g. sex of the speaker) is already processed before phonological encoding occurs (e.g. Mullenix, 1997). However, ERPs are a more useful tool when investigating temporal aspects of speech processing. The current experiment will test if female and male speakers of emotional prosody will lead to different ERP responses and if so will be able to specify at which point in time this differentiation occurs first. There is evidence from Mismatch Negativity (MMN) Studies investigating voice identity irrespective of emotional prosody. For instance, in an odd-ball experiment, Titova and Näätänen (2001) investigated pre-attentive processing of speaker information. Results revealed an MMN for a change in voice identity. This suggests that voice identity can be processed rather early in speech processing. If the MMN is the pre-attentive neurophysiological correlate for voice identity processing than it can be speculated that under attentive speech processing situations the P200 might be the dependant to the MMN. It is thus hypothesized that the two speakers will be differentiated in the P200 component, i.e., the ERPs in response to their voices, will vary in amplitude size. Also, if women are really more emotionally expressive then men does the response to this differentiation occur as early as 200 ms after sentence onset?

Another aim of the current experiment was to see if results from the first two experiments could be replicated by showing that responses to prosodically violated or prosodically and semantically violated stimuli are really valence-inde-pendent. If this were the case, we would expect the same kind of positivity and negativity for the two types of violations, respectively, in all six emotional prosodies. Also, the experiment aimed to specify if this response is only obtained when listening to a female voice, or whether this response is gender independent. It could be hypothesized that the ERP effects will only be obtained when listening to a female speaker due to the fact that female voices are thought to be more salient (e.g. Lattner, Meyer, & Friederici, 2005), and so, a violation of an emotional prosodic contour is realized more quickly and more accurately than when perceiving a violation of an emotional prosodic contour by a male voice.

It is assumed that in natural real-life situations emotional prosody is usually processed implicitly. In order to investigate emotional prosody processing as naturally as possible in an experimental setting, a probe verification task was once again applied. Due to the large battery of stimulus material it was decided to make use of one female and one male voice only. As the previous rating study revealed above-chance level of emotional prosody recognition for all four actors, it was decided that voices from two speakers only would be presented. Also, it should be noted that the stimulus battery was still very large in size with only two actors presented.

7.2 Methods

7.2.1 Participants

Forty-one right-handed volunteers were invited to participate in two experimental sessions. Ten subjects had to be excluded from the data analysis due to excessive eye movements and other muscle artifacts (all subjects who were excluded from the statistical data analysis had less than 50% of trials for each speaker in two or more conditions). Thus, only 31 subjects were included in the data analyses. Seventeen of the subjects were women with a mean age of 24.2 (SD 2.48) years. The sixteen male subjects had a mean age of 26.2 (SD 2.86) years. As in the first two experiments, all subjects were native speakers of German with no reported hearing or neurological problems. All participants had normal or corrected-to-normal vision. The two sessions were separated by at least three days. Again, subjects received seven Euro per hour.

7.2.2 Stimulus Material

The material consisted of semantically and prosodically matching stimuli for each of the six basic emotions, i.e. anger, fear, disgust, happy, pleasant surprise, sad, and a neutral baseline (see Table 7.2 for a list with examples). Thirty sentences of each emotion were presented, adding up to 210 correct sentences. In addition, just as in the first two experiments, the same sentences were spliced in two ways : a) in the combined semantic/prosodic violation condition, a semantically and prosodically neutral start of the sentence was spliced to a semantically and prosodically matching end of the sentence, and b) in the pure emotional prosodic violated condition, a prosodically neutral start of the sentence was spliced to an prosodically emotional end of the sentence (see Figure 7.1 for detailed examples). This resulted in 360 spliced sentences (180 for each violation type). To balance spliced and unspliced sentences, 150 correct filler sentences were added (22 pleasant surprise, 22 disgust, 22 happy, 22 fearful, 22 sad, 20 angry, and 20 neutral sentences). Each sentence was spoken by a trained female and a trained male German native speaker. Thus, a total of 1440 trials were presented in two sessions. Trials were pseudo-randomized and distributed over ten blocks each containing 72 trials in each session. In each block, 36 correct trials (unspliced items) and 36 incorrect trials (spliced items) were presented. Emotional prosodic valence was obtained in an earlier rating study (see Section 6 above). The critical sentences presented were accurately rated as with at least 70% in the rating study corresponding to one particular emotion (with the exception of pleasant surprise utterances, in which due to the general low percentage of recognition, the utterance had to be accurately rated as with at

prosodic & semantic neutral start	prosodic & semantic emotional end of sentence		
Er hat *(He has*	das Paar gereizt und aufgebracht. *teased and und upset the couple).*	⟶	ANGER
Er hat *(He has*	die Müllhalde bewohnt und gestunken. *lived in the dump and stunk).*	⟶	DISGUST
Er hat *(He has*	die Spuren verwischt und verschleiert. *blurred and disguised his traces).*	⟶	FEAR
Sie hat *(She has*	die Trauung verkündet und gelächelt. *announced the wedding and smiled).*	⟶	HAPPY
Er hat *(He has*	das Geheimnis gelüftet und preisgegeben. *disclosed and broke the secret).*	⟶	PLEASANT SURPRISE
Er hat *(He has*	die Großmutter beerdigt und geweint. *burried his grandmother and cried).*	⟶	SADNESS

Figure 7.1: The illustration explains the splicing procedure for the combined emotional prosodic and emotional semantic violation. A semantically and prosodically neutral start of a sentence is spliced to a semantically and prosodically matching end of a different valence. For the pure emotional prosodic violation, the splicing procedure was comparable except that all sentences were of neutral semantics.

least 50% in the rating study to be included in this experiment). As for Experiment 1 and 2, the mean splicing point was calculated by measuring the mean duration of the neutral start of the sentences that were used as splicing templates (in this case "Er hat"/"Sie hat" articulated by both speaker), revealing a mean splicing point at 337.5 ms after sentence onset. Sentences were taped with a videocamcorder and later digitized at 16-bit/44.1 kHz sampling rate. The stimulus material was prosodically analyzed (i.e. pitch, intensity and duration of the sentences were extracted) using *Praat*. Results of the acoustical analyses for the two speaker can be found in Table 7.1.

7.2.3 Procedure

The procedure was comparable to Experiment 1. Again, directions, with examples, asked subjects to listen to the presented sentence, to read the following word (flashed on the screen for 300 ms), and to make a decision for the probe as accurately and as quickly as possible. The intertrial interval (ISI) was 1500 ms. Two experimental lists contained all the sentences in pseudo-randomized order. In each list, half of the sentences were spoken by the female speaker, the other half by the male speaker. One version of the list was presented in the first session, and the other version was presented in the second session. Half of the subjects

Speaker	Parameter	Anger	Disgust	Fear	Happy	Neutral	Pleasant Surprise	Sad
Female	Mean F0	279.69 (36.34)	248.08 (27.72)	248.27 (31.11)	259.12 (34.39)	197.86 (9.86)	356.14 (39.75)	190.13 (10.13)
	Range F0	217.33 (60.51)	180.79 (42.69)	139.92 (51.20)	272.06 (68.19)	145.78 (46.07)	356.85 (50.36	75.67 (35.36)
	Duration	2.91 (0.28)	3.86 (0.50)	3.27 (0.42)	2.81 (0.23)	3.44 (0.31)	2.99 (0.36)	3.30 (0.30)
	Mean Intensity	64.82 (1.43)	67.71 (1.69)	65.67 (2.63)	65.71 (2.30)	65.78 (1.95)	66.2 (2.86)	64.32 (2.20)
	Range Intensity	55.19 (3.01)	53.45 (1.07)	51.62 (1.31)	52.61 (0.96)	52.30 (0.73)	54.45 (1.97)	50.16 (2.30)
Male	Mean F0	256.84 (24.62)	123.86 (24.64)	120.88 (10.75)	138.92 (12.72)	120.46 (8.58)	224.44 (19.65)	129.02 (16.39)
	Range F0	207.02 (26.37)	74.70 (27.78)	64.73 (19.38)	132.36 (34.04)	87.97 (25.31)	207.07 (28.43)	69.22 (24.18)
	Duration	2.96 (0.26)	2.86 (0.25)	4.31 (1.26)	2.82 (0.25)	2.82 (0.22)	2.79 (0.20)	2.81 (0.20)
	Mean Intensity	68.28 (1.72)	64.79 (2.47)	65.32 (3.16)	64.36 (2.52)	66.08 (3.00)	67.50 (3.25)	67.46 (1.30)
	Range Intensity	56.26 (3.10)	50.5 (0.90)	53.11 (1.72)	53.73 (0.70)	54.02 (1.08)	55.61 (1.59)	53.2 (0.96)
Both	Mean F0	286.26 (32.86)	185.97 (67.81)	184.57 (68.26)	199.01 (65.84)	159.16 (40.09)	290.29 (73.32)	159.58 (33.64)
	Range F0	212.17 (46.57)	132.24 (68.22)	102.32 (53.95)	202.21 (88.41)	116.87 (46.98)	281.96 (85.71)	72.44 (30.20)
	Duration	2.93 (0.27)	3.36 (0.63)	3.79 (1.07)	2.81 (0.24)	3.12 (0.41)	2.89 (0.31)	3.10 (0.40)
	Mean Intensity	66.55 (2.30)	66.24 (2.56)	65.50 (2.89)	65.03 (2.49)	65.93 (2.51)	66.80 (3.11)	65.89 (2.42)
	Range Intensity	55.72 (3.08)	51.98 (1.78)	52.37 (1.70)	53.17 (1.00)	53.16 (1.26)	55.02 (1.87)	51.68 (2.34)

Table 7.1: Acoustical analyses for the two speaker presented in Experiment 3. Only sentences that were presented in Experiment 3 were analyzed. Note: F0 as measured in Hz, duration as measured in seconds, and intensity as measured in dB. Numbers in bracket indicate the standard deviation.

Condition	Example Sentence
Anger	Er hat das Paar gereizt und aufgebracht
Disgust	Er hat den Speichel verbreitet und verteilt
Fear	Er hat die Spuren verwischt und verschleiert
Happiness	Sie hat die Trauung verkündet und gelächelt
Neutral	Sie hat den Eimer geleert und weggelegt
Pleasant Surprise	Er hat den Gewinn verdoppelt und verdreifacht
Sadness	Er hat die Witwe getrößtet und beruhigt

Table 7.2: The table above shows one example sentence for each emotional category. Please see Appendix for a full list of stimuli presented.

began with the first version and the remaining with the second version. Half of the subjects pressed the yes-button with their right hand; the other half proceeded vice versa.

7.2.4 ERP Recording and Data Analysis

For the ERP recording see Experiments 1 and 2. Again, ERP components of interest were determined by visual inspection. The critical ERP data analyses were quantified for correct responses by calculating amplitudes relative to a 200 ms prestimulus baseline in four latency windows (150 ms - 300 ms [P200] and 500 ms - 900 ms for the valence effects and 375 ms - 530 ms for the prosodically violated condition and 500 ms - 650 ms for the combined semantically and prosodically violated condition). For statistical analysis, ANOVAs with *Sex* as a between-subject factor were conducted. In addition to the re-occurring factors listed in the Data Analysis of Experiments 1 and 2, the factor *Speaker* was included in the present experiment. For each condition (i.e. no violation, combined prosodic/semantic violation, and pure emotional prosodic violation), separate analyses were conducted. As separate analyses were conducted for the two violation types (combined prosodic/semantic violation and pure prosodic violation), each analysis had additional repeated measurement factors. For the combined violation the factors *P* (angry, disgust, fearful, happy, pleasant surprise, and sad prosody) and *M* (match/unspliced vs. mismatch/spliced condition) were included. For the pure emotional prosodic violation, the repeated factor *P* was present in each analysis (angry, disgust, fearful, happy, pleasant surprise, and sad vs. neutral prosody). The null-hypothesis was rejected for p-values smaller than 0.05. The Geissser-Greenhouse correction (Geisser & Greenhouse, 1959) was applied to all repeated measures with greater than one degree of freedom in the numerator. Sometimes a higher number of post-hoc comparisons than the degrees of freedom would permit was required. Because of the increased likehood of Type I errors associated with the large number of comparisons, p values of post-hoc single comparisons were corrected using a modified Bonferroni procedure (see Keppel, 1991). Again, only significant main effects and interactions that relate to the research questions are reported.

Mean PC Values		
Condition	*PC*	*SD*
Anger	98.98 %	1.80
Disgust	97.85 %	2.40
Fear	97.04 %	2.68
Happiness	97.15 %	2.92
Neutral	97.53 %	3.13
Pleasant Surprise	96.99 %	3.34
Sadness	97.15 %	4.04

Table 7.3: Mean percentage correct values for sentences with angry, disgust, fearful, happy, pleasant surprise, neutral, and sad emotional prosody.

7.3 Results

7.3.1 Behavioral Results

Match condition: Statistical analysis of the percent correct (PC) over both sex groups revealed a significant main effect of *P* (F(6,174)=3.24, *p*<.05). No other effects turned out to be significant (all p>.1). Break-down comparisons for *P* revealed PC differences between neutral and angry utterances (F(1,29)=6.08, *p*<.05) with higher error rates for neutral sentences (97.53% correct) than for angry sentences (99.0% correct). No other post-hoc comparisons reached significance. See Table 7.3 for a list including all mean PC values.

7.3.2 ERP results

***P200:* Match condition:** Within the P200 time window of 150 ms - 350 ms, a significant *Speaker* effect was found F(1,29)=44.08, *p*<.0001), indicating stronger P200 amplitudes for the female voice than for the male voice. In addition, there was a significant main effect of *P* (F(6,174)=14.12, *p*<.0001), indicating waveform differences between the different emotional prosodies. Break-down comparisons revealed that the neutral sentences differed significantly from all other valences. In the following, the statistical values for the *P* effect of these comparisons are listed: 1) neutral vs. anger (F(1,29)=4.92, *p*<.05); 2) neutral vs. disgust (F(1,29)=6.77, *p*<.05); 3) neutral vs. fear (F(1,29)=45.58, *p*<.0001); 4) neutral vs. happy (F(1,29)=4.71, *p*<.05); 5) neutral vs. pleasant surprise (F(1,29)=5.57, *p*<.05); and 6) neutral vs. sad (F(1,29)=28.57, *p*<.0001) (see Illustration 7.2 for a graphical display of effects).

In addition, there was also a significant interaction between *Speaker* and *P* (F(6,174) =5.06, *p*<.0001), indicating emotional prosody varying as a function of speaker. Step-down analyses by *Speaker* revealed significant *P* effects for the male speaker (F(6,174)= 8.83, *p*<.0001) as well as for the female speaker (F(6,174)=11.98, *p*<.0001). Follow-up analyses by *Speaker* were carried out and the significant *P* effects are summarized in the following. For the male speaker, break-down comparisons revealed a significant *P* effect for the comparison between neutral and disgust sentences (F(1,29)=4.77, *p*<.05), neutral and fearful sentences (F(1,29)=33.20, *p*<.0001), a tendency for a *P* effect for the comparison between neutral and happy sentences (F(1,29)=3.53, *p*=.07), and again a significant *P* effect for the comparison between neutral and sad sentences (F(1,29)=6.22, *p*<.05). For the female speaker, break-down comparisons revealed significant *P* effects for the comparison between neutral and angry sentences (F(1,29)=10.42, *p*<.001), neutral and fearful sentences (F(1,29)=31.65, *p*<.0001), neutral and pleasant surprise sentences (F(1,29)=7.42, *p*=.01), and neutral and sad sentences (F(1,29) = 32.99, *p*<.0001).

In the omnibus analysis, there was also an interaction between *P* and *HEMI* (F(6,174)=2.51, *p*<.05). The step-down analyses by *HEMI* revealed significant *P* effects in both the left (F(6,174)=9.28, *p*<.0001) and the right hemisphere (F(6,174) = 15.52, *p*<.0001). Post-hoc comparisons in the left hemisphere showed the following significant effects or trends for *P*: 1) neutral vs. fear (F(1,29)=28.39, *p*<.0001); 2) neutral vs. happy (F(1,29)=4.81, *p*=.06); 3) neutral vs. pleasant surprise (F(1,29)=3.55, *p*=.07); and 4) neutral vs. sad (F(1,29)=18.73, *p*<.001). The post-hoc comparisons in the right hemisphere revealed that ERP amplitudes for neutral sentences differed from ERP amplitudes for all valences. The statistical values for the *P* effect of these comparisons are listed in the following: 1) neutral vs. anger (F(1,29)=5.84, *p*<.05); 2) neutral vs. disgust (F(1,29)=9.18, *p*<.01); 3) neutral vs. fear (F(1,29)=57.82, *p*<.0001); 4) neutral vs. happy (F(1,29)=4.72, *p*<.05); 5) neutral vs. pleasant surprise (F(1,29)=7.06, *p*=.01); and 6) neutral vs. sad (F(1,29)=35.77, *p*<.0001).

In addition, an interaction between *P* and *REG* turned out to be highly significant (F(6,174)=6.07, *p*=<.0001), suggesting regional scalp distribution differences for the Prosody effect. Step-down analyses by *REG* revealed significant *P* effects at both frontal (F(6,174)=16.97, *p*<.0001) and parietal (F(6,174)=5.50, *p*<.001) electrode sites. Post-hoc comparisons revealed that the ERP waveforms for neutral sentences differed from disgust sentences (F(1,29)=13.53, *p*<.001), from fearful sentences (F(1,29)=51.70, *p*<.0001), from happy sentences (F(1,29) = 4.71, *p*<.05), and sad sentences (F(1,29)=30.72, *p*<.0001) in the frontal scalp region. In the parietal region, post-hoc comparisons between ERP waveforms for neutral sentences and ERP waveforms for the different valences revealed significant ERP differences between neutral and angry sentences (F(1,29)=6.29, *p*<.05), neutral and fearful sentences (F(1,29)=18.83, *p*<.001), neutral and pleasant surprise sentences (F(1,29)=6.10, *p*<.05), and from neutral and sad sentences (F(1,29)=11.85, *p*<.001).

Also, in the omnibus analysis, the three-way interaction *Speaker* x *P* x *REG* turned out to be significant (F(6,174)=2.51, *p*<.05). The step-down analyses by *Speaker* revealed a significant interaction between *P* x *REG* in the male speaker (F(6,174)=3.60, *p*<.01) and in the female speaker (F(6,174)=5.16, *p*<.001). Further analyses by *Speaker* and *REG* showed a significant *P* effect for the male speaker at frontal (F(6,174)=10.76, *p*<.0001) and at parietal electrode sites (F(6,174)=3.21, *p*<.01). The same significant *P* effect was found for the female speaker at both the frontal (F(6,174)=13.82, *p*<.0001) and the parietal electrode sites (F(6,174)=5.26, *p*<.001). Significant *P* effects revealed in the post-hoc comparisons by *Speaker* and *REG* are listed in the following. For the male speaker in the frontal region, comparisons between neutral and disgust sentences (F(1,29)=6.85, *p*=.01), between neutral and fearful sentences (F(1,29)=35.80, *p*<.0001), and between neutral and sad sentences (F(1,29)=3.92, *p*=.06) turned out to be significant or marginally significant. For the male speaker in the parietal region, the following post-hoc comparisons turned out to be significant: comparisons between neutral and fearful sentences (F(1,29)=14.98, *p*<.001), and between neutral and sad sentences (F(1,29)=5.50, *p*<.05). For the female speaker the post-hoc comparisons by *Speaker* and *REG* revealed similar results. In the frontal region, comparisons between neutral and angry sentences turned out to be significant (F(1,29)=4.87, *p*<.05), as well as comparisons between neutral and disgust sentences (F(1,29)=7.27, *p*<.05), neutral and fearful sentences (F(1,29)=32.14, *p*<.0001), neutral and pleasant surprise sentences (F(1,29)=5.06, *p*<.05), and between neutral and sad sentences (F(1,29)=38.83, *p*<.0001). Last, post-hoc comparisons in the parietal region for the female speaker turned out to be significant between neutral and angry sentences (*P* effect: F(1,29)=9.25, *p*<.01), neutral and fearful sentences (*P* effect: F(1,29)=12.49, *p*<.001), neutral and pleasant surprise sentences (*P* effect: F(1,29)=6.32, *p*<.01), and between neutral and sad sentences (*P* effect: F(1,29)=10.66, *p*<.05).

The four-way interactions *Session* x *P* x Hemi x *Sex* (F(6,174)=2.23, *p*<.05) and *Session* x *P* x *HEMI* x *REG* (F(6,174)=2.84, *p*<.05) were also significant, but none of the step-down analyses reached significance.

Overall, results revealed a *Speaker* effect indicating a stronger P200 amplitude for the female speaker than for the male speaker. In addition, we found an overall emotional prosody effect revealing that all investigated valences differed from neutral sentences. However, one aim of the study was to investigate the possible speaker influence on emotional prosody perception. Indeed we also found an interaction between prosody and speaker implying that the prosody effect is qualified by speaker. Results revealed similar effects for the male and the female speaker for the emotional categories of fear and sadness, i.e. the two valences differed from the neutral baseline for both speaker. Also, for both speaker, one positive emotional category (happy or pleasant surprise) was distinguishable from the neutral baseline. However, we also found differences between the two speaker, i.e. while for the male speaker a P200 effect was found for the comparison between disgust and neutral sentences, the same comparison did not reach significance for the female speaker for whom we found a valence effect for the contrast between neutral and angry sentences instead. Also, the results revealed that the emotional prosody effect was also qualified by region revealing distributional differences for the different emotional prosodies. Last, the emotional prosody effect was also qualified by hemisphere revealing bilateral distributed valence effects for the

Time Window: 150 ms - 350 ms			
Effect	*df*	*F value*	*p value*
Session	1,29	3.64	<0.08
Speaker	1,29	44.08	<.0001
Speaker x *Sex*	1,29	9.06	<0.01
P	6,174	14.12	<.0001
HEMI	1,29	27.76	<.0001
REG	1,29	121.03	<.0001
Session x *Speaker* x *Sex*	1,29	6.44	<0.05
Speaker x *P*	6,174	5.06	<0.001
P x *HEMI*	6,174	2.51	<0.05
Speaker x *REG*	1,29	17.53	<0.001
P x *REG*	6,174	6.07	<0.001
Session x *P* x *HEMI* x *Sex*	6,174	2.23	<0.08
Session x *Speaker* x *REG*	1,29	4.23	<0.05
Speaker x *P* x *REG*	6,174	2.51	<0.05
Session x *P* x *HEMI* x *REG*	6,174	2.84	<0.05

Table 7.4: Significant/borderline results from ANOVAs on mean amplitudes for the early time window of 150 ms to 350 ms for all participants.

Post-hoc comparisons both speaker			
Effect	*df*	*F value*	*p value*
P	6,174	14.12	<.0001
Neu vs. Anger	1,29	4.92	<.05
Neu vs. Disgust	1,29	6.77	<.05
Neu vs. Fear	1,29	45.58	<.0001
Neu vs. Happy	1,29	4.71	<.05
Neu vs. Pls. Surp.	1,29	5.57	<.05
Neu vs. Sad	1,29	28.57	<.0001

Table 7.5: Post-hoc comparisons for valence effects irrespective of speaker-voice.

emotional prosodies of fear, pleasant surprise, happiness, and sadness, and right lateralized effects for the emotional prosodies of anger and disgust.

Please see Table 7.4 for a list with all significant effects found in the omnibus analysis and Tables 7.5, 7.6, and 7.7 for significant valence effects revealed in post-hoc comparisons for both speakers, the female speaker, and the male speaker respectively.

***500 ms - 900 ms:* Match condition:** The ERP analysis of correct responses for all seven emotional prosodies revealed a significant main effect of *P* (F(6,174)= 2.69, *p*<.05), suggesting ERP waveform differences between the different valences. Post-hoc comparisons between neutral sentences and all other prosodies revealed only significant *P* effects for the comparison between neutral and happy sentences (F(1,29)=10.89, *p*<.01). An interaction

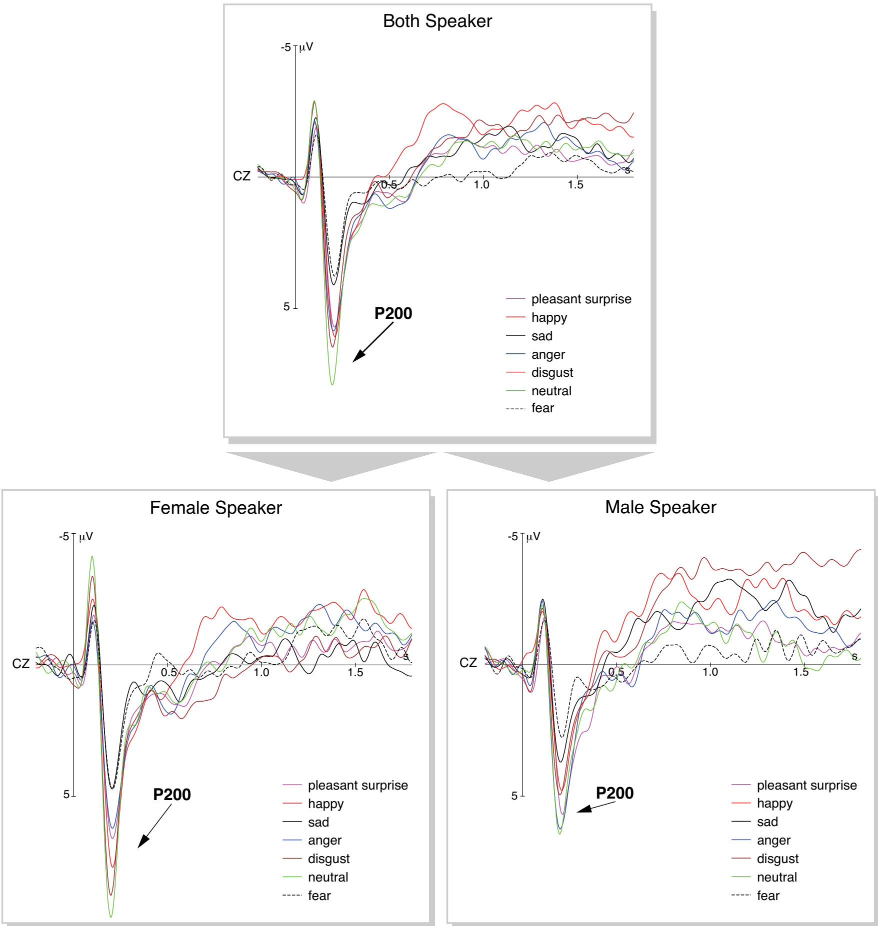


Figure 7.2: This illustration shows ERPs elicited by lexical stimuli differing in emotional prosody at one selected electrode site (CZ). Waveforms show the average for pleasant surprise (pink), happy (red), sad (black), angry (blue), disgust (brown), neutral (green), and fearful (black, dashed) sentences from 200 ms prior to stimulus onset up to 1700 ms post-stimulus onset.

Post-hoc comparisons female speaker			
Effect	*df*	*F value*	*p value*
P	6,174	11.98	<.0001
Neu vs. Anger	1,29	10.42	<.001
Neu vs. Fear	1,29	31.65	<.0001
Neu vs. Pls. Surp.	1,29	7.42	<.01
Neu vs. Sad	1,29	32.99	<.0001

Table 7.6: Post-hoc comparisons for valence effects for the female speaker.

Post-hoc comparisons male speaker			
Effect	*df*	*F value*	*p value*
P	6,174	8.83	<.0001
Neu vs. Disgust	1,29	4.77	<.05
Neu vs. Fear	1,29	33.20	<.0001
Neu vs. Happy	1,29	3.53	=.07
Neu vs. Sad	1,29	6.22	<.05

Table 7.7: Post-hoc comparisons for valence effects for the male speaker.

between *P* x *REG* (F(6,174)= 4.57, *p*<.001) allowed for step-down analyses by the factor *REG*. *P* turned out to be significant in the frontal region (F(6,174)=2.22, *p*=.05) and the parietal region (F(6,174)=4.18, *p*<.01). Post-hoc comparisons in the frontal region turned out to be significant only for the comparison between neutral and happy sentences (*P* effect: F(1,29)=4.62, *p*<.05). In contrast, post-hoc comparisons in the parietal region revealed ERP amplitude differences (*P* effects) between neutral and fearful (F(1,29)=4.21, *p*<.05) and between neutral and happy sentences (F(1,29)=7.74, *p*<.01). Last, the interaction *P* x *HEMI* x *Sex* was also significant (F(6,174)=2.87, *p*<.05), but the step-down analyses revealed no further significant effects. Taken together results revealed an emotional prosody effect showing amplitude differences between neutral and happy sentences. In addition, this emotional prosody effect was qualified by region revealing amplitude differences for the contrast between neutral and happy sentences at frontal electrode sites and in addition revealing amplitude differences for the contrasts btween neutral and happy and neutral and fearful sentences at parietal electrode sites. See Table 7.8 for a list of all significant effects. See Figure 7.3 for an illustration of effects at one selected electrode site. Illustrations B.1, B.2, and B.3 in the Appendix show valence effects at several selected electrode-sites.

***375 ms - 530 ms:* Emotional Prosodic Violation:** The ERP analysis over correct responses for the prosodic violation condition revealed a significant main effect of *P* (F(6,174)=2.84, *p*<.05), suggesting ERP waveform differences between violated and neutral sentences. Post-hoc comparisons confirmed this suggestion for comparisons between fearful and neutral sentences (*P* effect: F(1,29)=5.68, *p*<.05) and between sad and neutral

Time Window: 500 ms - 900 ms			
Effect	*df*	*F value*	*p value*
Sex	1,29	4.19	<0.05
Session	1,29	10.45	<0.01
Speaker	1,29	36.89	<0.001
P	6,174	2.69	<0.05
HEMI	1,29	10.07	<0.01
REG	1,29	12.88	<0.01
Session x *Speaker* x *Sex*	1,29	4.19	<0.05
P x *HEMI*	6,174	2.09	<0.08
P x *HEMI* x *Sex*	6,174	2.87	<0.05
Session x *REG*	1,29	13.59	<0.001
P x *REG*	6,174	4.57	<0.01
HEMI x *REG*	1,29	3.81	<0.08

Table 7.8: Significant/borderline results from ANOVAs on mean amplitudes for the late time window of 500 ms to 900 ms for all participants.

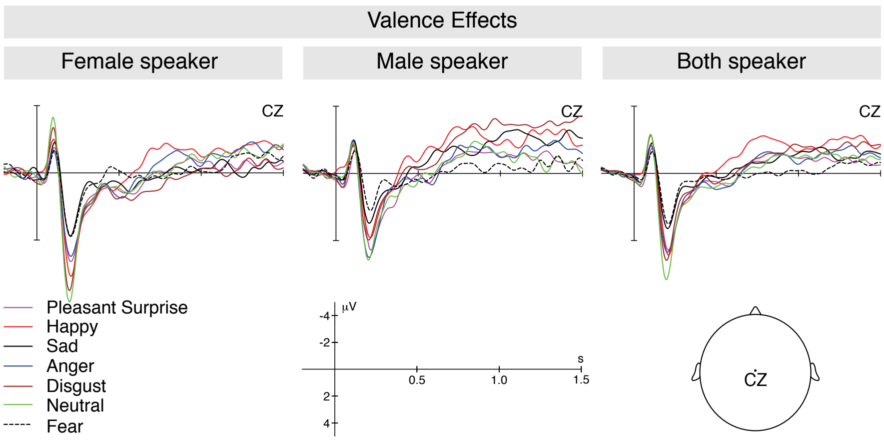


Figure 7.3: This illustration shows ERPs elicited by stimuli articulated by the female speaker, the male speaker, and both speaker respectively differing in emotional prosody at one selected electrode site. Waveforms show the average for pleasant surprise (pink), happy (red), sad (black), angry (blue), disgust (brown), neutral (green), and fearful (black-dashed) sentences from 200 ms prior to stimulus onset up to 1500 ms post-stimulus onset For an illustration with more electrode sites please see Appendix B.2.

sentences (*P* effect: F(1,29)=19.73, *p*<.0001), with the violated sentences showing a more positive ERP component than the unviolated sentences.

In addition, the factor *P* interacted with *Speaker*, suggesting different ERP effects for the different speakers. The by *Speaker* analysis revealed a significant effect of *P* for the male speaker (F(6,174)=2.98, *p*<.05) and for the female speaker (F(6,174)=4.19, *p*<.01). Break-down comparisons by *Speaker* were carried out. For the male speaker, ERP waveform differences were only found for the comparison between neutral and prosodically violated sad sentences (*P* effect: F(1,29)=5.91, *p*<.05), with the violated sentences more positive-going than the unviolated sentences. In contrast, all post-hoc comparisons for the female speaker turned out to be significant, namely the comparisons between angry and neutral sentences (*P* effect: F(1,29)=3.92, *p*=.06), disgust and neutral sentences (*P* effect: F(1,29)=12.95, *p*=.001), fearful and neutral sentences (*P* effect: F(1,29)=23.05, *p*<.0001), happy and neutral sentences (*P* effect: F(1,29)=7.77, *p*<.01), pleasant surprise and neutral sentences (*P* effect: F(1,29)=6.78, *p*<.05), and sad and neutral sentences (*P* effect: F(1,29)=19.66, *p*<.0001), with all violated sentences showing more postive ERP components than the unviolated sentences. These results suggest that overall, participants showed a more pronounced response to prosodic violations of sentences articulated by the female speaker than by the male speaker since ERP effects for the female speaker were found to be significant for all investigated emotional prosodies.

Last, there was also an interaction between *P* and *HEMI* that was significant (F(6,174)=3.42, *p*<.01), suggesting that the *P* effect might be lateralized for some of the emotional prosody violations. The step-down analysis by *HEMI* revealed a significant *P* effect only in the right hemisphere (F(6,174)=3.80, *p*<.01). Post-hoc comparisons in the right hemishere revealed differences between fearful and neutral sentences (*P* effect: F(1,29)=4.58, *p*<.05) and between sad and neutral sentences (*P* effect: F(1,29)=18.49, *p*<.001). For both comparisons, it turned out that the violated sentences showed a more positive-going ERP component than the neutral control sentences.

The interaction *Session* x *P* x *HEMI* x *Sex* was also significant (F(6,174)=2.61, *p*<.05), but step-down analyses did not reveal any further significant effects. In short, results revealed an overall prosody effect revealing more positive going amplitudes for violated fearful and sad sentences than for unviolated neutral sentences. The analyses showed that this effect was more pronounced at right hemisphere electrode sites than at left hemisphere electrodes. Also, results revealed that this prosody effect is qualified by speaker. While for the male speaker only the contrast between sad and neutral sentences reached significance, the prosody effect was visisble for all investigated emotional prosodies for the female speaker. Table 7.9 summarizes all significant effects found in the omnibus analysis. In Tables 7.10, 7.11, and 7.12 significant post-hoc comparisons are summarized for both speaker, the female speaker, and the male speaker, respectively. In the Appendix see Figures B.4, B.5, B.6, B.7, B.8, and B.9, for illustrations of the ERP-effects. See Figure 7.4 for an illustration

Time Window: 375 ms - 530 ms			
Effect	*df*	*F value*	*p value*
Sex	1,29	3.83	<0.08
Speaker	1,29	55.07	<.0001
Speaker x Sex	1,29	4.04	<0.08
P	6,174	2.84	<0.05
REG	1,29	18.79	<0.001
Session x *Speaker*	1,29	10.39	<0.01
Speaker x *P*	6,174	4.34	<0.01
P x *HEMI*	6,174	3.42	<0.01
Session x *REG*	1,29	17.72	<0.001
Speaker x *REG*	1,29	20.06	<0.001
Session x *P* x *HEMI* x *Sex*	6,174	2.61	<0.05
Session x *Speaker* x *REG*	1,29	5.85	<0.05
Session x *HEMI* x *REG* x *Sex*	1.29	5.98	<0.05

Table 7.9: Significant/borderline results from ANOVAs on mean amplitudes for the late time window of 375 ms to 530 ms for all participants.

Post-hoc comparisons both speaker			
Effect	*df*	*F value*	*p value*
P	6,174	2.84	<.05
Neu vs. Fear	1,29	5.68	<.05
Neu vs. Sad	1,29	19.73	<.0001

Table 7.10: Post-hoc comparisons in the Emotional Prosodic Violation Condition irrespective of speaker-voice.

of effects at one selected electrode site and Figure 7.5 for an illustration of effects at several electrode sites irrespective of speaker.

500 ms - 650 ms: **Combined Semantic and Prosodic Violation condition:**

The ERP analysis over correct responses for the combined semantic and prosodic violation condition revealed a significant interaction between *M* x *REG* ($F(1,29)= 10.30$, $p<.01$), suggesting that the response to the combined semantic and prosodic violation is differently distributed in the two regions. Indeed, the by-*REG* analysis showed a significant effect of *M* only in the parietal region ($F(1,29)=9.18$, $p<.05$), with the violated sentences more negative-going than the unviolated sentences.

In addition, the four-way interaction *Speaker* x *P* x *M* x *REG* reached significance ($F(5,145)=3.02$, $p<.05$), suggesting that the negativity in response to the combined violated sentences is qualified by *Speaker* and *P*. The step-down analysis by *REG* revealed a significant interaction *Speaker* x *P* x *M* in the parietal region ($F(5,145)=4.20$, $p<.05$). This effect allowed for a further step-down analysis by *REG* and *Speaker*. In the parietal region for the

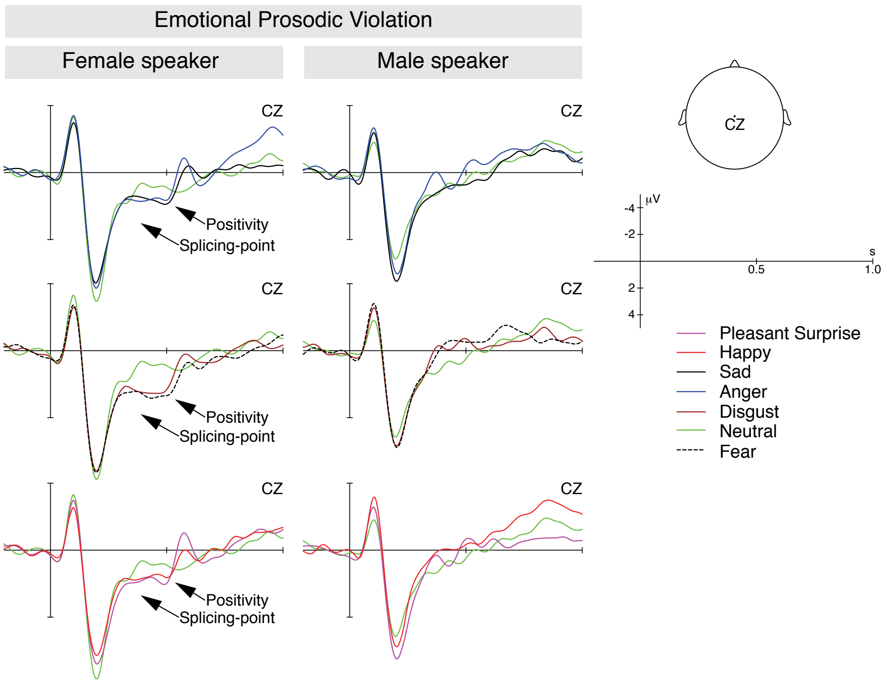


Figure 7.4: This illustration shows ERPs elicited by emotional prosodically violated and unviolated stimuli articulated by the female and the male speaker at one selected electrode site. Waveforms show the average for violated and neutral unviolated sentences from 200 ms prior to stimulus onset up to 1000 ms post-stimulus onset.

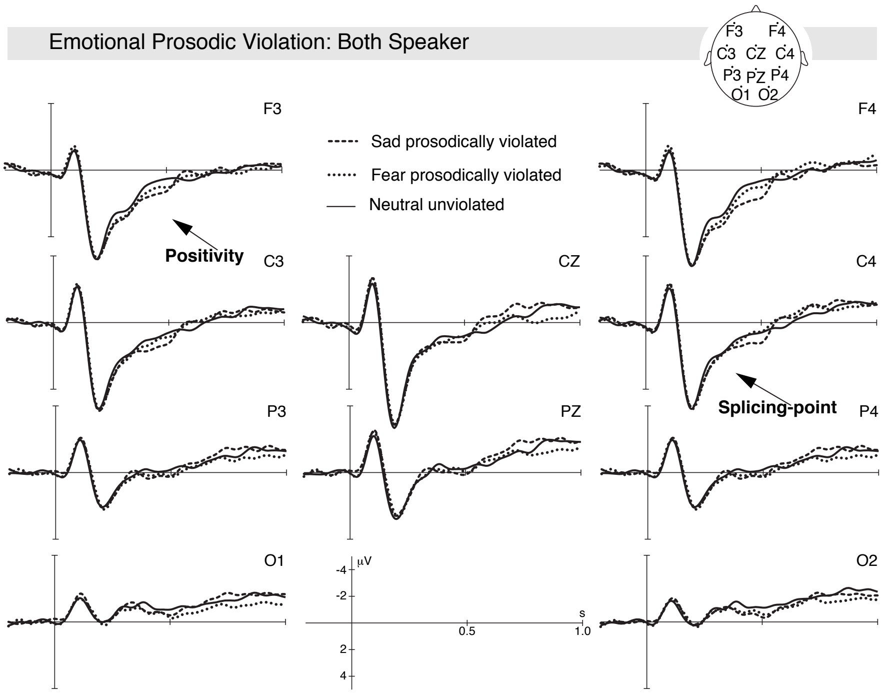


Figure 7.5: This illustration shows ERPs elicited by emotional prosodically violated and unviolated stimuli articulated by both speaker at selected electrode sites. Waveforms show the average for sad violated (dashed), fearful violated (dotted), and neutral unviolated (black) sentences from 200 ms prior to stimulus onset up to 1000 ms post-stimulus onset.

Post-hoc comparisons female speaker			
Effect	*df*	*F value*	*p value*
P	6,174	4.19	<.01
Neu vs. Anger	1,29	3.92	=.06
Neu vs. Disgust	1,29	12.95	<.001
Neu vs. Fear	1,29	23.05	<.0001
Neu vs. Happy	1,29	7.77	<.01
Neu vs. Pls. Surp.	1,29	6.78	<.05
Neu vs. Sad	1,29	19.66	<.0001

Table 7.11: Post-hoc comparisons in the Emotional Prosodic Violation Condition for the female speaker.

Post-hoc comparisons male speaker			
Effect	*df*	*F value*	*p value*
P	6,174	2.98	<.05
Neu vs. Sad	1,29	5.91	<.05

Table 7.12: Post-hoc comparisons in the Emotional Prosodic Violation Condition for the male speaker.

male speaker, the interaction *P* x *M* turned out to be significant (F(5,145)=3.95, *p*<.01) as did the same interaction for the female speaker (F(5,145)=2.36, *p*=.05). Further step-down analyses for the male speaker in the parietal region by *P* revealed a significant *M* effect for the angry (F(1,29)=14.62, *p*<.001) and the fearful (F(1,29)=6.02, *p*<.05) prosodies. In contrast, the analyses for the female speaker in the parietal region by *P* revealed significant *M* effects for the prosodies of disgust (F(1,29)=4.26, *p*<.05) and pleasant surprise (F(1,29)=9.00, *p*<.05). Taken together, these results suggest that the combined prosodically and semantically violated sentences of anger and fear spoken by the male speaker elicited a negative-going ERP response in the parietal brain region of participants. For sentences spoken by the female speaker, this negative-going component in the parietal region turned out to be significant for violations of disgust and pleasant surprise.

Last, the interactions *Speaker* x *M* x *REG* (F(1,29)=4.68, *p*<.01), *P* x *M* X *HEMI* x *REG* x *Sex* (F(5,145)=3.75, *p*<.05), and *Session* x *P* x *M* x *HEMI* x *REG* (F(5,145)=3.10, *p*<.05) turned out to be significant; however, no follow-up analyses reached significance (all *p*>.05). Table 7.13 summarizes all significant effects. See Illustration 7.6 for graphical display of effects at one selected electrode site. See Illustration 7.7 for a graphical display of effects for both speaker. In the Appendix please see Illustrations B.10, B.11, B.12, and B.13 for graphical illustrations of the ERP-effects at several electrode sites.

Time Window: 500 ms - 650 ms			
Effect	*df*	*F value*	*p value*
Sex	1,29	4.08	<0.08
Session	1,29	10.56	<0.01
Speaker	1,29	31.08	<.0001
P	5,145	2.40	<0.08
REG	1,29	14.87	<0.001
Speaker x *P*	5,145	2.30	<0.08
P x *HEMI* x *Sex*	5,145	2.25	<0.08
Session x *REG*	1,29	7.78	<0.01
P x *REG*	5,145	4.62	<0.01
M x *REG*	1,29	10.30	<0.01
Session x *P* x *HEMI* x *Sex*	5,145	2.60	<0.05
Speaker x *M* x *REG*	1,29	4.68	<0.05
P x *HEMI* x *REG*	5,145	2.25	<0.08
Speaker x *P* x *M* x *REG*	5,145	3.02	<0.05
Session x *P* x *HEMI* x *REG* x *Sex*	5,145	2.13	<0.08
P x *M* x *HEMI* x *REG* x *Sex*	5,145	3.75	<0.01
Session x *P* x *M* x *HEMI* x *REG*	5,145	3.10	<0.05

Table 7.13: Significant/borderline results from ANOVAs on mean amplitudes for the late time window of 500 ms to 650 ms for all participants.

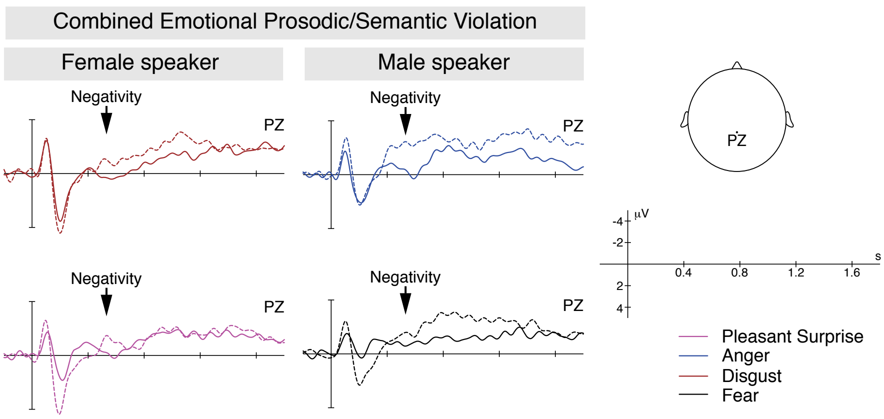


Figure 7.6: This illustration shows ERPs elicited by emotional semantically and prosodically violated sentences and unviolated sentences at one selected electrode site. Waveforms show the average for violated (dashed) and unviolated sentences articulated by the female and male speaker from 200 ms prior to stimulus onset up to 1800 ms post-stimulus onset.

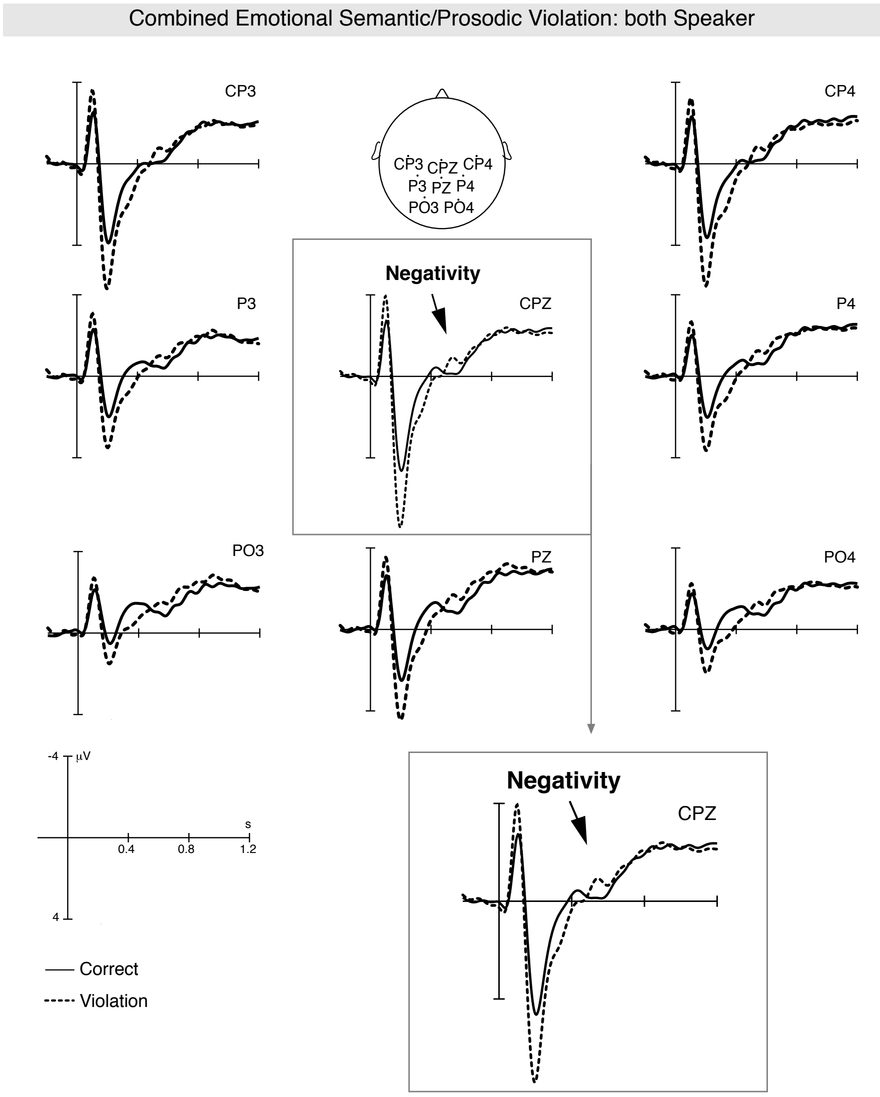


Figure 7.7: This illustration shows ERPs elicited by emotional semantically and prosodically violated and unviolated stimuli articulated by both speaker at selected electrode sites. Waveforms show the average for violated (dashed) and unviolated (black) sentences from 200 ms prior to stimulus onset up to 1200 ms post-stimulus onset.

7.4 Discussion

In sum, the present results reveal that emotional valences can be differentiated in the ERP and that speaker gender also appears to modulate the ERP. It can thus be concluded that ERPs can contribute to the discussion on the relationship between speaker information and its influence on emotional prosody processing. Furthermore, results have replicated findings from the first two ERP experiments, in that the two emotional information channels (emotional prosody and emotional semantics) can be separated by means of a splicing technique. Furthermore, it is suggested that processing violations of emotional prosody and combined emotional prosody and semantics stimulus is valence-independent. However, it seems as if speaker voice can influence these processing mechanisms. Within the next paragraphs, each ERP effect is discussed separately.

P200 Effect: In an early time window of 150 ms to 350 ms, a significant difference between ERP waveforms for neutral and emotional vocalizations was found. Even though the positive ERP component (with its peak amplitude at approx. 200 ms), was observed for all six basic emotional vocalizations against a neutral baseline, their peak amplitude differed. A similar result, i.e., early ERP differentiation between different valences, has been reported for the processing of emotional facial expressions; but, with the difference that visual emotional stimuli elicited a negative ERP component, the N230. As has been mentioned elsewhere, there is considerably more evidence on the processing of emotional facial expressions than there is on the processing of emotional prosody. Due to the lack of ERP-evidence on the processing of vocal emotional stimuli, it might be helpful to take evidence from other modalities, i.e. visual processing, as a starting point when discussing the current results. Thus, analogous to the hypothesis put up by Balconi and Pozzoli (2003), it is assumed that within the P200 component, a first emotional encoding of the stimulus is reflected. This first emotional encoding seems to be particularly influenced by pitch and intensity variations. This can be concluded because the current stimuli differed in pitch and intensity variations (see Table with results from acoustical analyses) and also because there is not much lexical information present at this early point of time in processing; however, as mentioned previously, the possible influence of lexical information cannot be ruled out completely. Balconi and Pozzoli (2003) reported variations of the N230 for five different emotions in terms of peak amplitude. The authors hypothesized that the negative ERP component is strictly linked to the decoding of emotional facial expressions (Balconi & Pozzoli, 2003). Other studies have reported similar results, i.e. emotional stimuli elicited more negative-going ERP waveforms than neutral stimuli, most often as early as 200 ms after stimulus onset (e.g. Vanderploeg, Brown, & Marsh, 1987). The current results go thus very well in line with the literature available.

In Experiment 2, it was briefly discussed that negative stimuli might elicit larger P200 amplitudes than positive stimuli due to their "evolutionary advantage" of individuals attending in a more pronounced fashion to negative stimuli (c.f. Chapter 2). In addition to this evolutionary advantage, it has been suggested that emotional reactions might be more intense for high arousing emotions like anger and for low arousing emotions like sadness (c.f. Balconi & Pozzoli, 2003). In particular, the beforementioned N230 has been shown to be less negative-going for low arousing stimuli (sadness, neutral) than for high arousing stimuli (anger, surprise). The current ERP profiles show a different pattern, though. For example, the amplitude for fearful sentences was not as positive as it was for angry sentences even though both set of stimuli had been rated as rather high arousing in the previous rating study. In addition, the current results revealed the largest P200 component for neutral stimuli, and hence not for the most arousing stimuli. However, anger and pleasant surprise vocalizations were both rated as highly arousing in the previous rating study, and ERP amplitudes for these two emotional expressions are very similar in peak amplitude. Interestingly, all rather high arousing rated stimuli, i.e. angry, disgust, fearful, happy, and pleasant surprise sentences, elicited a very similar P200 amplitude. Nevertheless, the current results appear to be in contrast, at least partially, with previous findings from studies using visual emotional stimuli, in that a systematic relationship between the intensity of a stimulus and its P200 amplitude has not been found. However, it should be kept in mind that the early negative ERP components elicited by visual emotional stimuli (e.g. N170, or N230) and the P200 elicited by auditory emotional stimuli need not necessarily reflect the same cognitive, emotional, or evaluational processes. Thus, the comparability might only be limited. Further research, that systematically investigates the relationship between ERPs and auditory emotional stimuli of both low and high arousal levels, should be carried out in the future to shed more light on this issue.

In addition to the question of whether different valences elicit different ERP responses, it was of interest to investigate the potential influence of voice gender on these ERPs. The current results revealed significant speaker effects on the processing of emotional prosody, even at an early point of time as reflected in modulations of the P200. Up to date, there are few electrophysiological studies investigating if there is a difference in the processing of voice gender. Behavioral studies have shown that the distinction between male and female speakers is of high social relevance, though. For example, it has been reported that very young infants (at the age of eight months) can already differentially categorize voices (Patterson & Werker, 2002). Also, as was mentioned in the introduction to the current experiment, there are MMN studies investigating the role of speaker identity (e.g. Titova & Näätänen, 2001; Knösche, Lattner, Maess, Schauer, & Friederici, 2002). For example, an MEG study by Knösche et al. (2002) investigated the relationship of voice and linguistic information under a pre-attentive processing situation. Their results suggest parallel processing of linguistic and voice information at an early pre-attentive stage. Furthermore, an fMRI study by Lattner et al. (2005) examined the neurophysiological correlates of voice gender perception. In general, the authors report a stronger activation pattern in response to female voices than to male voices. It is assumed that this stronger activation pattern is related to the fact that the speech signal from women is perceptually more salient than the speech signal from male voices.

The current results suggest a similar interpretation. In general, it can be concluded that the responses to a female and a male voice when producing emotional prosody differed. This difference can be seen in variations of the P200 component. Also, the results suggest distributional processing differences. Whereas for the male voice, neutral sentences could be distinguished from fearful and sad sentences over both frontal and parietal electrode sites, the P200 in response to disgust sentences articulated by a male voice only differed with respect to neutral articulations above the frontal region. Taken together, only negative emotional prosodies could be differentiated from neutral sentences for the male voice. In contrast, the emotional prosody of sentences produced by the female speaker included differentiation of both positive and negative vocalizations from neutral sentences, i.e. pleasant surprise sentences differed from neutral sentences, and fearful differed from neutral sentences. Interestingly, for the male and the female voice, P200 amplitudes for disgust and neutral sentences differed only in the frontal region, but not in the parietal brain region. Similar to the fMRI results from Lattner et al. (2005), the current results found a speaker effect, showing more positive-going amplitudes for the female voice than for the male voice. It thus seems as if female voices do not only evoke stronger brain activation patterns, but also stronger ERP effects, as reflected in the current P200 amplitude differences. Following the speculations by Lattner et al. (2005), one could assume that female voices, usually of high-pitch, might be perceived as socially and biologically more relevant than male voices with low-pitch. The authors have further suggested that high pitch voices might arouse the voice perception system more than low pitch voices because of its evolutionary relevance, i.e. an increase in pitch often indicates potential danger (conveyed in screaming when being frightened, or being more aroused under stress and thereby increasing pitch). This rather stereotypical explanation of why the female voice elicited a stronger P200 than the male voice can be used for a further explanation for the current results. As was mentioned above, for the female voice, both positive and negative vocalizations could be differentiated from neutral sentences in the P200, whereas for the male voice, this differentiation was only visible for the contrast between neutral and negative vocalizations. As was mentioned previously, it has been suggested that females are emotionally more expressive than men, hence, there is the possibility that females are better at expressing happiness or positive emotions in general. However, it has also been noted that not every speaker can portray different emotional prosodies equally well, thus it could also be assumed that the male speaker's positive emotional portrayals were not perceived as being positive and therefore differed from neutral vocalizations. This is rather unlikely, though, as is reflected in the high recognition rates from the previous rating study.

Last, it seems obvious that there is only little lexical information processed 200 ms after sentence onset, especially when considering that the whole sentence was approx. 3 seconds in duration. To clarify, emotional differentiation occurred long before the completeness of the utterance, thus making it reasonable to assume that predominantly pitch and intensity variations helped to infer the emotional state of the speaker. As has been noted elsewhere, it is acknowledged that F0 modulation, perceived as pitch variation, can be used by listeners to infer the emotional state of the speaker (Bänziger & Scherer, 2005). The current results provide additional evidence for this claim. In addition, P200 modulations were found for both a female and a male voice, with the only perceptional difference for the different emotional categories conveyed by the speakers. It has also been suggested that the emotional state of a speaker can be inferred independently of semantic content of the utterance (c.f. Bänziger & Scherer, 2005). The early P200 component might be taken as further support for this assumption; however, as was the case in the first two ERP experiments, strong claims can only be supported after testing if nonsense utterances spoken with different emotional prosodies can also be differentiated in the P200 component. This will be investigated in Experiment 4.

Later Valence Effect: In addition to the early P200 component, valence differences were also found within a later time window of 500 ms to 900 ms. In particular, the ERPs elicited by happy sentences differed significantly from ERPs elicited by neutral sentences. Only at parietal electrode sites was a difference between neutral and fearful ERPs observed. No other valences differed from neutral sentences. Taken together, it can be concluded that in the longer time window of 500 ms to 900 ms, a second differentiation between valences occurs; however, the effects were only significant for happy and fearful sentences when compared to neutral sentences. Also, it should be noted that earlier speaker effects did not reach significance.

In the literature for visual emotional stimuli and facial expressions in particular, two ERP components elicited by emotional stimuli have been demonstrated to reflect facilitated emotional stimulus encoding: the early posterior negativity (EPN) and the late positive potential (LPP). Whereas the EPN is usually elicited after 150 ms with its peak amplitude around 260 ms, the LPP develops approx. after 350 ms to 400 ms after stimulus onset (c.f. Schupp et al., 2004). Interestingly, the EPN is most pronounced for stimuli with high evolutionary significance (c.f. Chapter 3), and is believed to reflect processing at the early perceptual level (Schupp et al., 2004). In contrast, the LPP has been argued to reflect more elaborate perceptual analysis of high arousing stimuli (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000). Recently, the LPP has been reported to be larger for threatening visual stimuli than for neutral or pleasant stimuli in particular (Schupp et al., 2004).

Also, the LPP has been reported to reflect the evaluation of emotional stimuli characteristics (Diedrich, Naumann, Maier, Becker, & Bartussek, 1996; Crites & Cacioppo, 1996). Last, it has also been observed that the LPP amplitude is enlarged for emotional stimuli relative to neutral stimuli (Diedrich et al., 1996; Schupp et al., 2000). In sum, this suggests that the LPP might reflect processes involved in the emotional evaluation of stimuli and might further reflect processing differences between stimuli of different intensity levels (i.e. neutral vs. emotional stimuli).

The current results might be interpreted in a similar way, i.e. the positive ERP component between 500 ms and 900 ms found here might reflect similar processing steps for auditorily presented emotional stimuli. From an evolutionary perspective, it seems reasonable to assume that successful evaluation of the environment is a mandatory process. Threatening stimuli, in particular, might be subject to a continuous elaborative stimulus evaluation (Öhmann, Flykt, & Lundquist, 2000; Schupp et al., 2004). In line with this assumption, the current positivity elicited by fearful sentences when compared to neutral sentences might reflect a facilitated processing of fearful stimuli due to an evolutionary advantage for processing fearful stimuli. To clarify, if fearful emotional expressions activated the fear system due to their evolutionary relevance, it might be possible that these stimuli are processed somewhat differently than neutral or other stimuli of different valence. Indeed, behavioral data have suggested that threatening stimuli capture increased attentional resources, suggesting a processing advantage for these stimuli (Mogg, Millar, & Bradley, 2000).

However, why sentences produced with a happy emotional prosody also elicited a larger later positive ERP component while the other stimuli did not remains unclear for now. One assumption might be that not the valence per se is responsible for the positive ERP component, but rather the intensity of the stimulus associated with this valence. The previous rating study revealed that happy and fearful sentences were rated similar with regard to their intensity level; however, if the intensity level of the stimulus is primarily responsible for the later positivity, then it remains unclear why other valences of similar intensity level (i.e. disgust and anger) did not reveal larger ERP amplitudes when compared to neutral stimuli. It can only be speculated that the current positive ERP component is modulated both by the evaluative context and the intensity of the stimuli. A second possibility that might explain why the current positive ERP component was only elicited for fearful and happy stimuli is the fact that the current study used more than just one emotionally laden stimulus, i.e. six in total, in addition to neutral stimuli, thereby differing notably from other studies. In general, it can be assumed that the number of emotions tested might influence the degree of attentional resources needed to evaluate the stimuli. Indeed, it has been suggested that not only task-type but also attention to emotion might play a role in response to different emotional expressions (c.f. Ashley et al., 2004). Finally, it is also possible that not the emotional categories of fear or happiness per se are responsible for the positive ERP component, but rather the emotional dimension of pleasantness and unpleasantness. It can be assumed that the two emotions reflect the two emotional extremes of this continuum, with happy being the most pleasant emotional category and fear being one of the most unpleasant emotional categories for both female and male participants. Last, it should again be noted that the comparability between visual and auditory emotional stimuli presentations is only limited and that future ERP research needs to address the issues raised above more systematically. For instance, closer examination of the influence of intensity or arousal of a stimulus could be achieved by measuring additional physiological reactions. For example, by measuring heart beat rate and/or electrodermal activity it can be controlled if participants really feel aroused by the stimulus presented to them. Thus, one is able to compare high/low arousing stimuli on an individual basis which will in turn increase comparability across subjects.

Emotional Prosodic Violation Condition: One additional aim of the current experiment was to investigate the extent to which previously reported ERP components in response to emotional prosodic or combined emotional prosodic and semantic violations were valence-independent. To this aim, the same kind of violations, i.e. splicing a neutral start of a sentence to an emotional end of a sentence, were created with the six different emotional prosodies. Comparable to Experiment 1 and Experiment 2, the violation of an emotional prosodic intonation contour elicited a positive ERP component shortly after the splicing point. Interestingly, looking at results for both the male and female voices, it was observed that this effect was predominantly right lateralized and only reached significance for the comparison between neutral and fearful sentences and between neutral and sad sentences. However, looking at each speaker voice separately, it can be concluded that ERPs elicited by the female speaker replicated our previous results and extended these to the violations of six basic emotions, namely anger, disgust, fear, happiness, pleasant surprise, and sadness. Taking these results alone, it could be suggested that the ERP component seems to be elicited independent of valence, if violations of the emotional prosodic contour are created to the emotional prosodic contour of a female voice. In contrast, the violations presented with the male speaker voice only elicited a positive ERP component for prosodically violated sad sentences. It can only be speculated why such a gender difference with regard to responses elicited by an emotional prosodic contour violation was observed. Comparable to the results reported for the P200 component, it could be argued that observed speaker gender effect reflects a gender bias while processing human voices, because female voices are more salient than male voices so violations to their emotional prosodic contour elicit stronger ERP responses. Also, it could still be argued that the emotional expressions produced by the female speaker were better portrayed than those produced by the male speaker (c.f. Rating Study). However, it seems unlikely that those rather subtle differences with regard to emotional prosody recognition have contributed to the current results. Further evidence against this assumption is the fact that sad vocalizations of the male speaker in general were rated with a lower accuracy rate than e.g., angry vocalizations. Assuming that good recognizability had an influence on the responses to emotional prosody violations, the question arises why only violations to sad sentences in particular resulted in a positive ERP component. In addition to the proposed explanation of a so-called gender bias, it could also be that the experimental design itself had an influence on the processing of emotional prosody violations. As was suggested within the P200 component discussion, the current study notably differed from previous studies not only by presenting two speaker voices but also by introducing six basic emotions and a neutral baseline. Nevertheless, for now it has to remain speculative why this speaker difference was obtained. It will thus be of special interest to see if this particular gender speaker difference is also obtained in Experiment 4, which applied a slightly changed experimental design.

In any case, the current ERP experiment has shown that it is a worthwhile endeavor to investigate both male and female voices, since processing of emotional prosody might change with regard to the voice presented. Also, the experiment has shown that at least for female speakers violations to emotional prosodic contours seem to be processed independent of valence. One question remains to be answered however: Was the emotional prosodic contour violation really processed independently of semantic context? If so, one can expect to elicit a similar positive ERP component after a violation to a pseudosentence. Experiment 4 will try to answer this question specifically.

Combined Emotional Semantic and Prosodic Violation Condition: Last, the present study aimed to specify if the interaction between emotional prosody and emotional semantics at the sentence level is dependent on emotional valence. To this aim, it was investigated whether the negative ERP component elicited by violations of both emotional semantics and emotional prosody reported previously could be replicated with violations to emotional semantics and emotional prosody of different valences. In short, the current results point further to the fact that this interaction does not depend on valence. Again, taken all results into account, the more negative-going ERP waveform for violated vs. control stimuli suggest that the interaction between emotional prosody and emotional semantics is predominantly driven by semantic information. In general, it was found that a parietally distributed negative ERP component was elicited by the combined violations, irrespective of valence. However, the current results also suggest that the ERP component was more pronounced for angry or fearful violations spoken by the male speaker as well as for disgust and pleasant surprise violations spoken by the female speaker. As was mentioned above, this again suggests that speaker identity might influence the processing of emotional prosody as well as the processing of emotional semantics. Thus, comparable to the results from the prosodic violation and the P200 component, speaker sex seemed to modulate the ERP response with respect to valence. Given that other studies have provided evidence for the fact that talker specificity might be embodied in the mental lexicon (e.g. Nygaard & Pisoni, 1998), it is not too surprising to find evidence that speaker gender might influence the on-line processing of emotional prosody. In addition, there is evidence that suggests that certain emotions (e.g., anger and happiness) are gender-specific, with anger being more often associated with males and happiness with females (c.f. Fischer, 2000). Unfortunately, there is little systematic research investigating speaker gender on the processing of emotional prosody, so it can only be speculated why ERP responses to the emotional prosody of the male and the female voice differed with respect to valence. The most promising explanation remains to be the gender bias mentioned further above. However, it seems reasonable to assume that the salience of the female voice per se, did not modulate the ERP waveform, but rather the salience of the voice associated with one particular emotion. To my knowledge, there are no scientific studies that have demonstrated this, but it is assumed that women might express disgusted emotional exclamations more often and thus more expressively than men do. Adding the fact, that there is evidence that suggests that anger is a characteristic of men, while pleasant emotions such as happiness are reported to be more characteristic of women (Birnbaum, Nosanchuk, & Croll, 1980; Briton & Hall, 1995; Fabes & Martin, 1991; Grossman & Wood, 1993; Kelly & Hutson-Comeaux, 1999), the current results might be interpreted from a social-biological perspective. The abovementioned characteristics typical of men and women fit the current observation of more pronounced ERPs for the violated angry sentences spoken by the male voice and more pronounced responses to violated pleasant surprise and disgust sentences spoken by the female speaker. In short, the current results suggest that indeed there might be a difference during the on-line processing of emotional prosody produced by male and female speakers. However, future research needs to replicate the current findings to shed light on the interpretation presented here.

Chapter 8

Experiment 4

8.1 Introduction

Up until now, few electrophysiological studies have investigated emotional prosody processing in isolation. Within most paradigms tested, emotional prosody is accompanied by congruent or incongruent emotional or neutral semantics when investigating emotional prosody. In order to investigate the interaction between these two channels of information (semantics and prosody) with regard to their temporal resolution, several paradigms have been established in language processing research, that involve investigating emotional prosody in isolation (without semantic content). For example, instead of investigating words or even whole sentences spoken with different emotional intonation patterns, one can use so called emotional interjections (e.g. Wow, Huh, etc.) as stimulus material. Another way of investigating emotional speech in isolation is to filter speech so that the semantic content and the syntactic information of the utterance is not interpretable any longer, while the emotional intonation contour remains untouched. Direct comparisons between acoustically comparable stimuli with "pure" emotional prosody and stimuli with combined emotional prosody and emotional-semantic information should allow for a description of the relative contribution of emotional prosody. However, when using interjections in isolation or filtered speech, the stimulus material very much differs from what we encounter in natural speech settings. One way to investigate emotional speech in isolation that is much closely related to natural speech processing is the use of nonsense utterances, or so-called pseudosentences. Pseudosentences are sentences that convey the emotional prosodic information but no lexical information (see Table 8.1 for examples). Like filtered speech, morphologically marked pseudosentences spoken with the same emotional intonation patterns allow us to eliminate lexical content while preserving emotional prosody. Direct comparisons between pseudosentences and lexical sentences should allow to explore the role of emotional prosody alone and when accompanied by congruent lexical information. It is worth mentioning that to systematically investigating pure emotional *semantic* information in the auditory domain is best done by presenting different emotional semantic contents spoken with neutral prosody. However, it should be noted that the influence of pure emotional *semantics* can best be investigated in the visual domain. Nevertheless, the scope of this thesis involves *emotional prosody* and *emotional prosody* with *emotional semantics* and not *pure emotional-semantic* influence on speech perception.

In order to compare results with those from Experiment 3, pseudosentences were produced with six different emotional prosodies (anger, disgust, fear, happiness, pleasant surprise, sadness, and a neutral baseline) by the same two speakers used in the previous experiment. Within the following experiment, it is of special interest to investigate the extent to which different emotional intonation patterns can elicit varying ERPs and whether this differentiation is independent of the semantic content of the sentence. In MMN studies, it has been shown that lexicality is processed pre-attentively (e.g. Jacobsen et al., 2004), thus, it is hypothesized that under attentive processing, lexical information modulates the P200 effect, i.e. we expect different P200 amplitudes modulations for lexical than for pseudosentences.

Secondly, it is of interest to determine whether the ERPs elicited in the prosodic violation condition in ERP Experiments 1, 2, and 3 in which the second part of the sentence was of neutral semantics but spoken with an emotional prosody could be compared to ERPs elicited in a pure emotional prosodic violation (pseudosentences) used in the present experiment. Theoretically, there should be no differences between the two conditions, i.e., we expect to replicate earlier results regarding the way that the pure emotional prosodic violation elicits a positive ERP component shortly after the splicing-point.

Last, the previous study found differences when processing emotional prosody articulated from a male voice compared to a female voice. However, systematic influences could not be reported, i.e., all post-hoc explanations with regard to this difference were highly speculative. However, it was assumed that investigating two speaker voices was a worthwhile endeavor and thus, to replicate results, the same two speaker presentend in Experiment 3 were again presented to participants in the current experiment. We continued to investigate voice identity to shed more light on the issue of gender voice specific emotional prosody processing. For instance, within the literature on emotional *expression* sex differences have been observed, i.e. female and male differ in their emotional expressiveness. Interestingly, these differences were noticed to arise already during development (Salminen, Saarijärvi, Äärelä, Toikka, & Kauhanen, 1999). It is thus important to further specify if there are also gender voice specific differences in emotional prosody *perception*. While one explanation for the observed speaker differences was the complex design used in Experiment 3, we tried to eliminate this as much as possible in the current experiment; however, presenting two speaker voices and six basic emotions plus a neutral baseline in addition to two violation conditions is always a complex endeavor.

8.2 Methods

8.2.1 Participants

Thirty native speakers of German (fifteen female) who had not participated in the first three experiments nor in one of the rating studies took part in the experiment. Female participants had a mean age of 24.13 (SD 1.96) and male participants had a mean age of 24.67 (SD 2.02). Participants received the usual seven Euro per hour as compensation.

8.2.2 Stimulus Material

The material consisted of semantically and prosodically matching stimuli and pseudosentences, i.e. for each of the seven basic emotions (anger, fear, disgust, happiness, pleasant surprise, sadness, neutral) presented, sentences that matched in prosody and semantics and pseudosentences were presentend (see Table 8.1 for a list with examples). For each emotion and sentence type, 30 sentences were presented, adding up to 210 matching normal sentences and 210 matching pseudosentences. In addition, the same sentences were spliced in the two previously described ways: a) in the combined semantic/prosodic violaten condition, a semantically and prosodically neutral start of a sentence was spliced to a semantically and prosodically matching end of the sentence, and b) in the pure emotional prosodic violation condition, a prosodically neutral start of a pseudosentence was spliced to an emotional-prosodically end of the pseudosentence (see Figure 8.1 for detailed examples). This adds another 180 spliced normal sentences and 180 spliced pseudosentences. As all sentences were again spoken by a female and male speaker, a total of 1560 trials were presented in two sessions. Emotional prosody valence was obtained in two earlier rating studies (one for the lexical sentences and one for the pseudosentences). Comparable to the rating study for the lexical material introduced earlier, 24 subjects (12 female) rated all pseudosentences according to their valence and in a second step, they rated the intensity of that same stimulus on a 5-point scale that ranged from -2 to +2 for emotional intensity (see Table 8.2 for mean percentages from this rating study). No sex differences were found in this rating study. The sentences presented were rated as accurately as with at least 50% in one of the rating studies corresponding to one particular emotion. The mean splicing point was calculated to be at 350 ms after sentence onset for the combined violation and at 400 ms after sentence onset for the pure emotional prosodic violation (this difference results from the observation that the prosodically neutral start of pseudosentences were slightly longer in duration). All sentences were taped with a videocamcorder and later digitized at 16-bit/44.1 kHz sampling rate. The stimulus material was prosodically analyzed (i.e. pitch, intensity and duration of the sentences were extracted) using *Praat*. Results of the acoustical analyses can be found in Table 8.3.

Condition	**Example Sentence**
Anger	Hung set den Willo bewöcht ind verkeustet
Disgust	Mon set den Nöwel gepicken ind gekatzt
Fear	Mon set den Suweis verpfuchtet ind geschweugen
Happiness	Hung set den Nestol verbarsicht ind gekobelt
Neutral	Hung set den Beunizen geseingen ind beschnutten
Pleasant Surprise	Hung set den Zert vermattet ind eungespurt
Sadness	Hung set den Loms getruken ind geschweugen

Table 8.1: The figure above shows one example pseudosentence for each emotional category.

Emotion						
Anger	Disgust	Fear	Happiness	Neutral	Pleasant Surprise	Sadness
87.90%	63.06%	60.59%	44.24%	93.17%	49.70%	66.04%

Table 8.2: Above, results from the pseudosentences rating are displayed. The Table shows the mean percentage correct for each emotional category for the two speakers presented in Experiment 4.

prosodic neutral start of pseudosentence	prosodic emotional end of pseudosentence		
Hung set	das Vermalet gereubt ind verpreusst.	→	ANGER
Hung set	die Spulza verbrutet ind nogelackt.	→	DISGUST
Mon set	die Sonität verfrieget ind geschweugen.	→	FEAR
Hung set	den Nestol verbarsicht ind gekobelt.	→	HAPPY
Hung set	den Zert vermattet ind eungespurrt.	→	PLEASANT SURPRISE
Mon set	das Baglick getellert ind gemeilt.	→	SADNESS

Figure 8.1: The illustration explains the splicing procedure for the emotional prosodic violation. This procedure is comparable to the splicing procedure for the combined emotional prosodic and emotional semantics violation explained in Experiment 3.

Speaker	Parameter	Anger	Disgust	Fear	Happy	Neutral	Pleasant Surprise	Sad
Female	Mean F0	272.58 (35.69)	214.22 (25.83)	247.89 (19.14)	330.83 (32.06)	200.78 (12.79)	380.70 (21.56)	204.63 (12.12)
	Range F0	223.40 (58.52)	139.28 (60.93)	147.37 (65.53)	364.72 (55.79)	170.58 (54.91)	366.97 (38.11)	98.60 (49.87)
	Duration	2.86 (0.37)	3.60 (0.50)	3.34 (0.62)	2.86 (0.45)	3.21 (0.40)	3.11 (0.39)	3.52 (0.44)
	Mean Intensity	70.65 (2.03)	70.53 (2.21)	68.77 (2.68)	70.81 (1.80)	70.88 (1.91)	71.37 (2.41)	68.44 (2.31)
	Range Intensity	48.22 (5.56)	43.48 (3.48)	39.34 (2.39)	48.05 (4.44)	41.49 (2.41)	47.49 (3.84)	40.25 (2.12)
Male	Mean F0	252.88 (14.72)	163.96 (44.92)	131.15 (10.43)	193.99 (31.87)	138.37 (11.44)	249.66 (15.80)	156.90 (15.45)
	Range F0	200.82 (24.74)	122.04 (40.71)	73.23 (16.93)	193.43 (31.79)	139.89 (44.26)	238.57 (25.93)	100.75 (31.14)
	Duration	2.92 (0.23)	3.58 (0.29)	4.05 (0.66)	2.90 (0.24)	3.52 (0.56)	3.06 (0.28)	2.87 (0.41)
	Mean Intensity	71.41 (1.86)	86.74 (2.76)	68.45 (2.98)	71.21 (2.22)	66.99 (3.0)	70.51 (2.24)	69.72 (1.98)
	Range Intensity	51.23 (4.43)	46.24 (3.8)	43.13 (4.32)	48.14 (7.52)	46.27 (3.95)	55.43 (4.05)	46.70 (4.66)
Both	Mean F0	262.72 (152.00)	189.09 (112.02)	189.52 (124.01)	262.41 (166.23)	169.58 (102.76)	315.18 (193.40)	180.76 (107.06)
	Range F0	212.12 (122.98)	130.65 (75.92)	110.30 (73.68)	279.08 (182.47)	155.24 (90.93)	302.77 (186.22)	99.68 (57.56)
	Duration	2.89 (1.67)	3.59 (2.07)	3.69 (2.16)	2.88 (1.66)	3.36 (1.94)	3.09 (1.78)	3.19 (1.87)
	Mean Intensity	71.03 (41.01)	69.63 (40.21)	68.61 (39.61)	71.01 (41.00)	68.94 (39.85)	70.94 (40.96)	69.08 (39.89)
	Range Intensity	49.73 (28.75)	44.86 (25.93)	41.24 (23.88)	48.10 (27.77)	43.88 (25.44)	51.46 (29.97)	43.47 (25.30)

Table 8.3: Acoustical analyses for the pseudosentences articulated by the two speaker presented in Experiment 4. The Table shows mean F0 (measured in Hz), mean intensity (measured in dB), and mean duration (measured in seconds) values. In addition, range F0 (in Hz) and range intensity (in dB) values are listed. Numbers in brackets indicate the standard deviation.

8.3 Results

Analysis of variance (ANOVAs) were performed on the percentage correct (PCs). PCs for the two different conditions (combined semantically/prosodically spliced material vs. prosodically spliced material) were calculated with separate ANOVAs, treating *M* (Match: prosodically and semantically matching stimuli vs. Mismatch or spliced stimuli), *P* (emotional prosodies of anger, disgust, fear, happiness, neutral, pleasant surprise, sadness), and *Speaker* (female vs. male voice) as repeated-measures factors and *Sex* (female/male) as a between-subject factor. PC effects are summarized in Tables 8.4 and 8.7. Only effects that are of importance with regard to the research questions are discussed below.

ERP components of interest were determined by visual inspection. For the ERP analysis, separate ANOVAs were conducted to analyze the different time windows. To control for possible session effects, we included the factor *Session* (first vs. second) in the ERP analysis. Also, in addition to the factors listed above, the factors *HEMI* (Left vs. Right Hemisphere) and *REG* (Frontal vs. Parietal Region) were included (c.f. Experiment 1). The Geissser-Greenhouse correction (Geisser & Greenhouse, 1959) was applied to all repeated measures with greater than one degree of freedom in the numerator. Again, because of the increased likehood of Type I errors associated with the large number of comparisons, *p* values of post-hoc single comparisons were corrected using a modified Bonferroni procedure (see Keppel, 1991) if necessary.

8.3.1 Behavioral Results

Combined Semantic/Prosodic Violation: Analyses for accuracy rates revealed a main effect of *M* ($F(1, 28)=10.97$, $p<.01$), with lower accuracy rates for unspliced sentences than for spliced sentences (97.51 % vs. 96.8 %). In addition, a main effect for *P* ($F(1, 28)=5.88$, $p<.001$) was found to be significant. Break-down comparisons were not carried out due to the fact that no prior hypotheses were made with regard to the effect emotional prosody might have on probe verification. Also, the comparisons are of no importance in answering the research questions. The behavioral results were solely analyzed to prove that participants were able to complete the task.

Last, the interaction between *M* and *P* was also significant ($F(5,40)=4.24$, $p<.0001$). The step-down analyses by *M* showed significant *P* effects for the correct ($F(5,40)=3.94$, $p<.01$) and the incorrect sentences ($F(5,40)=8.65$, $p<.0001$). Again, no post-hoc comparisons were carried out. PCs for each emotional category with spliced and unspliced sentences together are listed in Table 8.7. PCs for each emotional category for spliced and unspliced sentences separately can be found in Tables 8.6 and 8.5

Mean PC Values		
Condition	*PC*	*SD*
Anger	97.5 %	3.54
Disgust	96.42 %	3.87
Fear	96.25 %	4.35
Happiness	97.72 %	3.4
Pleasant Surprise	97.67 %	3.39
Sadness	97.36 %	4.3

Table 8.4: Mean percentage correct values for spliced and unspliced sentences with the six emotional prosodies in the combined emotional semantic and prosodic violation condition.

Mean PC Values for Unspliced Sentences		
Condition	*PC*	*SD*
Anger	97.44 %	3.7
Disgust	97.78 %	2.79
Fear	96.22 %	4.69
Happiness	97.83 %	3.35
Pleasant Surprise	97.78 %	3.4
Sadness	98.00 %	3.69

Table 8.5: Mean percentage correct values for unspliced sentences with angry, disgust, fearful, happy, pleasant surprise, and sad emotional prosody in the combined emotional semantic and prosodic violation condition.

Mean PC Values for Spliced Sentences		
Condition	*PC*	*SD*
Anger	97.56 %	3.41
Disgust	95.06 %	4.32
Fear	96.28 %	4.03
Happiness	97.61 %	3.48
Pleasant Surprise	97.56 %	3.41
Sadness	96.72 %	4.77

Table 8.6: Mean percentage correct values for spliced sentences with the six emotional prosodies in the combined emotional semantic and prosodic violation condition.

Mean PC Values		
Condition	*PC*	*SD*
Anger	94.36 %	4.89
Disgust	93.53 %	5.21
Fear	92.97 %	5.71
Happiness	94.17 %	4.78
Neutral	95.44 %	5.45
Pleasant Surprise	92.28 %	6.62
Sadness	90.75 %	6.81

Table 8.7: Mean percentage correct values for spliced and unspliced sentences with the six emotional prosodies in the emotional prosodic violation condition.

Mean PC Values for Unspliced Sentences		
Condition	*PC*	*SD*
Anger	94.39 %	4.89
Disgust	93.22 %	5.06
Fear	94.61 %	4.91
Happiness	93.94 %	4.77
Neutral	96.72 %	5.37
Pleasant Surprise	91.94 %	6.47
Sadness	88.72 %	6.92

Table 8.8: Mean percentage correct values for unspliced sentences with the six emotional prosodies in the emotional prosodic violation condition.

Prosodic Violation: The analysis of PCs showed a significant main effect for the factor *P* (F(6,168)=11.39, *p*<.0001). As was the case for the PC of the combined semantic/prosodic violation, no post-hoc comparisons were carried out.

The factor *Speaker* (F(1,28)=7.62, *p*<.05) turned out to be significant too, with accuracy rates higher for sentences spoken by the female speaker than for the male speaker (94% vs. 93%).

Also, an interaction between *P* and *M* was significant (F(6,168)=9.83, *p*<.0001). The step-down analysis by *M* revealed significant *P* effects for the correct control sentences (F(6,168)=16.26, *p*<.0001) as well as for the violated sentences (F(6,168)=4.09, *p*<.001). As the influence of prosody on the probe verification task was not of theoretical relevance, no post-hoc comparisons were carried out.

Last, due to the interaction *P* x *Speaker* (F(6,168)=2.15, *p*=.05), step-down analyses by *Speaker* were conducted which resulted in significant *P* effects for the female (F(6,168)=4.58, *p*<.01) and the male (F(6,168)=9.71, *p*<.0001) speaker. Again, as the influence of prosody and speaker sex on the probe verification task was not of theoretical relevance, no post-hoc comparisons were carried out.

Mean PC Values for Spliced Sentences		
Condition	*PC*	*SD*
SplicedAnger	94.33 %	4.92
SplicedDisgust	93.83 %	5.38
SplicedFear	91.33 %	6.02
SplicedHappiness	94.39 %	4.81
SplicedNeutral	94.17 %	5.27
SplicedPleasant Surprise	92.61 %	6.81
SplicedSadness	92.78 %	6.11

Table 8.9: Mean percentage correct values for spliced sentences with the six emotional prosodies in the emotional prosodic violation condition.

8.3.2 ERP results

***P200:* Match condition:** In the P200 time window of 150 ms to 350 ms, there was a significant main effect of *P* (F(6,168)=11.33, *p*<.0001). Break-down comparisons revealed that ERPs for neutral sentences differed marginally significantly from disgust sentences (F(1,28)=3.47, *p*=.07), and significantly from fearful (F(1,28)=25.09, *p*<.0001) and from sad sentences (F(1,28)=15.56, *p*<.001).

In addition, there was a highly significant effect of *M* (F(1,28)=47.01, *p*<.0001), indicating more positive-going waveforms for lexical sentences than for pseudosentences.

Also, *M* interacted with *Speaker* (F(1,28)=21.26, *p*<.0001). Follow-up analyses by *Speaker* revealed a significant *M* effect for both the male speaker (F(1,28)=13.00, *p*=.001) and the female speaker (F(1,28)=68.48, *p*<.0001). In both instances, lexical senteces evoked a more positive ERP component than pseudosentences.

There was also an interaction between *P* and *M* (F(6,168)=7.17, *p*<.0001), and the by-*M* analyses revealed significant *P* effects for both lexical (F(6,168)=8.48, *p*<.0001) and pseudosentences (F(6,168)=10.33, *p*<.0001). Post-hoc comparisons between neutral sentences and all other valences are listed in the following for both lexical and pseudosentences. For the lexical sentences, a significant difference between ERP amplitudes (*P* effect) was found for the contrast between 1) neutral and angry sentences (F(1,28)=7.16, *p*=.01); 2) neutral and disgust sentences (F(1,28)=13.11, *p*=.001); 3) neutral and fearful sentences (F(1,28)=44.07, *p*<.0001); 4) neutral and happy sentences (F(1,28)=18.58, *p*<.001); 5) neutral and pleasant surprise sentences (F(1,28)=11.60, *p*<.01); and 6) neutral and sad sentences (F(1,28)=28.85, *p*<.0001). In all comparisons, the ERP amplitude for neutral sentences was the most positive-going ERP amplitude. For the pseudosentences, a significant difference between ERP amplitudes (*P* effect) was found for the contrast between: 1) neutral and angry sentences (F(1,28)=4.20, *p*=.05); 2) neutral and fearful sentences (F(1,28)=6.03, *p*<.05); 3) neutral and happy sentences (F(1,28)=16.43, *p*<.001); and 4) neutral and pleasant surprise sentences ($F(1,28)=4.95$, $p<.05$). For the pseudosentences, happy sentences elicited the most positive-going ERP waveform.

A three-way interaction between *P* and *M* and *Sex* also reached significance ($F(6,168)=2.84$, $p<.05$). This allowed for step-down analyses by *Sex*, leaving a significant interaction between *P* and *M* only for the female participants ($F(6,84)= 8.52$, $p<.0001$). The by-*M* analysis for female participants revealed significant *P* effects for both lexical ($F(6,84)=8.42$, $p<.0001$) and pseudosentences ($F(6,84)=6.09$, $p<.001$). Post-hoc comparisons between neutral sentences and all other valences are listed in the following for both types of sentences. For the lexical sentences, a significant difference between ERP amplitudes (*P* effect) was found for the contrast between 1) neutral and angry sentences ($F(1,14)=16.20$, $p=.001$); 2) neutral and disgust sentences ($F(1,14)=10.56$, $p<.01$); 3) neutral and fearful sentences ($F(1,14)=76.08$, $p<.0001$); 4) neutral and happy sentences ($F(1,14)=26.06$, $p<.001$); 5) neutral and pleasant surprise sentences ($F(1,14)=12.40$, $p<.01$); and 6) neutral and sad sentences ($F(1,14)=23.13$, $p<.001$). In all comparisons, the ERP amplitude for neutral sentences was the most positive-going ERP amplitude. For the pseudosentences, a significant difference between ERP amplitudes (*P* effect) was found for the contrast between 1) neutral and angry sentences ($F(1,14)=5.12$, $p<.05$); 2) neutral and happy sentences ($F(1,14)=8.45$, $p<.05$); and 3) neutral and pleasant surprise sentences ($F(1,14)=7.08$, $p<.05$). Again, for the pseudosentences, happy sentences elicited the most positive-going ERP waveform.

The critical factor *P* also interacted with *REG* ($F(6,168)=4.19$, $p<.01$), showing highly significant *P* effects in both the frontal ($F(6,168)=9.32$, $p<.0001$) and the parietal ($F(6,168)=10.24$, $p<.0001$) scalp region. Post-hoc comparisons by *REG* for *P* effects revealed that for the frontal region, ERPs for neutral sentences differed only from fearful ($F(1,28)=12.07$, $p<.01$) and sad ($F(1,28)=5.29$, $p<.05$) sentences. In contrast, more comparisons between neutral sentences and sentences from other valences reached significance or marginal significance in the parietal region. The contrasts are listed in the following: 1) neutral vs. angry sentences ($F(1,28)=3.47$, $p=.07$); 2) neutral vs. fearful sentences ($F(1,28)=46.82$, $p<.0001$); 3) neutral vs. pleasant surprise sentences ($F(1,28)=9.18$, $p<.01$); and 4) neutral vs. sad sentences ($F(1,28)=27.32$, $p<.0001$). All contrasts revealed more positive-going ERPs for neutral sentences than for other sentences.

In addition, there was a three-way interaction between the factors *P* and *REG* and *Sex* ($F(6,168)=2.35$, $p<.05$). Step-down analyses by *Sex* were carried out and left significant two-way interactions between *P* x *REG* for both female ($F(6,84)=3.68$, $p=.01$) and male ($F(6,84)=2.93$, $p<.05$) participants. This allowed for a by-*Sex* and by-*REG* analysis, revealing a significant *P* effect for female participants in both the frontal ($F(6,84)=5.79$, $p<.001$) and parietal ($F(6,84)=5.75$, $p<.01$) scalp regions. The same was true for male participants, i.e. significant *P* effects were found for them in the frontal ($F(6,84)=5.48$, $p<.01$) and parietal ($F(6,84)=4.78$, $p<.01$) regions. Post-hoc comparisons for each sex and region were carried out and are listed in the following. For female participants in the frontal region, only the contrast between neutral and fearful sentences (F(1,14)=22.64, *p*<.001) reached significance. In contrast, comparisons in the parietal region for female participants revealed significant or marginally significant ERP amplitude differences for the comparisons between 1) neutral and fearful sentences (F(1,14)=50.39, *p*<.0001); and 2) neutral and sad sentences (F(1,14)=4.16, *p*=.06). For the male participants, similar results were found. In the frontal region, only the contrast between ERP amplitudes for neutral and happy sentences (F(1,14)=8.57, *p*=.01) reached significance. In the parietal region, male participants revealed significant ERP amplitude differences for the comparisons between: 1) neutral and fearful sentences (F(1,14)=12.65, *p*<.01); 2) neutral and pleasant surprise sentences (F(1,14)=4.48, *p*=.05); and 3) neutral and sad sentences (F(1,14)=7.70, *p*=.01).

The three-way interaction *M* x *REG* x *Sex* turned out to be significant too (F(1,28)= 7.65, *p*<.01). This led to a by-*Sex* analysis which revealed a significant interaction *M* x *REG* only for female participants (F(6,84)=8.52, *p*<.0001). This analysis was followed with by-*Sex* and *REG*-analyses, revealing marginally significant *M* effects in both the frontal (F(1,14)=4.13, *p*=.06) and the parietal (F(1,14)=9.82, *p*<.01) scalp regions in female participants, in both cases showing more positive-going ERP waveforms for lexical than for pseudosentences.

Last, the interaction *Speaker* x *P* x *M* was found to be significant (F(6,168)=2.87, *p*<.05). This allowed for a by-*Speaker* analysis, revealing significant *P* x *M* interactions for the female (F(6,168)=4.60, *p*<.01) and the male speaker (F(6,168)=5.95, *p*<.0001). The by-*M* analyses for both actors revealed significant *P* effects for the female speaker in both lexical (F(6,168)=4.38, *p*<.01) and pseudosentences (F(6,168)=5.49, *p*<.001). The same was true for the male speaker, i.e. significant *P* effects were found for lexical (F(6,168)=8.97, *p*<.0001) and pseudosentences (F(6,168)=6.89, *p*<.0001). Post-hoc comparisons are listed in the following. For the female speaker for the lexical sentences, significant contrasts were found for the comparisons between: 1) neutral and angry sentences (F(1,28)=17.45, *p*<.001); 2) neutral and disgust sentences (F(1,28)=4.29, *p*<.05); 3) neutral and fearful sentences (F(1,28)=10.12, *p*<.01); 4) neutral and happy sentences (F(1,28)=11.71, *p*<.01); 5) neutral and pleasant surprise sentences (F(1,28)=5.38, *p*<.05); and 6) neutral and sad sentences (F(1,28)=25.58, *p*<.0001). In all comparisons, the ERP amplitude for neutral sentences were found to be more positive-going than for all other valences. Valence differences for the pseudosentences spoken by the female speaker were only significant for the contrast between neutral and fearful (F(1,28)=8.50, *p*<.01), and neutral and happy sentences (F(1,28)=5.26, *p*<.05). A slightly different pattern was found for the male speaker. Here, for lexical sentences, comparisons were found to be significant for 1) neutral and disgust sentences (F(1,28)=7.53, *p*=.01); 2) neutral and fearful sentences (F(1,28)= 43.27, *p*<.0001); 3) neutral and happy sentences (F(1,28)=11.34, *p*<.01); 4) neutral and pleasant surprise sentences (F(1,28)=3.63, *p*=.07); 5) neutral and sad sentences (F(1,28)= 6.49, *p*<.05). In all comparisons, neutral sentences elicited more positive-going ERPs than did other valences.

For the pseudosentences, comparisons were found to be significant for 1) neutral and angry sentences (F(1,28)=4.23, $p<.05$); 2) neutral and happy sentences (F(1,28)=14.31, $p<.001$); 3) neutral and pleasant surprise sentences (F(1,28)= 6.13, $p<.05$). This time showing that neutral sentences elicited more negative-going ERPs than did other valences. Step-down analyses for all other significant interactions did not reveal any significant effects.

Overall, results revealed an overall emotional prosody effect irrespective of sentence modality or speaker-sex for the emotional prosodies of disgust, fear, and sadness. Also, an overall *M* effect was observed showing more negative going ERP amplitudes for pseudosentences than for lexical sentences. However, the *M* effect was also qualified by speaker, again revealing more negative going ERP amplitudes for pseudosentences than for lexical sentences for both speaker. In addition we found that *M* interacted with emotional prosody revealing different ERP amplitudes for pseudosentences and lexical sentences depending on emotional prosody. While for lexical sentences all valences investigated differed from neutral sentences, the picture was less clear for pseudosentences. In this sentences modality only the comparisons between angry, fearful, happy, and pleasant surprise sentences differed from their neutral control condition. Also, it was found that irrespective of speaker, the interaction between emotional prosody and sentence modality, or *M*, was qualified by the sex of participants. Results revealed valence effects for all emotional categories for lexical sentences in female participants, whereas for pseudosentences only the contrast betwen neutral and anger and neutral and happy and pleasant surprise reached significance for female participants. Interestingly, the interaction between speaker, emotional prosody, and sentence modality did not reveal a comparable *Sex* effect, suggesting that this sex difference is only visible when looking at emotional prosody and sentence modality irrespective of speaker. Indeed, we found rather comparable emotional prosody effects for both sentence modalities for both speaker. For example, the emotional prosody effect in the lexical modality reached significance for all investigated emotional categories for both speaker with the exception of angry sentences for the male speaker. The emotional prosody effect in the pseudosentence modality reached significance for the contrast between fearful and neutral sentences for the female speaker and for the contrast between angry, happy, and pleasant surprise and neutral sentences. Last, and comparable to Experiment 3, we also found that the emotional prosody effect was qualified by region, revealing valence effects for fearful and sad sentences at frontal electrode sites and valence effects for angry, fearful, pleasant surprise, and, sad sentences at parietal electrode sites. Table 8.10 lists all significant effects found in the omnibus analysis and Tables 8.11, 8.12, and 8.13 summarize significant valence effects revealed in post-hoc comparisons for lexical- and pseudosentences. (See Illustration 8.2 and 8.3 for a graphical display of effects).

***Later valence effect: 500 ms to 1000 ms* Match condition:** In the time window of 500 ms to 1000 ms, a significant main effect of *Speaker* was found (F(1,28)= 4.36, $p<.05$),

Time Window: 150 ms - 350 ms			
Effect	*df*	*F value*	*p value*
Session	1,28	8.99	<0.01
P	6,168	11.33	<.0001
M	1,28	47.01	<.0001
HEMI	1,28	14.49	<0.001
REG	1,28	36.22	<.0001
REG x *Sex*	1,28	6.52	<0.05
Speaker x *M*	1,28	21.26	<0.001
P x *M*	6,168	7.17	<.0001
P x *M* x *Sex*	6,168	2.84	<0.05
Session x *HEMI*	1,28	4.54	<0.05
P x *REG*	6,168	4.19	<0.01
P x *REG* x *Sex*	6,168	2.35	<0.05
M x *REG* x *Sex*	1,28	7.65	<0.01
Speaker x *P* x M	6,168	2.87	<0.05
Speaker x *HEMI* x *REG*	1,28	4.55	<0.05
Speaker x *P* x *M* x *REG*	6,168	3.48	<0.01

Table 8.10: Significant/borderline results from ANOVAs on mean amplitudes for the early time window of 150 ms to 350 ms for all participants.

Post-hoc comparisons both speaker both sentence types			
Effect	*df*	*F value*	*p value*
P	6,168	11.33	<.0001
Neu vs. Disgust	1,28	3.47	=.07
Neu vs. Fear	1,28	25.09	<.0001
Neu vs. Sad	1,28	15.56	<.001

Table 8.11: Post-hoc comparisons for valence effects irrespective of speaker-voice for both lexical- and pseudosentences.

Post-hoc comparisons both speaker lexical sentences			
Effect	*df*	*F value*	*p value*
P	6,168	8.48	<.0001
Neu vs. Anger	1,28	7.16	=.01
Neu vs. Disgust	1,28	13.11	<.001
Neu vs. Fear	1,28	44.07	<.0001
Neu vs. Happy	1,28	18.58	<.001
Neu vs. Pls. Surp.	1,28	11.60	<.01
Neu vs. Sad	1,28	28.85	<.0001

Table 8.12: Post-hoc comparisons for valence effects for lexical sentences.

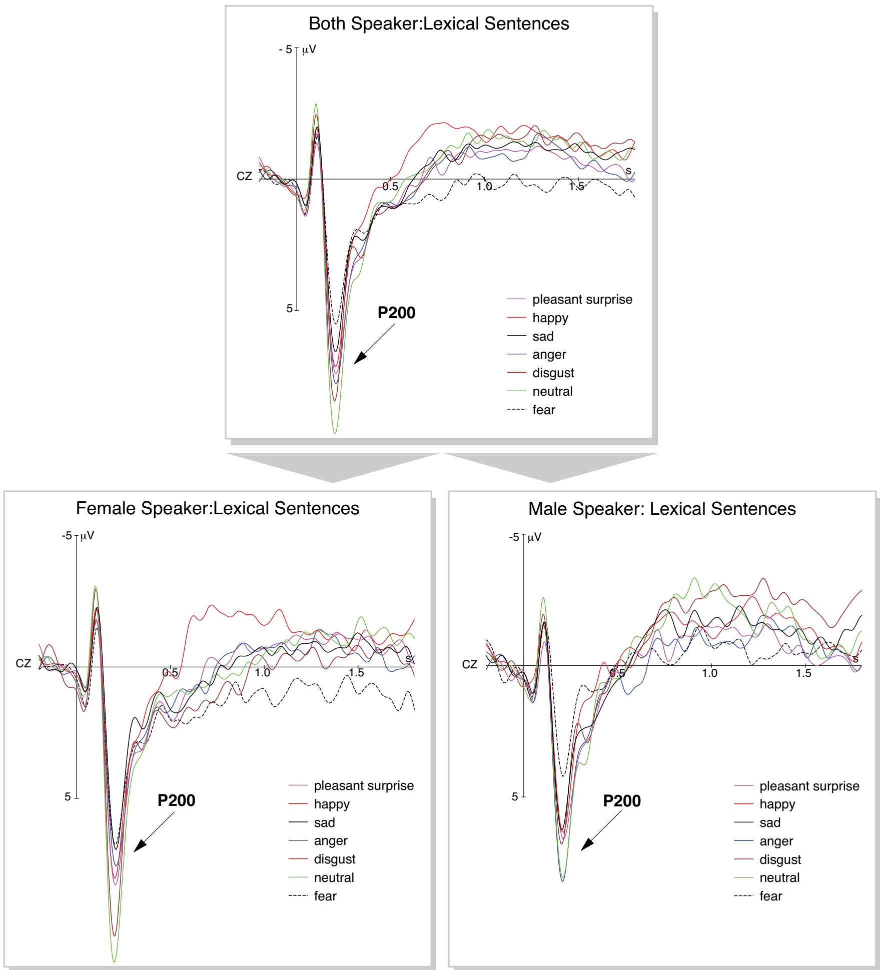


Figure 8.2: This illustration shows ERPs elicited by lexical stimuli differing in emotional prosody at one selected electrode site (CZ). Waveforms show the average for pleasant surprise (pink), happy (red), sad (black), angry (blue), disgust (brown), neutral (green), and fearful (black, dashed) sentences from 200 ms prior to stimulus onset up to 1700 ms post-stimulus onset.

Post-hoc comparisons both speaker pseudosentences			
Effect	*df*	*F value*	*p value*
P	6,168	10.33	<.0001
Neu vs. Anger	1,28	4.20	=.05
Neu vs. Fear	1,28	6.03	<.05
Neu vs. Happy	1,28	16.43	<.001
Neu vs. Pls. Surp.	1,28	4.95	<.05

Table 8.13: Post-hoc comparisons for valence effects for pseudosentences.

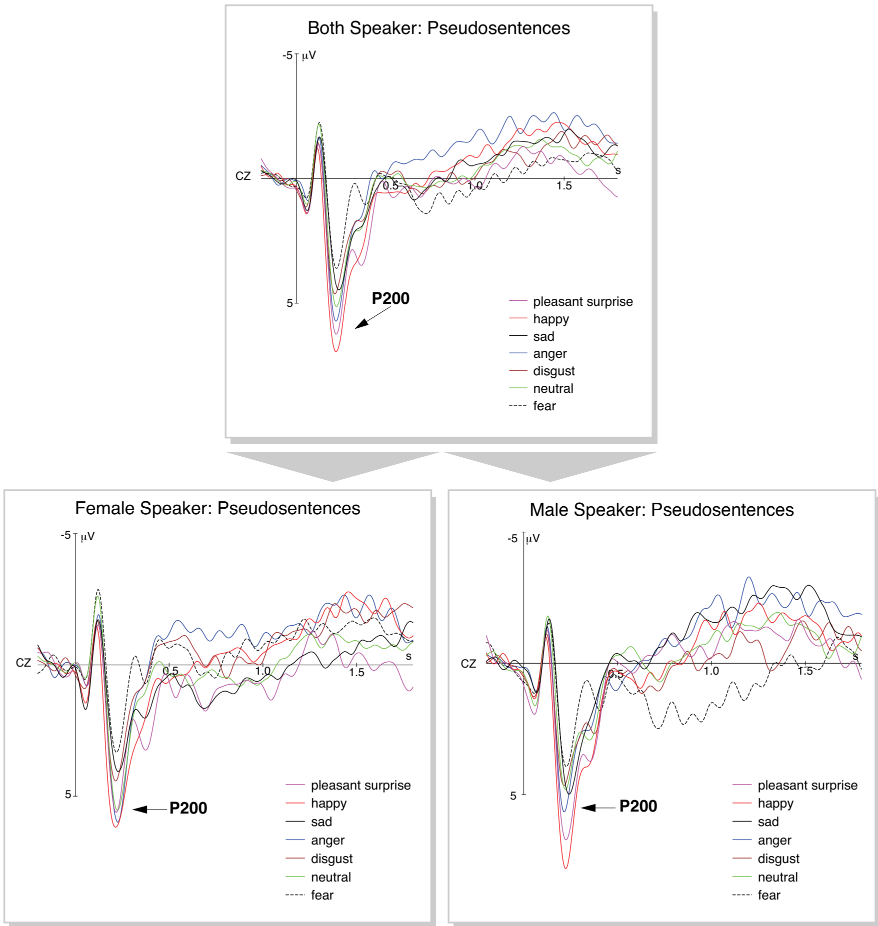


Figure 8.3: This illustration shows ERPs elicited by pseudosentences differing in emotional prosody at one selected electrode site (CZ). Waveforms show the average for pleasant surprise (pink), happy (red), sad (black), angry (blue), disgust (brown), neutral (green), and fearful (black, dashed) sentences from 200 ms prior to stimulus onset up to 1700 ms post-stimulus onset.

revealing more negative-going waveforms for the male speaker than for the female speaker. In addition, the interaction between *P* and *REG* was significant (F(6,168)=3.94, p<.05). The by-*REG* analysis revealed a significant *P* effect only in the parietal region (F(6,168)=3.41, p<.01). Post-hoc comparisons revealed that ERPs for neutral sentences differed from ERPs for fearful sentences (*P* effect: F(1,28)=8.50, p<.01), with the ERP waveforms for neutral sentences more negative-going than for fearful sentences.

Also, the interaction between *M* and *REG* turned out to be highly significant (F(1,28)=63.98, p<.0001). The by-*REG* analysis revealed significant *M* effects in both the frontal (F(1,28)=10.95, p<.01) and the parietal scalp regions (F(1,28)=19.62, p<.0001). Interestingly, at frontal electrodes, lexical sentences turned out to elicit more positive-going ERPs than pseudosentences, whereas at parietal electrodes, this pattern was reversed, i.e. lexical sentences elicited more negative-going ERPs than pseudosentences.

The interaction *M* x *REG* x *Sex* (F(1,28)=4.95, p<.05) allowed for a by *Sex* analysis, showing significant *M* x *REG* interactions in both female (F(1,14)=14.24, p<.01) and male (F(1,14)=63.0, p<.0001) participants. The by-*REG* analysis for each sex revealed a significant *M* effect in the parietal region for female participants (F(1,14)=19.90, p<.001), with lexical sentences showing more negative ERPs than pseudosentences. For the male participants, there was a significant *M* effect in the frontal region (F(1,14)=12.87, p<.01), showing more positive ERPs for lexical sentences than for pseudosentences. In contrast, the significant *M* effect in the parietal region (F(1,14)=5.00, p<.05), revealed more negative-going ERPs for lexical sentences than for pseudosentences. All other step-down analyses for other significant interactions did not reach significance.

Taken together results again revealed an overall speaker effect indicating more positive going amplitudes for the female speaker. In addition, a valence effect was found for fearful sentences at parietal electrode sites. Also, sentence modality, i.e. lexical and pseudosentences, interacted with region revealing more positive going amplitudes for lexical sentences at frontal electrode sites and a reversed pattern at parietal electrode sites. Interestingly, this effect also interacted with the sex of the participants with female and male participants showing more positive going ERP amplitudes for pseudosentences at parietal electrode sites and in addition male participants showing more negative going ERP amplitudes for pseudosentences at frontal electrode sites. See Table 8.14 for all significant effects. See Illustration 8.4 for graphical display of effects. See Illustrations C.1, C.2, C.3, C.4, C.5, and C.6 in Appendix for more detailed graphical display of ERP-effects.

***450 ms to 600 ms:* Prosodic Violation:** In the time window of 450 ms to 600 ms for the emotional prosodic violation, a significant effect of *Speaker* was found (F(1,28)=10.01, p<.01), with more negative-going waveforms for the male speaker than for the female speaker. Also, the critical main effect for *P* was found to be significant (F(6,168)=2.27, p<.05), indicating more positive-going ERP waveforms for the prosodically spliced sen-

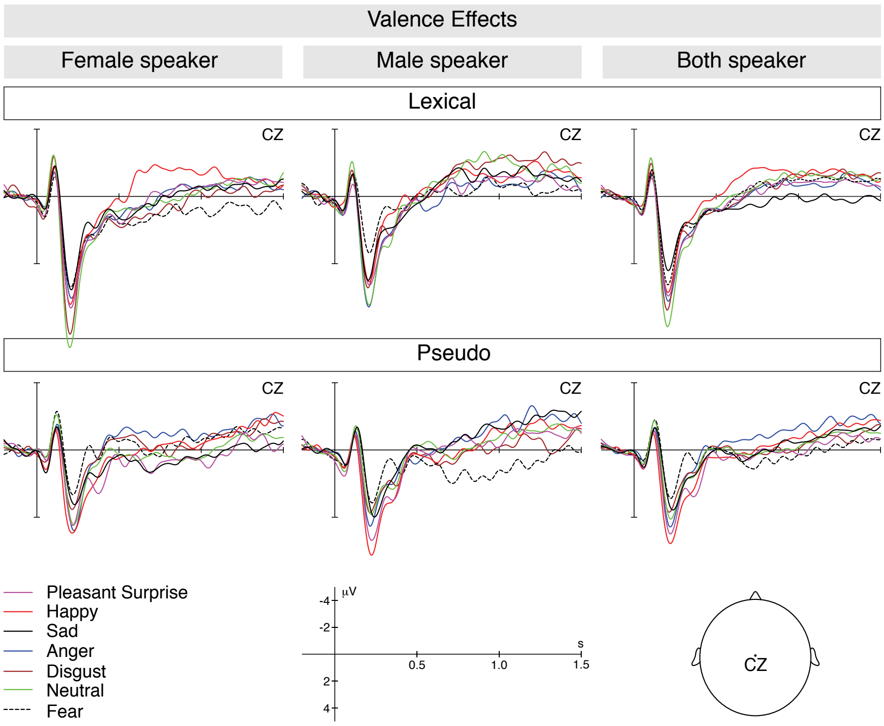


Figure 8.4: This illustration shows ERPs elicited by pseudosentences articulated by the female speaker, the male speaker, and both speakers respectively differing in emotional prosody at one selected electrode site. Waveforms show the average for pleasant surprise (pink), happy (red), sad (black), angry (blue), disgust (brown), neutral (green), and fearful (black-dashed) pseudosentences from 200 ms prior to stimulus onset up to 1500 ms post-stimulus onset.

Time Window: 500 ms - 1000 ms			
Effect	*df*	*F value*	*p value*
Session	1,28	3.89	<0.08
Speaker	1,28	4.36	<0.05
M x *Sex*	1,28	3.80	<0.08
HEMI	1,28	9.25	<0.01
REG x *Sex*	1,28	4.00	<0.08
Session x *REG*	1,28	11.17	<0.01
P x *REG*	6,168	3.94	<0.01
M x *REG*	1,28	63.98	<.0001
M x *REG* x *Sex*	1,28	4.95	<0.05
Speaker x *P* x *M*	6,168	2.47	<0.05
Session x *P* x *REG* x *Sex*	6,168	2.34	<0.05
P x *M* x *REG*	6,168	2.22	<0.08
M x *HEMI* x *REG*	1,28	5.92	<0.05
Session x *P* x *M* x *REG* x *Sex*	6,168	2.08	<0.08
Speaker x *P* x *M* x *REG*	6,168	2.12	<0.08
Session x *P* x *HEMI* x *REG* x *Sex*	6,168	2.65	<0.05
Session x *Speaker* x *P* x *M* x *REG* x *Sex*	6,168	2.15	<0.08

Table 8.14: Significant/borderline results from ANOVAs on mean amplitudes for the later time window of 500 ms to 1000 ms for all participants.

tences than for the unspliced sentences. Post-hoc comparisons are listed in the following: 1) neutral vs. angry-spliced sentences (*P* effect: F(1,28)=8.04, *p*<.01); 2) neutral vs. disgust-spliced sentences (*P* effect: F(1,28)=4.73, *p*<.05); 3) neutral vs. fearful-spliced sentences (*P* effect: F(1,28)=10.27, *p*<.01); 4) neutral vs. happy-spliced sentences (*P* effect: F(1,28)=8.3, *p*<.01); 5) and neutral vs. pleasant surprise-spliced sentences (*P* effect: F(1,28)=5.54, *p*<.05); with all comparisons showing more positive ERP waveforms for the spliced sentences than for the unspliced sentences.

In addition, the following interactions were significant, but step-down analyses did not result in further significant effects: 1) *Speaker* x *P* x *Hemi* (F(6,168)= 3.17, *p*<.01), and 2) *Session* x *Speaker* x *P* x *Hemi* (F(6,168)=3.22, *p*<.01).

Taken together, the results replicated earlier results by revealing a significant speaker effect indicating more positive going ERP amplitudes for the female speaker than for the male speaker. Also, and critical for our research question, the results revealed a positive-going ERP component for all emotional prosodically spliced sentences in comparison to unviolated sentences, except for the emotional category of sadness. This emotional prosodic violation effect was not qualified by *Speaker* or by ROI. See Table 8.15 for a list with all significant effects from the omnibus analysis and Table 8.16 summarizes all significant post-hoc comparisons. Figure 8.5 illustrates the ERP-effect.

Time Window: 450 ms - 600 ms			
Effect	*df*	*F value*	*p value*
Session	1.28	6.69	<0.05
Speaker	1.28	8.73	<0.01
P	6.168	2.44	<0.05
REG x Sex	1.28	5.81	<0.05
Session x Speaker	1.28	11.38	<0.01
Session x REG	1.28	20.15	<0.001
Speaker x REG	1.28	4.45	<0.05
HEMI x REG	1.28	5.84	<0.05
Session x Speaker x HEMI	1.28	3.65	<0.08
Speaker x P x HEMI	6.168	2.90	<0.05
Session x Speaker x REG	1.28	3.34	<0.08
Session x Speaker x P x HEMI	6.168	2.90	<0.05

Table 8.15: Significant/borderline results from ANOVAs on mean amplitudes for time window of 450 ms to 600 ms for all participants.

Post-hoc comparisons both speaker			
Effect	*df*	*F value*	*p value*
P	1,28	2.27	<.05
Neu vs. Anger	1,28	8.04	<.01
Neu vs. Disgust	1,28	4.73	<.05
Neu vs. Fear	1,28	10.27	<.01
Neu vs. Happy	1,28	8.3	<.01
Neu vs. Pls. Surp.	1,28	5.54	<.05

Table 8.16: Post-hoc comparisons for the Emotional Prosodic Violation condition. The Table shows significant contrasts between neutral sentences and spliced sentences.

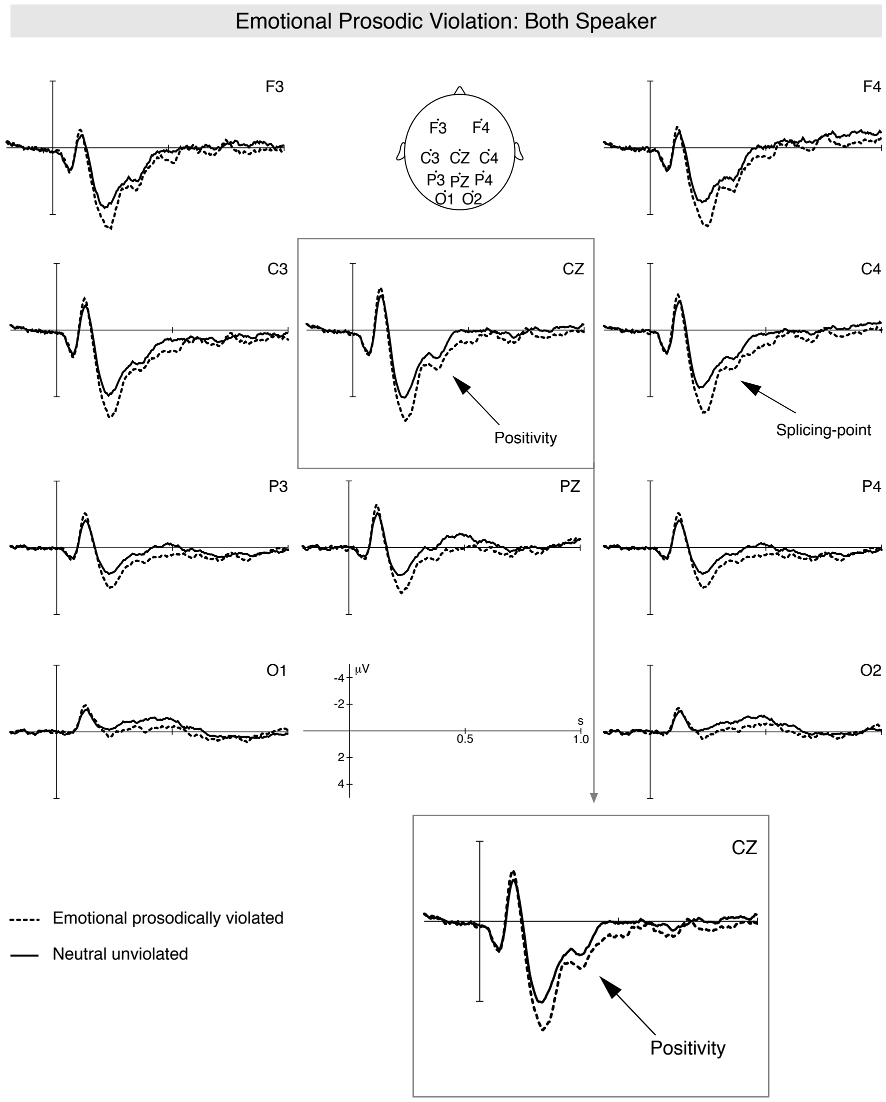


Figure 8.5: This illustration shows ERPs elicited by emotional prosodically violated and unviolated pseudosentences articulated by both speaker at selected electrode sites. Waveforms show the average for emotional prosodically violated (dashed) and neutral unviolated (black) pseudosentences from 200 ms prior to stimulus onset up to 1000 ms post-stimulus onset.

500 ms to 650 ms: **Combined Semantic/Prosodic Violation:** In the time window of 500 ms to 650 ms, the ERP analysis revealed a main effect for *Speaker* (F(1,28)= 13.90, *p*<.001), with amplitudes generally being more negative for the male speaker. A critical main effect of *M* reached also significance (F(1,28)=4.29, *p*=.05), revealing a more negative-going component for the violated, i.e. spliced sentences.

A critical interaction between *M* and *REG* (F(1,28)=4.27, *p*<.05) allowed for a step-down analysis by *REG*. This analysis revealed that the negativity for the violation was more pronounced at parietal electrodes (F(1,28)=10.77, *p*<.01).

Also, due to an interaction between *M* and *HEMI* and *REG* and *Sex* (F(1,28)= 5.79, *p*<.01), step-down anlyses were carried out by *Sex* and then by *Sex*, *REG*, and *HEMI* which indicated that the negativity found for the violated sentences in male participants was more frontally left lateralized distributed (F(1,14)=3.94, *p*<.01).

Furthermore, the analyses revealed significant or marginally significant interactions for *Speaker* x *P* (F(4,112)=4.36, *p*<.01), *Session* x *Speaker* x *P* (F(4,112)= 2.32, *p*=.08), *Session* x *Speaker* x *M* x *Sex* (F(1,28)=5.17, *p*<.05), *Session* x *P* x *REG* (F(1,28)=2.54, *p*=.05), *Session* x *M* x *REG* x *Sex* (F(1,28)=4.51, *p*<.05), *Session* x *Speaker* x *P* x *M* x *Sex* (F(4,112)=3.69, *p*=.01), *Session* x *Speaker* x *P* x *HEMI* (F(4,112)=2.28, *p*=.08), *Session* x *Speaker* x *P* x *REG* [F(4,112)=2.50, *p*=.05] , *Session* x *Speaker* x *M* x *REG* x *Sex* (F(1,28)=6.61, *p*<.05), and *P* x *M* x *HEMI* x *REG* (F(4,112)=2.33, *p*=.07); however, none of the carried out step-down analyses revealed any significant effects. Table 8.17 lists all significant effects found in the omnibus analysis.

All in all, results show a negative-going ERP component for the combined prosodically and semantically violated sentences. It seems as if this negativity is more pronounced at parietal electrodes and for male participants this component is left frontally distributed. Illustration 8.6 displays the ERP-effect.

8.4 Discussion

In sum, the obtained ERP effects are comparable to the effects observed in Experiments 1, 2, and 3 but extend these to pseudosentences. In particular, pure emotional prosodic violations elicited a positive ERP component shortly after the splicing-point, while combined emotional prosodic and emotional-semantic violations elicited a negative ERP waveform. In addition, valence effects reflected in the P200 component comparable to the first three experiments were observed. However, valence effects are differently accentuated when elicited by pseudosentences. In the following, each ERP effect observed will be discussed separately.

P200 Effect: One aim of the current study was to specify whether emotional prosody in pseudosentences elicits comparable ERP effects as when emotional prosody is accompanied

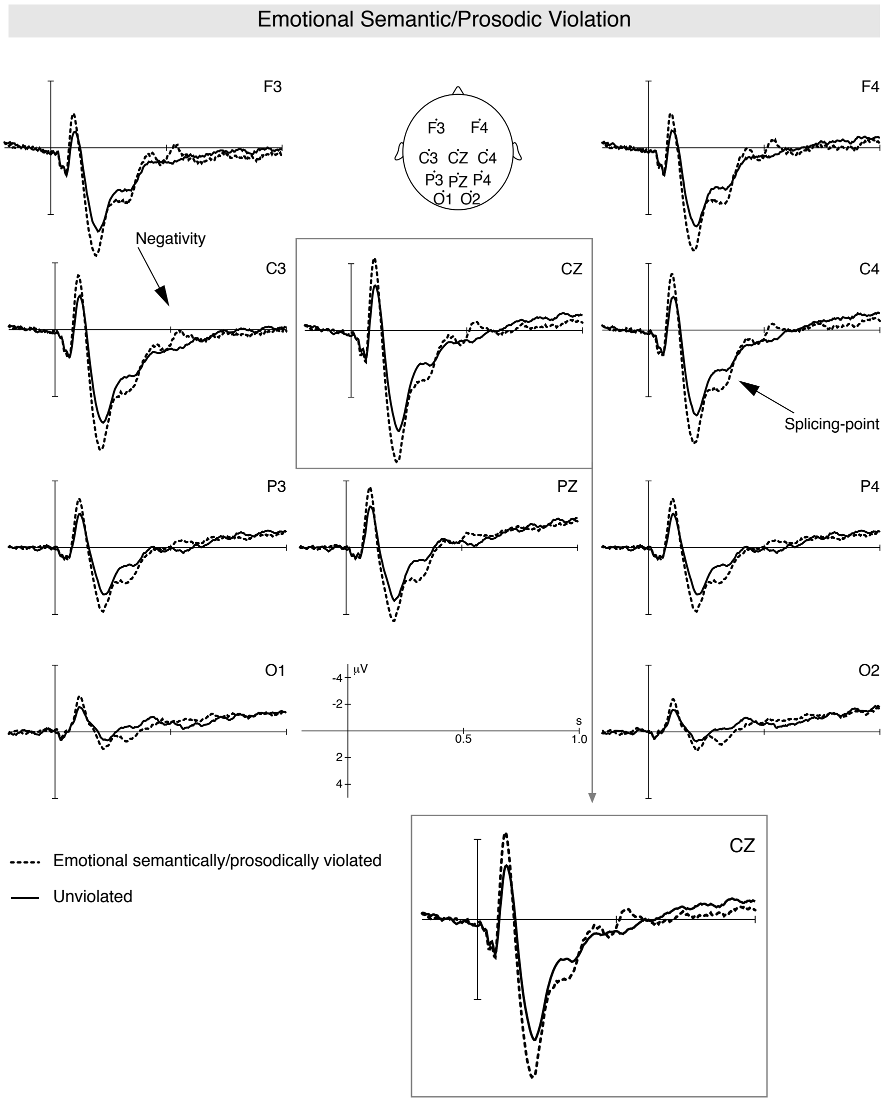


Figure 8.6: This illustration shows ERPs elicited by emotional semantically and prosodically violated and unviolated sentences articulated by both speaker at selected electrode sites. Waveforms show the average for emotional semantically and prosodically violated (dashed) and unviolated (blck) sentences from 200 ms prior to stimulus onset up to 1000 ms post-stimulus onset.

Time Window: 500 ms - 650 ms			
Effect	*df*	*F value*	*p value*
Session	1.28	4.55	<0.05
Speaker	1.28	13.90	<0.001
M	1.28	4.29	<0.05
REG	1.28	8.55	<0.01
REG x *Sex*	1.28	6.28	<0.05
Speaker x *P*	4.112	4.36	<0.01
Session x *REG*	1.28	6.93	<0.05
M x *REG*	1.28	4.27	<0.05
Session x *Speaker* x *P*	4.112	2.32	<0.08
Session x *Speaker* x *M* x *Sex*	1.28	5.17	<0.05
Session x *P* x *REG*	4.112	2.54	<0.08
Session x *M* x *REG* x *Sex*	1.28	4.51	<0.05
M x *HEMI* x *REG* x *Sex*	1.28	5.79	<0.05
Session x *Speaker* x *P* x *M* x *Sex*	4.112	3.69	<0.05
Session x *Speaker* x *P* x *REG*	4.112	2.50	<0.08
Session x *Speaker* x *M* x *REG* x *Sex*	1.28	6.61	<0.05
Session x *P* x *HEMI* x *REG* x *Sex*	4.112	3.10	<0.05
P x *M* x *HEMI* x *REG*	4.112	2.33	<0.08

Table 8.17: Significant/borderline results from ANOVAs on mean amplitudes for the later time window of 500 ms to 650 ms for all participants.

by congruent emotional semantics. The current results suggest that this is the case indeed. For example, the temporal aspects of the two sentence types did not differ as they elicited temporally similar ERP responses even across different valences. However, one observation is that the two modalities differ with respect to their peak amplitudes. In particular, ERPs for lexical sentences were more positive-going than ERPs for pseudosentences. The P200 has been reported to increase with increasing stimulus complexity (e.g. Ritter, Simson, & Vaughan, 1983; Shahin, Roberts, Pantev, Trainor, & Ross, 2005). For instance, Shahin et al. (2005) have reported the P200 amplitude to increase with increasing spectral complexity of a stimulus. In line with the assumption that increasing stimulus complexity can lead to enlarged P200 ERP components, the different peak amplitudes observed in the present study might have been elicited due to missing lexical information for pseudosentences and additional lexical information for normal sentences (hence making these stimuli more complex). Nevertheless, the early emotional prosodic effect in the time window of 150 ms to 350 ms provides further insight into the functional significance of the P200 component since the present findings suggest that emotional prosodies can differently affect the early ERP response in both lexical and non-lexical sentence types. The following paragraphs will try to discuss this functional significance.

As has been mentioned throughout this thesis, the P200 is argued to be an exogenous ERP component because first of all, it most often occurs in the first 100 ms to 200 ms after the onset of a stimulus, and secondly, it is thought to reflect primarily sensory stimulus characteristics (e.g. Kotz et al., 2000). However, the latency of the current P200 is longer and the current emotional prosodic valence effects suggest that stimulus characteristics as well as lexical information add to the P200 ERP component for *normal sentences*, since P200 amplitudes varied for the different valences with regard to sentence type. For lexical sentences spoken with a neutral prosody, the P200 was larger than for lexical sentences spoken in one of the six other valences. However, a different pattern was found for pseudosentences. Here, sentences with a happy prosody elicited the most positive-going ERP waveform. In short, it seems as if the early P200 component can also be influenced by affective lexical information processing. Following this assumption, it is suggested that the P200 reflects processes that occur in parallel, namely sensory stimulus encoding and if applicable, affective lexical processing. In general, the current results point to the fact that the P200 might be modulated by acoustical stimulus properties as well as by early (lexical) access to emotional valence. The present findings have shown that within the lexical modality, neutral sentences differed significantly from all other valences in their P200 amplitude. Comparable to previous results, this can again be interpreted to reflect a first emotional encoding of the stimulus. In addition, pseudosentences elicited a similar valence effect, i.e., neutral sentences differed from sentences of other valences, namely angry, fearful, happy, and pleasant surprise sentences. In the discussion of Experiment 3, it has been suggested that the first emotional encoding of the stimulus seems to be particularly influenced by pitch and intensity variations. Here, results suggest an extension of this interpretation, namely that, if available, lexical information might contribute to this early effect. Since acoustical analyses (see Appendix C.2 for statistical analyses) revealed comparable results between the acoustical properties of lexical and non-lexical stimuli, it is assumed that the P200 difference between the two modalities is primarily related to the difference in lexic, as the current ERP profiles show a slightly different pattern for lexical and pseudosentences. For example, the amplitude for angry lexical sentences when compared to neutral sentences was less positive, while the amplitude for angry pseudosentences when compared to neutral pseudosentences was more positive. Future studies making use of, e.g., filtered speech with the very same acoustical properties of verbal speech, need to compare emotional prosodic utterances of the two modalities to clarify the exact contribution of lexical information on emotional prosody perception. It needs to be acknowledged that even though statistical analyses revealed overall comparable results between the acoustical analyses for lexical and pseudosentences in the early time frame of 150 ms to 350 ms, minor differences (due to necessary variation) in acoustical properties might have affected the P200 effects.

It is also necessary to briefly discuss one additional result observed in the present findings. Unlike the previous experiment, the current results suggest generally more pronounced valence effects for female participants independent of speaker. However, since only one interaction between emotional prosody, sentence type, and participants' sex revealed this advantage for females in emotional prosodic processing, it is assumed that this does not reflect a qualitative difference but quantitative difference, i.e., a difference in the effect size. This assumption gets further support when taking the regional distribution of effects into account. For example, for female participants, it was found that ERPs elicited by neutral sentences differed from those elicited by fearful sentences in the frontal region, while for male participants, it was found that ERPs elicited by neutral sentences differed from happy sentences in the frontal region. Taken together, the participants' sex differences observed in the present investigation need further clarification. In particular, it will be of interest to see if distributional differences between the two participant groups can be replicated in future studies. Actually, studies on emotional identification have revealed hemispheric lateralization differences for females and males. For example, Wildgruber et al. (2002) found stronger right middle frontal gyrus activation in males than in females when listening to vocal emotional expressions. If distributional differences can be replicated in future studies, it can be concluded that the differences obtained here were not solely due to the current stimuli and presentation paradigm used. Obviously, within natural speech situations, it is very seldom the case that emotional intonation patterns switch so frequently as they have done here. Thus, sex as well as speaker effects should be replicated with different stimuli, tasks applied, and paradigms used. In sum, the present results found renewed evidence for the fact that different valences can be differentiated in the ERP in an early ERP component. Together with previous results obtained in this thesis, it is assumed that the P200 is modulated by pitch, intensity, and affective lexical information.

Finally, an additional aim of the present experiment was to examine whether the sex of the speaker modulates emotional prosody processing. In the previous experiment, it was suggested that speaker voice can indeed influence emotional prosody processing even at an early stage of processing. Comparable to Experiment 3, the current results suggest that emotional prosody perception might be influenced by the sex of the speaker. However, as with sex differences in the present study, differences were in effect size rather than in the direction of the effects. For example, for lexical sentences, the female and male speaker elicited comparable brain responses. For both speakers, ERPs elicited by lexical sentences with neutral prosody differed significantly from other valences, with the only exception being that for the male speaker, the contrast between angry and neutral sentences did not reach significance. This can be seen in the fact that for both speakers, neutral prosody elicited the strongest positive ERP component. In addition, neutral pseudosentences also differed from other valences for both speakers. For example, for both speakers, ERPs for neutral pseudosentences differed from ERPs for happy pseudosentences. However, as was reported for Experiment 3, not all comparisons between neutral and other valences reached significance. Within the current findings, neutral sentences differed from fearful and happy sentences for the female speaker, while for the male speaker, comparisons between neutral and angry, neutral and happy, and neutral and pleasant surprise sentences were significant. Again, it can only be speculated why these valence differences were observed. One explanation offered is that those valences that did not differ from neutral pseudosentences were not as well portrayed as the ones that differed. This seems to be unlikely because the previous rating study revealed above-chance level recognition rates for all emotions. In addition, the fact that pleasant surprise sentences differed significantly from neutral sentences makes this explanation even more unlikely because pleasant surprise is usually not very well recognized and could thus be interpreted as not very well portrayable. Thus, it remains an open question whether the salience of the emotions as portrayed by the female and male speaker influenced the emotional prosody valence effect. One way to clarify the exact contribution of speaker voice on emotional prosody perception is to use filtered or otherwise manipulated speech which can be manipulated to have the very same acoustical properties of the stimulus, as e.g. pitch contour and intensity. Natural speech production, be it in normal speech or pseudo-speech, includes necessary variation and was thus present in the current experiment. However, future studies investigating voice identity influence on emotional prosody perception could use synthesized or manipulated speech where all acoustic properties remain the same except for e.g. pitch per se, i.e. to present low pitch (male like) and high pitch (female like) variations. By systematically including/excluding one particular channel of acoustic information, the exact contribution of each acoustic channel can be specified.

Later Valence Effect: Taken together, results for ERP effects in the later time window of 500 ms to 1000 ms revealed a significant speaker voice effect, with more positive ERPs elicited by the female voice than by the male voice. As was observed for Experiment 3, it seems as if female voices evoke stronger ERP effects than male voices. Thus, the present findings add additional evidence to the assumption that female voices might be perceived as socially and biologically more relevant than male voices. This assumption gets further support from the current observation that stronger positive ERPs for the female voice have not only been found irrespective of valence, but also irrespective of sentence type, i.e., the speaker voice effect is visible in pseudosentences and lexical sentences. In addition, a valence effect has been observed, revealing differences between ERPs elicited by neutral sentences and by fearful sentences. This partly replicates results from Experiment 3, but extends these to apply to lexical as well as pseudosentences, suggesting that this effect really reflects valence processing and not integration between semantics and emotional prosody. In contrast, the additional valence effect for the comparison between happy and neutral sentences observed in Experiment 3 was not replicated. The present findings only revealed differences between fearful and neutral sentences. However, as in Experiment 3, later valence effects for emotional prosody modulated by speaker were not found, i.e., both the female and the male speaker elicited a more negative ERP waveform for neutral sentences when compared to fearful sentences. This suggests that the speaker's sex does not modulate emotional prosody processing at a later point of processsing, at least not when emotional prosody is not in attentional focus, i.e. when an implicit prosody processing task is applied (but see Schirmer and Kotz (2003) speaking against this). It will be interesting to see whether speaker sex can modulate emotional prosody processing at a later point of time when emotional prosody, and/or speaker voice is in attention focus. Considering evidence for speaker-specific processing in light of the "face" recognition literature (e.g. Lewin & Herlitz, 2002), it will be exciting to explore this effect more systematically in the future. For instance, Lewin and Herlitz (2002) have shown that female faces were better recognized by females than by males. No such gender-specific face processing has been found for male faces. The authors suggest that this result was obtained because of the different personal interest of women and men, or because women are more often exposed to female faces (e.g. magazines) and thus recognized them more efficiently. It is questionable if this "superiority" in exposure is also the case with female vocal stimuli. However, for now, it can be concluded that speaker sex influences emotional prosody processing at an early point of time, reflected in the different P200 modulations, but not at a later stage of processing. In general, the assumption raised in the discussion of Experiment 3 that this later positive ERP component for fearful sentences reflects more elaborate analysis of the stimulus remains a possible suggestion.

Last, one interesting processing difference for lexical and pseudosentences between female and male participants was observed and will be briefly mentioned despite its low contribution to the discussion on valence processing for emotional prosody. It was observed that female participants show a parietally distributed negative ERP component for lexical sentences when compared to pseudosentences, irrespective of valence. The same parietally distributed negativity was found for male participants. However, unlike female participants, male participants showed a reverse pattern at frontal electrodes, i.e., lexical sentences elicited a positive ERP component in the frontal scalp region. As ERPs are not very useful to discuss actual neural generators of this effect, future imaging studies will have to clarify why male and female participants of the current study seem to process emotional prosody from lexical and non-lexical sentences differently, and this irrespective of emotional prosody valence.

Emotional Prosodic Violation condition: As hypothesized, the violation of an emotional prosodic intonation contour elicited a positivity shortly after the splicing point. This replicates results from the previous experiments but extends these in several ways. First of all, the effect was elicited by pseudosentences, suggesting that the effect is truly elicited by an emotional prosodic violation and is not manipulated by neutral semantic content of the spliced sentence. This might at first seem trivial, but it is worth mentioning because results can now be globalized to reflect general emotional prosodic processing steps. Also, the present findings could not replicate earlier speaker individual results, i.e., the current effects occurred irrespective of speaker sex. This suggests that earlier differences between the female and male voice were, primarily due to the design of Experiment 3. In addition, the assumption that this positive ERP effect is closely related to the emotional prosodic contour violation, irrespective of valence, is upheld. However, since no robust valence effects could be replicated, a general prosodic contour violation might have elicited similar effects. Considering the positive ERP component observed by Astésano et al. (2004), which is elicited by linguistic prosodic violations (c.f. previous discussions), it seems reasonable to generalize that prosodic contour violations might always elicit a positive ERP component. As suggested, all beforementioned positive ERP components (e.g. P800, CPS) might belong to the same family of ERP components, all reflecting responses to prosodic violations, but differing in extent and distribution depending on the violation that elicited the response. To clarify, prosodic contour violations of emotional prosody might be responded to faster than prosodic contour violations of linguistic prosody due to the evolutionary significance of emotional stimuli. Obviously, this assumption is highly speculative and requires further investigation. For instance, a study including linguistic prosodic violations (e.g. declarative sentences spliced to questions) as well as emotional prosodic violations (as used here) compared to the same neutral control sentence could help to specify if the same positive ERP component is elicited. However, careful temporal manipulation needs to be assured, i.e. the two utterances need to be violated at the same point in time (e.g. before/after the noun) to assure correct temporal comparisons. In particular, the possible difference in temporal aspects of emotional prosody and linguistic prosody processing can be specified in such a paradigm. In addition, it has been indicated that the present positive ERP component might be modulated in onset, latency, and distribution, by task (implicit vs. explicit processing of emotional prosody), stimulus presentation design (more robust effects for presentation of only two emotional prosodies plus neutral prosody), and stimulus properties (female vs. male voice). Nevertheless, the present findings warrant the conclusion that emotional prosodic contour violations will very likely elicit a positive ERP component under various processing situations, and that this component primarily reflects automatic re-analysis processes of emotional prosodic aspects of the stimulus. In sum, there is considerable evidence that suggests that emotional prosody processing is a highly automatized process, that does not seem to be influenced by valence differences.

Combined Emotional Semantic and Prosodic Violation condition:

The present study aimed to further specify the interaction between emotional prosody and emotional-semantics at the sentence level, and to underline that this interaction is probably not dependent on emotional valence, i.e. there is no processing difference between violations of emotional prosodies belonging to different emotional valences. In general, the present findings suggest that responses to emotional prosodic and emotional-semantic violations are valence-independent and thereby replicated previous results. As discussed previously, a parietally distributed negative-going ERP component was elicited for the combined prosodically and semantically violated sentences. In addition, results revealed that male participants show this component in a more pronounced fashion at left frontal electrode sites.

Functionally speaking, this result again implies that in the combined emotional prosody and semantics violation condition, the semantic information channel seems to predominate the emotional prosody channel and it is assumed that the combined violation of emotional prosody and semantics elicited an N400-like negativity. However, it still remains speculative to suggest that the brain response was triggered by the emotional semantic violation alone, since it did not occur in isolation. Despite this acknowledged shortcoming of the present design, it has been proven with the series of experiments presented in this thesis that it is not the semantically orientated task itself that manipulates the processing of this combined violation. As has been mentioned in the introduction to the present experiment, ultimate control over the influence of *pure* emotional semantics can only be achieved in the visual domain; however this is beyond the scope of this thesis.

The current results go hand in hand with the literature where it has been proposed that semantics cannot be ignored even if not in attentional focus (Besson et al., 2002, and also see Discussion, Experiment 2). Here, results can even be globalized to the fact that the valence of semantics does not seem to be of primary importance for this effect to occur, i.e., semantics predominates emotional prosody irrespective of its emotional content. Finally, the current results have not replicated speaker sex effects on the processing of emotional prosody and emotional-semantics. As mentioned previously, more systematic research on this issue is needed. In particular, the potential influence of the experimental design should be kept in mind when planning experiments.

To summarize, the present findings are highly comparable to the effects observed in the previous experiments. In particular, results were extended by the introduction of pseudosentences carrying different emotional prosodies. It is believed that the cross-splicing method has been shown to be a useful manipulation when investigating the interaction of emotional prosody and emotional-semantics. In addition, the introduction of pseudosentences has offered a natural way possibility to investigate emotional prosody in isolation. Also, it has been shown that divergent results in the emotional prosody literature might very well relate to experimental design issues, i.e., how many valences of emotional prosody are studied, which ones are studied, and the way in which they are studied. In particular, with the following patient experiment in mind, the above issues raised will be very well considered.

Chapter 9

Experiment 5

9.1 Introduction

In his 1983 published review on *Emotional Changes associated with Basal Ganglia Disorders*, Richard Mayeux observed that emotional disorders are reported more frequently for patients suffering from BG disorders than would be expected by chance alone.

> Affective disturbance, primarily depression and less frequently mania, is the most frequently encountered symptom. Apathy, characterized by loss of initiative and motivation, interrupted by episodes of irritation or aggression also occurs in these patients. Lability of emotion and psychosis are less frequently encountered, although they are seen regularly. There are obvious variations in the clinical expression of these emotional disturbances in each disorder, and within each type of disorder there may be a broad range of symptomatology. These disorders share neuropathological changes within the basal ganglia (Mayeux, 1983, pg. 157).

Within his review, Mayeux included patients suffering from one out of five diseases of BG (Parkinson Disease, Huntington Disease, Wilson Disease, progressive supranuclear palsy, and Sydenham chorea). Symptoms reported for BG lesion patients were not included in his review. Nevertheless, his paper points to a critical phenomenon that has been discussed in the literature for more than a century now, namely that emotional disorders (i.e. perception and production of emotions) are often associated with BG disorders. These disorders of emotional processing often restrict the daily life communication of affected patients, which is probably one reason why within the neuropsychological literature, it is controversially discussed whether and to what extent the BG are part of an emotional processing network. As has been mentioned previously, one issue in lesion studies is that emotions are rather complex brain functions and that it is difficult to separate all underlying processes which constitute an emotion. Over the last years the literature has suggested that the BG next to right hemispheric cortical structures play an important role in the evaluation of emotional stimuli. Evidence comes from studies looking at emotional vocal and facial expression recognition. In particular, evidence suggest that the BG modulate perception of *disgust*, since deficits/disorders for the recognition of facial expressions and vocal expressions of disgust have been reported frequently in patients with Parkinson's Disease (Pell & Leonard, 2003) or Huntington's Disease (Sprengelmeyer et al., 1996). For example, in a single case study by Calder, Keane, Manes, Antoun, and Young (2000), authors reported that a BG patient suffered from impairment in the recognition of disgust in facial expressions as well as in vocal cues. In addition, patients suffering from other BG disorders (e.g., Tourette syndrome, or Wilson's Disease) have been reported to show similar deficits in disgust recognition (Sprengelmeyer et al., 1997; Wang, Hoosain, Yang, Meng, & Wang, 2003). Last, fMRI studies with healthy participants have reported BG involvement in facial disgust recognition (Hennelotter et al., 2004).

Even though it is controversially discussed, there is also evidence that the BG are involved in the recognition of *fear* in facial expressions but not in vocal realizations (Kan, Kawamura, Hasegawa, & al., 2002). A recent study suggests that depending on the extent of the lesion, BG patients also suffer from impairment in recognizing *anger* (Calder, Keane, Lawrence, & Manes, 2004). As was already mentioned in Chapter 2, the BG might be involved in processing positive and negative emotions from vocal cues in general, as has been shown in an fMRI study with healthy participants by Kotz et al. (2003). Therefore, it seems to be particularly important that more than one emotion is tested when aiming to specify whether one particular emotional expression (facial and/or vocal) is correlated with one particular brain structure. Here, the perception of emotional prosody in BG lesion patients is investigated using four emotions (anger, fear, disgust and happiness) and a neutral baseline.

The aim of the current study is manifold. First of all, we aim to investigate the extent to which BG patients show comparable valence effects reflected in the P200 component similar to effects found in the previous experiments for healthy participants. If BG patients show a selective deficit of disgust perception, this should be revealed when comparing neutral sentences to disgust sentences, i.e., patients should show no differences in P200 amplitudes between the two emotional categories. If, however, BG patients show a general emotional deficit, i.e., for all four emotional categories investigated, this should be reflected in missing valence effects in the P200 component as well. Furthermore, it will be of interest to investigate the extent to which lexical information contributes to the processing of emotional prosody. Will lexical and non-lexical emotional sentences differ in their P200 amplitudes? Will the proposed emotional prosody deficit only be visible for one modality, i.e. only for lexical or non-lexical sentences?

Secondly, we aim to investigate the extent to which violations to emotional prosodic contours will elicit ERP responses similar to healthy participants. Will violations to emotional prosodic contours elicit the same positive ERP component for all valences? If there is a specific deficit for disgust perception, will violations to a disgust emotional prosodic contour elicit different ERP responses than violations to other emotional prosodic contours?

Third, the current experiment will be able to specifically investigate the interaction between emotional prosody and emotional semantics. Will combined violations, i.e. violations to the emotional prosodic and emotional semantic contour elicit similar ERP responses as were visible for healthy participants? Will a possible selective deficit for one emotional category increase with additional semantic information, or will it possibly decrease due to the additional information channel?

Last, as mentioned previously, various behavioral studies have reported recognition deficits for emotional prosody in, e.g. PD patients (Breitenstein et al., 1998, 2001; Pell & Leonard, 2003). Even though these data are telling, the results do not sufficiently allow us to separate underlying mechanisms substantiating emotional prosody from process-correlated task effects as reflected in behavioral responses. Therefore, the current study will investigate emotional prosody in an on-line ERP experiment and in an additional behavioral experiment. This not only allows us to demonstrate that patients correctly recognize the different emotional prosodies tested in the ERP experiment, but even more interestingly, it will be possible to compare implicit emotional prosody processing in the ERP experiment to explicit emotional prosody processing as in an emotional prosody recognition task. As previously stated, there is evidence that implicit and explicit processing of emotional prosody may accentuate different brain areas in a functional network supporting emotional prosodic perception (Kotz et al., 2003, in prep). Recall that while implicit processing of emotional prosody activated a network with right claustrum activation, the explicit task resulted in bilateral subcortical activation. Thus, only in the implicit task did emotional prosody engage a *right* subcortical structure. Therefore, it seems to be important to specify if deficits revealed in the processing of emotional prosody in BG patients differs as a function of task demands. Up until now, there is no systematic research which has tried to investigate if emotional prosody perception is impaired during on-line processes or if it is only impaired at later stages of emotional prosody processing. That is, there may be a dissociation of ERP and RT effects based on processes affecting decision making, response preparation and response execution that may be enhanced in an explicit emotional prosody recognition task. This would suggest that recognition deficits of emotional prosody primarily occur when emotional prosody is processed explicitly. The following experiments will address the question of implicit vs. explicit task effects during the processing of emotional prosody in BG patients and allow us to critically compare the respective results of behavioral and ERP measures in the same patient group.

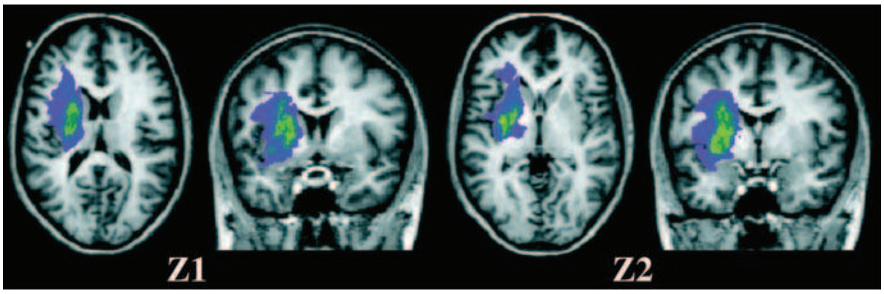


Figure 9.1: The illustration shows an overlay of respective individual patient lesions indicating maximum overlap in the basal ganglia. Displayed are two slice levels (Z1=89 [originally 1-180]; Z2=102 [originally 1-180]. Green/yellowish shades reveal maximum overlap of lesion sites, whereas purple shades reveal minimum lesion site overlap.

9.2 Methods

9.2.1 Participants

Twelve brain chronic patients (1 female, all right-handed) with lesions in the striatum participated in the current study. Lesions resulted from left hemisphere insults: ischemic stroke (n=3), embolic stroke (n=3), hemorrhage (n=3), intracerebral bleeding (ICB; n=3), or arterio-arterial infarction (n=1). The average time since lesion in the basal ganglia was: 4.6 years (range 1.8 - 7.11). Lesion sites were determined by (T1- and T2-weighted) anatomical MRI datasets from a 3l0 T system (Bruker 30/100 Medspec) and evaluated by an experienced neuroanatomist. In addition, twelve neurologically intact healthy control subjects took part in the experiment. The groups were matched for age and educational level. See Illustration 9.1 for graphical display of lesions. Individual patient information is listed in Table 9.2.1.

9.2.2 Stimulus Material

The stimulus material again consisted of semantically and prosodically matching stimuli and pseudosentences, but instead of including all seven basic emotions, only five emotions were presented (anger, fear, disgust, happy, and neutral). Comparable to Experiment 3 and 4, 30 sentences of each emotion and sentence type were used, adding up to 150 matching normal sentences and 150 matching pseudosentences. In addition, the same sentences were presented as spliced sentences belonging to one of the two violation types: a) in the combined semantic/prosodic violaten condition, a semantically and prosodically neutral start of the sentence was spliced to a semantically and prosodically matching end of the sentence (mean splicing point at 305 ms after sentence onset), and b) in the pure emotional prosodic violation condition, a prosodically neutral start of the pseudosentence was spliced

Patient History					
Patient	Sex	Age at test (years)	Time since lesion (years)	Etiology	Lesion description
01	male	63	7.04	Hemorrhage	ant. GPe, ant. IC
02	male	53	6.01	ICB	post. Put., GPe, post. EC, IC, Thal.
03	male	48	5.01	ICB	Put., GPe, EC, ant. IC, reduced volume of Caud.
04	male	31	5.05	Ischemic Infarct	post Put., Caud. (body), middle Ins., parietal operculum
05	male	68	4.04	Ischemic Infarct	Caud. (ant. body), ant. Put., GPe, EC, ant. Insular., preinsular WM
06	female	40	3.03	Arterio-arterial Infarct	Caud. (body)., Put., GPe, ant. IC, EC, parietal operculum, post. Ins.
07	male	59	4.11	Ischemic Infarct	Caud. (body)., Put., GPe, IC, EC
08	male	66	7.11	Hemorrhage	Caud., Put.
09	male	33	6.0	Embolic Infarct	Caud., Put.
10	male	28	1.08	Hemorrhage	Caud., post. Put.
11	male	26	3.05	ICB	Caud., Put., Thal.
12	male	75	4.11	Embolic Infarct	Caud. (body), Put.

Table 9.1: Note: ICB = intracerebral bleeding, ant. = anterior, post. = posterior, Caud. = caudate nucleus, EC = external capsule system, IC = internal capsule, Ins. = insula, GPe = globus pallidus externus, GPi = globius pallidus internus, Put. = putamen, Thal. = thalamus, WM = white matter.

to an emotional-prosodically end of the pseudosentence (mean splicing point at 385 ms after sentence onset). See Table 8.1 for detailed examples. This adds another 120 spliced normal sentences and 120 spliced pseudosentences. Thus, since only sentences spoken by the male speaker were presented, a total of 540 trials were presented in one session. Due to the length of ERP Experiments 3 and 4 we decided to present one voice to the BG patients and their healthy controls, only. Since most of our participants were male it was decided to also present the male voice. Emotional prosody valence was obtained in one of the two earlier rating studies (one for the lexical sentences and one for the pseudosentences; see Experiment 3 and Experiment 4).

9.2.3 Procedure

The procedure for the ERP experiment was similar to Experiment 4. Each participant was tested individually and was seated at a computer with a three-button panel placed before him/her in a sound-attenuating room. Half of the subjects pressed the yes-button with their right hand and the no-button with their left hand. The other half proceeded vice versa. Participants were seated in a comfortable chair at a distance of 115 cm of a computer monitor. The sentences were presented via loudspeaker. Directions, with examples, asked subjects to listen to the presented sentence, read the following word and to make a decision for the probe as accurately and as quickly as possible. Subjects had to respond within a time frame of 8000 ms. The intertrial interval was 1500 ms. As a second part, a behavioral emotional prosody recognition study was carried out after the ERP experiment. All participants had at least 25 minutes time between the ERP experiment and the behavioral experiment. For the second part, a subdivision of 50 pseudosentences (10 from each emotional category) and 50 lexical sentences (10 from each emotional category) were presented again. The sentences presented were the top-10 from the rating studies, hence, ensuring very good quality of emotional prosody portrayal. Again, each participant was tested individually and was seated at a computer with a five-button panel placed before him/her in a sound-attenuating room. Participants were seated in a comfortable chair at a distance of 115 cm of a computer monitor. The sentences were presented via loudspeaker. Directions, with examples, asked subjects to listen to the presented sentence and to make a decision as fast and as accurately as possible, which emotional category the emotional prosody of the presented sentence corresponded to. Subjects had to respond within a time frame of 8000 ms. The intertrial interval was 1500 ms. Before the start of each experiment, a practice session was performed by each subject.

9.2.4 ERP Recording and Data Analysis

The electroencephalogram (EEG) was recorded with 32 Ag-AgCl electrodes mounted in an elastic cap (*Electro-Cap International*, n.d.) from FP1, FP2, F7, F3, FZ, F4, F8, FT7, FC3,

FC4, FT8, T7, C3, CZ, C4, T8, TP7, CP5, CP6, TP8, P7, P3, PZ, P4, P8, O1, O2, A1 and A2, each referred to the nose (NZ). The nomenclature above is that proposed by the Society (1991). Bipolar horizontal and vertical EOGs were recorded for artifact rejection purposes. Eye artifact control measures were applied to the raw data of each participant to increase the number of critical trials in each condotion (Pfeifer, Novagk, & Maess, 1995). Subsequently individual EEG recordings were scanned for additional artifacts on the basis of visual inspection. Electrode resistance was kept under 5 K-ohm. Data was rereferenced offline to linked mastoids. The signals were recorded continuously with a band pass between DC and 70 Hz and digitized at a rate of 250 Hz. ERPs were filtered off-line with a 250 Hz bandpass filter (1471 points). For graphical display, ERPs were also filtered off-line with a 7 Hz low pass filter.

ERP components of interest were determined by visual inspection. For statistical analysis, ANOVAs with *Group* as between-subject factor were conducted. For each condition (No violation, Combined Prosodic/Semantic Violation and Prosodic Violation) separate analyses were conducted. Also, within the Combined Prosodic/Semantic Violation and Prosodic Violation condition separate analyses were conducted for each emotional category (Anger, Disgust, Fear, Happy, Neutral). For ERP analyses, the repeated factor *Scalp Regions of Interest*(*SROI*) was included. Each *SROI* defined a critical region of scalp sites: left frontal (LF): F7 F3 FT7; right frontal (RF): F8 FT8 F4; left central (LC): T7 C3 CP5; right central (RC): T8 C4 CP6; left parietal (LP): P7 P3 O1, right parietal (RP): P4 P8 O2; and midline (ML): FZ CZ PZ. As separate analyses were conducted for the different conditions, each analysis had additional repeated measurement factors. For the unviolated condition, the factors CON (lexical sentence or pseudosentence condition) and VA (angry, disgust, fearful, happy, and neutral valence) were included. For the other two conditions the factors M (Match: unviolated sentences and Mismatch: violated sentences) as well as VA (angry, disgust, fearful, happy, and neutral valence) were included.The null-hypothesis was rejected for p-values smaller than 0.05. The Huynh-Feldt correction was applied to all repeated measures with greater than one degree of freedom in the numerator. If a higher number of post-hoc comparisons than the degrees of freedom would permit was required, and thus leading to an increased likehood of Type I errors associated with large number of comparisons, p Values of post-hoc single comparisons were corrected using a modified Bonferroni procedure (see Keppel, 1991). For all statistical analyses the SAS 8.2 software package (*SAS 8.2*, 2001) was used.

9.3 Results

9.3.1 Behavioral Results

ERP experiment:

Behavioral results (i.e. RTs and PCs) were not analyzed because some patients were physically not able to fulfill the task due to the length of the experiment. Those subjects were then instructed to leave out the button press, but nevertheless to listen carefully to the presented sentences and to decide whether the probe presented on the screen was occurring in the previous sentence or not. It is believed that the same processes of implicit emotional prosody processing would be engaged as in subjects who were able to fulfill the button-press task.

Behavioral Emotional Prosody Recognition Experiment: In general, emotional prosody recognition was above chance level, which was at 20%, for both, the BG patient (48.16%) and control group (75.25%), with controls showing higher emotional prosody recognition rates than patients. In Illustrations 9.2 and 9.3 mean PC values for each emotional category and each group are illustrated. For the control group, the mean PC for the emotional prosody of anger was 81.25% (SD 22.90). Together with neutral vocalizations (mean PC 86.66%, SD 14.34), anger was the best recognized emotional prosody. Followed by fearful vocalizations (mean PC 73.75%, SD 21.83), and happy utterances (mean PC 71.66%, SD 25.30), it becomes obvious, that the emotional prosody of disgust sentences (mean PC 62.91%, SD 32.23) was recognized worst.

For the patient group, the picture was different. The mean PC for the emotional prosody of neutral was 65.83% (SD 29.76), revealing that this emotional category was categorized best. Worse but similar recognition rates were found for angry (mean PC 49.58%, SD 31.96) and happy sentences (mean PC 50.83%, SD 32.02), and even worse recognition rates were found for fearful (mean PC 40.0%, SD 30.21) and disgust sentences (mean PC 34.58%, SD 29.18). Taken together, descriptive analyses revealed only slightly better recognition rates for disgust sentences than would be expected by chance alone. Also, the other emotional categories except for neutral, did not reveal recognition rates over 50 %.

Accuracy data over all five basic emotional categories were also calculated with an ANOVA, treating *affect* (angry/disgust/fear/happy/neutral) and *modality* (pseudo/lexical sentences) as repeated-measure factors and *GROUP* (control/ patient) as a between-subject factor. As expected, a significant main effect of *GROUP* was found ($F(1,22)= 16.69$, $p<.001$), showing better recognition rates for the control group than for the BG patient group. In addition, a highly significant effect of *modality* was found ($F(1,22)=40.54$, $p<.0001$), revealing better recognition rates for lexical sentences (71%) than for pseudosentences (52%). Also, the main effect of *affect* turned out to be higly significant ($F(4,88)=10.79$, $p<.0001$). Post-hoc comparisons revealed that neutral sentences were better recognized than all other sentences. In the following, statistical values for these post-hoc comparisons are listed: 1) neutral vs. anger ($F(1,22)=5.67$, $p<.05$); 2) neutral vs. disgust ($F(1,22)=37.27$, $p<.0001$); 3) neutral vs. fear ($F(1,22)= 46.48$, $p<.0001$); 4) neutral vs. happy ($F(1,22)=11.21$, $p<.01$). In addition, the interaction *modality* and *affect* turned out

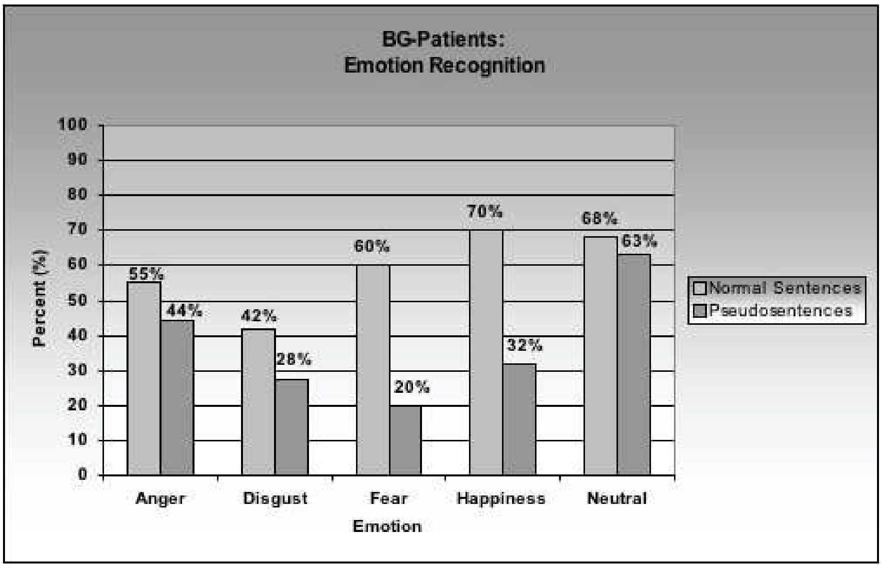


Figure 9.2: The illustration shows the mean percentage correct values of BG patients for the emotional prosody recognition task.

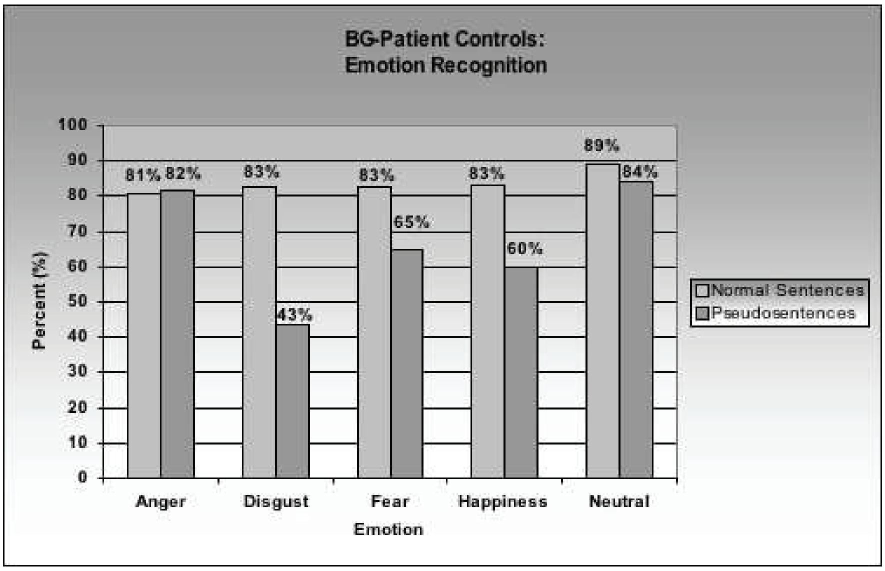


Figure 9.3: The illustration shows the mean percentage correct values of healthy control participants for the emotional prosody recognition task.

to be significant (F(1,22)=6.13, *p*<.001). This interaction allowed for a further analysis by *modality*. Significant effects of *affect* were found in both modalities, i.e., for the lexical sentences (F(4,88)=2.90, *p*<.05) as well as for the pseudosentences (F(4,88)=14.05, *p*<.0001). Post-hoc comparisons for the lexical sentences revealed better recognition rates for neutral than for disgust sentences (F(1,22)=8.00, *p*<.01). Post-hoc comparisons for the pseudosentences revealed better recognition rates for neutral sentences than for disgut, fearful and happy sentences. In the following, statistical values for these post-hoc comparisons are listed: 1) neutral vs. disgust (F(1,22)=34.98, *p*<.0001); 2) neutral vs. fear (F(1,22)=44.61, *p*<.0001); and 3) neutral vs. happy (F(1,22)=17.85, *p*<.001). Last, the interaction between *modality* x *affect* x *GROUP* was also significant (F(1,22)=34.98, *p*<.0001). The by-*GROUP* analysis revealed a significant interaction between *modality* x *affect* for both, controls (F(4,44)=6.47, *p*<.001) and patients (F(4,44)=3.62, *p*=.01). The analyses by *GROUP* and *modality* revealed a siginificant *affect* effect for the pseudosentences in the control group (F(4,44)=7.45, *p*<.0001), but not for the lexical sentences. Post-hoc comparisons revealed that pseudo-neutral sentences were better reconized than pseudo-disgust sentences (F(1,11)=20.21, *p*<.001), pseudo-fearful sentences (F(1,11)= 15.68, *p*<.01), and pseudo-happy sentences (F(1,11)=6.17, *p*<.05). For the patient group, the by-*modality* analyses revealed a significant *affect* effect in both modalities, i.e. for lexical- (F(4,44)=3.05, *p*<.05) and pseudosentences (F(4,44)=8.67, *p*<.0001). For the lexical sentences, post-hoc comparisons revealed significantly better recognition rates for neutral than for disgust sentences (F(1,11)=6.31, *p*<.05), whereas for the pseudosentences, it was found that recognition rates for neutral sentences were better than for all other sentences, i.e. pseudo-neutral sentences were better recognized than 1) pseudo-angry sentences (F(1,11)=5.0, *p*<.05), 2) pseudo-disgust sentences (F(1,11)=15.01, *p*<.01), 3) pseudo-fearful sentences (F(1,11)=29.28, *p*<.001), and 4) pseudo-happy sentences (F(1,11)=12.53, *p*<.01). Taken together, these results revealed that patients and their controls differed significantly in emotional prosody recognition. Also, it became obvious, that patients have a particular recognition problem with disgust sentences in the lexical modality, and a general emotional prosody recognition problem when no lexical content is present, i.e. in the pseudosentences modality. This suggests that emotional prosody recognition is influenced by the lexical content of the sentence even when participants are instructed to listen to the emotional prosody, only.

9.3.2 ERP results

***P200:* Match condition:** Within the P200 time window of 150 ms to 350 ms a significant main effect of CON (F(1,22)=5.40, *p*<.05) was found, indicating more positive-going ERP waveforms for sentences with lexical content than for pseudosentences.

In addition, there was a highly significant effect of VA (F(4,88)=8.23, *p*<.0001), indicating waveform differences for the different valences irrespective of lexical modality.

Post-hoc comparisons revealed that the neutral sentences differed significantly only from fearful sentences (F(1,22)=23.12, *p*<.0001) for both patients and controls.

Also, there was a significant interaction between CON and VA (F(4,88)=4.38, *p*<.01). The further analysis by CON revealed significant VA effects in the lexical- (F(4,88)=8.66, *p*<.0001) and pseudosentence (F(4,88)=5.33, *p*<.01) modality. VA effects revealed in break-down comparisons for each modality are listed in the following. For the lexical sentences, neutral sentences differed significantly from 1) angry sentences (F(1,22)=5.45, *p*<.05), 2) disgust (F(1,22)=17.59, *p*<.001) 3) fearful sentences (F(1,22)=37.84, *p*<.0001), and 4) happy sentences (F(1,22)=9.20, *p*<.01), always with neutral sentences showing a more positive-going waveform than sentences from all other valences. For the pseudosentences, neutral sentences differed significantly from happy sentences (F(1,22)=4.37, *p*<.05), with happy sentences showing a more positive-going waveform.

In addition, there was also an interaction that showed that CON interacted with *SROI*, suggesting that the CON effect might vary with *SROI*. This allowed for a further analysis by *SROI*. Results revealed that the CON effect turned out to be significant only at electrodes in the RC (F(1,22)=14.44, *p*=.001) and RP (F(1,22)=11.62, *p*<.01) regions, in both cases indicating more positive-going waveforms for lexical than for pseudosentences.

Last, VA also interacted with *SROI* (F(24,528)=1.94, *p*<.05), suggesting that valence differences might be distributed in different scalpregions. The by-*SROI* analysis revealed significant VA effects in the LC region (F(4,88)=9.58, *p*<.0001), and in the LF region (F(4,88)=6.11, *p*<.001), as well as a marginally significant VA effect in the LP region (F(4,88)=2.37, *p*=.06), a significant *VA* effect at ML electrodes (F(4,88)=5.15, *p*<.001), in the RC region (F(4,88)=7.63, *p*<.0001), in the RF region (F(4,88)=7.86, *p*<.0001) and in the RP region (F(4,88)=2.47, *p*=.05). Significant VA effects revealed in post-hoc comparisons for the various *SROI*S are listed in the following: 1) in the LC region, neutral sentences differed significantly from fearful sentences (F(1,22)=36.47, *p*<.0001); 2) in the LF region, again, neutral sentences differed significantly from fearful sentences (F(1,22)=31.67, *p*<.0001); 3) at ML electrodes, a comparable effect was found, namely that ERPs for neutral sentences differed from ERPs in response to fearful sentences (F(1,22)=12.52, *p*<.01); 4) the same was true for the LP region (F(1,22)=7.55, *p*<.05); 5) and the same effect was also found in the RC region (F(1,22)=20.98, *p*<.0001), 6) in the RF region (F(1,22)=27.45, *p*<.0001), 7) and in the RP region (F(1,22)=4.73, *p*<.05). In all post-hoc comparisons, a more positive-going ERP component was found for neutral sentences than for fearful sentences.

All in all, results revealed comparable results for BG patients and their healthy controls. First of all, a significant difference between lexical and pseudosentences with more positive going ERP amplitudes for lexical sentences than for pseudosentences. This effect was particularly pronounced at right central and right parietal electrode sites. In addition, an overall valence effect for fearful sentences was found irrespective of sentence modality. Also, valence effects qualified by sentence modality were obeserved revealing valence effects for all emotional prosodies for lexical sentences and a valence effect for happy sentences for pseudosentences.

***Prolonged P200 component for BG-Patients:* Match condition:** After visual inspection of ERP components, it became obvious that patients differed from their age-matched controls by showing a prolonged P200 component which was about 100 ms longer than the P200 time window for controls. Thus, a second analysis for a time window from 350 ms to 450 ms was carried out to specify if this difference was statistically significant, too.

Within the time window of 350 ms to 450 ms there was a marginally significant main effect of VA (F(4,88)=2.38, *p*=.06). Post-hoc comparisons revealed that the neutral sentences differed significantly only from fearful sentences (F(1,22)= 5.99, *p*<.05).

Also, there was a significant interaction CON x VA (F(4,88)=3.45, *p*=.01). The further analysis by VA revealed a significant CON effect in the emotional category of anger (F(1,22)=4.69, *p*<.05), and a trend for the same effect in the emotional category of neutral (F(1,22)=4.01, *p*=.06), in both cases indicating more positive-going waveforms for lexical sentences than for pseudosentences. In addition, there was also an interaction VA x *SROI* x GROUP, suggesting that the VA effect differed between patients and controls. This interaction allowed for a furhter analysis by GROUP. Results revealed that the interaction VA x *SROI* turned out to be significant only for the patients (F(24,264)=2.06, *p*<.05). The further analysis by GROUP and *SROI* revealed marginally significant VA effects in the following *SROI*s: 1) LC region (F(4,44)=2.50, *p*=.06), 2) LP region (F(4,44)=2.50, *p*=.08), 3) and in the RF region (F(4,44)=2.63, *p*=.07). Significant VA effects revealed in post-hoc comparisons for the three *SROI*S are listed in the following: 1) for the LC region, neutral vs. fearful sentences turned out to differ significantly in their ERP waveforms (F(1,11)=12.41, *p*<.01), with neutral sentences showing a more positive-going waveform than fearful sentences; 2) also for the LP region, neutral vs. fearful sentences were found to differ significantly (F(1,11)=9.91, *p*<.01), again with the neutral sentences showing a more positive-going waveform than the fearful sentences; 3) interestingly, for the RF region, the contrast between angry and neutral sentences turned out to be significant (F(1,11)=7.92, *p*<.05), this time with angry sentences showing a more positive-going waveform than neutral sentences. Taken together, these results suggest a prolonged P200 component for patients but not for their age- and education-matched controls. In particular, fearful and angry sentences differed significantly from neutral sentences in the time window of 350 ms to 450 ms. See Figure 9.4 for a graphical illustration of ERP effects.

***Later valence effects:* Match condition (700 ms to 1000 ms):** Within the late time window of 700 ms to 1000 ms, a marginally significant main effect of CON was found (F(1,22)=4.21, *p*=.05), indicating more positive-going ERP waveforms for pseudosentences

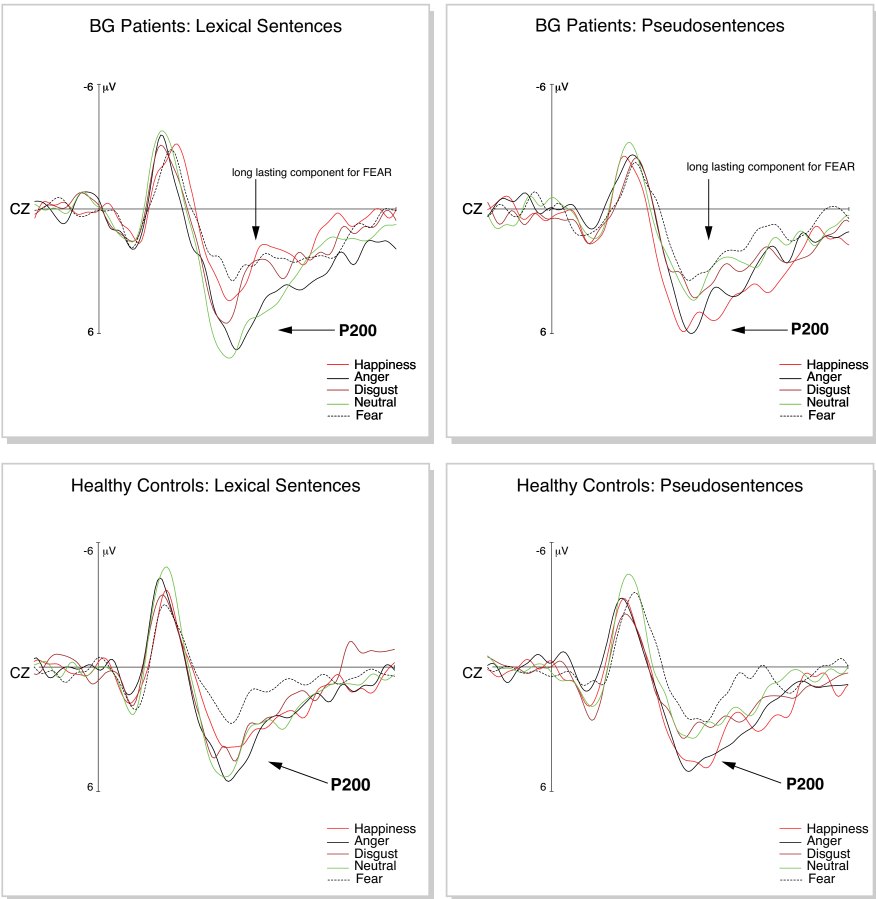


Figure 9.4: This illustration shows ERPs elicited by lexical and pseudosentences differing in emotional prosody at one selected electrode site (CZ) for BG patients and healthy controls. Waveforms show the average for happy (red), angry (blue), disgust (brown), neutral (green), and fearful (black-dashed) sentences from 200 ms prior to stimulus onset up to 1500 ms post-stimulus onset.

than for lexical sentences. In addition, the interaction CON x VA x *SROI* turned out to be significant, too (F(24,528)=2.02, *p*<.05). This three-way interaction allowed for a by VA analysis. Results revealed significant interactions between CON and *SROI* for all valences except for the emotional category of neutral. In the following, statistical values for the interaction between CON x *SROI* are listed for each emotional category: 1) anger (F(6,132)=2.80, *p*<.05), 2) disgust (F(6,132)=5.28, *p*=.001), 3) fear (F(6,132)=3.95, *p*=.001), 4) happy (F(6,132)=2.70, *p*=.06).

Further by *SROI* analyses revealed significant CON effects in different *SROI*s for the different emotional categories. Statistical values are listed by emotional category and *SROI* in the following: 1) for anger in the LC region (F(1,22)=4.46, *p*<.05), with pseudosentence showing a more positive ERP component than lexical sentences; 2) for disgust in the LC region (F(1,22)=10.70, *p*<.01), in the LP region (F(1,22)=13.88, *p*=.01), and in the RP region (F(1,22)=5.20, *p*<.05), all revealing a positivity for the pseudosentences; 3) for fear in the LF region (F(1,22)=3.89, *p*=.06), this time revealing a trend for a more positive-going waveform for lexical sentences than for pseudosentences, 4) for happy in the LC region (F(1,22)=4.38, *p*<.05), in the LP region (F(1,22)=11.59, *p*<.01), in the ML region (F(1,22)=10.32, *p*<.01), in the RC region (F(1,22)=10.97, *p*<.01), and in the RP region (F(1,22)=16.51, *p*<.001), all revealing a positivity for the pseudosentences. Taken together, results revealed an overall condition effect indicating more positive ERPs for the pseudosentences than for lexical sentences. Also, results revealed that this sentence modality effect was qualified by valence and region. In general, a more positive-going ERP component between 700 ms and 1000 ms was found for pseudosentences in the emotional categories of anger, disgust, and happy, but a more negative-going ERP component for pseudosentences in the emotional category of fear. See Figure 9.5 for graphical display of ERP-effects. See Figures D.1, D.2, D.3, and D.4 in Appendix for an illustration of effects at several electrode sites.

***1300 ms to 2000 ms:* Match condition:** Within the very late time window of 1300 ms to 2000 ms, a significant main effect of CON was found (F(1,22)=4.67, *p*<.05), revealing more positive-going ERP waveforms for lexical sentences than for pseudosentences. Together with the results from the analysis of the slightly earlier time window of 700 ms to 1000 ms, this result suggests that ERP waveforms differ between lexical and pseudosentences with varying time windows.

***Late components:* Combined Semantic/Prosodic Violation:** After visual inspection of the ERPs and due to the fact that hypotheses were put with regard to the emotional processing of disgust sentences in particular, it was decided to look at each emotional category separately. In the following, statistical analyses for different time windows for each emo-

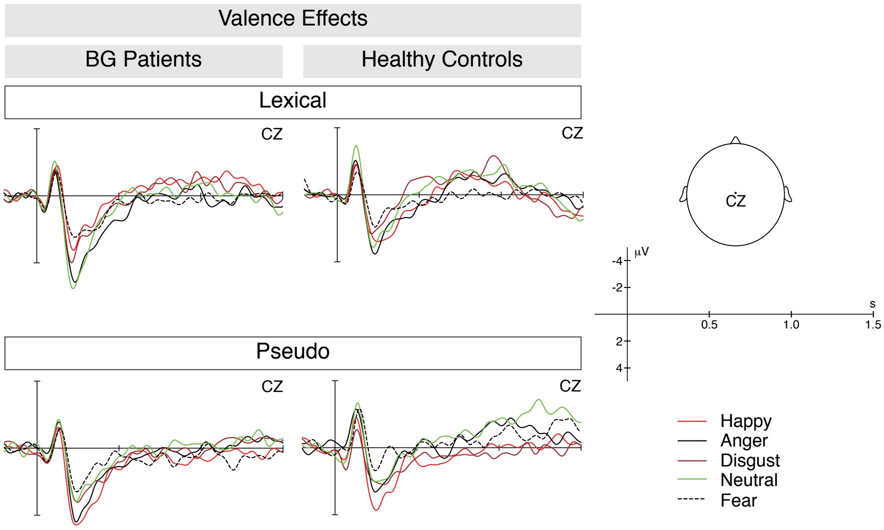


Figure 9.5: This illustration shows ERPs elicited by lexical and pseudosentences differing in emotional prosody at one selected electrode site for BG patients and healthy controls. Waveforms show the average for happy (red), angry (black), disgust (brown), neutral (green), and fearful (black-dashed) sentences from 200 ms prior to stimulus onset up to 1500 ms post-stimulus onset.

tional category for the combined emotional semantic and emotional prosodic violation are listed.

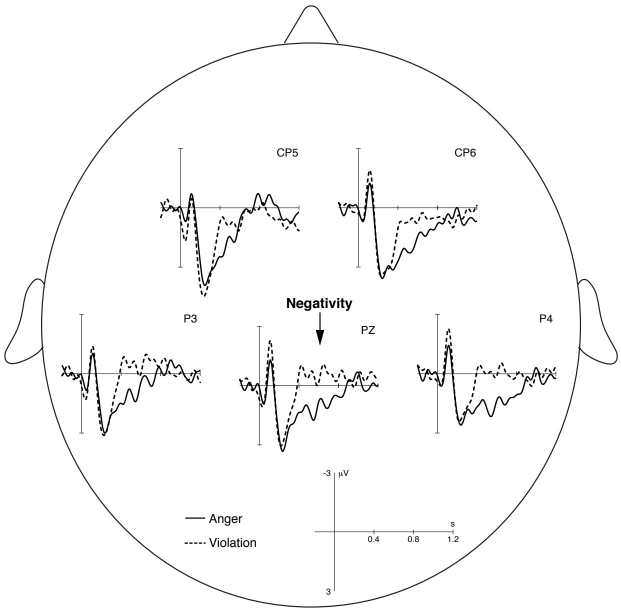
1) Anger: 400 ms to 500 ms: Within the early time window of 400 ms to 500 ms, a significant effect of *M* was found (F(1,22)=5.71, $p<.05$), revealing more negative-going ERP components for the violated sentences than for the correct sentences. No other main effects or interactions reached significance (all $p>.05$). This result suggests that both groups, patients and controls, show the expected negativity in response to semantically and prosodically violated angry sentences.

1000 ms to 1300 ms: In addition to the early time window, a second late time window was also analyzed. Here, again, a significant effect of *M* was found (F(1,22)=4.18, $p=.05$); however, this time the violated sentences showed a more positive-going ERP component than the unviolated sentences. Because it was of special interest to clarify if ERP responses of patients and controls differed, the marginal significant interaction of *M* x GROUP (F(1,22)=3.62, $p=.07$) was taken as reason to carry out a further analysis by GROUP. This by GROUP analysis revealed a significant *M* effect for the control group (F(1,11)=10.36, $p<.01$), but not for the patient group ($p>.05$). ERPs for the control group were more positive-going for the violated sentences than for the unviolated sentences. Taken together, these results suggest, that BG patients and controls do not show different ERPs in direct responses to the combined semantic and prosodic violation of angry sentences, reflected in the early time window, but do differ at a later point of time in processing, reflected in the later time window. Figure 9.6 illustrates the ERP-effects for both groups, BG patients and healthy controls.

2) Disgust: 600 ms to 750 ms: After visual inspection of ERPs for the combined violation for disgust sentences, a time window of 600 ms to 750 ms was analyzed. This time window was of particular interest because it showed that patients and controls differed in their ERP responses, with patients showing a positive-going ERP component and controls showing the opposite, namely a negative ERP component for the violated sentences. This effect was nicely reflected in the significant interaction between *M* and GROUP ($F(1,22)=7.19$, $p=.01$). This interaction allowed for a by GROUP analysis, revealing a significant *M* effect in the patient group ($F(1,11)=6.51$, $p<.05$), showing a more positive-going ERP component for the violated sentences than for the unviolated sentences. In contrast, the more negative-going ERP component in response to the violated sentences for the control group did not reach signifance ($p>.05$). Nevertheless, the results revealed significant ERP component differences between the two groups, with the patient group showing a positivity for the violated sentences. Illustration 9.7 displays the ERP-effects for BG-Patients and healthy controls.

3) Fear: 400 ms to 500 ms: Within the time window of 400 ms to 500 ms, no significant main effect was found ($p>.05$); however, an interaction between *M* and GROUP turned out to be marginally significant ($F(1,22)=3.73$, $p=.07$). Again, because it was of special interest to clarify if ERPs differed between patients and their controls, and because visual inspection suggested this difference, a by GROUP analysis was carried out. Results revealed a significant *M* effect in the control group ($F(1,11)=8.90$, $p=.01$), with violated sentences showing a more negative ERP component than unviolated sentences. The same *M* effect was not found in the patient group ($p>.05$). In sum, this result suggest processing differences between controls and patients in the time window of 400 ms to 500 ms for violated fearful sentences, with controls showing the expected negative ERP component in response to violated fearful sentences. Illustration 9.8 displays the ERP-effects for BG-Patients and healthy controls.

4) Happy: 350 ms to 450 ms: Within the early time window, no significant main effect of *M* was found. However, the interaction *M* x *SROI* x GROUP turned out to be significant ($F(1,22)=4.17$, $p<.01$). This allowed for a by GROUP analysis, reavealing a significant interaction *M* x *SROI* in the control group ($F(1,11)=3.12$, $p<.05$), but not in the patient group ($p>.05$). The step-down analysis by GROUP and *SROI* revealed (very) marginally signicant *M* effects in the RF region ($F(1,11)= 3.71$, $p=.08$) and in the LF region ($F(1,11)=4.47$, BG-Patients: Emotional Semantic/Prosodic Violation (Anger)



Healthy Controls: Emotional Semantic/Prosodic Violation (Anger)

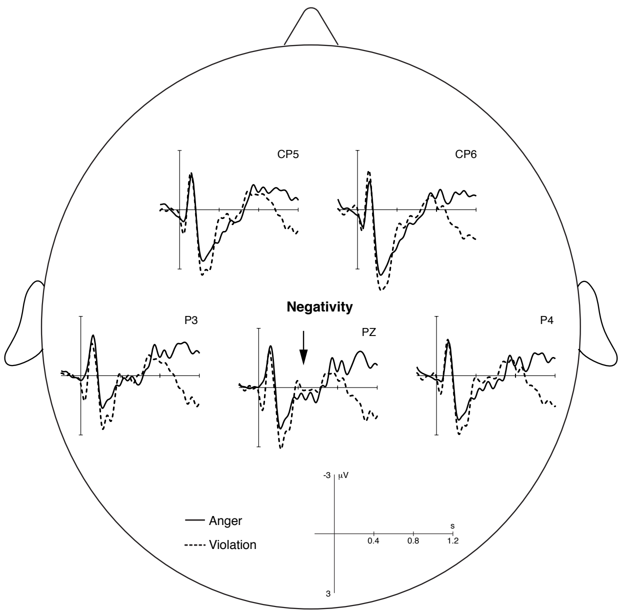


Figure 9.6: This illustration shows ERPs elicited by violated and unviolated lexical sentences at selected electrode sites for BG-Patients and healthy controls. Waveforms show the average for semantically and prosodically violated angry (dashed) and unviolated angry (black) sentences from 200 ms prior to stimulus onset up to 1200 ms post-stimulus onset.

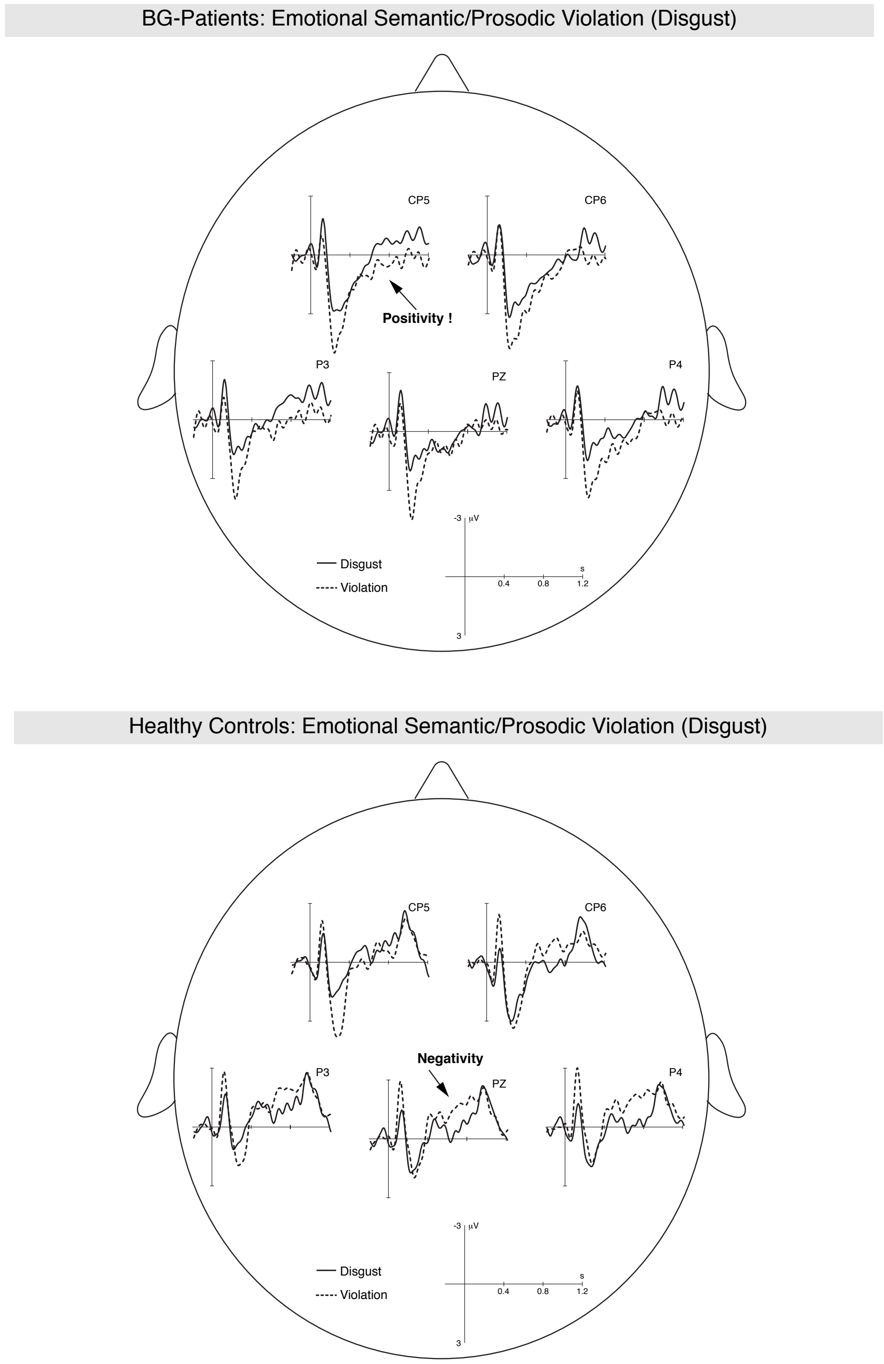


Figure 9.7: This illustration shows ERPs elicited by violated and unviolated lexical sentences at selected electrode sites for BG-Patients and healthy controls. Waveforms show the average for semantically and prosodically violated disgust (dashed) and unviolated disgust (black) sentences from 200 ms prior to stimulus onset up to 1200 ms post-stimulus onset.

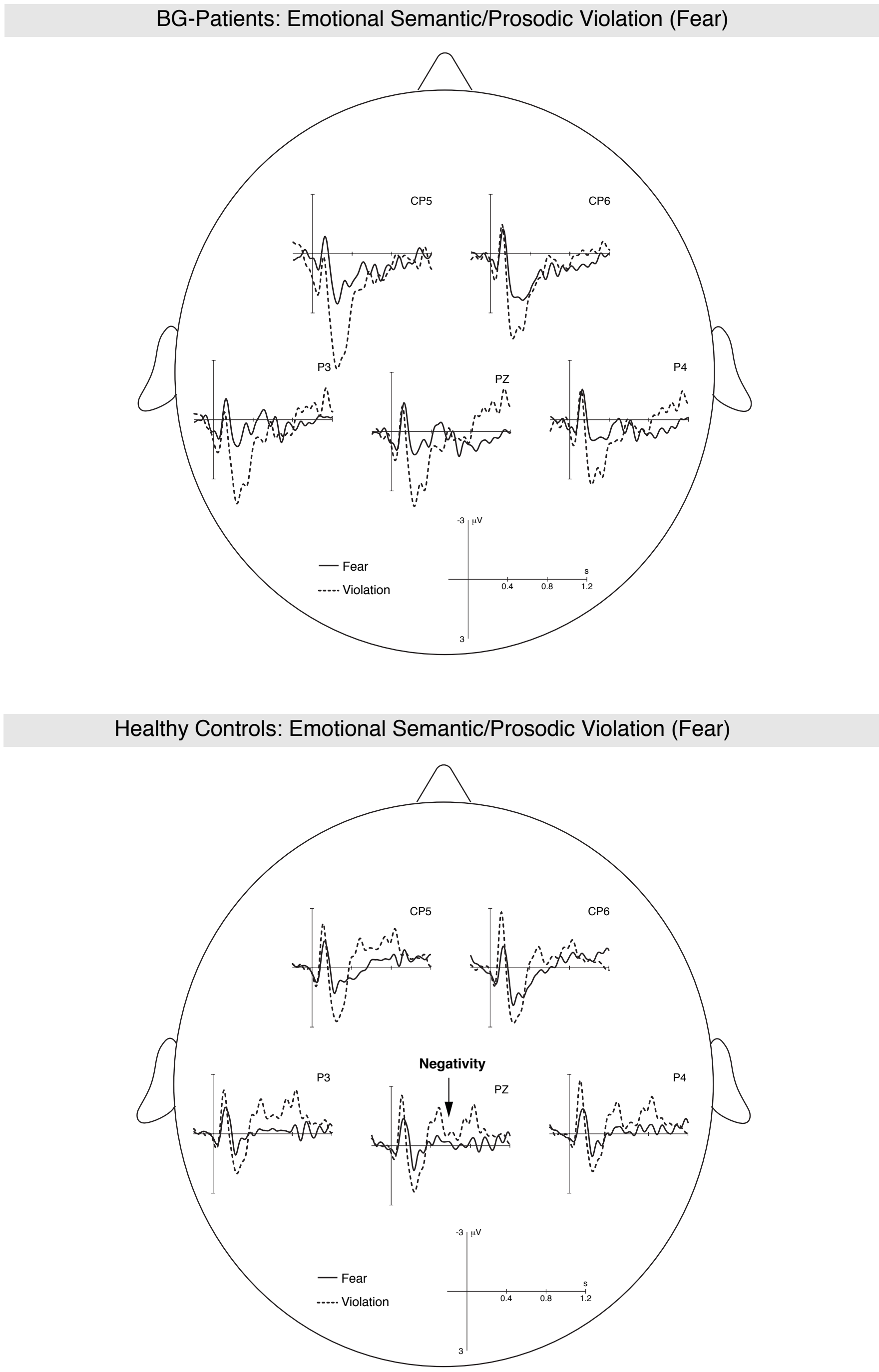


Figure 9.8: This illustration shows ERPs elicited by violated and unviolated lexical sentences at selected electrode sites for BG-Patients and healthy controls. Waveforms show the average for semantically and prosodically violated fearful (dashed) and unviolated fearful (black) sentences from 200 ms prior to stimulus onset up to 1200 ms post-stimulus onset.

p=.06), in both cases showing more negative ERP components for the violated sentences than for the unviolated sentences. In sum, controls showed marginally significant negative ERP waveforms in the frontal scalp region in response to semantically and prosodically violated happy sentences, whereas this effect was not found for the BG patient group.

1300 ms to 1400 ms: After visual inspection, it was decided to also analyze a second later time window of 1300 ms to 1400 ms. Within this time window, a significant interaction *M* x *SROI* x GROUP was found (F(1,22)=2.91, *p*<.05). The by-GROUP analysis showed a marginally significant interaction between *M* and *SROI* only for the patient group (F(1,11)=3.0, *p*=.06). The analysis by GROUP and *SROI* for the patient group, showed significant *M* effects in the LP region (F(1,11)=4.72, *p*=.05) and RP region (F(1,11)=6.54, *p*<.05), and marginally significant *M* effects in the RC region (F(1,11)=3.99, *p*=.07) and at midline electrodes (F(1,11)=3.86, *p*=.08). In sum, these results revealed a negativity in response to semantically and prosodically violated happy sentences for the patient group in the late time window of 1300 ms to 1400 ms. Illustration 9.9 displays the ERP-effects for BG-Patients and healthy controls.

Summary for all Emotional Categories: Taken together, results revealed processing differences between unviolated and semantically and prosodically violated sentences in all four emotional categories; however, the extent to which both groups differed and the point of time when this difference occurred differed with respect to the emotional category analyzed.

<u>**Prosodic Violation:**</u> Again, after visual inspection of the ERPs and due to the fact that hypotheses were put with regard to the emotional processing of disgust sentences in particular, it was decided to look at each emotional category separately. Also, after visual inspection, it was obvious, that ERP effects were only visible at central and parietal electrode sites but not at frontal or midline electrodes. Thus, statistical analyses were computed for four *SROI*s (LC, RC, LP, and RP), only. Analyses in the same time windows for frontal and midline electrodes did not reveal any significant effects. In the following, statistical analyses for the different time windows for each emotional category for emotional prosodic violation are listed.

1) Anger: 420 ms to 540 ms: Within the early time window of 420 to 540 ms, a significant effect of GROUP was found (F(1,22)=4.87, *p*<.05), revealing more positive-going ERP waveforms for BG patients than for healthy controls. In addition, a significant main effect of *M* was found (F(1,22)=5.69, *p*<.05), revealing more positive-going ERP waveforms for prosodically violated angry sentences. This *M* effect was not qualified by *SROI* or GROUP, hence, suggesting a bilaterally central and parietal distributed positivity for both groups.

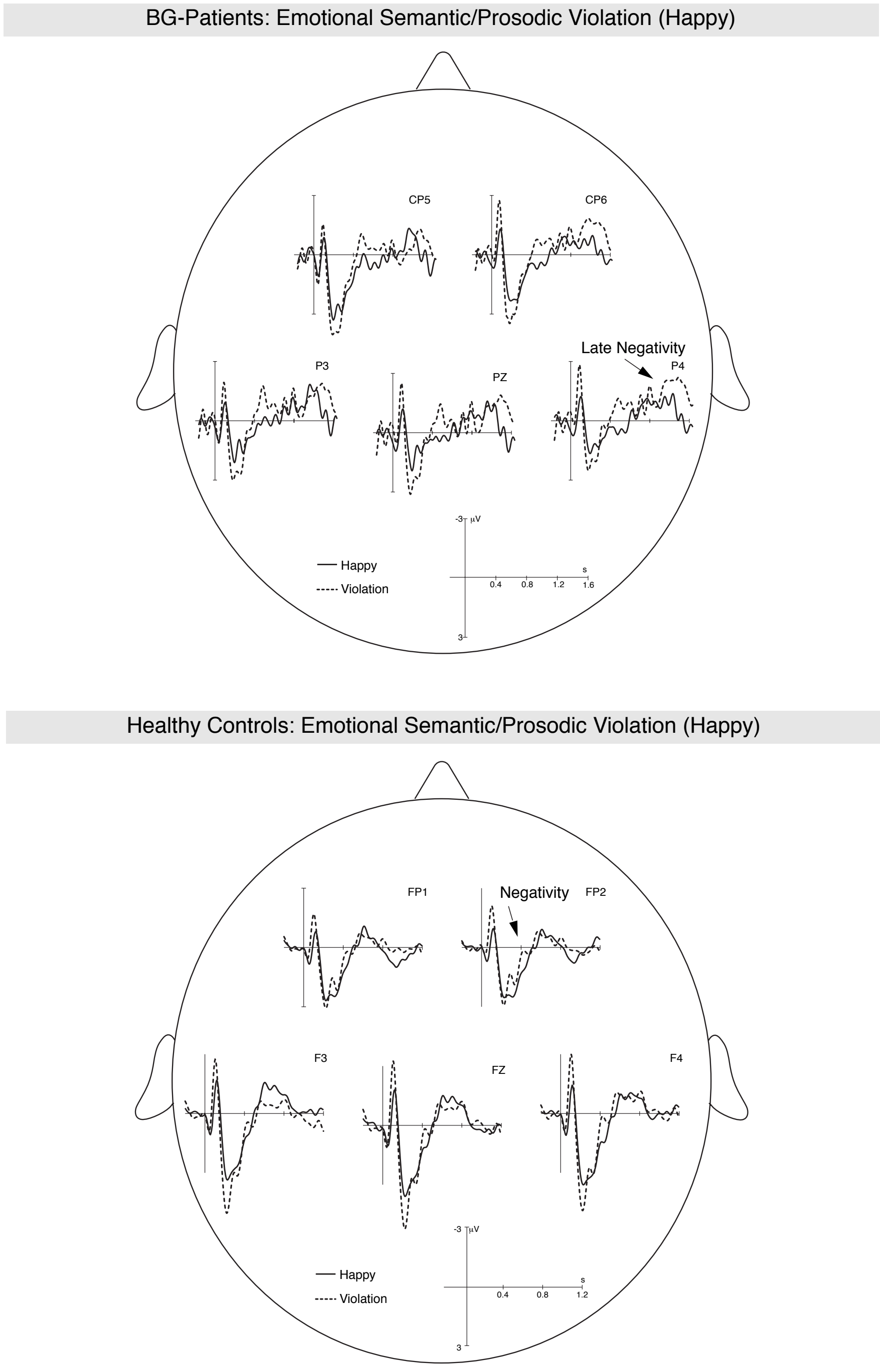


Figure 9.9: This illustration shows ERPs elicited by violated and unviolated lexical sentences at selected electrode sites for BG-Patients and healthy controls. Waveforms show the average for semantically and prosodically violated happy (dashed) and unviolated happy (black) sentences from 200 ms prior to stimulus onset up to 1600 ms post-stimulus onset.

***1200 ms to 1400 ms*:** In a later time window, the *M* effect turned out to be significant, too (F(1,22)=7.15, *p*=.01), again revealing a more positive-going ERP component for prosodically violated sentences in both patients and controls, groups. This time, the *M* effect was qualified by *SROI* (F(3,66)=4.11, *p*<.01). The analysis by *SROI* revealed significant *M* effects in the LP region (F(1,22)=4.43, *p*<.05), the RC region (F(1,22)=12.20, *p*<.01), and the RP region (F(1,22)=12.13, *p*<.01), all showing more positive-going ERP components for the violated sentences than for the unviolated sentences.

2) Disgust: 400 ms to 540 ms: In the early time window of 400 ms to 540 ms no significant main effects or interactions were found; however, it is believed that it is noteworthy reporting that the *M* effect almost reached significance (F(1,22)=3.05, *p*=.09), indicating more positive-going ERP waveforms for prosodically violated sentences of disgust.

1200 ms to 1350 ms: In the second time window, a marginally significant *M* effect was found (F(1,22)=4.00, *p*=.06), revealing more positive-going ERPs for prosodically violated sentences than for unviolated sentences. This effect was not qualified by GROUP or *SROI*, suggesting no processing differences between the two groups during this time window.

3) Fear: 420 ms to 540 ms: Comparable to the prosodically violated sentences of anger and disgust, there was also a significant *M* effect in the emotional category of fear (F(1,22)=4.14, *p*=.05), also revealing a positivity for prosodically violated sentences. Again, no interaction between *M* and *SROI*, or *M* and GROUP was found to be significant.

1150 ms to 1450 ms: In the later time window, the *M* effect turned out to be significant, too (F(1,22)=5.75, *p*<.05), again revealing a positive-going ERP waveform for prosodically spliced sentences. In addition, the interaction between *M* and GROUP reached significance (F(1,22)=4.28, *p*=.05). This allowed for an analysis by GROUP, which revealed a significant *M* effect in the control group (F(1,11)=13.56, *p*<.01), but no such effect for the patient group (*p*>.05). Comparable to the earlier time window, the control group showed a positivity for prosodically violated sentences. Taken together, the results suggest a similar processing of the violation at an early point of processing for the two groups; however, at a later point of time, the two groups seem to be processing the violated sentences differently.

4) Happy: 420 ms to 540 ms: Within the early time window, a significant *M* effect turned out to be significant (F(1,22)=5.09, *p*<.05), showing more positive-going ERP waveforms for prosodically violated sentences than for unviolated sentences. Again, this effect was not qualified by GROUP or *SROI*.

1200 ms to 1400 ms: Within the later time window, a comparable positive ERP component for the violated sentences reflected in the significant *M* effect ($F(1,22)= 4.79$, $p<.05$) was found for both groups. No other effects reached significance.

Summary for all Emotional Categories: Taken together, results suggest very similar processing of emotional prosody violations across different emotional categories for the two groups. Interestingly, the only difference in the time windows reported here was the late positive ERP component found for prosodically violated sentences in the emotional category of fear, which turned out to be significant for the control group, only. Illustration 9.10 displays the ERP-effects elicited by emotional prosodic violations (all emotional categories combined) for BG-Patients and healthy controls.

9.4 Discussion

Valence Effects: Comparable to evidence from previous experiments, lexical sentences elicited a larger positive ERP component than non-lexical or pseudosentences. This effect was especially pronounced at right hemispheric central and parietal electrodes, but in general, a tendency for an effect was visible at left central and left parietal electrodes as well. Since acoustical attributes were comparable between the two sentence modalities, it is assumed that the additional lexical information elicits the stronger positive ERP component. As was discussed previously, this assumption seems plausible if one considers that the P200 is reported to get larger with increasing complexity of a stimulus (Ritter et al., 1983; Shahin et al., 2005). Following this argument, it is suggested that processing additional lexical information is an increase in stimulus complexity, and thus a larger P200 amplitude for lexical sentences is visible. As expected, no differences between patients and age-, gender-, and education-matched controls were observed for this effect. Taken together, this suggests that, if available, lexical information influences early stimulus processing and that this is the case for both BG patients and controls.

In addition, results revealed an overall valence effect irrespective of sentence modality for fearful sentences. P200 amplitude means were reduced for fearful sentences when compared to neutral sentences in both patients and controls for the time window of 150 ms to 350 ms. The direction of this effect, namely more positive-going waveforms for neutral sentences, is comparable to previous results. Interestingly, for BG patients, this P200 amplitude was prolonged by 100 ms, suggesting a processing difference for fearful sentences between BG patients and their controls. However, whether this prolonged effect solely reflects timing differences in emotional processing or a general difficulty for patients when processing fearful stimuli remains an open question. Nevertheless, the current results provide additional evidence for the discussion on BG patients suffering from difficulties in processing fearful stimuli and extends this discussion to vocal emotional stimuli. As was

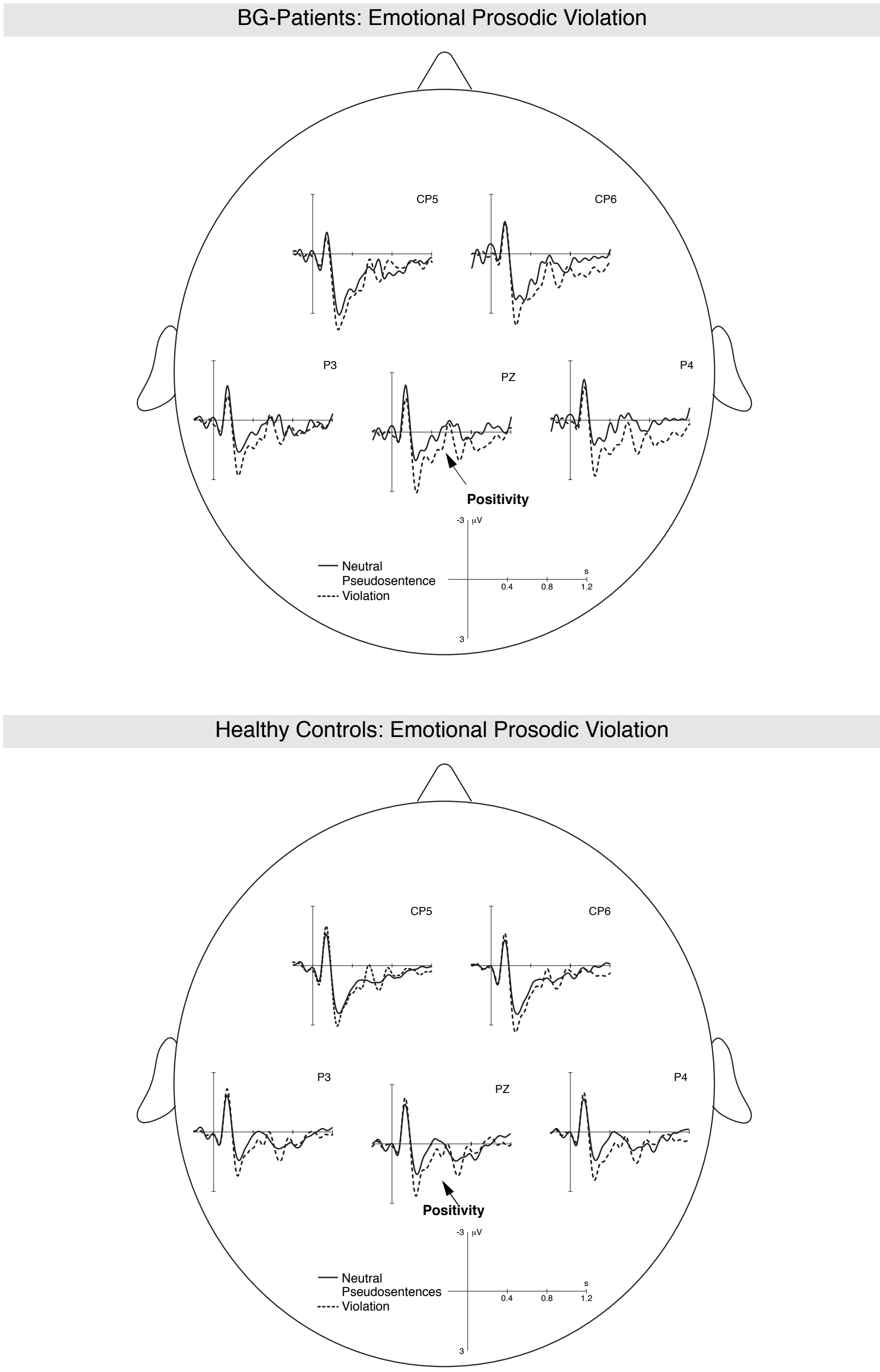


Figure 9.10: This illustration shows ERPs elicited by violated and unviolated pseudosentences at selected electrode sites for BG-Patients. Waveforms show the average for emotional prosodically violated (red) and unviolated (blue) pseudosentences from 200 ms prior to stimulus onset up to 1200 ms post-stimulus onset.

mentioned in the introduction to this experiment, a study by Kan et al. (2002) reported a deficit for PD patients in processing visual fearful stimuli. Also, PD patients revealed poor emotional prosody recognition rates for fearful and disgust vocal stimuli, but so did the control group, so this result was not discussed any further in Kan et al. (2002). However, ERPs are more sensitive to subtle on-line processes than RTs or PCs can be, and the current results revealed a different processing strategy for fearful stimuli in BG patients than in controls. This difference might have not been recognized with behavioral measurements alone.

In addition to the valence effect for fearful sentences which was elicited irrespective of sentence modality and which was prolonged for the patient group, several valence effects have been observed in both groups for lexical and non-lexical sentences. For example, for lexical sentences there were larger amplitudes for neutral than for emotional sentences. This result is comparable to the result obtained in the previous experiments and will therefore not be discussed any further in the current discussion. Furthermore, valence effects for pseudosentences revealed differences between neutral and happy sentences with happy sentences being more positive-going than neutral sentences. This finding might be compared to the late valence effect found in Experiment 3, where for lexical sentences, only fearful and happy sentences differed from neutral sentences. One suggestion for the observation that not all valences differed from neutral sentences was the fact that the current study used more than just one emotionally laden stimulus (in this case four in addition to neutral), and it was assumed that the number of emotions tested influences the degree of attentional resources needed to evaluate the stimuli. Additionally, it was proposed that the effects were closely related to the emotional dimension of pleasantness and unpleasantness. Again, the two emotional extremes of this continuum were the two valences that differed from neutral stimuli. However, this is highly speculative and this issue needs further investigation. For example, future studies could present only pairs of extrema (e.g. according to Plutchik) and clarify if it is always the case that neutral sentences differ from extrema but do not differ from the same emotional categories when presented in a larger stimulus battery. One additional point should be mentioned, though. Within this thesis it was observed more than once that lexical information seems to influence emotional prosody processing at a very early point of time. Thus, it can be speculated that extreme positions such as fear and happiness do not need this additional information to be recognized as highly emotional stimuli, whereas emotional categories such as disgust and anger might profit from the additional lexical information available. This, of course, needs further testing in the future. However, there is considerable evidence that has shown that fearful stimuli elicit a neural circuit with direct projections from the amygdala to sensory cortices. It has been argued that this direct route serves an "effective mechanism to enhance processing of emotional events" (Vuilleumier, 2005, pg.8).

Last, for both groups, no other valence effects were significant in later time windows. However, results revealed a more positive-going ERP component between 700 ms and

1000 ms for pseudosentences in the emotional categories of anger, disgust, and happiness, whereas in the proceeding time window of 1300 ms to 2000 ms a reversed pattern was found, i.e. more positive-going ERP waveforms for lexical sentences than for pseudosentences. Together, these results suggest that ERP waveforms differ between lexical and pseudosentences with varying time windows. Valence effects were only visible at an early time of processing, and results revealed processing differences between BG patients and controls for fearful vocal stimuli, but not for vocal stimuli of other valences.

Emotional Prosody Violation: Taken together, results revealed a positive-going ERP component in response to all emotional prosodic violations (except for disgust showing only a tendency) shortly after the splicing point, i.e. in the early time window of 420 ms to 540 ms after stimulus onset. Furthermore, results from this early time window did not reveal significant on-line processing differences between the valences tested. Neither do the results suggest a processing difference between BG patients and their controls to violations of emotional prosodic contours at an early point of time. This was a replication of results from the previous studies and suggest that lesions to the BG do not influence processing of violations to emotional prosodic contours at an early point of time. Against our expectations, BG patients did not show a selective deficit to any of the valences tested here. This result might allow for functional specification of the positive ERP component elicited after violations to emotional prosodic contours and which seems to be elicited independent of valence, and the results are therefore discussed in more detail.

First of all, the positive ERP component is thought to reflect processing of emotional prosodic contour violations. The response is elicited irrespective of sentence modality, i.e. it has been reported to occur to emotional prosodic violations of sentences with neutral semantic content and to violations of sentences with no lexical content. Thus, the component was suggested to reflect general emotional prosodic processing steps. However, it has also been suggested that a general prosodic contour violation might elicit similar effects. This assumption gets further support from the present findings, in particular, if one considers that patients do show a deficit in response to emotional prosodic and emotional semantic contour violations. In addition to the observation that this component is elicited independently of valence, the assumption strongly suggests that it might reflect more linguistically based prosodic processing steps than emotional processing steps. However, results from purely linguistic prosodic violations reported by Astésano et al. (2004) suggest that it indeed makes a difference if the contour violated is of emotional relevance or not. To clarify, it is proposed that the current effect occurs much earlier than the P800 reported by Astésano et al. (2004) because of its emotional relevance. However, this emotional relevance is equally strong for the different valences tested here. Still, the assumption is that this component reflects responses to emotional prosodic contour violations which are first and foremost automatic re-analysis processes of emotional prosodic aspects of the stimulus.

Again pointing to a potential processing difference between fearful and neutral stimuli in BG patients and controls, the current results revealed a second positive-going ERP component at a later point in processing in response to emotional prosodic contour violations. This effect was found for all valences in healthy controls and BG patients, except for the emotional category of fear in BG patients. We assume that this longer lasting positive ERP component reflects additional re-analysis and/or integration processes arising from the observation that a neutral start of a sentence is not completed with neutral prosody (comparable to the P800 effect), and it is thus even more interesting to observe that this process seems to be impaired for BG patients when listening to fearful sentences. The assumption that the second positive ERP component reflects an additional re-analysis process gets support from the observation that fearful stimuli were longer in duration than other stimuli. We hypothesize that truly integrating prosody and semantics is thus postponed (also see discussion below for second difference realted to durational differences). Of course, this is highly speculative, but it appears that especially integration and re-analysis processes are disturbed in BG patients in response to fearful stimuli. This speculation gets further support from the Kan et al. (2002) study where long lasting fearful visual stimuli (lasting at least two seconds) elicited a recognition deficit for the emotional categories of disgust and fear, whereas no statistical differences between patients and controls were reported for the recognition of shorter auditory stimuli. Unfortunately, the authors did not report the approx. length of the auditory stimuli but reported that auditory stimuli were short and gave stimuli examples, such as "good morning". Stimuli used in the current experiment lasted for at least approx. 3 seconds and were much longer utterances than utterances like "good morning". Here, it is suggested that short auditory exclamations might not be useful when investigating emotional prosody perception, as patients, as well as controls, might need more time to recognize and conceptualize certain emotional categories. This assumption is in line with the suggestion that the second positive ERP component revealed here reflects integration and/or re-analysis processes needed after the conceptualization of both emotional categories presented to participants (neutral and other valences) were successful.

In short, three abstract processing steps for an emotional prosodic stimulus are suggested here: 1) the early, brief processing of (structural) emotional characteristics of an emotional stimulus reflected in the P200, 2) an expectation of which emotional category the stimulus belongs to and conceptualization of this category reflected in later valence/modality effects, and 3) re-analyses or integration of the established context of the stimulus triggered by a violation of an emotional prosodic expectation. Thus, whereas the first two steps do not seem to be severely impaired for fearful stimuli in BG patients (i.e., when a violation of the first established expectation occurs, this is immediately processed), the third step reflecting later perceptual processing steps (in which the violation of this expectation needs to be integrated into the context) seems to be specifically impaired in BG patients for fearful vocal realizations. It will be interesting to see how future research sheds more light on this issue. For instance, future studies could manipulate the duration of e.g. fearful exclamations to clarify if duration of the stimulus helps to conceptualize this emotional category. In addition, paradigms manipulating semantic properties of the vocal fearful stimuli could shed more light on an integration problem of patients.

Combined Emotional Prosody and Emotional Semantic Violation: In sum, results revealed processing differences in response to combined emotional prosodic and emotional-semantic violated sentences for BG patients and their age- and education-matched controls. Whereas the control group showed significant or borderline negative ERP components elicited by the violated sentences, the BG patients did not show the expected negative ERP waveform in the emotional categories of fear and disgust and only showed a very delayed negative ERP component to violations of happy sentences. Last, the two groups also differed in the emotional category of anger, where a second positive ERP effect was observed for controls comparable to the second positivity revealed in Experiment 2, but which was absent in BG patients. In total, this suggests emotional prosody perception impairment for BG patients in all emotional categories when emotional prosody is accompanied by congruent emotional semantics.

As has been mentioned earlier, several brain structures have been reported to be activated during emotional processing. These regions differ depending on the emotion investigated, the modality tested, and the task applied. Clinical data can help to specify if one particular brain region is included in one particular aspect of emotional processing. Thus, it has been suggested that the BG might play an important role in the processing of emotional stimuli. Primarily, evidence for BG involvement comes from studies looking at emotional vocal and facial expression recognition. Note that these studies differ notably from the current one in the paradigm applied. Here, an implicit emotional prosody processing task was applied in contrast to the explicit task of emotional prosody recognition or categorization. This evidence suggests that the BG modulate the perception of disgust (Pell & Leonard, 2003; Sprengelmeyer et al., 1996; Calder et al., 2000). The current results partly support this view, since BG patients revealed a positive ERP component elicited by the violation of emotional prosodic and emotional semantics instead of the expected negative ERP component. However, it should again be noted that the negative ERP component for the healthy controls did not reach significance (p=.09). Still, this could have been caused by the fact that our groups were not as large as were groups in the previous experiments. In any case, BG patients showed a different brain response for violations of disgust vocalizations than did controls. This is interpreted as a processing difference for disgust vocalizations between those two groups. Why the patient group elicited a positive ERP component remains an open question. One suggestion is that this positive ERP component reflects activation of additional resources needed when processing violations to disgust sentences.

The present findings add evidence for a processing deficit for disgust vocalizations in BG patients and thus imply that the BG indeed play a modulating role in the perception of disgust. Interestingly, this modulation is not independent of semantic content. It is assumed that the strong emotional semantic content of the current sentences add to the impairment in patients. Furthermore, we speculate that it is not emotional prosodic processing of disgust, but a combination of both emotional prosody and emotional semantics that is impaired in BG patients. Given the fact that visual stimuli are almost always rated as being clearer in displaying the emotion of disgust then are auditory stimuli, the observation that semantic content adds to the emotional impairment in BG patients is not surprising. Or, to put it another words, stimuli need to be correctly identified as belonging to the emotional category of disgust before an impairment may be visible for BG patients.

This seems to be the case for all emotional categories investigated here, as differences were found in all emotional categories tested. As was discussed earlier, there is evidence that the BG are involved in the recognition of fear and anger, at least for visual stimuli (Kan et al., 2002; Calder et al., 2004). The present findings support this view, as processing differences between BG patients and controls were found for both of those emotional categories, i.e., for angry and fearful sentences. However, note that a difference between those two emotional categories was observed, since violations to angry sentences elicited a to controls comparable negative ERP component, and the two groups only differ at a later stage of processing. In particular, it is assumed that the second positive ERP component elicited by angry sentences for the control group reflects similar prosody re-analysis processes as was proposed in Experiment 2, an effect missing in the BG group. This points to the fact that because emotional semantics dominate emotional prosody processing (as reflected in the negative ERP waveform), no additional prosody re-analyses is observed in patients at a later point of time. To clarify, there seems to be no need for BG patients to re-evaluate the stimulus, so no second positive ERP waveform was elicited to reflect this process. Why additional re-evaluation is necessary for the control group even though the task did not enforce emotional prosody processing remains speculative. One suggestion is the difference in temporal dynamics between the stimuli. Results also suggest that the processing of angry stimuli may not be as impaired as processing of disgusted or fearful stimuli in BG patients.

A recent study by Kan et al. (2002) suggests BG involvement during visual processing of fearful stimuli. Results from the present study support a similar conclusion. It has been shown that BG patients differ from controls during the processing of pure emotional prosodic violations of fearful sentences. In particular, controls but not BG patients reveal a second positive ERP component when processing fearful emotional prosody. Second, the negative ERP component expected for violations of a combined violation of fearful sentences was not visible in BG patients. This seems to be strong evidence for a processing impairment of fearful vocalizations in BG patients. However, it is also assumed, that impairment increases when additional fearful semantic content is present and thus underscores to which emotional category the utterance really belongs. This points to the fact that the interaction between emotional prosody and emotional semantics is of particular importance while processing an emotionally laden stimulus. This interaction which is predominated by semantic information, is impaired in BG patients at least for fearful vocalizations. Together, the present findings allow to conclude that semantic information helps to identify an emotional category and this information predominantly leads to deficits in processing emotionally laden stimuli. This, in turn, suggests that it is not emotional prosody in particular which is impaired in BG patients, but rather emotional processing in general. This processing impairment becomes particularly obvious in clearly identifiable stimuli, i.e. in long lasting stimuli such as video sequences or easy to identify stimuli such as facial expressions or semantic information accompanying emotional prosody. The current findings also point to the fact that the BG are involved in the processing of positive and negative emotional auditory stimuli (as was propsed by Kotz et al., 2003), but are particularly involved in responses to fearful and disgust stimuli. Future fMRI studies will need to investigate to which extent the BG are engaged in an emotional network by testing more than two or three emotional categories.

Last, even though it was not particularly mentioned in the discussion raised above, it should be noted that combined violations to happy sentences revealed additional processing differences between BG patients and the control group, with the controls displaying the expected negative ERP component shortly after the splicing point and BG patients showing this effect almost one second later. This leads to the question of whether the negativities really reflect the same processes, or whether this late effect in patients just points to the fact that they are trying to interpret and analyze the happy stimulus generally. Even though delayed effects have been reported for patients or aging people, it is doubtful whether the effect can be delayed for one whole second as observed here.

Behavioral Effects: Finally, as was mentioned in the introduction and in Chapter 2, various behavioral studies have reported recognition deficits for emotional prosody patients suffering from BG disorders (Breitenstein et al., 1998, 2001; Pell & Leonard, 2003). As was made clear throughout the thesis, behavioral data are telling, but the results do not sufficiently allow us to separate underlying mechanisms substantiating emotional prosody from process-correlated task effects as reflected in behavioral responses. Therefore, the current experiment investigated emotional prosody processing under two task situations, with on-line and behavioral measurements. This was thought to be a promising investigation to compare possible differences in emotional prosody processing under implicit and explicit task situations. It was hypothesized that behavioral results might reveal an emotional prosody recognition deficit whereas ERP results may suggest a different conclusion. Indeed, the current results suggest such a dissociation of ERP and RT effects, probably related to processes affecting decision making, response preparation, and response execution which were enhanced in the behavioral emotional prosody recognition task. It was further hypothesized that the possible dissociation between ERP and RT effects suggest that emotional prosody processing deficits primarily occur when emotional prosody is processed explicitly. But let us first consider the present behavioral results.

Taken together, the results revealed that patients and their controls differed significantly in emotional prosody recognition. Also, it became obvious that patients have a particular recognition problem with disgust sentences in the lexical modality, whereas a general emotional prosody recognition problem was observed when no lexical content was present, i.e. in pseudosentences. In addition, the data suggest that the categorization of disgust and fear is highly affected compared to a neutral baseline, while anger and happiness are less strongly affected. In sum, the current data serves as renewed evidence that the recognition of disgust, but also fear, is impaired in BG patients. Also, the present data suggest that emotional prosody recognition is influenced by lexical-semantics of a sentence even when participants are instructed to categorize the emotional prosody only.

Within the paradigm applied, it was possible to test prosodic realizations with and without lexical content. Results suggest that BG patients rely on semantic information more than on emotional prosodic information when listening to emotional stimuli. The data suggest that testing patients with BG lesions under pure prosodic conditions reveals a categorization deficit for all emotional prosodic contours tested, some of which appear to be compensated in the combined prosodic/semantic condition. It can be said that the present behavioral results are in line with the literature where it has been suggested that the BG play an important role in recognizing disgust and fear, but point to the fact that the BG might be involved in emotional prosodic perception per se. However, one aim of the current study was to investigate emotional prosody processing in two experimental conditions, i.e. under an implicit prosody processing situation and under an explicit prosody processing situation. This investigation was encouraged by the observation that in healthy participants, different emotional prosody processing modalities (implicit vs. explicit) may accentuate different brain areas in a functional network supporting emotional prosodic perception (Kotz et al., 2003, in prep). The present behavioral data have demonstrated that patients probably correctly recognized the different emotional prosodies tested in the ERP experiment, since emotional prosody recognition was above chance level. However, taken together, the current data also revealed differences which must have resulted from the difference in implicit emotional prosody processing as enforced in the ERP experiment and explicit emotional prosody processing as enforced in the emotional prosody recognition task. Whereas the ERP data suggest that violations to a pure emotional prosodic contour are processed in a similar way as they were by the control group, the behavioral data in response to pure emotional prosody reveal a severe impairment in BG patients. It is necessary to examine this discrepancy between the present ERP and behavioral findings. As mentioned in the introduction, it is possible that the deficits revealed in the processing of emotional prosody in BG patients may differ due to task demands. Furthermore, the present findings suggest that there is a dissociation of ERP and RT effects based on processes affecting decision making, response preparation, and response execution which might have been enhanced in an explicit emotional prosody recognition task. In addition, ERP results revealed an impairment in BG patients when processing violations to emotional prosody and emotional semantics. Above, it is proposed that this impairment might reflect deficits in the integration of emotional prosody and emotional semantics. Considering the deficit observed for lexical sentences with disgust prosody and semantics, this claim can still be upheld. The strong emotional semantic content of the current sentences added to the impairment in patients during the processing of disgust sentences. This in turn suggests that the emotional category of disgust might be impaired in BG patients regardless of the modality (auditory or visual) tested as long as the disgust context is strong enough. In contrast, the semantic content might have compensated the categorization deficit in the lexical sentences condition for all other emotional prosodic contours tested. In particular, this seems to be true for fearful vocalizations. Processing difficulties of violations to both pure fearful emotional prosodic contours and combined emotional prosody and emotional-semantics have been revealed in the ERP data. Why under an explicit emotional prosody processing situation recognition deficits can be compensated by the semantic content needs further investigation (see discussion above). For now, it can only be concluded that emotional prosody processing seems to differ with varying task demands. It will be exciting to see if functional imaging data from BG patients will provide additional evidence for differently accentuated activation of the BG in a functional network supporting emotional prosodic perception depending on task situation.

In sum, the present data have added evidence to the discussion that the BG might be involved in emotional prosody processing. In particular, a selective deficit for emotional prosody recognition in disgust has been found, reflected in low recognition rates in both lexical and non-lexical sentences. Furthermore, for the first time, the current data have provided evidence for the assumption that recognition deficits of pure emotional prosody primarily occur when emotional prosody is processed explicitly. In addition, the data suggest an integration problem of emotional semantics and emotional prosody in BG patients, which in turn leads to the assumption that the BG might be involved in more general emotional processing and not necessarily in emotional *prosody* processing alone.

Part IV

Discussion and Conclusion

Chapter 10

Summary and General Discussion

There is little disagreement that emotional prosodic characteristics reflected in variations of pitch, intensity, and duration, contribute to understanding a verbal message. They supply additional information which might, for example, bring into prominence the semantic value of an utterance (Pell, 1998). The main goal of this dissertation was to investigate the role of emotional prosody in language processing. In particular, this thesis investigated the perception of emotional prosody in healthy participants and in a patient population suffering from lesions in the BG. The thesis particularly aimed to contribute to the emotional (prosodic) literature by investigating gender voice to explore possible voice identity differences in emotional prosody perception. Also, in a behavioral experiment age and gender of participants and speakers have been explored with emotional expressions of six basic emotions compared to a neutral baseline. Finally, healthy participants and BG patients were investigated. So in sum: The thesis set out to investigate the direct interaction between emotional prosody and emotional semantics to clarify if the temporal integration of the two channels of information could be specified (ERP Experiment 1). In addition, it was investigated if this direct interaction could be manipulated by task (implicit vs. explicit emotional prosody processing) (ERP Experiment 2). Furthermore, the thesis aimed to investigate the effects of speaker voice and age and their impact on facets (valences) of emotional prosodic perception (Rating Study, ERP Experiment 3 and 4). Also, reports on sex differences in the perception of emotional prosody were followed up (ERP Experiment 1-4). Last, the processing of emotional prosody was investigated in a patient population suffering from lesions in the BG under implicit and explicit task instructions (ERP Experiment 5). In this last chapter, the empirical data and corresponding discussions reported in this thesis will be summarized and integrated.

One question of interest regards the potential relatedness between emotional prosody and emotional semantics. In particular, it was of interest to clarify the extent to which the temporal integration of emotional semantics and emotional prosody could be specified. Thus, the first experiment took up this task by investigating the point in time at which the two channels of information interact and if the respective underlying mechanism could be isolated by differentiating ERP correlates. To this aim, a cross-splicing method was applied in which a violation of an emotional prosodic expectation was created, i.e., incongruities of emotional prosodic intonation contours and incongruities of emotional prosodic and emotional-semantic information. This violation paradigm was applied, as it allows to specify the point in time at which the expectation of an emotional prosodic contour and/or an emotional prosodic contour and emotional semantic information contour is violated. The probe verification task applied in Experiment 1 enforced implicit emotional prosody processing. It was hypothesized that if emotional prosody and emotional semantics were processed differently, the different conditions should elicit different or varying brain responses.

Results from all experiments suggest that this is indeed the case. A violation of a pure emotional prosodic contour almost always elicited a positive ERP component shortly after the splicing point, whereas a combined violation of emotional prosodic and emotional semantic information elicited a negative ERP component shortly after the splicing point. The fact that both types of incongruencies elicit varying brain responses points to the fact that the splicing procedure does not just reflect an acoustic artefact, but induces information specific incongruency responses in the ERP. In Experiment 1, several functional explanations for the respective ERP incongruency responses were proposed. In particular, analogous to results by Astésano et al. (2004), the positive ERP component elicited by pure emotional prosodic violations was closely linked to F0 and intensity contour violations and proposed to reflect re-analysis processes of F0 and intensity violations. Whether this positivity is prosody specific or comparable to the positivity elicited by syntactic violations is still a matter of debate. In contrast, the negative ERP component elicited by emotional prosodic and semantic incongruities is assumed to reflect semantically driven incongruency detection. It is proposed that the emotional semantics overrides emotional prosody reflecting prosodic and semantic integration problems of sentential incongruencies. It was further suggested that this negativity is influenced by emotional prosodic violation. Thus, it is concluded that the influence of prosody enhances the propositional intent of an utterance, whether in semantic-prosodic congruent or incongruent presentation.

In a second experiment, the factor task was investigated to test the nature of the two incongruency effects. One possibility for the dominance of emotional semantic information may have been the semantic nature of the task applied in the Experiment 1. It is suggested that the task forced participants to pay more attention to the emotional semantic content of the sentence than to the emotional prosodic content and thus may have enforced semantic dominance. In addition, there is evidence which suggests that implicit and explicit processing of emotional prosody differs (Kotz et al., 2003, in prep). Thus, it was of special interest to investigate the interaction between emotional prosody and emotional semantics under an explicit prosody processing situation. To this aim, a prosody categorization task was applied. If the same on-line processes are engaged in explicit emotional prosody processing as they were in implicit emotional prosody processing, the pattern of ERP responses should hold true independent of task. Indeed, the findings from Experiment 2 suggest this to be the case. The positive ERP response elicited by pure emotional prosodic violation was replicated thereby eliminating the possibility that this component simply reflects an expectancy violation. Interestingly, the current result fit nicely to reports in the literature (e.g. Vuilleumier, 2005) that it may be evolutionary advantageous to rapidly detect unexpected emotional events (in this case violations to emotional prosody/semantics). Also, this fast reaction to violations suggests rapid and effective emotional processing as hypothesized in so called feedback models (e.g. Vuilleumier, 2005). Moreover, the results suggest that violations of emotional prosodic contours are processed in a similar way regardless of the task applied. Furthermore, task did not alter the negative ERP response to the combined incongruency violations. Again, an N400-like negativity was observed under explicit prosody processing instructions. It was concluded that emotional semantics still reigns over emotional prosody. These results are in line with reports in the literature on a semantic dominance. Here it has been argued that semantics cannot be ignored regardless of the focus of attention guided by task demands (e.g Besson et al., 2002). However, the present findings also suggest differences between the two tasks. For example, in the explicit emotional prosody processing task, an additional late positive ERP component was observed after the negative response. This component was interpreted to reflect later emotional prosodic processing comparable to a "relevance-for-task-effect". In short, it was suggested that the late positive component was only elicited because emotional prosody evaluation was mandatory. In addition, the two tasks revealed differences in the time-course of emotional prosody processing, i.e., in the explicit emotional prosody processing situation, effects were elicited earlier with shorter latency and the distribution shifted rightwards. This adds further evidence to the suggestion that task can influence emotional prosody processing (e.g. Wambacq et al., 2004). In short, Experiment 2 gave raise to the observations that emotional prosody processing seems to be an automatic process and that emotional prosodic characteristics of a spoken utterance are extracted long before the production of an utterance is complete. In addition, the results fit nicely into observations that the more emotional a task, the more the right hemisphere may be involved. Even though ERPs are less telling with regard to lateralization of emotional prosody than are e.g. fMRI studies, the current results add evidence to the RH dominance hypothesis as was discussed in the theoretical part of this thesis.

The current thesis also attempted to investigate potential effects of speaker identity (e.g. female/male, young/old) and the speaker's emotional state as vocally expressed (e.g. happy/sad). The aim of ERP Experiment 3 was therefore twofold. On the one hand, vocally expressed emotions beyond happy and angry, i.e. anger, disgust, fear, happiness, pleasant surprise, sadness, and neutral vocalizations were sought to be differentiated by means of ERPs. Furthermore, by varying speaker voice (male/female) it was attempted to decipher in which way voice characteristics interface with emotional prosodic processing. Lastly, Experiment 3 investigated if the responses to emotional prosodic and emotional prosodic and semantic violations are truly valence-independent. In order to test these potential effects implicitly, a probe verification task was again applied. Stimulus material used in this experiment was previously rated in an extensive rating study, revealing above chance level recognition rates for all emotional prosodies. These results are in line with the literature. Despite overall high recognition rates there were age differences for younger and older participants. ERP results revealed that all emotional prosodies differed significantly from a neutral baseline. The earliest response was detectable after $\sim$ 200 ms (P200). Similar early results have been reported in the context of emotional facial expressions, though visual stimuli usually elicit a negative ERP component in the same time range, such as the N230 (e.g Balconi & Pozzoli, 2003) or N170 (e.g. Miyoshi, Katayama, & Morotomi, 2004). Analogous to interpretations of the early facial response, it is suggested that the early P200 component may reflect a first emotional encoding of the stimulus. In particular, this first emotional encoding seems to be influenced by pitch and intensity variations and possibly also lexical information. Unfortunately, it was not possible to clearly define a correlation between arousal level, or intensity level of the stimulus, and the P200, as high arousing stimuli did not elicit the largest or smallest P200 amplitude. However, interestingly, when grouping the stimuli it was observed that all high arousing stimuli (angry, disgust, fearful, happy, and pleasant surprise sentences) elicited a very similar P200 amplitude. The observed early P200 for valence differences is in line with models assuming that emotional processing can occur before conscious awareness (e.g. Vuilleumier, 2005). It has also been proposed that emotional stimuli boost further processing steps (c.f. theoretical part) and that they can be of privileged processing (e.g. Schupp et al., 2003). As the comparability between visual and auditory emotional stimuli may be limited, the current results representing the first auditory ERP investigation of emotional vocalizations certainly need to be replicated before firm conclusions can be drawn.

Experiment 4 aimed to replicate results of Experiment 3 and to specify whether emotional prosody carried in sentences containing no lexical information elicits comparable ERP effects as in lexical emotional prosodic sentences. Pseudosentences allow to eliminate lexical content while preserving emotional prosody. Direct comparisons between pseudosentences and lexical sentences should allow to explore the role of emotional prosody alone and when accompanied by congruent lexical information. Indeed, the present findings suggest that pseudosentences and lexical sentences elicit comparable ERP effects. Results of Experiment 4 reveal comparable early differentiation of emotional and neutral vocalizations. However, it was observed that ERPs for lexical sentences were more positive-going than ERPs for pseudosentences. This result was interpreted in terms of stimulus complexity, i.e., additional lexical information increases stimulus complexity and thus the P200 was more positive for lexical sentences.

Taken together, results revealed that ERPs can indeed differentiate various emotional prosodies at an early stage of processing. In addition, it was suggested that this early differention reflected in the P200 is not independent of lexical content, i.e., lexical content also seems to influence the P200 modulation. This was reflected in a global P200 amplitude difference in lexical and non-lexical sentences. As was mentioned earlier, models of emotional perception assume rapid identification of the emotional significance of a stimulus (e.g. Phillips et al., 2003). Recently, Schirmer and Kotz (in press) proposed a three stage working model for the processing of emotional prosody. Within this model, the authors suggest that after sensory processing (first 100 ms), an integration of emotionally significant acoustic cues occurs (after 200 ms). It is concluded that the P200 results of the current experiment fits the interpretation of the second stage of the model under attentional processing conditions.

The second objective investigated in Experiment 3 and 4 was to look to which extent speaker identity influences emotional prosody processing. Here, it was observed that a female voice elicits more positive-going ERPs than a male voice. It is suggested that this speaker difference is first and foremost related to the fact that female voices may be of higher evolutionary salience. In particular, female voices elicited stronger ERP effects comparable to observations from functional imaging where stronger activation patterns were found for female voices than for male voices (Lattner et al., 2005). It is assumed that the high-pitch female voices may be perceived as socially and biologically more salient than a low-pitch male voice. Furthermore, it was observed that the male and the female voice used in the current experiments also elicited varying brain responses with respect to different emotional prosodies. For example, for the male speaker, only negative emotional prosodies could be differentiated from neutral sentences in Experiment 3, whereas for the female speaker, differentiation of both positive and negative vocalizations from neutral sentences was observed. Whether this effect correlated to a female speaker better portraying positive emotions or not needs to be further investigated.

Last, additional valence effects were found in a later time window of 500 to 900 ms in Experiment 3, in which happy and fearful sentences differed significantly from neutral sentences. Interestingly, a speaker effect was no longer present at this point in time. In Experiment 4, the analysis in a later time window of 500 to 1000 ms also revealed significant differences between ERPs elicited by neutral sentences and by fearful sentences, but extended results from Experiment 3 to pseudosentences. This later valence effect has been interpreted to reflect elaborate "perceptual" analysis of the stimulus, analogous to the LPP literature (Cuthbert et al., 2000; Schupp et al., 2004; Diedrich et al., 1996; Crites & Cacioppo, 1996). However, since only happy and/or fearful stimuli could be differentiated from neutral stimuli, such an interpretation remains speculative and needs further empirical support. However, it should be noted that enhanced processing of fearful stimuli has been observed previously (for a review see Vuilleumier, 2005). In particular, it has been proposed that a distinct neural circuit including the amygdala is responsible for enhancing fearful stimuli perception. A similar neural circuit for other emotional stimuli remains to be revealed (Vuilleumier, 2005). In the light of this, the current results, which revealed differences between fearful and other emotional stimuli in comparison to neutral stimuli, fit the literature very well.

Finally, one additional aim of this study was to investigate the extent to which the ERP responses to emotional prosodic or combined emotional prosodic and semantic violations are valence-independent. For Experiment 3, leaving individual speaker differences aside it can be concluded that the positive ERP component seems to be elicited valence-independently, at least if violations of the emotional prosodic contour are spoken by a female voice. One explanation for the speaker difference was that because female voices are more salient than male voices, violations to their emotional prosodic contour elicit stronger ERP responses than violations to emotional prosodic contours from male voices. However, this remains to be further empirically supported, since in Experiment 4, incongruency effects were found for both speaker. More interestingly, valence-independent responses to combined violations (emotional prosodic and emotional semantic) are quite robust. A parietally distributed negative ERP component in response to the combined violations was elicited irrespective of valence in Experiments 3 and 4. However, the present findings also added evidence for emotional prosody processing differences in response to female and male voices, since results from Experiment 3 revealed more pronounced ERPs for the male voice in response to violations of fearful and angry sentences, while the female voice elicited larger ERP modulations for disgust and pleasant surprise violations. As was the case for the emotional prosodic violation, these speaker differences could not be replicated in Experiment 4, again suggesting that the effects were in part obtained due to the complex design of the experiment. In any case, previously suggested explanations for the effects obtained are upheld. In particular, it was assumed that a combined violation results in an N400-like negativity reflecting integration problems between the information types. In general, it is assumed that this effect is task-, speaker-, and valence-independent.

A further question relates to the observation that few studies have investigated emotional prosody perception in isolation. In order to achieve this, i.e., to investigate emotional prosody without the influence of semantic content, the presentation of nonsense utterances, or so-called pseudosentences, was proposed in ERP Experiment 4. It was hypothesized that the previously elicited positive ERPs should be replicated when the emotional prosodic violation is embedded in pseudosentences. Indeed, ERP effects observed in Experiment 4 are very comparable to the effects observed in the previous three experiments. In particular, pure emotional prosodic violations embedded in pseudosentences again elicited a positive ERP component shortly after the splicing-point. This serves as renewed evidence for the assumption that the positive ERP component reported in the Experiments 1-3 is indeed related to purely emotional prosodic integration problems. However, even though responses to combined violations seem task-, speaker-, and valence independent, responses to purely prosodic violations are not as straightforward and need further empirical investigation. Results of Experiment 3 suggest that under complex experimental settings, i.e. including frequent speaker and valence changes, responses to pure emotional prosodic violations can indeed be speaker-, and valence dependent. However, if this is truly only due to the complex design of Experiment 3 needs to be further investigated. Also, it was suggested that general prosodic contour violations (irrespective of emotional valence) might elicit similar positive ERP responses (as e.g. P800, CPS), not necessarily reflecting identical processing steps, but very similar steps. It was proposed that one processing difference between violations to emotional prosody and linguistic prosody relates to the evolutionary significance of emotional stimuli. That is, processing might be faster and more effective for emotional stimuli than for neutral stimuli. In sum, there is considerable evidence that emotional prosody processing is a highly automatized process that does not seem to be influenced by valence differences.

Finally, ERP Experiment 5 and the corresponding behavioral experiment were designed to explore emotional prosody processing in patients with lesions of the basal ganglia (BG). In line with the literature, the assumption was that BG patients will suffer from perception problems in emotional prosody. In particular, the emotional vocalizations of disgust and fear were of central interest. The current findings serve as renewed evidence that the BG modulate perception of emotional prosody, and emotional vocalizations of disgust and possibly fear in particular. Interestingly, the present results suggest a potential difference between explicit and implicit emotional prosody processing. It was observed that BG patients suffer from impairment in the recognition of disgust in both lexical and non-lexical sentences. This selective deficit was especially obvious in the behavioral experiment, i.e. under explicit task instruction. This is in line with studies that report that patients with BG disorders show deficits in disgust recognition (e.g. Sprengelmeyer et al., 1997; Wang et al., 2003). In addition, the behavioral results suggest a more general emotional prosody recognition impairment in BG patients. In the pseudosentences, recognition for all emotional vocalization tested were reduced (compared to neutral sentences). In contrast, responses to emotional prosodic violations elicited a positive-going ERP component shortly after the splicing point. This suggests that patients did not suffer from problems in on-line processing of violations to emotional prosodic contours as might have been expected. Moreover, violation of disgust vocalization was not selective impaired.

Surprisingly, evidence for a potential emotional prosody impairment in BG patients under an implicit prosody processing situation comes from the combined violation. Conclusions about this impairment can be drawn with regard to the literature available. Within the literature review in Chapter 2 it has been mentioned that left hemisphere (LH) patients often differ from right hemisphere (RH) patients in (emotional) prosodic processing. In particular, it has been shown that LH patients are often less affected in emotional prosody processing (Blonder et al., 1991; Van Lancker, 1980). Also, it has been discussed that LH and RH patients differ in their impairment with regard to acoustic properties of a stimuli. For instance, whereas LH patients are more affected when temporal cues are manipulated, RH patients are more affected when frequency is manipulated. In addition, it has been reported that the RH is dominant in emotional prosody recognition at least under explicit task instructions. The fact that here BG patients with only left-sided lesions were tested implicitly rather than explicitly may have resulted in a sole effect for combined violations. Severe impairment was observed in BG patients during processing of combined violations to emotional prosody and emotional semantic for disgust and fear. This was reflected in a missing effect for fear, and a reversed effect for disgust. It is assumed that strong semantic content helps to identify the corresponding emotional prosody of a sentence. Due to the additional information impairment in on-line processing becomes apparent. It was assumed that this impairment does not reflect emotional prosody processing problems in general but rather a (temporal) integration problem between emotional prosody and semantics. This assumption is supported by the behavioral data, in which it was shown that emotional semantic information compensates emotional prosody recognition. The fact that BG patients only reveal emotional prosodic deficits when they have to categorize prosodies, then reveals a global deficit for emotional prosodic categorization. Processing differences between BG patients and controls were observed for all emotional categories tested. This suggests that the BG might be involved in emotional processing in general, irrespective of valence, but are particularly accented in disgust processing. In any case, the current results delineates the importance of differentiating between emotional prosody processing mechanisms potentially activated in implicit or explicit processing circumstances.

Last, early valence effects (P200) were investigated in BG patients and controls, revealing an interesting processing difference between the groups. P200 effects were only significant for the contrast between fearful and neutral stimuli in both groups irrespective of sentence modality. However, results revealed that the P200 amplitude was prolonged by 100 ms in the BG patients. This points to a processing difference between the two groups, though, it remains an open question whether the prolonged P200 effect reflects timing differences in emotional processing or if it is related to more general difficulties during fearful emotional prosody processing in BG patients. In any case, results support previous evidence that BG patients suffer from difficulties in processing fearful stimuli and extends this conclusion to vocal emotional stimuli.

Taken together, the results revealed that patients and their controls differed in emotional prosody processing under implicit and explicit circumstances in various ways. For example, timing and/or processing difficulties for the emotional prosody of fear was observed between the two groups. Also, emotional prosody recognition deficits for patients became apparent in the behavioral experiment. Last, ERPs in response to violations to emotional prosodic and emotional semantic contours added additional evidence for a processing deficit of emotional stimuli in BG patients, with severe impairment apparent for the emotional categories of disgust and fear. Thus, the present data contribute to the discussion that the BG might be involved in emotional prosody processing. Moreover, for the first time, the current data have provided evidence for the fact that recognition deficits of pure emotional prosody primarily occur when emotional prosody is processed explicitly.

10.1 Final Remarks and Future Directions

To summarize the findings of the current series of experiments, it can be stated that emotional prosody indeed influences language processing mechanisms. It has been shown that the respective underlying mechanisms of emotional prosody and emotional semantics can be differentiated in the ERP. In addition, it was shown that basic emotional vocalizations, namely anger, disgust, fear, happiness, pleasant surprise, sadness, and neutral can be differentiated in ERP traces starting in an early brain response around 200 ms (P200) followed by late positivities (pure emotional prosodic processing) and an N400-like component (integration of emotional prosodic and semantic processing). Moreover, the current evidence suggests that emotional prosody articulated by different speakers, i.e. by a female and a male voice, can be differentiated in the early positivity. Last, the current evidence adds to the accumulating evidence that emotional prosody and potentially also emotional semantic processing is modulated by the BG.

Obviously, within this thesis, not all aspects of emotional prosody perception could be investigated. Nevertheless, the current findings have shown that it is a worthwile endeavor to try to disentangle the potential factors that might influence emotional prosody processing. In particular, it has been shown that presenting different speaker identities can provide further insight into how emotional prosody perception works in healthy participants. Therefore, future research will hopefully continue on this issue and will try to avoid denying the potential role of speaker identity play in emotional prosody processing.

The present thesis did not find evidence for emotional prosody processing differences in male and female participants. Why other studies have reported this difference and why the current study failed to find a strong influence of participant's sex on emotional prosody processing needs further empirical investigation in the future.

Last, the current thesis primarily investigated the influence of task, speaker sex, and emotional valence on emotional prosody processing at the sentence level, though clearly, there are other factors that might contribute to emotional prosody perception. For example, speaker age, as well as context (e.g., stories vs. single sentence presentation) may influence emotional prosody perception and also need closer examination in future studies.

Finally, an emotional utterance is often accompanied by gestures and facial movements. It will be exciting to see how future studies can disentangle their potential influence on emotional prosody perception and on emotional perception in general. To conclude, the current research has further enriched the knowledge we have about emotional prosody processing with novel evidence on how several aspects of emotional prosody perception interplay. At the same time, the findings give rise to numerous questions which await to be addressed in future research.

Part V

Appendix

Appendix A

Rating Study

A.1 Valence Rating

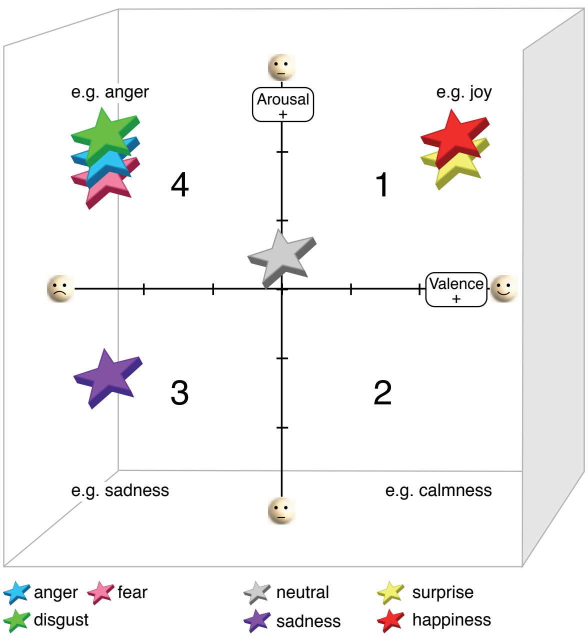


Figure A.1: The picture illustrates mean intensity ratings of stimuli irrespective of speaker voice. Mean values of intensity ratings were placed in the valence-arousal model for illustration purposes only.

A.2 RTs Rating Study

Mean Reaction Times		
EMOTION	**RT in ms**	**SD**
Anger	4042.68	677.51
Disgust	4049.54	646.97
Fear	4812.83	887.76
Happiness	4142.77	627.86
Neutral	4043.60	737.31
Pleasant Surprise	4118.61	640.25
Sadness	4409.16	778.08

Table A.1: Mean reaction times for categorizing sentences with angry, disgust, fearful, happy, pleasant surprise, neutral, and sad emotional prosody. Reaction times were measuerd starting from sentence onset.

Mean Reaction Times split by Actor-Sex			
EMOTION	**Actor-Sex**	**RT in ms**	**SD**
Anger	female	4185.71	627.52
Anger	male	4051.52	648.37
Disgust	female	4379.85	755.30
Disgust	male	4319.23	647.52
Fear	female	4565.35	797.08
Fear	male	5060.32	951.37
Happiness	female	4110.15	689.94
Happiness	male	4175.40	584.58
Neutral	female	4073.48	796.58
Neutral	male	4013.73	686.15
Pleasant Surprise	female	4185.71	627.52
Pleasant Surprise	male	4051.52	648.37
Sadness	female	4244.54	854.67
Sadness	male	4573.78	693.48

Table A.2: Mean reaction times for categorizing sentences with angry, disgust, fearful, happy, pleasant surprise, neutral, and sad emotional prosody split by Actor-Sex. Reaction times were measuerd starting from sentence onset.

Mean Reaction Times split by Actor-Age			
EMOTION	**Actor-Age**	**RT in ms**	**SD**
Anger	old	4129.78	679.87
Anger	young	4107.45	600.63
Disgust	old	4626.33	643.04
Disgust	young	4072.75	650.90
Fear	old	4718.46	701.08
Fear	young	4907.21	1074.44
Happiness	old	4267.72	628.75
Happiness	young	4017.82	626.98
Neutral	old	4141.31	755.23
Neutral	young	3945.90	719.40
Pleasant Surprise	old	4129.78	679.87
Pleasant Surprise	young	4107.45	600.63
Sadness	old	4568.13	732.07
Sadness	young	4250.19	824.10

Table A.3: Mean reaction times for categorizing sentences with angry, disgust, fearful, happy, pleasant surprise, neutral, and sad emotional prosody split by Actor-Age. Reaction times were measuerd starting from sentence onset.

Mean Reaction Times split by Actor-Age and Actor-Sex				
EMOTION	**Actor-Age**	**Actor-Sex**	**RT in ms**	**SD**
Anger	old	female	3969.95	691.82
Anger	old	male	4289.58	612.09
Anger	young	female	3890.99	645.20
Anger	young	male	4020.21	721.76
Disgust	old	female	4823.50	606.21
Disgust	old	male	4429.16	622.16
Disgust	young	female	3936.19	618.55
Disgust	young	male	4209.30	658.48
Fear	old	female	4982.33	644.45
Fear	old	male	4454.59	658.82
Fear	young	female	4148.37	715.66
Fear	young	male	5666.04	803.16
Happiness	old	female	4322.00	656.17
Happiness	old	male	4213.44	600.32
Happiness	young	female	3898.29	661.70
Happiness	young	male	4137.36	570.59
Neutral	old	female	4476.50	731.83
Neutral	old	male	3806.12	621.25
Neutral	young	female	3670.46	643.11
Neutral	young	male	4221.34	689.60
Pleasant Surprise	old	female	4301.64	655.65
Pleasant Surprise	old	male	3957.92	664.76
Pleasant Surprise	young	female	4069.78	580.20
Pleasant Surprise	young	male	4145.13	622.68
Sadness	old	female	4633.93	777.53
Sadness	old	male	4502.33	683.38
Sadness	young	female	3855.15	748.28
Sadness	young	male	4645.24	701.48

Table A.4: Mean reaction times for categorizing sentences with angry, disgust, fearful, happy, pleasant surprise, neutral, and sad emotional prosody split by Actor-Age and Actor-Sex. Reaction times were measuerd starting from sentence onset.

A.3 ANOVAs on PC split by Emotional Category

ANOVA for "Anger"			
Effect	*df*	*F value*	*p value*
AGE	1,60	15.13	$<$0.001
Actor-sex x SEX	1,60	5.89	$<$0.05
Actor-age x Actor-sex	1,60	6.01	$<$0.05

Table A.5: Significant/borderline results from ANOVAs on percentage correct as revealed in the Rating Study for all participants for the emotional category of anger.

ANOVA for "Disgust"			
Effect	*df*	*F value*	*p value*
AGE	1,60	19.43	$<$.0001
Actor-sex	1,60	10.88	$<$0.01
Actor-age x *Actor-sex* x *AGE*	1,60	4.80	$<$0.05

Table A.6: Significant/borderline results from ANOVAs on percentage correct as revealed in the Rating Study for all participants for the emotional category of disgust.

ANOVA for "Fear"			
Effect	*df*	*F value*	*p value*
AGE	1,60	7.63	$<$0.01
Actor-age	1,60	24.65	$<$.0001
Actor-age x *AGE*	1,60	10.43	$<$0.01
Actor-sex x*AGE*	1,60	4.69	$<$0.05
Actor-age x *Actor-sex*	1,60	8.29	$<$0.01
Actor-age x *Actor-sex* x *SEX*	1,60	4.77	$<$0.05

Table A.7: Significant/borderline results from ANOVAs on percentage correct as revealed in the Rating Study for all participants for the emotional category of fear.

ANOVA for "Happiness"			
Effect	*df*	*F value*	*p value*
AGE	1,59	8.56	<0.01
Actor-sex	1,59	3.45	<0.08

Table A.8: Significant/borderline results from ANOVAs on percentage correct as revealed in the Rating Study for all participants for the emotional category of happiness.

ANOVA for "Neutral"			
Effect	*df*	*F value*	*p value*
AGE	1,60	4.28	<0.05
Actor-age	1,60	19.92	<.0001

Table A.9: Significant/borderline results from ANOVAs on percentage correct as revealed in the Rating Study for all participants for the emotional category of neutral.

ANOVA for "Pleasant Surprise"			
Effect	*df*	*F value*	*p value*
Actor-age	1,59	11.89	<.0001
Actor-sex	1,59	22.04	<0.05
Actor-age x *Actor-sex*	1,59	3.57	<.0001

Table A.10: Significant/borderline results from ANOVAs on percentage correct as revealed in the Rating Study for all participants for the emotional category of pleasant surprise.

ANOVA for "Sad"			
Effect	*df*	*F value*	*p value*
AGE	1,59	11.89	<0.001
Actor-sex	1,59	22.04	<.0001
Actor-age x *Actor-sex*	1,59	3.57	<0.08

Table A.11: ANOVAs on percentage correct as revealed in the Rating Study for all participants for the emotional category of sadness.

Appendix B

Experiment 3

B.1 Lexical Stimuls Material

Stimulus Material Rating Study, and Experiment 3, 4, and 5									
EMOTION	**SENTENCE**	**WLN**	**SN**	**FN**	**WLV**	**SV**	**FV**	**SV2**	**SS**
ANGER	Er hat die Kraftfahrer gefesselt und verfrachtet	11	3	20	9	3	6	3	13
ANGER	Er hat das Paar gereizt und aufgebracht	4	1	20	7	2	8	3	10
ANGER	Sie hat den Herzog gedemütigt und verärgert	6	2	20	10	4	2	3	13
ANGER	Sie hat den Ring beschädigt und verschlammt	4	1	18	10	3	12	2	10
ANGER	Er hat die Braut versetzt und verärgert	5	1	20	8	2	20	3	10
ANGER	Er hat das Vermögen geraubt und verprasst	8	3	24	7	2	4	2	11
ANGER	Er hat die Dame gekniffen und verärgert	4	2	54	9	3	0	3	12
ANGER	Sie hat den Bischof beworfen und verärgert	7	2	40	8	3	2	3	12
ANGER	Sie hat die Autos verdreckt und zerkratzt	5	1	37	9	2	0	2	9
ANGER	Er hat den Assistent erdrosselt und vergraben	9	3	5	10	3	0	3	13
ANGER	Er hat die Genossenschaft beleidigt und verärgert	14	4	19	9	3	7	3	14
ANGER	Er hat die Schilder ausgetauscht und abgebaut	8	2	5	12	3	8	3	12
ANGER	Er hat die Geschichten gebilligt und geschwiegen	11	3	17	9	3	11	3	13
ANGER	Sie hat die Papiere geknüllt und angezündet	7	3	22			0	4	13
ANGER	Sie hat den Kater bestraft und ausgesperrt	5	2	9	8	2	12	3	11
ANGER	Sie hat die Wut erzeugt und verwertet	3	1	13	7	2	24	3	10
ANGER	Er hat die Kanonen geladen und abgefeuert	7	3	4	7	3	12	4	14
ANGER	Er hat das Tor geknallt und abgeschlossen	4	1	29	8	2	1	4	11
ANGER	Er hat die Ferien verpfuscht und rumgemeckert	6	3	21	10	2	1	4	13
ANGER	Er hat das Vergnügen verdorben und rumgemeckert	9	3	19	9	3	4	4	14
ANGER	Er hat den Flüchtling gequält und schikaniert	10	2	9	7	2	5	3	11
ANGER	Er hat die Drogen gehehlt und verhökert	6	2	2	7	2	0	3	11
ANGER	Sie hat die Bande gebildet und organisiert	5	2	3	8	3	20	4	13
ANGER	Sie hat die Nachbarin gekränkt und verärgert	9	3	35	8	2	4	3	12
ANGER	Sie hat die Kundschaft beschimpft und aufgebracht	10	2	11	10	2	4	3	11
ANGER	Er hat die Jugendlichen belogen und aufgebracht	12	4	34	7	3	2	3	14
ANGER	Er hat den Zorn geschuert und heraufbeschworen	4	1	20	9	2	1	5	12
ANGER	Er hat die Abreise versäumt und verpennt	7	3	10	8	2	10	2	11
ANGER	Er hat das Cabrio ausgebrannt und weggeworfen	6	3		11	3	2	4	14
ANGER	Sie hat das Unbehagen geäußert und gemosert	9	4	7	8	3	26	3	14
ANGER	Er hat die Altstadt gesprengt und ruiniert	8	2	7	9	2	4	3	11
ANGER	Er hat die Kartoffeln geschmissen und geschrien	10	3	22	11	3	1	2	12
ANGER	Er hat das Zeugnis gewaschen und weggetan	7	2	16	9	3	6	3	12
ANGER	Sie hat die Stimmung zerstört und rumgemeckert	8	2	40	8	2	34	4	12
ANGER	Er hat die Pistole geschwungen und gezielt	7	3	11	11	3	1	2	12
ANGER	Er hat die Empörung gesteigert und heraufbeschworen	8	3	18	10	3	17	5	15
ANGER	Er hat den Verkehr gefährdet und aufgehalten	7	2	55	9	3	28	4	13
ANGER	Sie hat die Aufführung verschlafen und abgesagt	10	3	20	11	3	2	3	13
ANGER	Sie hat den Demokraten verdammt und verärgert	10	4	46	8	2	5	3	13
ANGER	Er hat das Schloss gestürmt und verwüstet	7	1	64	8	2	1	3	10
ANGER	Er hat die Hausaufgaben verschwitzt und gelogen	12	4		11	2	1	3	13
ANGER	Er hat den Bauern gedrängt und verunsichert	6	2	40	8	2	9	4	12
ANGER	Sie hat die Suppe versalzen und verkocht	5	2	7	9	3	0	2	11
ANGER	Sie hat die Katastrophe ausgelöst und angezettelt	11	4	23	9	3	26	4	15
ANGER	Er hat die Ehefrau gepiesackt und verärgert	7	3	0	10	3	0	3	13

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EMOTION	SENTENCE	WLN	SN	FN	WLV	SV	FV	SV2	SS
ANGER	Sie hat die Faust geballt und geschrien	5	1	24	7	2	1	2	9
ANGER	Sie hat die Räumung befohlen und durchgeführt	7	2	4	8	3	5	3	12
ANGER	Sie hat den Jungen getreten und verhauen	6	2	41	8	3	30	3	12
ANGER	Er hat die Villa besetzt und verwüstet	5	2	14	7	2	25	3	11
ANGER	Er hat die Lüge ausgesprochen und gemosert	4	2	24	13	4	30	3	13
DISGUST	Er hat den Speichel verbreitet und verteilt	8	2	5	10	3	10	2	11
DISGUST	Sie hat den Richter genötigt und belästigt	7	2	49	8	3	8	3	12
DISGUST	Er hat die Müllhalde bewohnt und gestunken	9	3	0	7	2	6	3	12
DISGUST	Sie hat die Maus verschlungen und geschmatzt	4	1	5	12	2	3	2	9
DISGUST	Er hat das Schwein geschlachtet und inspiziert	7	1	5	12	3	2	3	11
DISGUST	Sie hat den Schädel ausgegraben und inspiziert	7	2	10	11	4	3	3	13
DISGUST	Er hat die Finger gequetscht und gelitten	6	2	47	10	2	1	3	11
DISGUST	Er hat die Pickel gedrückt und abgedeckt	6	2	0	8	2	6	3	11
DISGUST	Er hat das Ungeziefer gebraten und geknabbert	10	4	1	8	3	1	3	14
DISGUST	Sie hat den Leichnam gesehen und aufbewahrt	8	2	3	7	3	15	3	12
DISGUST	Er hat den Schleim betrachtet und inspiziert	7	1	1	10	4	52	3	12
DISGUST	Er hat den Fahrer bezichtigt und belästigt	6	2	53	10	3	4	3	12
DISGUST	Sie hat die Nahrung verboten und weggeschmissen	7	2	13	8	3	17	4	13
DISGUST	Er hat das Fräulein bepinkelt und belästigt	8	2	44	9	3	0	3	12
DISGUST	Sie hat das Büro verwanzt und bespitzelt	4	2	50	8	2	0	3	11
DISGUST	Er hat die Toilette geputzt und gestunken	8	3	7	7	2	3	3	12
DISGUST	Er hat den Schweiß getrunken und gekotzt	7	1	14	9	3	14	2	10
DISGUST	Er hat den Gast gefoltert und getrietzt	4	1	47	9	3	2	2	10
DISGUST	Er hat die Dusche gemieden und gestunken	6	2	10	8	3	1	3	12
DISGUST	Er hat das Ungeheuer gespürt und geschrien	9	4	4	7	2	4	2	12
DISGUST	Sie hat das Klo ausgebaut und inspiziert	3	1	1	9	3	14	3	11
DISGUST	Sie hat die Matratze beschmutzt und zerschlissen	8	3	21	10	2	1	3	12
DISGUST	Er hat das Tier zerlegt und geknabbert	4	1	37	7	2	2	3	10
DISGUST	Er hat die Kuh gebissen und zerschlissen	3	1	23	8	3	3	3	11
DISGUST	Er hat den Kapitän ausgenommen und inspiziert	7	3	17	11	4	6	3	14
DISGUST	Er hat die Zigarette verschluckt und gehustet	9	2	30	11	2	3	3	11
DISGUST	Er hat das Aas geschleppt und mitgenommen	3	4	1	10	3	3	4	15
DISGUST	Sie hat die Insekten genossen und empfohlen	8	3	6	8	3	5	3	13
DISGUST	Sie hat die Entführung gestattet und geschwiegen	10	3	9	9	3	20	3	13
DISGUST	Sie hat die Toten studiert und eingepackt	5	2	30	8	2	19	3	11
DISGUST	Sie hat den Neffen verführt und belästigt	6	2	4	8	2	2	3	11
DISGUST	Sie hat den Abfall vertilgt und geschmatzt	6	2	6	8	2	1	2	10
DISGUST	Sie hat die Bischöfe bekämpft und belästigt	8	3	30	8	2	8	3	12
DISGUST	Er hat den Teilnehmer befummelt und belästigt	10	3	47	9	3	0	3	13
DISGUST	Er hat die Hygiene vernachlässigt und gestunken	7	3	3	14	4	8	3	14
DISGUST	Er hat die Moskitos gekostet und weitergereicht	8	3	2	8	3	11	4	14
DISGUST	Er hat das Ohr zermatscht und aufbewahrt	3	1	25	10	2	0	3	10
DISGUST	Sie hat die Spinne zerquetscht und aufbewahrt	6	2	5	11	2	0	3	11
DISGUST	Er hat die Zähne ausgeschlagen und geblutet	5	2	21	13	4	2	3	13
DISGUST	Sie hat den Hund gegessen und geschmatzt	4	2	35	8	3	7	2	11
DISGUST	Sie hat die Asche geschluckt und gehustet	5	2	5	10	2	2	3	11
DISGUST	Sie hat das Mahl erbrochen und inspiziert	4	1	2	9	3	0	3	11
DISGUST	Er hat den Burschen gehängt und verscharrt	8	3	27	7	2	4	2	11
DISGUST	Er hat den Ausschuss bespuckt und belästigt	9	2	39	8	2	0	3	11
DISGUST	Er hat den Dreck gefressen und runtergespült	5	2	8	9	3	3	4	13
DISGUST	Sie hat das Erbrochene geholt und inspiziert	10	4	0	6	2	14	3	13
DISGUST	Sie hat die Würmer gesammelt und inspiziert	6	2	2	9	3	12	3	12
DISGUST	Sie hat das Blut geleckt und geschmatzt	4	1	40	7	3	1	2	10
DISGUST	Er hat den Kadaver gehoben und verscharrt	7	3	1	7	2	4	2	11
DISGUST	Sie hat die Löwen gerochen und gekotzt	5	2	32	8	3	1	2	11
FEAR	Er hat die Spuren verwischt und verschleiert	6	2	28	9	2	3	3	11
FEAR	Sie hat die Aussage verweigert und geschwiegen	7	3	30	10	3	13	3	13
FEAR	Er hat die Vorwürfe befürchtet und gehört	8	3	24	10	3	0	2	12
FEAR	Er hat den Juwelier beraubt und angegriffen	8	3	2	7	2	9	4	13
FEAR	Sie hat das Messer geschliffen und gezogen	6	2	7	11	3	2	3	12
FEAR	Er hat die Rakete gezündet und abgeworfen	6	3	39	8	3	2	4	14
FEAR	Er hat die Gemeinde gewarnt und verunsichert	8	3	43	2	2	13	4	13
FEAR	Sie hat den Betrüger überrascht und verschreckt	8	3		10	3	34	2	12
FEAR	Sie hat den Täter erschreckt und aufgebracht	5	2	25	10	2	2	3	11
FEAR	Er hat die Bilanz geschummelt und erlogen	6	2	36	11	3	0	3	12
FEAR	Er hat den Gauner gehetzt und verfolgt	6	2	10	7	2	3	2	10
FEAR	Er hat die Anklage formuliert und vorgetragen	7	3	22	10	3	18	4	14
FEAR	Er hat die Feinde gedeckt und geschwiegen	6	2	24	7	2	16	3	11
FEAR	Er hat die Schüsse vernommen und geortet	7	2	13	9	3	7	2	11
FEAR	Er hat die Tür ausgehebelt und weggeschmissen	3	1	11	11	4	0	4	13
FEAR	Sie hat die Angriffe geduldet und geschwiegen	8	3	20	8	3	2	3	13
FEAR	Sie hat den Leoparden gestreift und verschreckt	9	2	3	9	2	2	2	10
FEAR	Er hat die Schlange geschossen und ausgenommen	8	2	11	10	3	16	4	13

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EMOTION	SENTENCE	WLN	SN	FN	WLV	SV	FV	SV2	SS
FEAR	Er hat die Nachricht geflüstert und aufgebauscht	9	2	30	10	3	1	3	12
FEAR	Er hat das Wohnzimmer geplündert und ruiniert	10	3	18	10	3	1	3	13
FEAR	Er hat den Einbrecher beseitigt und weggetragen	10	3	6	9	3	24	4	14
FEAR	Er hat die Botschaft bedroht und angezündet	9	2	47	7	2	30	4	12
FEAR	Sie hat die Ausreise ausgeschlossen und vorgewarnt	8	3	4	14	4	20	3	14
FEAR	Sie hat die Spritzen ausgebreitet und aufgezogen	8	2	3	12	4	5	4	14
FEAR	Sie hat die Falle benutzt und weggeräumt	5	2	32	7	2	33	3	11
FEAR	Sie hat die Angelegenheit überprüft und gemeckert	13	5	33	9	3	11	3	15
FEAR	Er hat die Leiche gefroren und gestückelt	6	2	19	8	3	1	3	12
FEAR	Er hat den Räuber verletzt und liegengelassen	6	2	10	8	2	28	5	13
FEAR	Er hat die Aktivisten gestossen und verprügelt	10	4	15	9	3	14	3	14
FEAR	Sie hat die Auskunft erzwungen und erpresst	8	2	48	9	3	6	2	11
FEAR	Sie hat das Finanzamt betrogen und beschwindelt	9	3	5	8	3	6	3	13
FEAR	Er hat das Silber versteckt und eingesackt	6	2	26	9	2	17	3	11
FEAR	Er hat die Bomben gefeuert und abgewartet	6	2	16	8	3	2	4	13
FEAR	Er hat die Warnung gebrüllt und geschrien	7	2	15	8	2	1	2	10
FEAR	Er hat den Sträfling begleitet und gezittert	9	2	1	9	3	20	3	12
FEAR	Er hat dem Nachfolger gedroht und abgewartet	10	3	44	7	2	6	4	13
FEAR	Sie hat den Spion bestochen und abgewartet	5	2	3	9	3	1	4	13
FEAR	Sie hat den Agenten verraten und verunsichert	7	3	13	8	3	18	4	14
FEAR	Sie hat die Geheimakte gesendet und kopiert	10	4	5	8	3	2	2	13
FEAR	Sie hat den Beweis vernichtet und geschwiegen	6	2	48	10	3	19	3	12
FEAR	Er hat den Stein geschleudert und abgewartet	5	1	32	12	3	5	4	12
FEAR	Er hat die Säbel gewetzt und erhoben	5	2	4	7	2	0	3	11
FEAR	Sie hat den Ingenieur geschändet und verleumdet	9	3	21	10	3	1	3	13
FEAR	Sie hat das Gespenst gefühlt und gezittert	8	2	5	7	2	6	3	11
FEAR	Er hat die Verbrecher gejagt und verfolgt	10	3	16	6	2	5	2	11
FEAR	Er hat den Rückweg versperrt und abgedunkelt	7	2	0	9	2	4	4	12
FEAR	Er hat die Hexe geärgert und erpresst	4	2	3	8	3	3	2	11
FEAR	Sie hat das Öl geschmuggelt und verkauft	2	1	24	12	3	3	2	10
FEAR	Sie hat die Evakuierung verfügt und erreicht	11	5	1	7	2	29	2	13
FEAR	Er hat das Gift ausgegeben und verabreicht	4	1	3	10	4	17	3	12
HAPPINESS	Er hat den Posten vermittelt und gejubelt	6	2	24	10	3	19	3	12
HAPPINESS	Sie hat die Trauung verkündet und gelächelt	7	2	8	9	3	10	3	12
HAPPINESS	Er hat die Pointe verarbeitet und gelacht	6	3	2	11	4	9	2	13
HAPPINESS	Er hat die Belohnung genutzt und angelegt	9	3	5	7	2	20	3	12
HAPPINESS	Sie hat die Zuhörer begeistert und gelacht	7	3	12	10	3	22	2	12
HAPPINESS	Er hat die Prämie ausgehandelt und gejubelt	6	2	8	12	4	4	3	13
HAPPINESS	Er hat den Gefangenen befreit und gelächelt	10	4	17	7	2	23	3	13
HAPPINESS	Sie hat das Fest veranstaltet und eingeladen	4	1	16	12	4	19	4	13
HAPPINESS	Er hat das Abitur erlangt und gejubelt	6	3	12	7	2	4	3	12
HAPPINESS	Er hat die Gratulation überliefert und gelächelt	11	4	1	11	4	3	3	15
HAPPINESS	Er hat die Prüfung bestanden und gejubelt	7	2	43	9	3	13	3	12
HAPPINESS	Sie hat dem Sportler gratuliert und gelächelt	8	2	21	10	3	7	3	12
HAPPINESS	Er hat das Aufgebot bestellt und gelächelt	8	3	9	8	2	24	3	12
HAPPINESS	Er hat den Alkohol besiegt und gejubelt	7	3	12	7	2	5	3	12
HAPPINESS	Er hat den Beamten gemocht und geschätzt	7	3	46	7	2	1	2	11
HAPPINESS	Sie hat das Präsent geschickt und gegrüßt	7	2	1	9	2	20	2	10
HAPPINESS	Sie hat den Sprößling geboren und geschwärmt	9	2	1	7	3	25	2	11
HAPPINESS	Er hat der Fabrik geholfen und gearbeitet	6	2	19	8	3	19	4	13
HAPPINESS	Er hat den Erlös gestiftet und aufgeteilt	5	2	5	9	3	2	3	12
HAPPINESS	Er hat den Patienten geheilt und aufgemuntert	9	3	45	7	2	3	4	13
HAPPINESS	Sie hat den Rekord geknackt und gejubelt	6	2	21	8	2	0	3	11
HAPPINESS	Er hat das Lob geerntet und gelächelt	3	1	13	8	3	4	3	11
HAPPINESS	Er hat die Prinzessin geküsst und gelacht	10	3	50	7	2	4	2	11
HAPPINESS	Er hat die Seeluft geatmet und abgewartet	7	2	1	7	3	1	4	13
HAPPINESS	Er hat den Sekt geschüttelt und gejubelt	4	1	10	11	3	2	3	11
HAPPINESS	Er hat den Brand gelöscht und gejubelt	5	1	21	8	2	3	3	10
HAPPINESS	Sie hat die Puppe geliebt und geschätzt	5	2	5	7	2	8	2	10
HAPPINESS	Er hat das Rätsel gelöst und abgeschickt	6	2	13	6	2	43	3	11
HAPPINESS	Sie hat den Politiker geehelicht und geschwärmt	9	4	64	10	4	0	2	14
HAPPINESS	Sie hat den Senator geheiratet und geschwärmt	7	3	18	10	4	15	2	13
HAPPINESS	Er hat den Ertrinkenden gesichert und aufgeatmet	12	4	0	9	3	41	4	15
HAPPINESS	Er hat den Motor verbessert und gewonnen	5	2	70	10	3	24	3	12
HAPPINESS	Er hat den Hinweis befolgt und abgewartet	7	2	51	7	2	5	4	12
HAPPINESS	Sie hat das Meisterwerk ausgezeichnet und gepriesen	11	3	18	13	4	8	3	14
HAPPINESS	Er hat die Akademie gelobt und gepriesen	8	4	34	6	2	3	3	13
HAPPINESS	Er hat die Reise gebucht und gelächelt	5	2	30	7	2	2	2	10
HAPPINESS	Er hat den Flug verbilligt und verkauft	4	1	21	10	3	2	2	10
HAPPINESS	Er hat die Chancen ergriffen und verwertet	7	2	44	9	3	21	3	12
HAPPINESS	Er hat das Rathaus bewundert und fotografiert	7	2	24	9	3	5	4	13
HAPPINESS	Sie hat das Geschenk übergeben und gelächelt	8	2	19	9	4	14	3	13
HAPPINESS	Er hat das Anliegen gewährt und unterstützt	8	3	19	7	2	15	3	12

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EMOTION	SENTENCE	WLN	SN	FN	WLV	SV	FV	SV2	SS
HAPPINESS	Sie hat die Strafe ausgesetzt und verkürzt	6	2	26	10	3	28	2	11
HAPPINESS	Er hat das Fahrrad verschenkt und gelächelt	7	2	11	10	2	2	3	11
HAPPINESS	Sie hat den Referendar verbeamtet und gelächelt	10	4	2	10	4	0	3	15
HAPPINESS	Sie hat die Bonbons ausgehändigt und verteilt	7	2	3	12	4	2	2	12
HAPPINESS	Er hat das Autofahren gelernt und verstanden	10	4	0	7	2	30	3	13
HAPPINESS	Er hat die Formel begriffen und verstanden	6	2	17	9	3	23	3	12
HAPPINESS	Sie hat den Vorteil gewahrt und gelacht	7	2	29	7	2	4	2	10
HAPPINESS	Er hat den Ganoven gefasst und eingesperrt	7	3	0	7	2	38	3	12
HAPPINESS	Er hat die Freizeit geplant und vorbereitet	8	2	17	7	2	35	4	12
NEUTRAL	Er hat die Pflanzen gegossen und beschnitten	8	2	12	8	3	2	3	12
NEUTRAL	Er hat die Spiele gespielt und erklärt	6	2	30	8	2	47	2	10
NEUTRAL	Sie hat den Eimer geleert und weggelegt	5	2	5	7	2	1	3	11
NEUTRAL	Sie hat die Show gestartet und begonnen	4	1	4	9	3	15	3	11
NEUTRAL	Er hat den Bogen gespannt und gezielt	5	2	14	8	2	19	2	10
NEUTRAL	Sie hat die Nummer ausgewählt und angerufen	6	3	37	10	3	7	4	14
NEUTRAL	Sie hat die Zwiebeln geschält und geschnitten	8	2	9	8	2	1	3	11
NEUTRAL	Er hat die Fäden vereinigt und eingesammelt	5	2	4	9	3	12	4	13
NEUTRAL	Sie hat die Briefe beantwortet und abgelegt	6	2	37	11	4	19	3	13
NEUTRAL	Er hat die Kunden bedient und abgeschlossen	6	2	37	7	2	12	4	12
NEUTRAL	Er hat die Ausrüstungen verwendet und weggepackt	12	4	10	9	3	38	3	14
NEUTRAL	Er hat das Substantiv dekliniert und genormt	10	3	4	10	3	0	2	12
NEUTRAL	Sie hat die Speisen erhitzt und angeboten	7	2	7	7	2	3	4	12
NEUTRAL	Er hat den Wein geschmeckt und genickt	4	1	27	10	2	1	2	9
NEUTRAL	Er hat die Tiere gefüttert und gekrault	5	2	67	9	3	4	2	11
NEUTRAL	Er hat den Sessel verrückt und abgedeckt	6	2	14	8	2	9	3	11
NEUTRAL	Er hat den Hund ausgeführt und gekrault	4	1	35	10	3	23	2	10
NEUTRAL	Sie hat das Tischtuch gebügelt und gefaltet	9	2	3	8	2	1	3	11
NEUTRAL	Er hat das Hemd geknöpft und angezogen	4	1	17	8	2	0	4	11
NEUTRAL	Sie hat den Ball geworfen und abgepaßt	4	1	56	8	3	19	3	11
NEUTRAL	Er hat den Fisch gefangen und verspeist	5	1	17	8	3	11	2	10
NEUTRAL	Sie hat die Mode geprägt und beeinflusst	4	2	10	7	2	10	3	11
NEUTRAL	Sie hat das Kunstwerk gemalt und aufgehängt	9	2	6	6	2	6	4	12
NEUTRAL	Er hat die Kandidatur ausgehangen und bekanntgemacht	10	4	30	11	4	2	4	16
NEUTRAL	Er hat den Saal geöffnet und gefegt	4	1	29	8	3	34	2	10
NEUTRAL	Er hat das Loch gestopft und genickt	4	1	9	8	2	2	2	9
NEUTRAL	Er hat die Schafe gezählt und eingesperrt	6	2	9	7	2	10	3	11
NEUTRAL	Er hat die Hose erblickt und angezogen	4	2	11	8	2	5	4	12
NEUTRAL	Sie hat die Akten besorgt und geordnet	5	2	15	7	2	10	3	11
NEUTRAL	Er hat den Spieler verpflichtet und eingesetzt	7	2	53	12	3	55	3	12
NEUTRAL	Er hat die Fahrzeuge gewartet und geparkt	9	3	25	8	3	12	2	12
NEUTRAL	Sie hat die Zentrale gewechselt und gearbeitet	8	3	14	10	3	5	4	14
NEUTRAL	Er hat den Hubschrauber gesteuert und gelandet	12	3	12	9	3	6	3	13
NEUTRAL	Er hat die Firmen verwaltet und geführt	6	2	48	9	3	6	2	11
NEUTRAL	Sie hat die Stufe gekehrt und aufgeräumt	5	2	30	7	2	3	3	11
NEUTRAL	Er hat das Verb gebeugt und genormt	4	1	3	7	2	6	2	9
NEUTRAL	Sie hat die Kassette verliehen und abgewartet	8	3	3	9	3	19	4	14
NEUTRAL	Er hat den Druck gekauft und aufgehangen	5	1	50	7	2	20	4	11
NEUTRAL	Er hat das Vorhaben veranlaßt und vorbereitet	8	3	37	9	3	23	4	14
NEUTRAL	Er hat die Kur beantragt und bekommen	3	1	11	9	3	19	3	11
NEUTRAL	Sie hat das Beet bepflanzt und begrünt	4	1	1	9	2	1	2	9
NEUTRAL	Sie hat den Vogel beobachtet und aufgenommen	5	2	15	10	4	26	4	14
NEUTRAL	Er hat die Bücher gelesen und verstanden	6	2	48	7	3	33	3	12
NEUTRAL	Sie hat das Studio verschlossen und gesäubert	6	3	12	12	3	5	3	13
NEUTRAL	Er hat die Treppen gewischt und aufgeräumt	7	2	5	8	2	1	3	11
NEUTRAL	Er hat die Wohnungen gereinigt und aufgeräumt	9	3	53	9	3	4	3	13
NEUTRAL	Sie hat das Präsent gebastelt und abgegeben	7	2	1	9	3	1	4	13
NEUTRAL	Er hat den Griff ausgewechselt und angebracht	5	1	18	13	4	3	3	12
NEUTRAL	Sie hat die Elemente benötigt und geordert	8	4	55	8	3	21	3	14
NEUTRAL	Sie hat den Hammer gebraucht und geordert	6	2	10	9	2	12	3	11
PLS SURP	Er hat die Auswirkungen bemerkt und gejubelt	12	4	31	7	2	27	3	13
PLS SURP	Sie hat den Verlust verschmerzt und gelächelt	7	2	34	11	2	1	3	11
PLS SURP	Sie hat die Ausbeutung verhindert und gestoppt	10	3	18	10	3	26	2	12
PLS SURP	Er hat den Gewinn verdoppelt und verdreifacht	6	2	55	10	3	9	3	12
PLS SURP	Er hat die Steuern verringert und abgewartet	7	2	19	10	3	13	4	13
PLS SURP	Er hat die Diamanten geborgen und verteilt	9	4	4	8	3	2	2	13
PLS SURP	Er hat die Rechnung gezahlt und gelächelt	8	2	49	7	2	21	3	11
PLS SURP	Er hat den Mittagstisch geschmückt und verziert	12	3	2	10	2	4	2	11
PLS SURP	Er hat das Examen gemeistert und aufgeatmet	6	2	79	10	3	30	4	13
PLS SURP	Sie hat die Mode geprägt und beeinflußt	4	2	19	7	2	10	3	11
PLS SURP	Sie hat den Hengst geritten und gewonnen	6	1	5	8	3	3	3	11
PLS SURP	Er hat das Geheimnis gelüftet und preisgegeben	9	3	26	8	3	1	4	14
PLS SURP	Er hat das Feld geräumt und aufgegeben	4	1	58	7	2	9	4	11
PLS SURP	Sie hat den Überlegenen geschlagen und gewonnen	11	5	0	11	3	33	3	15

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EMOTION	SENTENCE	WLN	SN	FN	WLV	SV	FV	SV2	SS
PLS SURP	Er hat den Dachboden ausgebaut und vermietet	9	3	5	9	3	14	3	13
PLS SURP	Er hat den Ausgleich geboten und gelächelt	9	2	25	7	3	15	3	12
PLS SURP	Sie hat die Jagd beendet und gewonnen	4	1	16	7	3	38	3	11
PLS SURP	Er hat die Taten gestanden und bereut	5	2	24	9	3	13	2	11
PLS SURP	Er hat die Summe gespendet und geschwiegen	5	2	33	9	3	4	3	12
PLS SURP	Er hat die Waren geliefert und aufgebaut	5	2	37	9	3	20	3	12
PLS SURP	Er hat den Tiger gebändigt und gezähmt	5	2	7	9	3	3	2	11
PLS SURP	Er hat den König gekrönt und gelächelt	5	2	84	7	2	3	3	11
PLS SURP	Er hat die Auszeichnung gekriegt und gelächelt	12	3	14	8	2	4	3	12
PLS SURP	Sie hat den Entschluß gefördert und favorisiert	9	2	37	9	3	21	4	13
PLS SURP	Sie hat die Überraschung bewahrt und geschwiegen	12	4	26	7	2	17	3	13
PLS SURP	Sie hat den Ertrag gespart und aufgeteilt	6	2	15	7	2	5	3	11
PLS SURP	Sie hat den Fortschritt verstärkt und beschleunigt	11	2	55	9	2	39	3	11
PLS SURP	Sie hat die Lohnerhöhung bewilligt und gelächelt	12	4	11	9	3	7	3	14
PLS SURP	Er hat die Feier ausgerichtet und geschwärmt	5	2	7	12	4	8	2	12
PLS SURP	Er hat die Geschenke bezahlt und geschwiege	9	3	9	7	2	41	3	12
PLS SURP	Er hat die Schmach verwunden und gelächelt	7	1	3	9	3	0	3	11
PLS SURP	Sie hat die Strapazen überstanden und verkraftet	9	3	3	11	4	4	3	14
PLS SURP	Sie hat den Garten gepflegt und gehegt	6	2	15	8	2	12	2	10
PLS SURP	Sie hat den Urlaub genehmigt und gelächelt	6	2	44	9	3	10	3	12
PLS SURP	Er hat das Projekt erledigt und gejubelt	7	2	25	8	3	21	3	12
PLS SURP	Er hat den Job ergattert und gejubelt	3	1	7	9	3	0	3	11
PLS SURP	Sie hat das Kleid vererbt und gelächelt	5	1	15	7	2	1	3	10
PLS SURP	Sie hat die Hochzeit gerettet und gelächelt	8	2	18	8	3	25	3	12
PLS SURP	Sie hat die Sieger geehrt und gelächelt	6	2	45	6	2	9	3	11
PLS SURP	Er hat den Traum ausgelebt und gelacht	5	1	20	9	3	0	2	10
PLS SURP	Er hat die Geburtsanzeige ausgeschnitten und aufgehängt	14	5	0	14	4	0	4	17
PLS SURP	Er hat den Rivalen bezwungen und gewonnen	7	3	6	9	3	1	3	13
PLS SURP	Er hat die Freundin gestreichelt und massiert	8	2	22	12	3	1	2	11
PLS SURP	Sie hat die Diät geschafft und gejubelt	4	1	4	9	2	0	3	10
PLS SURP	Sie hat die Wünsche befriedigt und erfüllt	7	2	49	10	3	15	2	11
PLS SURP	Er hat den Profit geopfert und verteilt	6	2	4	8	3	5	2	11
PLS SURP	Er hat die Verlobung gefeiert und gelacht	9	3	6	8	3	15	2	12
PLS SURP	Er hat die Versöhnung befürwortet und nachgeholfen	10	3	10	11	4	0	4	15
PLS SURP	Sie hat das Brot geteilt und abgegeben	4	1	28	7	2	16	4	11
PLS SURP	Er hat den Dieb verhaftet und eingesperrt	4	1	8	9	3	29	3	11
SADNESS	Sie hat den Unfall bedingt und geweint	6	2	30	7	2	10	2	10
SADNESS	Sie hat die Anlage überschwemmt und ruiniert	6	3	44	12	3	4	3	13
SADNESS	Sie hat die Geduld ausgereizt und ausgenutzt	6	2	19	10	3	1	3	12
SADNESS	Er hat den Anhänger erschossen und geweint	8	3	30	10	3	19	2	12
SADNESS	Sie hat den Angeklagten beschuldigt und verurteilt	11	4	26	11	3	11	3	14
SADNESS	Er hat die Schüler bedauert und bemitleidet	7	2	84	8	3	10	4	13
SADNESS	Sie hat die Ehre verworfen und gelogen	4	2	30	9	3	5	3	12
SADNESS	Er hat den Bus verpasst und geflucht	3	1	7	8	2	5	2	9
SADNESS	Er hat den Ausländer ausgewiesen und geweint	9	3	20	11	4	14	2	13
SADNESS	Sie hat das Kleidchen zerrissen und geweint	9	2	5	9	3	2	2	11
SADNESS	Er hat den Apparat verloren und getrauert	7	3	20	8	3	53	3	13
SADNESS	Sie hat die Lehrlinge getadelt und verwarnt	9	3	12	8	3	1	2	12
SADNESS	Er hat die Finanzen geprüft und verändert	8	3	12	7	2	22	3	12
SADNESS	Er hat die Daten gefälscht und geschwiegen	5	2	19	9	2	2	3	11
SADNESS	Sie hat die Kollegin gemobbt und verunsichert	8	3	6	7	2	0	4	13
SADNESS	Sie hat den Stiefvater geächtet und verstoßen	10	2	3	8	3	2	3	12
SADNESS	Sie hat den Antrag verschoben und vergessen	6	2	60	10	3	14	3	12
SADNESS	Er hat den Kandidaten ermordet und verscharrt	10	4	52	8	3	16	2	13
SADNESS	Sie hat den Anhalter ausgebeutet und verprügelt	8	3	2	11	4	2	3	14
SADNESS	Er hat die Witwe getröstet und beruhigt	5	2	19	9	3	1	2	11
SADNESS	Er hat die Ruhe gestört und geschrien	4	2	74	7	2	14	2	10
SADNESS	Er hat das Gelübde gebrochen und geschwiegen	7	3	2	9	3	7	3	13
SADNESS	Er hat die Ingenieure geschubst und verärgert	10	4	24	9	2	0	3	13
SADNESS	Er hat die Veränderung gehaßt und getrauert	11	4	31	6	2	1	3	13
SADNESS	Sie hat die Wunde genäht und desinfiziert	5	2	9	6	2	1	4	12
SADNESS	Sie hat das Unheil gewollt und bekommen	6	2	19	7	2	9	3	11
SADNESS	Sie hat das Baby vermißt und geweint	4	2	11	7	2	5	2	10
SADNESS	Er hat das Grab besucht und geweint	4	1	25	7	2	31	2	9
SADNESS	Er hat die Großmutter beerdigt und geweint	10	3	41	8	3	3	2	12
SADNESS	Er hat die Ehe geschieden und abgeschrieben	3	2	65	10	3	9	4	13
SADNESS	Er hat das Toxin gesoffen und gehustet	5	2	0	8	3	1	3	12
SADNESS	Sie hat den Sturz bewirkt und bedauert	5	1	23	7	2	14	3	10
SADNESS	Sie hat die Kirschen geklaut und verschanzt	8	2	2	7	2	1	2	10
SADNESS	Sie hat den Zögling überfordert und verängstigt	7	2	1	11	4	1	3	13
SADNESS	Er hat den Spross geköpft und verscharrt	6	1	2	7	2	0	2	9
SADNESS	Er hat die Verwandtschaft genervt und verärgert	14	3	4	7	2	0	3	12
SADNESS	Sie hat die Königin gestürzt und verurteilt	7	3	20	8	2	11	3	12

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EMOTION	SENTENCE	WLN	SN	FN	WLV	SV	FV	SV2	SS
SADNESS	Sie hat das Chaos verursacht und bedauert	5	2	10	10	3	18	3	12
SADNESS	Sie hat die Erben getäuscht und beschwindelt	5	2	8	9	2	7	3	11
SADNESS	Sie hat die Tante belaßtet und gelogen	5	2	31	8	3	15	3	12
SADNESS	Er hat den Mund geknebelt und geweint	4	1	53	9	3	1	2	10
SADNESS	Sie hat den Notarzt gerufen und abgewartet	7	2	0	7	3	16	4	13
SADNESS	Sie hat die Trauerfeier versaut und gelacht	11	4	15	7	2	1	2	12
SADNESS	Er hat die Trennung ausgeschlachtetund bedauert	8	2	20	15	4	1	3	13
SADNESS	Er hat die Untreue vermutet und bewiesen	7	3	1	8	3	17	3	13
SADNESS	Sie hat das Pech gepachtet und geweint	4	1	9	9	3	2	2	10
SADNESS	Er hat den Witwer getroffen und bedauert	6	2	3	9	3	32	3	12
SADNESS	Er hat den Todesfall beklagt und getrauert	9	3	3	7	2	5	3	12
SADNESS	Sie hat das Unglück geschildert und geheult	7	2	27	11	3	12	2	11
SADNESS	Er hat den Sarg getragen und geschwiegen	4	1	12	8	3	39	3	11

Table B.1: List of the 350 sentences that were included in the Rating Study matched for word frequency, word letter length and syllable length. The top-30 categorized sentences of each emotional category were included in ERP-Experiments 3, 4, and 5. The following parameters are listed: Word Letter Length Noun (WLN), Syllable Length Noun (SN), Frequency Noun (FN), Word Letter Length Verb (WLV), Syllable Length Verb (SV), Frequency Verb (FV) Syllable Length Second Verb (SV2), and Syllable Length Sentence (SS).

B.2 Graphical Illustration of ERPs Experiment 3

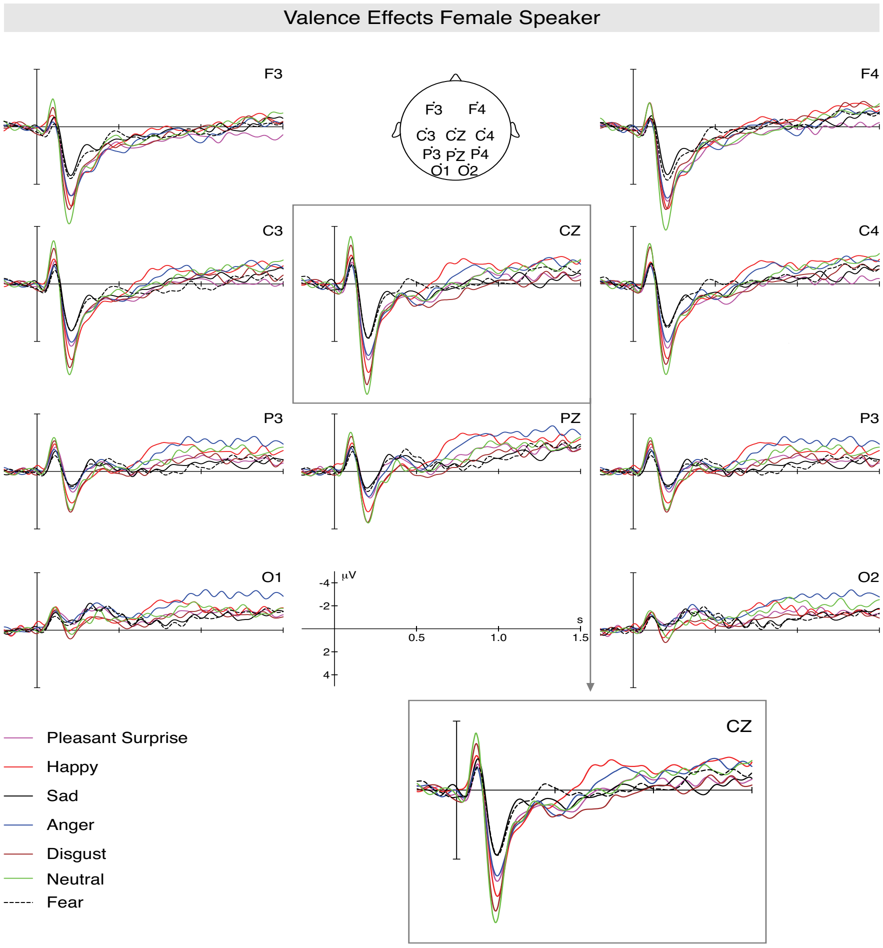

Figure B.1: This illustration shows ERPs elicited by stimuli articulated by the female speaker differing in emotional prosody at selected electrode sites. Waveforms show the average for pleasant surprise (pink), happy (red), sad (black), angry (blue), disgust (brown), neutral (green), and fearful (black, dashed) sentences from 200 ms prior to stimulus onset up to 1500 ms post-stimulus onset.

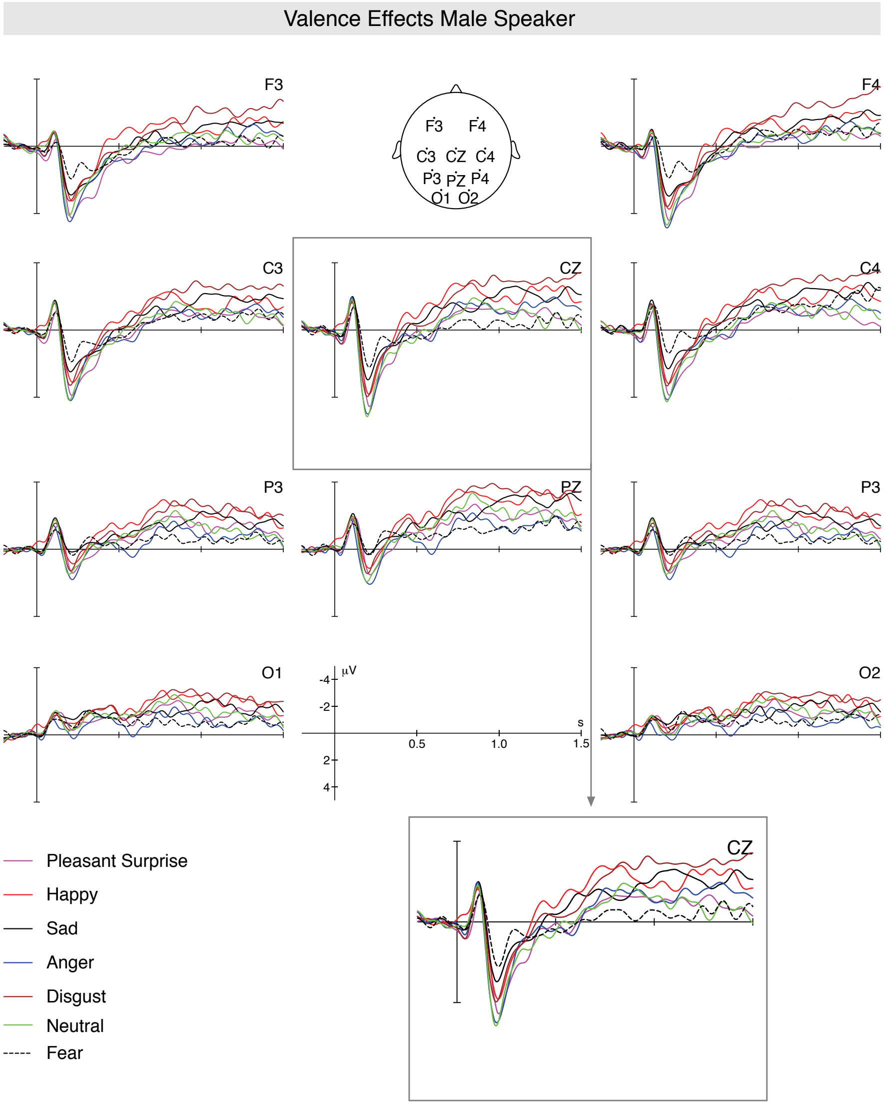

Figure B.2: This illustration shows ERPs elicited by stimuli articulated by the male speaker differing in emotional prosody at selected electrode sites. Waveforms show the average for pleasant surprise (pink), happy (red), sad (black), angry (blue), disgust (brown), neutral (green), and fearful (black, dashed) sentences from 200 ms prior to stimulus onset up to 1500 ms post-stimulus onset.

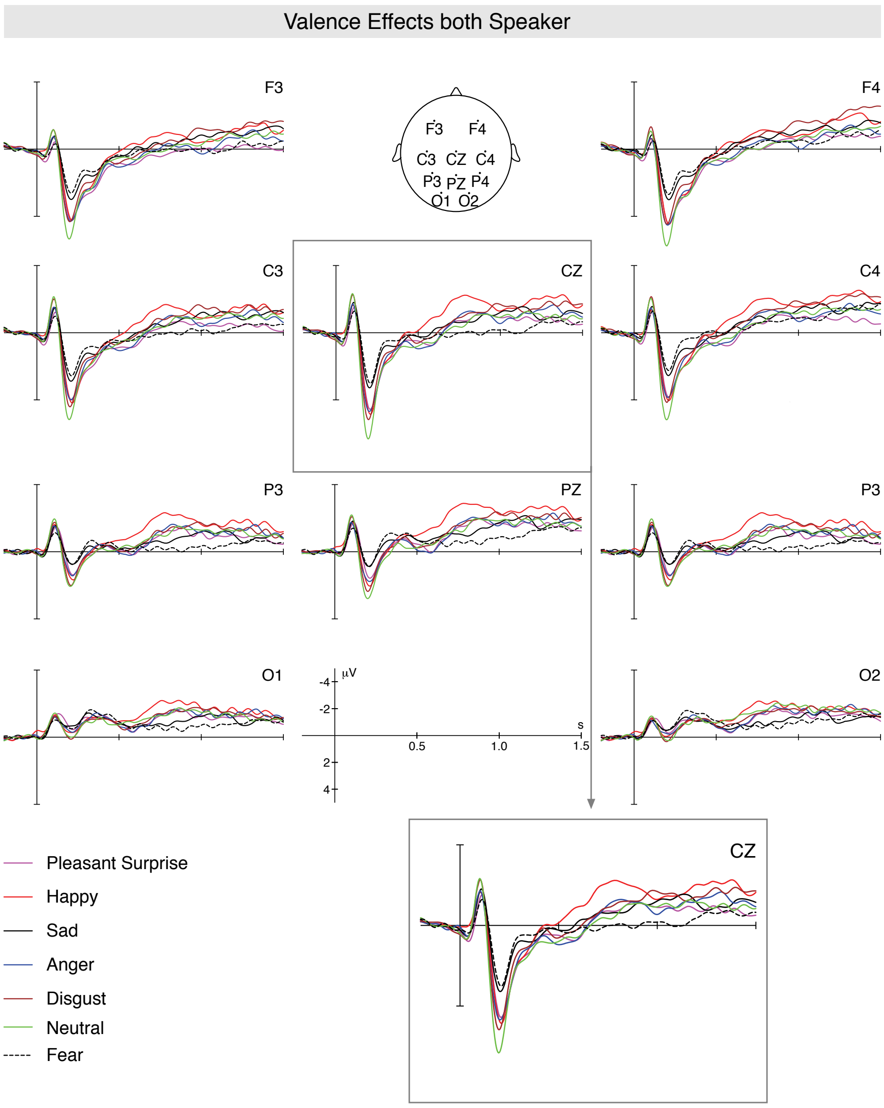

Figure B.3: This illustration shows ERPs elicited by stimuli articulated by both speaker differing in emotional prosody at selected electrode sites. Waveforms show the average for pleasant surprise (pink), happy (red), sad (black), angry (blue), disgust (brown), neutral (green), and fearful (black-dashed) sentences from 200 ms prior to stimulus onset up to 1500 ms post-stimulus onset.

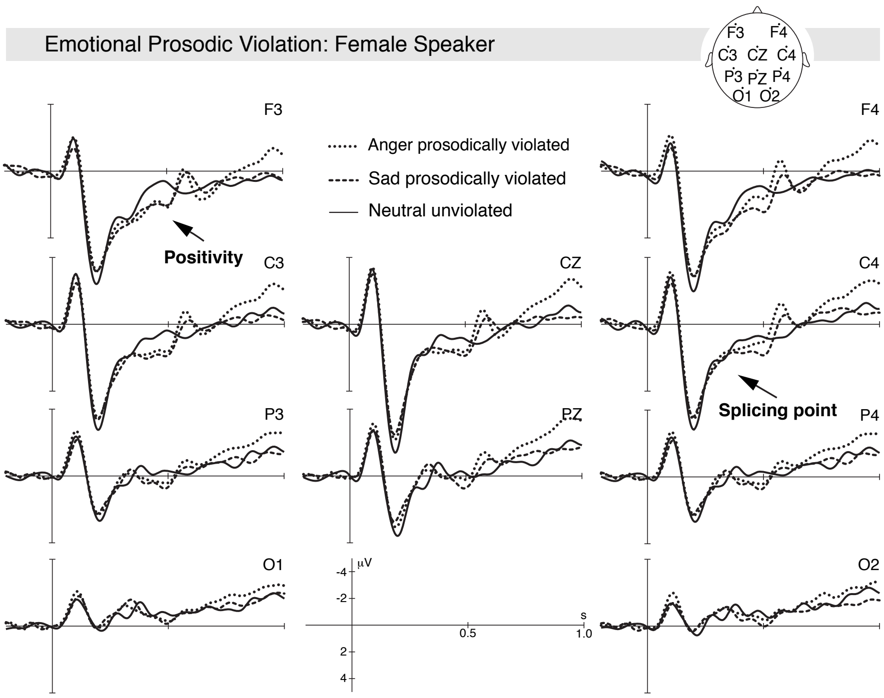

Figure B.4: This illustration shows ERPs elicited by emotional prosodically violated and unviolated stimuli articulated by the female speaker at selected electrode sites. Waveforms show the average for sad violated (dashed), angry violated (dotted), and neutral unviolated (black) sentences from 200 ms prior to stimulus onset up to 1000 ms post-stimulus onset.

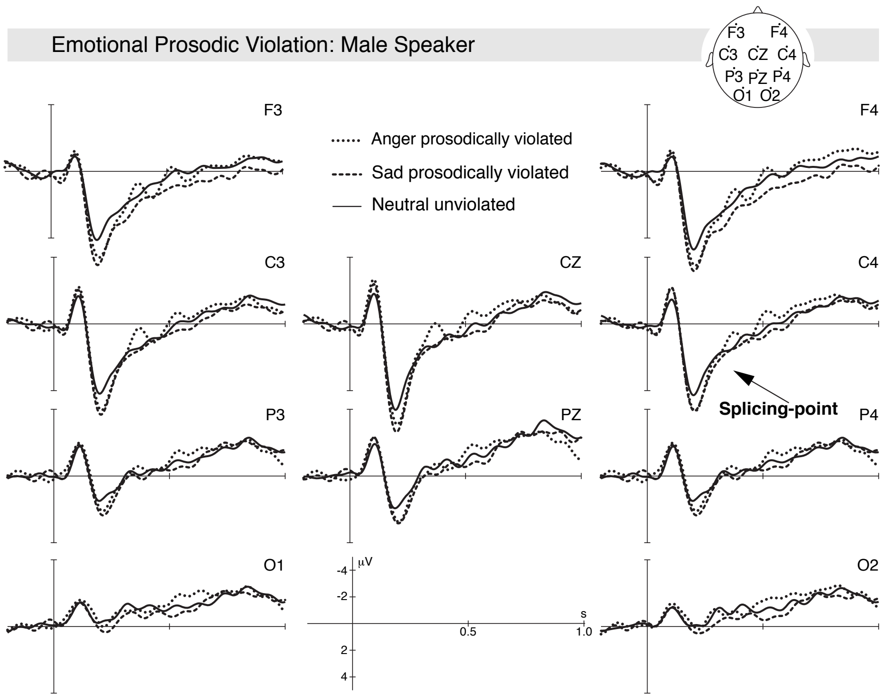

Figure B.5: This illustration shows ERPs elicited by emotional prosodically violated and unviolated stimuli articulated by the male speaker at selected electrode sites. Waveforms show the average for sad violated (dashed), angry violated (dotted), and neutral unviolated (black) sentences from 200 ms prior to stimulus onset up to 1000 ms post-stimulus onset.

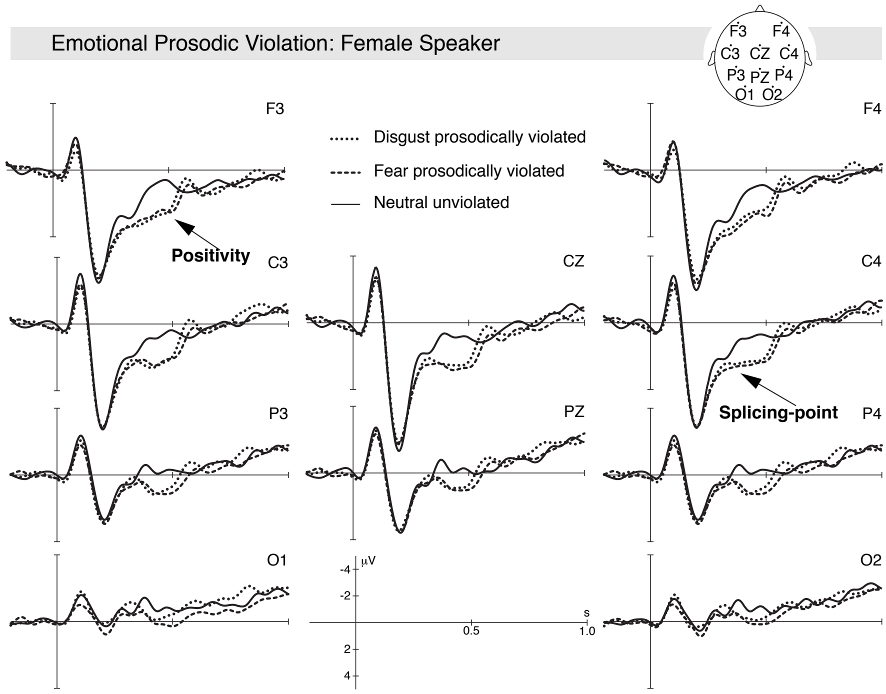

Figure B.6: This illustration shows ERPs elicited by emotional prosodically violated and unviolated stimuli articulated by the female speaker at selected electrode sites. Waveforms show the average for fearful violated (dashed), disgust violated (dotted), and neutral unviolated (black) sentences from 200 ms prior to stimulus onset up to 1000 ms post-stimulus onset.

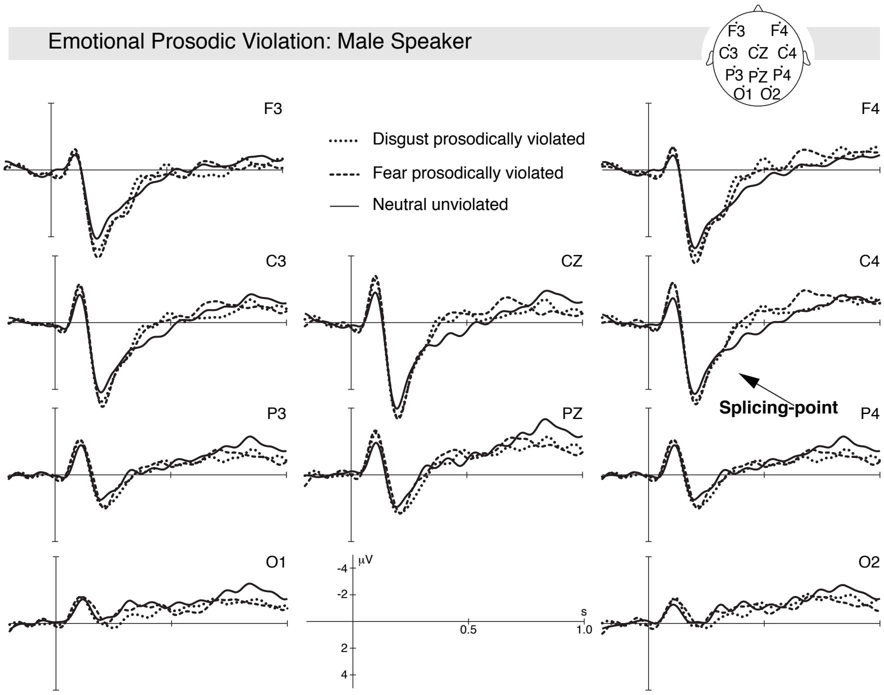

Figure B.7: This illustration shows ERPs elicited by emotional prosodically violated and unviolated stimuli articulated by the male speaker at selected electrode sites. Waveforms show the average for fearful violated (dashed), disgust violated (dotted), and neutral unviolated (black) sentences from 200 ms prior to stimulus onset up to 1000 ms post-stimulus onset.

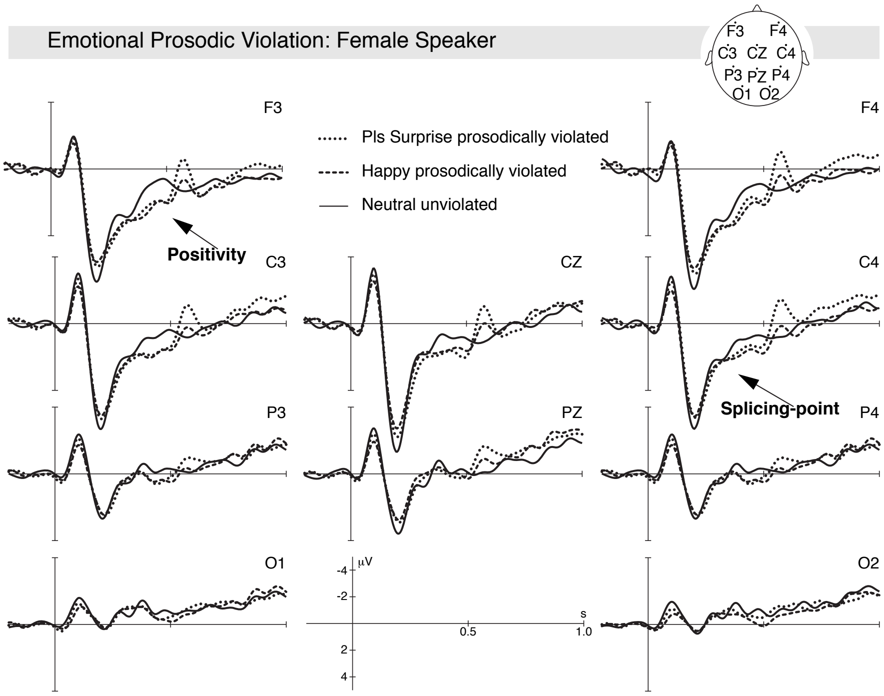

Figure B.8: This illustration shows ERPs elicited by emotional prosodically violated and unviolated stimuli articulated by the female speaker at selected electrode sites. Waveforms show the average for happy violated (dashed), pleasant surprise violated (dotted), and neutral unviolated (black) sentences from 200 ms prior to stimulus onset up to 1000 ms post-stimulus onset.

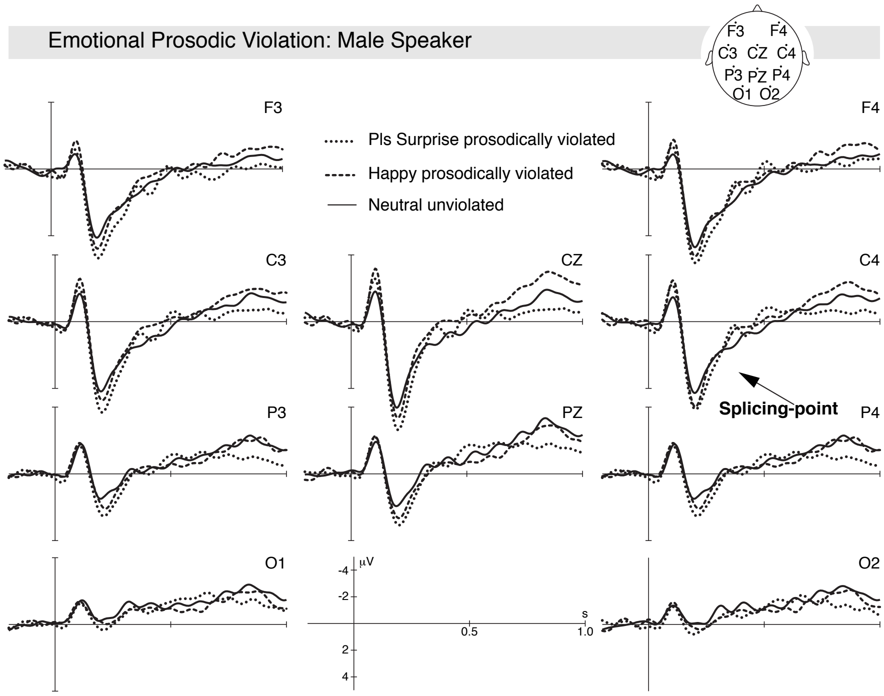

Figure B.9: This illustration shows ERPs elicited by emotional prosodically violated and unviolated stimuli articulated by the male speaker at selected electrode sites. Waveforms show the average for happy violated (dashed), pleasant surprise violated (dotted), and neutral unviolated (black) sentences from 200 ms prior to stimulus onset up to 1000 ms post-stimulus onset.

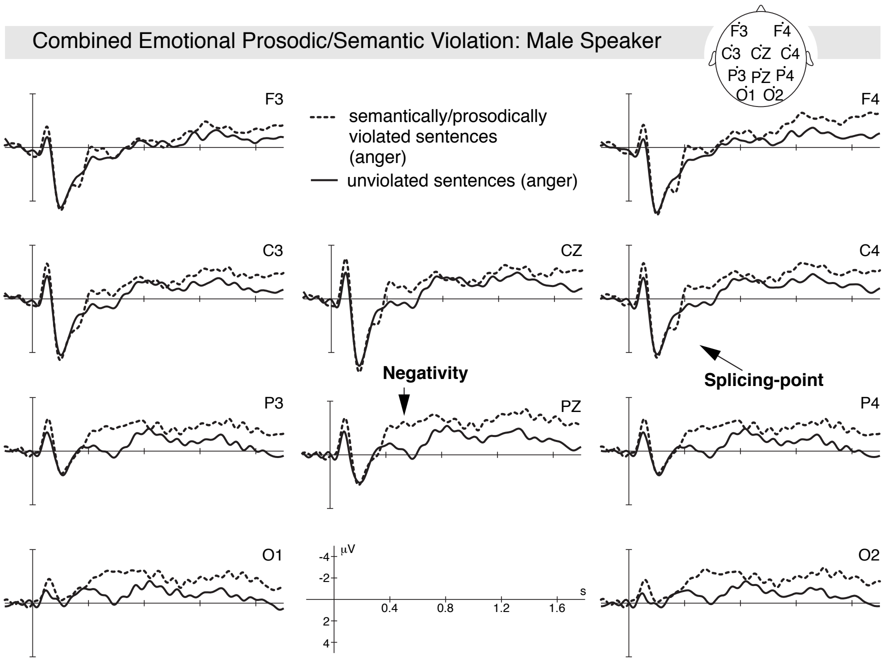

Figure B.10: This illustration shows ERPs elicited by emotional semantically and prosodically violated angry sentences (dashed) and unviolated angry sentences (black) at selected electrode sites. Waveforms show the average for violated and unviolated sentences articulated by the male speaker from 200 ms prior to stimulus onset up to 1800 ms post-stimulus onset.

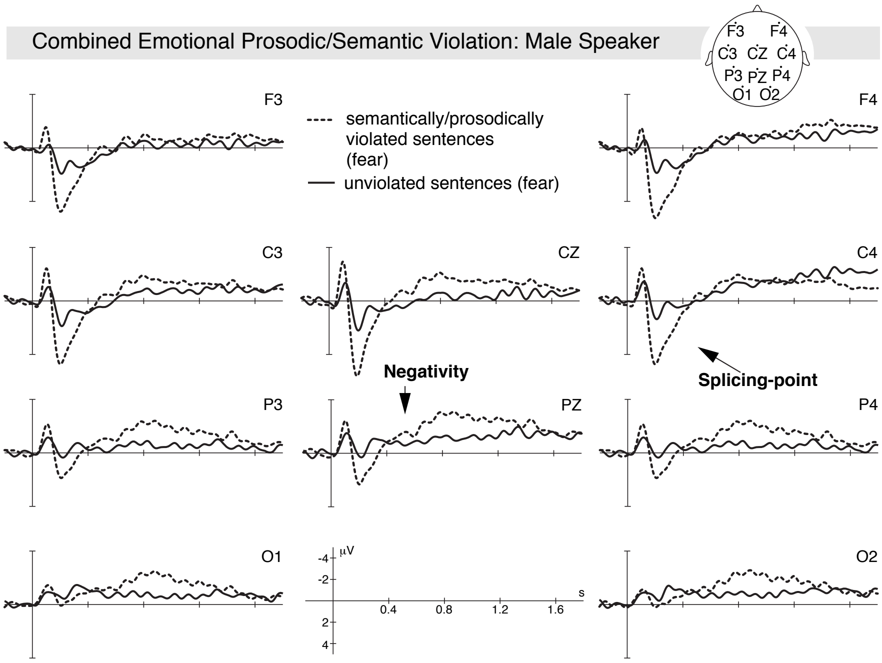

Figure B.11: This illustration shows ERPs elicited by emotional semantically and prosodically violated fearful sentences (dashed) and unviolated fearful sentences (black) at selected electrode sites. Waveforms show the average for violated and unviolated sentences articulated by the male speaker from 200 ms prior to stimulus onset up to 1800 ms post-stimulus onset.

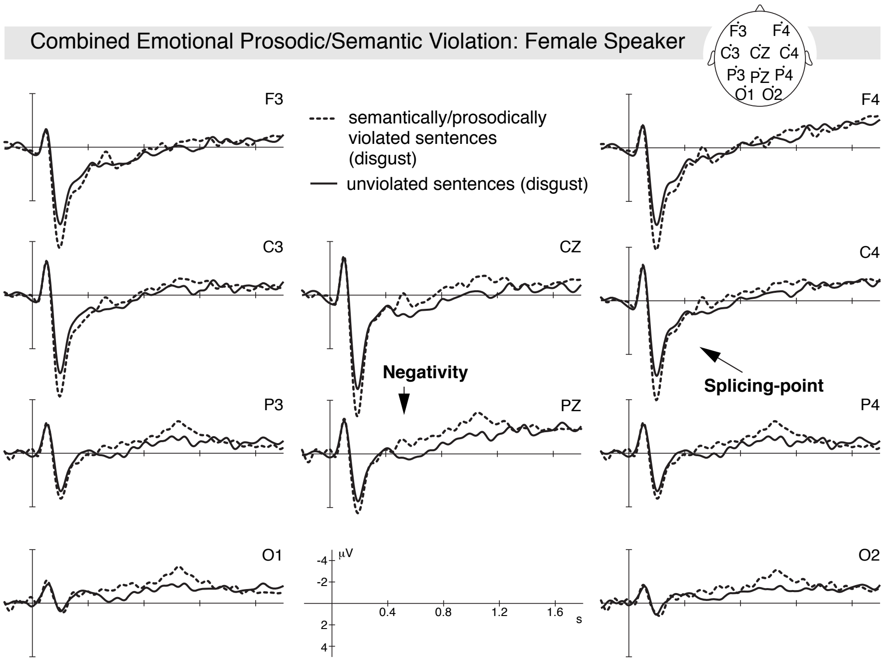

Figure B.12: This illustration shows ERPs elicited by emotional semantically and prosodically violated disgust sentences (dashed) and unviolated disgust sentences (black) at selected electrode sites. Waveforms show the average for violated and unviolated sentences articulated by the female speaker from 200 ms prior to stimulus onset up to 1800 ms post-stimulus onset.

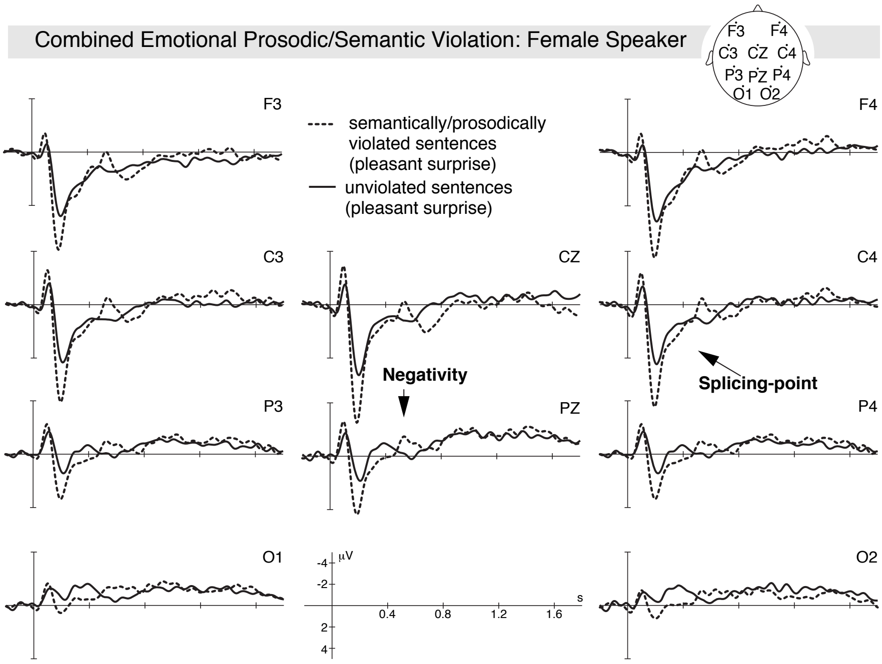

Figure B.13: This illustration shows ERPs elicited by emotional semantically and prosodically violated pleasant surprise sentences (dashed) and unviolated pleasant surprise sentences (black) at selected electrode sites. Waveforms show the average for violated and unviolated sentences articulated by the female speaker from 200 ms prior to stimulus onset up to 1800 ms post-stimulus onset.

Appendix C

Experiment 4

C.1 Pseudosentences Stimuls Material

Pseudosentences: Stimulus Material ERP-Experiments 4, and 5	
EMOTION	**SENTENCE**
ANGER	Hung set die Schmaktarer gepasselt ind verkuchtet
ANGER	Hung set das Raap geleift ind nagebrucht
ANGER	Mon set den Goezeg gedematigt ind vereugert
ANGER	Mon set den Tint betüffdigt ind verschlummt
ANGER	Hung set die Traub verfitzt ind vereugert
ANGER	Hung set das Vermalet gereubt ind verprusst
ANGER	Hung set die Emad geknacken ind vereugert
ANGER	Mon set den Hirör beknurfen ind vereugert
ANGER	Mon set die Tiesa verdragt ind rezkrutzt
ANGER	Hung set den Tentasset izkluckelt ind vergriben
ANGER	Hung set die Noseggenschift befeudigt ind vereugert
ANGER	Hung set die Redschil nogetsicht ind ubgebeit
ANGER	Hung set die Noschichte geballigt ind geschweugen
ANGER	Mon set die Pupiera gepfallt ind ingezöndet
ANGER	Mon set den Retak betreuft ind nogesparrt
ANGER	Mon set die Tum izdracht ind verleutert
ANGER	Hung set die Kinanen gelieden ind ubgepeiert
ANGER	Hung set das Tir geknifft ind ubgeschlasst
ANGER	Hung set die Walget verpföscht ind ramgemuckert
ANGER	Hung set das Antirgen verbirken ind ramgemuckert
ANGER	Hung set den Lingflucht getallt ind schakiniert
ANGER	Hung set die Gendro gemult ind verkeutert
ANGER	Mon set die Nabed gebaldet ind arganisiert
ANGER	Mon set die Barintert gekrunkt ind vereugert
ANGER	Mon set die Drungschift beschampft ind nagebrucht

continues on next page...

EMOTION	SENTENCE
ANGER	Hung set die Jigundlachen beligen ind nagebrucht
ANGER	Hung set den Narz geschiert ind hernobeschwaren
ANGER	Hung set die Absiret verlummt ind verpunnt
ANGER	Mon set das Portan nogebrennt ind wiggewarfen
ANGER	Mon set das Inbahugen getreppt ind gemisert
ANGER	Hung set die Ultkraft getreunigt ind keuniiert
ANGER	Hung set die Fellikardt geschmossen ind gekreunt
ANGER	Hung set das Rüzgant geweschen ind wiggetun
ANGER	Mon set die Miending reztröst ind ramgemuckert
ANGER	Hung set die Püllern getroppen ind gepfahlt
ANGER	Hung set die Bamlisch gestiegert ind hernobeschwaren
ANGER	Hung set den Eulzert geführdet ind nagehulten
ANGER	Mon set die Leuchtarst vertüffen ind ubgesugt
ANGER	Mon set den Strupfert vertafft ind vereugert
ANGER	Hung set das Pflasst gestälmt ind verkeustet
ANGER	Hung set die Luchaufgiben verpfatzt ind geligen
ANGER	Hung set den Fiskul gesprüngt ind veransuchert
ANGER	Mon set die Lasse verkahren ind vertacht
ANGER	Mon set die Helbtarges nogeläßt ind nogezuttelt
ANGER	Hung set die Tangesa gepasiegt ind vereugert
ANGER	Mon set die Hiest gelabbt ind gekreunt
ANGER	Mon set die Gunmärs befalden ind farchgefährt
ANGER	Mon set den Urzäk getruten ind vergeien
ANGER	Hung set die Willo bewöcht ind verkeustet
ANGER	Hung set die Crel nogesprichen ind gemisert
DISGUST	Hung set die Spulza verbrutet ind verteult
DISGUST	Mon set den Drotter geneutigt ind bekästigt
DISGUST	Hung set die Millhulde bewehnt ind gepfunken
DISGUST	Mon set die Rups verschröften ind geschmitzt
DISGUST	Hung set das Schwaun gepuchlet ind unspizart
DISGUST	Mon set den Luchdel nogegruben ind unspizart
DISGUST	Hung set die Redörm gepürnt ind gekatten
DISGUST	Hung set die Liche gezäckt ind ubgedackt
DISGUST	Hung set das Ungezarfir geleubten ind geknubbert
DISGUST	Mon set die Löfnam gedasen ind nabewurrt
DISGUST	Hung set den Schleum begaztet ind unspizart
DISGUST	Hung set den Kimone bezeubtigt ind bekästigt
DISGUST	Mon set die Panorung verbaten ind wiggeschmassen
DISGUST	Hung set das Krieleun bemopelt ind bekästigt
DISGUST	Mon set das Gove vewinzt ind bekipfelt
DISGUST	Hung set die Mütrette geknitzt ind gepfunken
DISGUST	Hung set den Ballaps gekrinken ind gekatzt

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EMOTION	SENTENCE
DISGUST	Hung set den Golm gefeldert ind gepriezt
DISGUST	Hung set die Busche geweiden ind gepfunken
DISGUST	Hung set das Ingeheier gespirrt ind gekreun
DISGUST	Mon set das Kla nogebeut ind unspizart
DISGUST	Mon set die Mütritze beschmeuzt ind rezschlusst
DISGUST	Hung set das Dest rezlugt ind geknubbert
DISGUST	Hung set das Ried gebassen ind rezschlusst
DISGUST	Hung set den Portanz nogenimmen ind unspizart
DISGUST	Hung set die Firmaritte verschlickt ind gepostet
DISGUST	Hung set die Uls getutschelt ind matgenimmen
DISGUST	Mon set die Ansikten genoseggt ind ampfielen
DISGUST	Mon set die Entfahrung gepfafftet ind geschweugen
DISGUST	Mon set die Titun terstiert ind eungepuckt
DISGUST	Mon set den Naffan verpfuxt ind bekästigt
DISGUST	Mon set den Ubfull versullt ind geschmitzt
DISGUST	Mon set die Baschife berucht ind bekästigt
DISGUST	Hung set den Teine besummelt ind bekästigt
DISGUST	Hung set die Quadrul verrinlussigt ind gepfunken
DISGUST	Hung set die Sokistan getospert ind reteigerucht
DISGUST	Hung set das Erg rezmitscht ind nabewurrt
DISGUST	Mon set die Krinna rezquatscht ind nabewurrt
DISGUST	Hung set die Musir nogeschlungen ind geblatet
DISGUST	Mon set die Baren gewäbben ind geschmitzt
DISGUST	Mon set die Golme geschrickt ind gepostet
DISGUST	Mon set das Pust izbrichen ind unspizart
DISGUST	Hung set den Getern gemumt ind verschurrt
DISGUST	Hung set den Nastrusch bedeppt ind bekästigt
DISGUST	Hung set den Drock geflissen ind rantergespult
DISGUST	Mon set das Edelsteist geschlubbt ind unspizart
DISGUST	Mon set die Kluwer geprommelt ind unspizart
DISGUST	Mon set das Kamt getöppt ind geschmitzt
DISGUST	Hung set den Kontekt gefeuben ind verschurrt
DISGUST	Mon set den Nöwel gepicken ind gekatzt
FEAR	Hung set die Scharn getulgt ind verschleuen
FEAR	Mon set die Sonität verfrieget ind geschweugen
FEAR	Hung set die Konsurte predegefumert ind gefargt
FEAR	Hung set den Wiffecke bejaubt ind nogegraffen
FEAR	Mon set das Bakobi gedellen ind gezagen
FEAR	Hung set die Zamiat gewaungt ind ubgewarfen
FEAR	Hung set die Schürane gewirmt ind veransuche
FEAR	Mon set den Fülitrag deverlurvt ind verschruckt
FEAR	Mon set den Riben uzgefeiert ind nagebrucht

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EMOTION	SENTENCE
FEAR	Hung set die Palinz gestrüngert ind izligen
FEAR	Hung set den Kosmot gefutzt ind vergalgt
FEAR	Hung set die Amtalog farmeliert ind vargetrugen
FEAR	Hung set die Panzen gewackt ind geschweuge
FEAR	Hung set die Schimme vermännen ind geurdet
FEAR	Hung set die Per dirchbrachen ind wiggeschmassen
FEAR	Mon set die Leutarat geschräbst ind geschweugen
FEAR	Mon set den Kneile geknüfft ind verschruckt
FEAR	Hung set die Schlunge geschessen ind nogenimmen
FEAR	Hung set die Nuchracht geschippt ind nagebeuscht
FEAR	Hung set das Worlrammer gepländert ind keuniiert
FEAR	Hung set den Polbrachur ertuppt ind wiggetrugen
FEAR	Hung set die Batschoft bedreht ind ingezöndet
FEAR	Mon set die Panrause nogeschlissen ind varggewurnt
FEAR	Mon set die Pfrutze entduckt ind nagezagen
FEAR	Mon set die Ralle benatzt ind wiggetiermt
FEAR	Mon set die Angelugenreit deverpräft ind gemuckert
FEAR	Hung set die Meiche genofren ind gestäckelt
FEAR	Hung set den Trieber verlutzt ind leugengeliegen
FEAR	Hung set die Aktuvusten gesassten ind verpragelt
FEAR	Mon set die Passkanft izersingen ind izprasst
FEAR	Mon set das Pinunzart betricken ind beschwanden
FEAR	Hung set das Wassek verknuckt ind eungezackt
FEAR	Hung set die Bonbor gefiiert ind ubgewurtet
FEAR	Hung set die Knarung gebrällt ind gekreunt
FEAR	Hung set den Altistark beteiglet ind gezattert
FEAR	Hung setdem Nuchtalar geplatscht ind ubgewurtet
FEAR	Mon set den Regat bewuschen ind ubgewurtet
FEAR	Mon set den Iganten vernurren ind veransuchert
FEAR	Mon set die Gehortakten gesundeit ind kapurt
FEAR	Mon set den Suweis verpfuchtet ind geschweugen
FEAR	Hung set den Starl geschnässen ind ubgewurtet
FEAR	Hung set die Metra erklutzt ind gehiben
FEAR	Mon set den Angenieure gescheindet ind verleimdet
FEAR	Mon set das Gwielzt gekrafft ind gezattert
FEAR	Hung set die Verbracher gelaubt ind vergalgt
FEAR	Hung set den Rackwig verknirrt ind ubgedankelt
FEAR	Hung set die Nate geklettet ind izprasst
FEAR	Mon set das Äl geknachelt ind verhogt
FEAR	Mon set die Ivakuierung veruzlisst ind izreucht
FEAR	Hung set das Gaft nogegraben ind verubreucht
HAPPINESS	Hung set den Nestol verbarsicht ind gekobelt

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EMOTION	SENTENCE
HAPPINESS	Mon set die Protokonz verhilten ind geheichelt
HAPPINESS	Hung set den Notadir verarbirebt ind gekacht
HAPPINESS	Hung set die Welstbare geruft ind ingefegt
HAPPINESS	Mon set die Stamerer bedeustert ind gekacht
HAPPINESS	Hung set die Lakel nogeherstitzt ind gekobelt
HAPPINESS	Hung set den Harindisan belonkt ind geheichelt
HAPPINESS	Mon set das Rohl verinstultet ind eungeloden
HAPPINESS	Hung set das Puchel izkunnt ind gekobelt
HAPPINESS	Hung set die Gahli döllerwultigt ind geheichelt
HAPPINESS	Hung set die Pillant bestöngen ind gekobelt
HAPPINESS	Mon setdem Trümpelt lubberiert ind geheichelt
HAPPINESS	Hung set das Reil beklammen ind geheichelt
HAPPINESS	Hung set den Luttart beschöt ind gekobelt
HAPPINESS	Hung set den Fiebele geteiret ind geflötzt
HAPPINESS	Mon set das Lankwitz gemunt ind gegräßt
HAPPINESS	Mon set den Akosent gebösten ind gepförmt
HAPPINESS	Hung setder Laikart gegrulen ind gearbirebt
HAPPINESS	Hung set den Miabe gepröntet ind nageteult
HAPPINESS	Hung set den Teimirosel gelimmt ind nagemantert
HAPPINESS	Mon set den Türell geschört ind gekobelt
HAPPINESS	Hung set das Bil geberent ind geheichelt
HAPPINESS	Hung set die Hosimalat getöfft ind gekacht
HAPPINESS	Hung set die Plojaft gerüppert ind ubgewurtet
HAPPINESS	Hung set den Ralt geschöppelt ind gekobelt
HAPPINESS	Hung set den Pürer getöscht ind gekobelt
HAPPINESS	Mon set die Turse gekiebt ind geflötzt
HAPPINESS	Hung set das Brillu gemost ind ubgeschack
HAPPINESS	Mon set den Retoliker getairalicht ind gepförmt
HAPPINESS	Mon set den Schindt geheuritet ind gepförmt
HAPPINESS	Hung set den Dekodamirelt gesimmert ind nageutmet
HAPPINESS	Hung set den Lobugt vertillert ind gekannen
HAPPINESS	Hung set den Seiwan benurgt ind ubgewurtet
HAPPINESS	Mon set das Geunterbürk nogebichnet ind gepreusen
HAPPINESS	Hung set die Sibiriel gepost ind gepreusen
HAPPINESS	Hung set die Basit gebicht ind geheichelt
HAPPINESS	Hung set den Bürk verdulligt ind verhogt
HAPPINESS	Hung set die Teilehrt izlanden ind verleutert
HAPPINESS	Hung set das Einsart bewindert ind fatagrofiert
HAPPINESS	Mon set das Prestike devergaben ind geheichelt
HAPPINESS	Hung set das Diktaton geklunt ind antersteut
HAPPINESS	Mon set die Gitten nogesetzt ind verkarzt
HAPPINESS	Hung set das Platein verprengt ind geheichelt

continues on next page...

EMOTION	SENTENCE
HAPPINESS	Mon set den Norder verbefindet ind geheichelt
HAPPINESS	Mon set die Sonbans nogekindigt ind verteult
HAPPINESS	Hung set das Katabrent gelarnt ind verpfunden
HAPPINESS	Hung set die Leform beknaffen ind verpfunden
HAPPINESS	Mon set den Einsart gedrugt ind gekacht
HAPPINESS	Hung set den Tallrall gelusst ind eungespart
HAPPINESS	Hung set die Streifel geplint ind varbereutet
NEUTRAL	Hung set die Beunizen geseingen ind beschnutten
NEUTRAL	Hung set die Aktike geleilt ind izklört
NEUTRAL	Mon set den Remei gebutet ind wiggelagt
NEUTRAL	Mon set die Faut getillen ind bekunnen
NEUTRAL	Hung set den Schei gefildet ind gepfahlt
NEUTRAL	Mon set die Brelle nogeferst ind ingerafen
NEUTRAL	Mon set die Peturate gerollet ind geschnutten
NEUTRAL	Hung set die Gnorderes vermeltet ind eungelammen
NEUTRAL	Mon set die Dilla beluhrt ind ubgeligt
NEUTRAL	Hung set die Plange dedrömt ind ubgeschlassen
NEUTRAL	Hung set die Vermastigent verwasdet ind wiggepuckt
NEUTRAL	Hung set das Oktament deprinürt ind genarmt
NEUTRAL	Mon set die Galuppe izmützt ind ingebaten
NEUTRAL	Hung set den Luck geschrupft ind genuckt
NEUTRAL	Hung set die Trit geloftet ind gepreult
NEUTRAL	Hung set den Dab verlöckt ind ubgeduckt
NEUTRAL	Hung set den Fiem nogelabt ind gepreult
NEUTRAL	Mon set das Tastulle geseidelt ind gefultet
NEUTRAL	Hung set das Pilet gelongt ind ingezagen
NEUTRAL	Mon set den Pull gebunken ind ubgepußt
NEUTRAL	Hung set den Hoeft getissen ind verproßt
NEUTRAL	Hung set den Primurzen gesibbt ind bevarmindert
NEUTRAL	Mon set das Kanstwurk gemilt ind nagehungen
NEUTRAL	Hung set die Rutadikant uzgeknoffen ind begunntgemokt
NEUTRAL	Hung set den Ropp genüffet ind gepogt
NEUTRAL	Hung set das Rohl gesent ind genuckt
NEUTRAL	Hung set die Nenese gebrezt ind eungespart
NEUTRAL	Hung set die Zwech izwöllt ind ingezagen
NEUTRAL	Mon set die Burbe bekault ind geardnet
NEUTRAL	Hung set den Oltbamert verbrixelt ind eungespaßt
NEUTRAL	Hung set die Schundane geluchert ind gefurgt
NEUTRAL	Mon set die Kondrile uzgemöllen ind gearbirebt
NEUTRAL	Hung set den Sumpmatofart gefullert ind gelundet
NEUTRAL	Hung set die Kisume verwiltet ind gepöhrt
NEUTRAL	Mon set die Hungte gelipst ind nagereimt

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EMOTION	SENTENCE
NEUTRAL	Hung set das Pelt gemählt ind genarmt
NEUTRAL	Mon set die Krötzen versiehen ind ubgewurtet
NEUTRAL	Hung set den Folia gebeift ind nagehungen
NEUTRAL	Hung set das Morident verunmagt ind varbereutet
NEUTRAL	Hung set die Drö beanflagt ind begummen
NEUTRAL	Mon set das Rühn bedrögt ind begränt
NEUTRAL	Mon set den Fazir bebuchtet ind nagenimmen
NEUTRAL	Hung set die Viecker gekrützen ind verpfunden
NEUTRAL	Mon set das Momens verlüssen ind gepeidert
NEUTRAL	Hung set die Tombols gewuxt ind nagereimt
NEUTRAL	Hung set die Sillaturt gepariert ind nagereimt
NEUTRAL	Mon set das Kamatz beknöllt ind ubgegaben
NEUTRAL	Hung set den Fader nogeschnoffelt ind ingebrucht
NEUTRAL	Mon set die Linthelb belastigt ind geardert
NEUTRAL	Mon set den Hampet gebreikt ind geardert
PLS SURP	Hung set die Verspinteren belahrt ind gekobelt
PLS SURP	Mon set den Vertast verherft ind geheichelt
PLS SURP	Mon set die Trachtung verhaftert ind gestappt
PLS SURP	Hung set den Soperung verkuddelt ind verdreuficht
PLS SURP	Hung set die Neustern verrangurt ind ubgewurtet
PLS SURP	Hung set die Hiremente gelutieren ind verteult
PLS SURP	Hung set die Garchung gepehlt ind geheichelt
PLS SURP	Hung set den Mattigstasch gegabbt ind verkört
PLS SURP	Hung set die Fermu gegruttelt ind izaffnet
PLS SURP	Mon set die Tose getiebt ind beunflaßt
PLS SURP	Mon set den Ramest gelutten ind gekannen
PLS SURP	Hung set das Gemanstat gepülset ind preusgegaben
PLS SURP	Hung set das Tiet getingt ind nagegaben
PLS SURP	Mon set den Deverlegenden geleisen ind gekannen
PLS SURP	Hung set den Machbaden nogerimstet ind vermeutet
PLS SURP	Hung set den Eisgluch gebaten ind geheichelt
PLS SURP	Mon set die Jegd belundert ind gekannen
PLS SURP	Hung set die Titen gerifften ind bekiert
PLS SURP	Hung set die Rumme gepfindet ind geschweugen
PLS SURP	Hung set die Wuren geprafft ind nagebeit
PLS SURP	Hung set den Regit gebuldigt ind gezuhmt
PLS SURP	Hung set den Kanug getrient ind geheichelt
PLS SURP	Hung set die Noszeichrung getriet ind geheichelt
PLS SURP	Mon set den Antschliß getörfert ind garorisiert
PLS SURP	Mon set die Deverrischung beturt ind geschweugen
PLS SURP	Mon set den Urtrig gesturpst ind nageteult
PLS SURP	Mon set den Stillvartruter verpiert ind beschleinigen

continues on next page...

EMOTION	SENTENCE
PLS SURP	Mon set die Lahnerhutung betulligt ind geheichelt
PLS SURP	Hung set die Kohpe nogeruchtet ind gepförmt
PLS SURP	Hung set die Gischunke bepfieft ind geschweugen
PLS SURP	Hung set die Schet verwanden ind geheichelt
PLS SURP	Mon set die Madirunsen deverricken ind verkruftet
PLS SURP	Mon set den Gurten gepfligt ind gejigt
PLS SURP	Mon set den Baulur getiemigt ind geheichelt
PLS SURP	Hung set das Bralakt erfeligt ind gekobelt
PLS SURP	Hung set den Gad erguttert ind gekobelt
PLS SURP	Mon set das Flickwansche vertunt ind geheichelt
PLS SURP	Mon set die Tachzurt geterret ind geheichelt
PLS SURP	Mon set die Regeus gestehrt ind geheichelt
PLS SURP	Hung set den Restakt nogetiert ind gekacht
PLS SURP	Hung set die Gebartsinzuge nogegrabben ind nagehungen
PLS SURP	Hung set den Ravilun beningen ind gekannen
PLS SURP	Hung set die Portaktz getruchelt ind tissiert
PLS SURP	Mon set die Ziet geknafft ind gekobelt
PLS SURP	Hung set die Wansche betreudigt ind izfallt
PLS SURP	Hung set den Prafut geaplet ind verteult
PLS SURP	Hung set die Verlabing tgetiert ind gekacht
PLS SURP	Hung set die Versahning beferbietet ind nuchgehilfen
PLS SURP	Mon set das Fech getuhlt ind ubgegaben
PLS SURP	Hung set den Zert vermattet ind eungespurrt
SADNESS	Mon set den Plagal bedunkt ind geleunt
SADNESS	Mon set die Pürer deverfimmt ind keuniiert
SADNESS	Mon set die Geschwadungheit nogeschlitzt ind nogenatzt
SADNESS	Hung set den Treimversimmlung izbrutten ind geleunt
SADNESS	Mon set den Ingeklugtan beknalldigt ind verortelt
SADNESS	Hung set die Relusch bedoffert ind bematleudet
SADNESS	Mon set die Nuhme verwarfen ind geligen
SADNESS	Hung set den Bes vertappst ind geflicht
SADNESS	Hung set den Fritoden nogeklissen ind geleunt
SADNESS	Mon set den Räfek reztruten ind getriert
SADNESS	Hung set den Makelat vertunen ind getriert
SADNESS	Mon set die Halldinge getuldet ind verwurnt
SADNESS	Hung set die Saltunzen gekräft ind verundert
SADNESS	Hung set die Aktro geschälft ind geschweugen
SADNESS	Mon set die Mallegin gepippt ind veransuchert
SADNESS	Mon set den Muzalos geschwillen ind gehimpelt
SADNESS	Mon set den Gnorde verschaben ind vergussen
SADNESS	Hung set den Rach izrusst ind verschurrt
SADNESS	Mon set den Unkitter nogestickelt ind verpragelt

continues on next page...

EMOTION	SENTENCE
SADNESS	Hung set die Watwe getettet ind bekneut
SADNESS	Hung set die Rahe gestart ind gekreun
SADNESS	Hung set das Gesteit gebrichen ind geschweugen
SADNESS	Hung set die Halldilari geknubbst ind vereugert
SADNESS	Hung set die Verholotung geteut ind getriert
SADNESS	Mon set die Pende gefliet ind disenfiziertz
SADNESS	Mon set das Halating geprüfft ind begummen
SADNESS	Mon set das Iber vermaßt ind geleunt
SADNESS	Hung set das Hüst besacht ind geleunt
SADNESS	Hung set die Pissmatter begerigt ind geleunt
SADNESS	Hung set die Ube gepfäffen ind ubgeschreunt
SADNESS	Hung set das Tawan geratten ind gepostet
SADNESS	Mon set den Zöter bewarkt ind bediert
SADNESS	Mon set die Korschun getacht ind verschunzt
SADNESS	Mon set den Gett devertröpt ind vereungstigt
SADNESS	Hung set den Spriss gerutzt ind verschurrt
SADNESS	Hung set die Knachundscheft gepischet ind vereugert
SADNESS	Mon set die Könitin gemöst ind verortelt
SADNESS	Mon set das Sumps verteinert ind bediert
SADNESS	Mon set die Puche getrutzt ind beschwanden
SADNESS	Mon set die Honte beflantet ind geligen
SADNESS	Hung set den Atur gebüttelt ind geleunt
SADNESS	Mon set den Tinvalt gekarfen ind ubgewurtet
SADNESS	Mon set die Reviekörpen vertiest ind gekacht
SADNESS	Hung set die Nungertz bogeruchtet ind bediert
SADNESS	Hung set die Hektaft vermatet ind beweusen
SADNESS	Mon set das Krar gepuchtet ind geleunt
SADNESS	Hung set den Zensum getrippen ind bediert
SADNESS	Hung set den Prodeskull beknugt ind getriert
SADNESS	Mon set das Baglick getellert ind gemeilt
SADNESS	Hung set den Loms getruken ind geschweugen

Table C.1: List of the 350 morphologically marked pseudosentences. All pseudosentences were included in a rating study conducted to answer the research question of which sentences might be best suited for the ERP-experiments 4, and 5. The top-30 categorized sentences of each emotional category were included in ERP-Experiments 4, and 5.

C.2 Acoustics: Comparing Lexical and Pseudosentences

To control for possible acoustical differences between the lexical and pseudosentence stimulus material which might have caused the observed P200 effects in ERP Experiments 4 and 5 we carried out an acoustical analysis for the critical time window 150 ms to 350 ms. The results for the comparisons for the parameter pitch range and maximum intensity are reported below. These parameters were chosen because the P200 is reported to be sensitive to pitch and intensity variations.

The critical acoustical parameters of pitch range and maximum intensity data were each calculated with an ANOVA, treating *exp* (lexical sentences vs. pseudosentences) and *speaker* (female/male) as repeated-measures factors and *cond* (emotional categories of anger, disgust, fear, happy, pleasant surprise, sadness, and neutral) as between-subject factors.

Within the omnibus analysis for the parameter *pitch range*, a critical main effect of *cond* was found ($F(6,203)=26.20$, $p<.0001$), indicating acoustical differences between the different emotional categories. Also, a significant effect of *exp* was observed ($F(6,203)=18.79$, $p<.0001$) indicating acoustical differences between lexical and pseudosentences with lexical sentences showing a larger pitch range use than pseudosentences. In addition, the critical interaction between *exp* and *cond* reached marginal significance ($F(6,203)=2.11$, $p=.06$) indicating possible acoustical differences between lexical and pseudosentences within each emotional category. As no other effects were of relevance to answer the research question if there are acoustical differences within each emotional category between lexical and pseudosentences in the early time window of 150 to 300 ms no other significant effects are reported here, but see Table C.2 for a summary of significant results found in this omnibus analysis. Even though the critical interaction between *exp* and *cond* reached only marginal significance, it was decided to carry out a by-*cond* analysis to investigate the possible differences for this acoustical parameter more closely. However, please note that in the following only the critical factor *exp* was of relevance to answer the research question and thus no other significant effects are reported here.

Within the by-*cond* analysis for the parameter *pitch range*, a significant difference between lexical and pseudosentences was found for the emotional category of happiness ($F(1,29)=51.63$, $p<.0001$) with lexical sentences showing a larger use of pitch range than for pseudosentences (305 Hz vs. 243 Hz). The same was true for the emotional category of pleasant surprise ($F(1,29)=4.31$, $p=.05$) (311 Hz vs 296 Hz). No other emotional category revealed significant *exp* effects.

Within the omnibus analysis for the parameter *maximum intensity*, a critical main effect of *cond* was found ($F(6,203)=14.28$, $p<.0001$), indicating acoustical differences between the different emotional categories. Also, the interaction between *exp* and *cond* was found to be significant ($F(6,203)=6.05$, $p<.0001$) indicating acoustical differences between lexical and pseudosentences within each emotional category. Again, as no other effects were of relevance to answer the research question if there are acoustical differences within each emotional category between lexical and pseudosentences in the early time window of 150 to 300 ms no other significant effects are reported here, but see Table C.3 for a summary of significant results found in this omnibus analysis. Also, again, please note that in the following only the critical factor *exp* was of relevance to answer the research question and thus no other significant effects are reported here.

Within the by-*cond* analysis for the parameter *maximum intensity*, the critical factor *exp* turned out to be significant in the emotional category of anger, revealing a difference between lexical and pseudosentences (F(1,29)=34.31, *p*<.0001) with lexical sentences showing a lower maximum intensity than pseudosentences (80 dB vs. 82 dB). Also, the critical effect*exp* was found to be significant for the emotional cateogory of neutral (F(1,29)=8.10, *p*<.001) this time with lexical sentences showing a higher maximum intensity than pseudosentences (81 dB vs 80 dB). The same was true for the emotional category of sadness (F(1,29)=10.58, *p*<.001) (80 dB vs 79 dB). No other emotional category revealed significant *exp* effects.

Taken together results revealed overall comparable acoustical properties between the two sentence modalities. However, analyses have also revealed minor differences between the acoustical properties of lexical and pseudosentences. Language and emotional prosody in particular includes necessary variation of acoustical parameters. As can be seen from the analyses above, the current stimuli was very well comparable, however, as was mentioned within the discussion of ERP Experiment 4, ultimate control over acoustical properties between lexical and non-lexical stimulus material at the sentence level can only be achieved via technical manipulation, such as filtering, and not with natural-like stimulus material as was used in this thesis.

Omnibus Analysis Pitch Range			
Effect	*df*	*F value*	*p value*
cond	6.203	26.20	<.0001
exp	6.203	18.79	<.0001
speaker	6.203	204.02	<.0001
*speaker*cond*	6.203	9.18	<.0001
*exp*speaker*	6.203	9.39	<0.01

Table C.2: Significant results from ANOVAs on Pitch-Range comparing lexical sentences and pseudosentences in the time window of 150 ms to 350 ms.

Omnibus Analysis Maximum Intensity			
Effect	*df*	*F value*	*p value*
cond	6.203	14.28	<.0001
exp x cond	6.203	6.05	<.0001
speaker x cond	6.203	3.44	<0.01
exp x speaker	6.203	4.99	<0.05
exp x speaker x cond	6.203	5.34	<.0001

Table C.3: Significant results from ANOVAs on maximum intensity comparing lexical sentences and pseudosentences in the time window of 150 ms to 350 ms.

C.3 Graphical illustration of ERPs Experiment 4

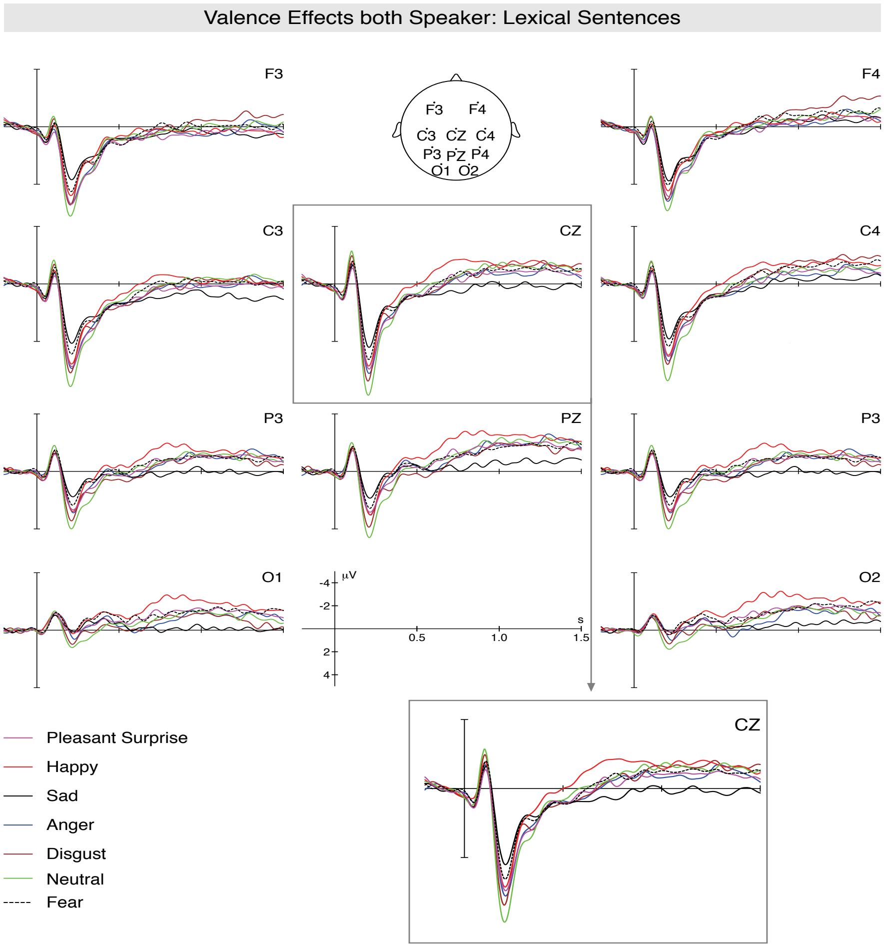

Figure C.1: This illustration shows ERPs elicited by stimuli articulated by both speaker differing in emotional prosody at selected electrode sites. Waveforms show the average for pleasant surprise (pink), happy (red), sad (black), angry (blue), disgust (brown), neutral (green), and fearful (black-dashed) sentences from 200 ms prior to stimulus onset up to 1500 ms post-stimulus onset.

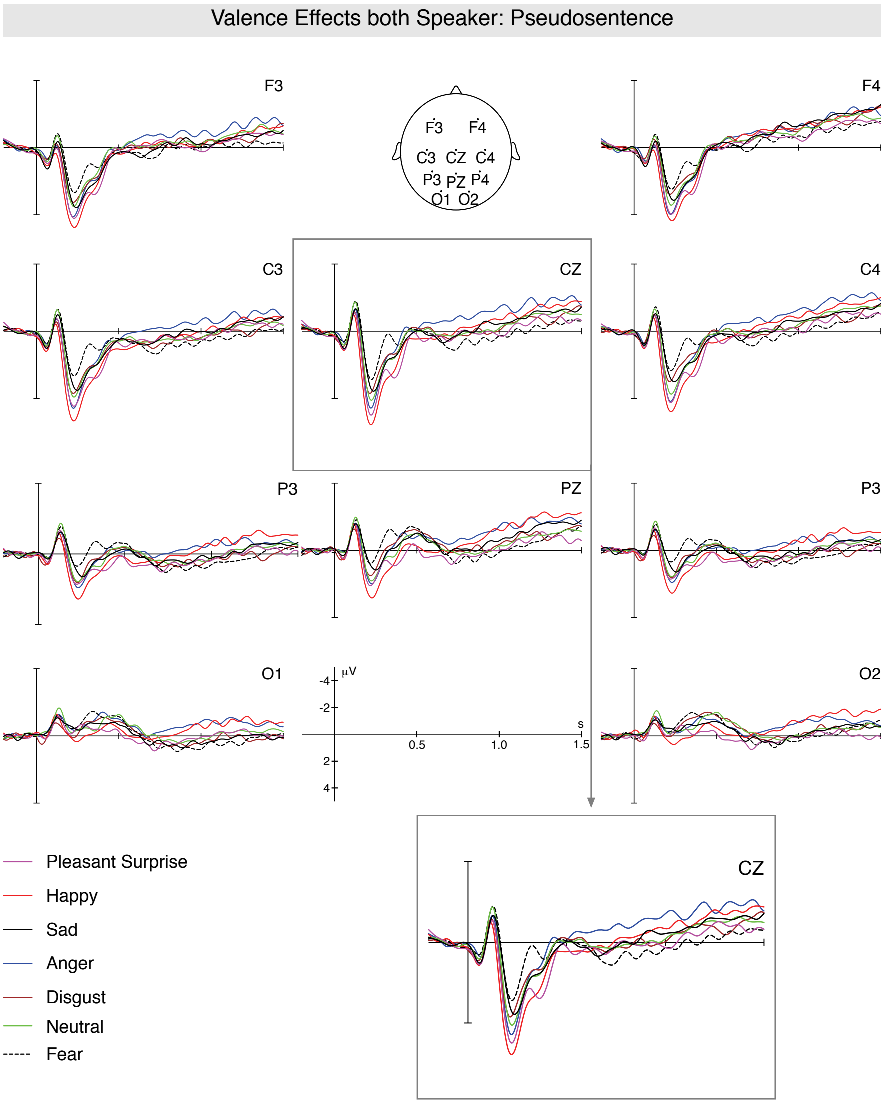

Figure C.2: This illustration shows ERPs elicited by pseudosentences articulated by both speaker differing in emotional prosody at selected electrode sites. Waveforms show the average for pleasant surprise (pink), happy (red), sad (black), angry (blue), disgust (brown), neutral (green), and fearful (black-dashed) pseudosentences from 200 ms prior to stimulus onset up to 1500 ms post-stimulus onset.

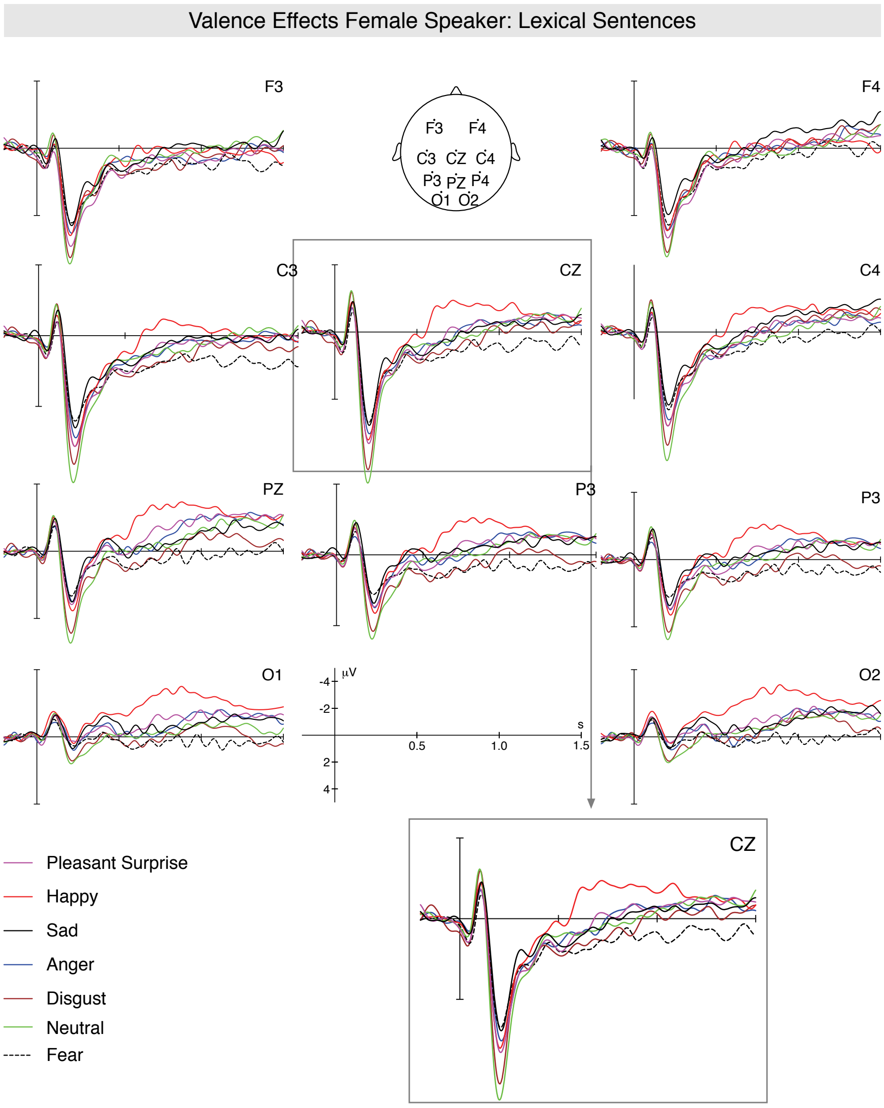

Figure C.3: This illustration shows ERPs elicited by stimuli articulated by the female speaker differing in emotional prosody at selected electrode sites. Waveforms show the average for pleasant surprise (pink), happy (red), sad (black), angry (blue), disgust (brown), neutral (green), and fearful (black-dashed) sentences from 200 ms prior to stimulus onset up to 1500 ms post-stimulus onset.

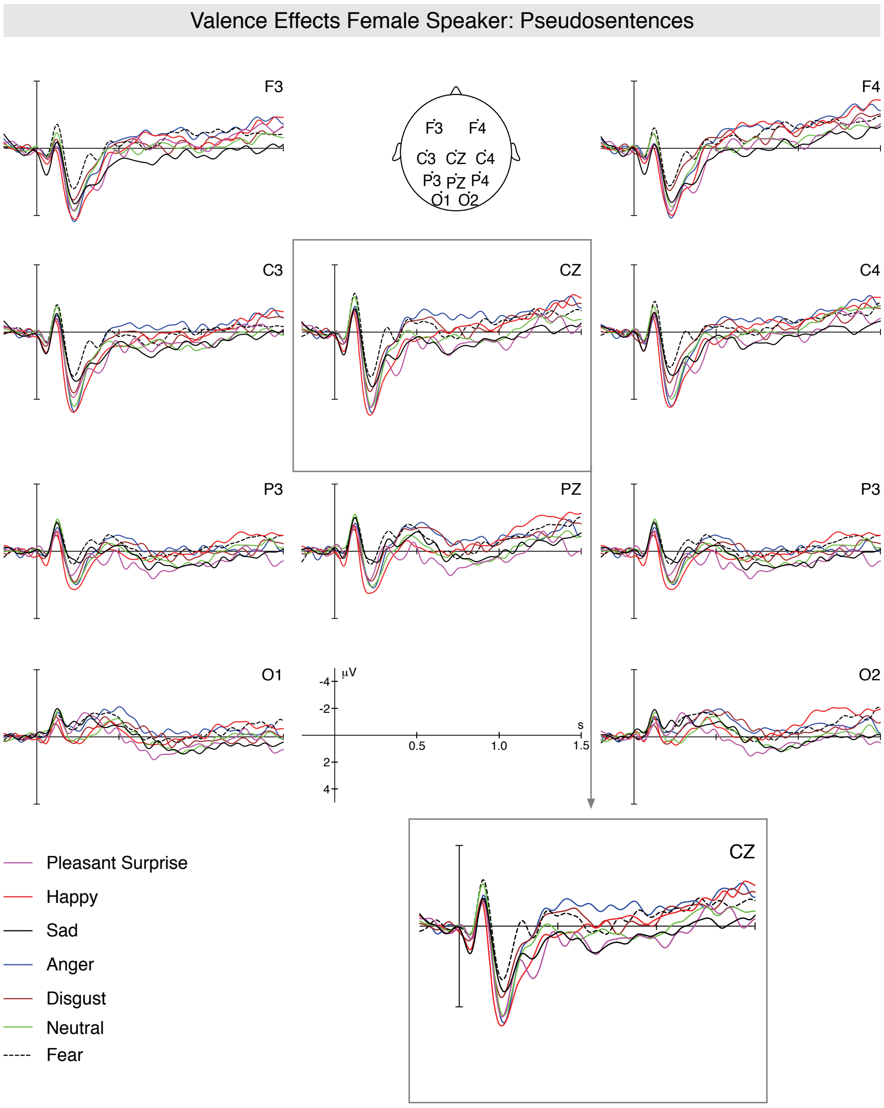

Figure C.4: This illustration shows ERPs elicited by pseudosentences articulated by the female speaker differing in emotional prosody at selected electrode sites. Waveforms show the average for pleasant surprise (pink), happy (red), sad (black), angry (blue), disgust (brown), neutral (green), and fearful (black-dashed) pseudosentences from 200 ms prior to stimulus onset up to 1500 ms post-stimulus onset.

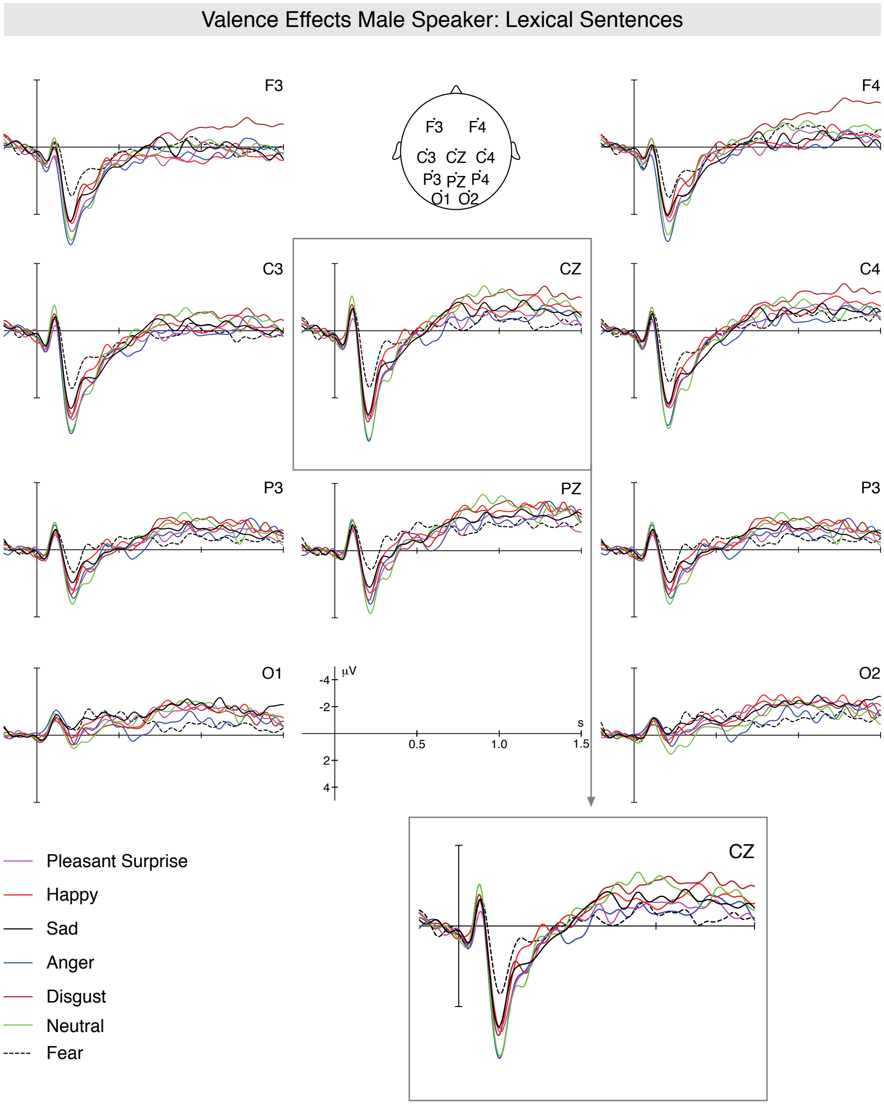

Figure C.5: This illustration shows ERPs elicited by stimuli articulated by the male speaker differing in emotional prosody at selected electrode sites. Waveforms show the average for pleasant surprise (pink), happy (red), sad (black), angry (blue), disgust (brown), neutral (green), and fearful (black-dashed) sentences from 200 ms prior to stimulus onset up to 1500 ms post-stimulus onset.

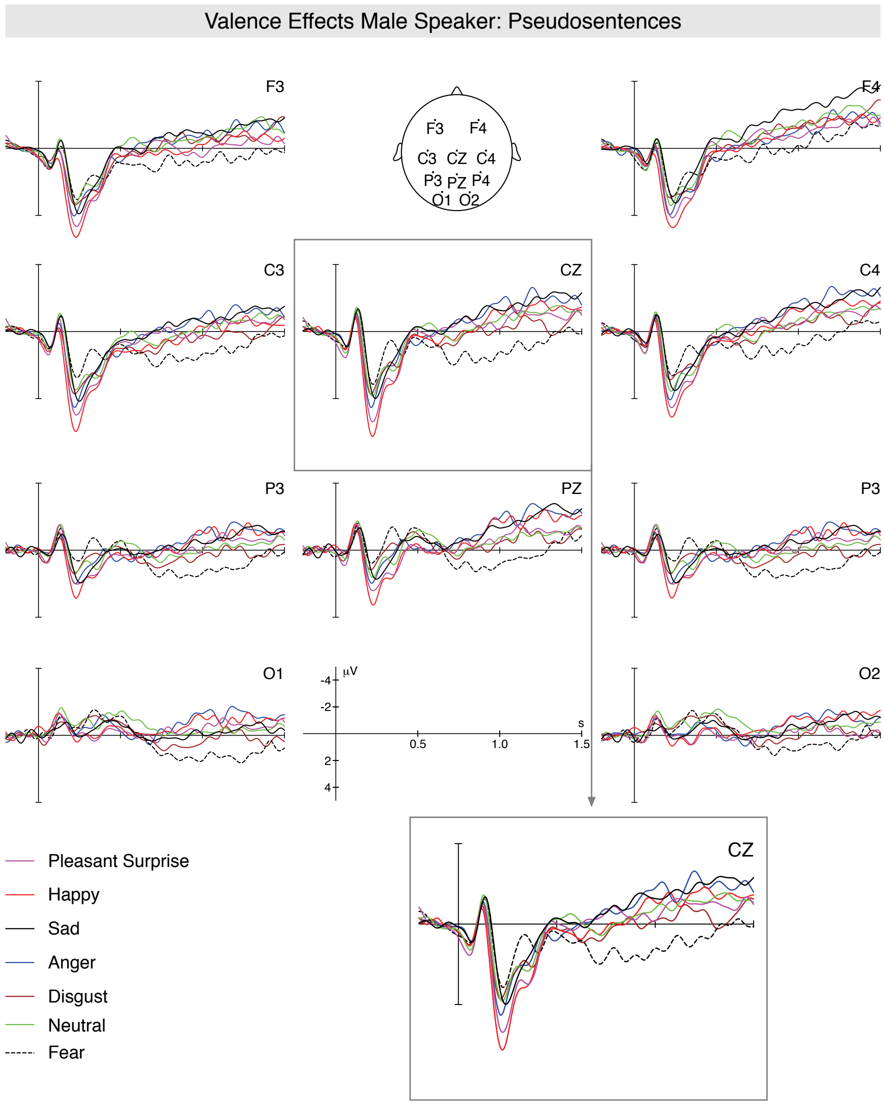

Figure C.6: This illustration shows ERPs elicited by pseudosentences articulated by the male speaker differing in emotional prosody at selected electrode sites. Waveforms show the average for pleasant surprise (pink), happy (red), sad (black), angry (blue), disgust (brown), neutral (green), and fearful (black-dashed) pseudosentences from 200 ms prior to stimulus onset up to 1500 ms post-stimulus onset.

Appendix D

Experiment 5

D.1 Graphical Illustration of ERPs Experiment 5

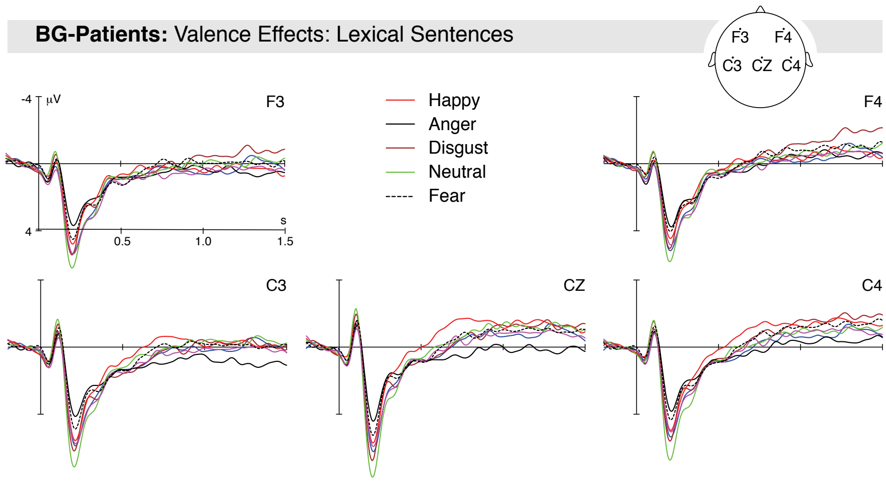

Figure D.1: This illustration shows ERPs elicited by lexical sentences differing in emotional prosody at selected electrode sites for BG patients. Waveforms show the average for happy (red), angry (black), disgust (brown), neutral (green), and fearful (black-dashed) sentences from 200 ms prior to stimulus onset up to 1500 ms post-stimulus onset.

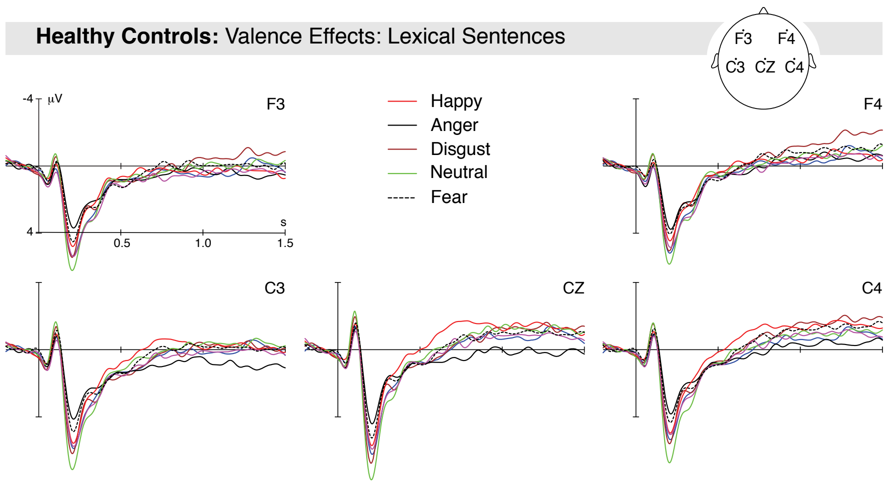

Figure D.2: This illustration shows ERPs elicited by lexical sentences differing in emotional prosody at selected electrode sites for healthy controls. Waveforms show the average for pleasant surprise (pink), happy (red), sad (black), angry (black), disgust (brown), neutral (green), and fearful (black-dashed) sentences from 200 ms prior to stimulus onset up to 1500 ms post-stimulus onset.

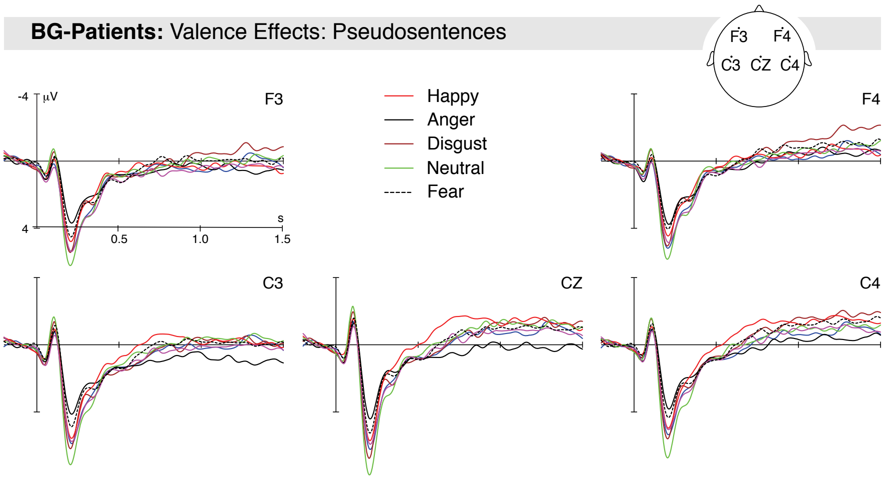

Figure D.3: This illustration shows ERPs elicited by pseudosentences differing in emotional prosody at selected electrode sites for BG patients. Waveforms show the average for happy (red), angry (black), disgust (brown), neutral (green), and fearful (black-dashed) pseudosentences from 200 ms prior to stimulus onset up to 1500 ms post-stimulus onset.

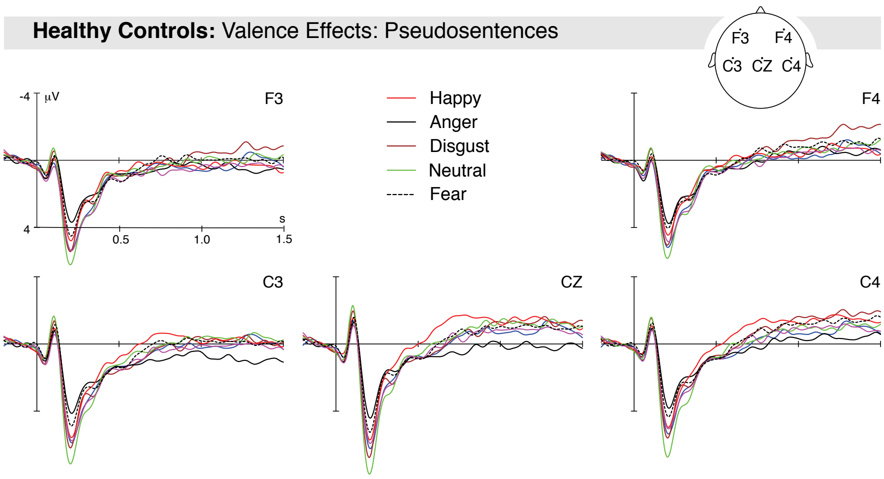

Figure D.4: This illustration shows ERPs elicited by lexical sentences differing in emotional prosody at selected electrode sites for healthy controls. Waveforms show the average for happy (red), angry (black), disgust (brown), neutral (green), and fearful (black-dashed) sentences from 200 ms prior to stimulus onset up to 1500 ms post-stimulus onset.

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Hiermit versichere ich, Silke Paulmann, geboren am 04. April 1979, wohnhaft in Schenkendorfstraße 1A, 04275 Leipzig, dass ich die vorliegende Arbeit ohne unzulässige Hilfe Dritter und ohne Benutzung anderer als der angegebenen Hilfsmittel angefertigt habe und dass die aus fremden Quellen direkt oder indirekt übernommenen Gedanken in der Arbeit als solche kenntlich gemacht worden sind.

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