

MOVING EMOTIONS

An examination of the role of facial mimicry
in emotion understanding



STEPHANIE BLOM

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Moving Emotions:

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Emoties doen bewegen

Een onderzoek naar de rol van gezichtsexpressie nabootsing in het begrijpen van emoties
(met een samenvatting in het Nederlands)

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Chapter 1

Introduction and Overview

This dissertation deals with the way people process emotions they observed in others. Human interaction relies heavily on emotional information. For instance, others can tell us explicitly how they feel or think about something. However, such situations of explicit sharing of internal states are not very frequent (see however Rimé, 2009). How then do we know how others feel and what their concerns are? Often, our attention naturally goes towards their facial expression.

Consider for example the following situation: you are in a crowded and loud environment, and it is impossible to understand what someone is saying. Probably the main thing you will be focusing on is this person's facial expression in order to get an idea of their feelings and thoughts. In other everyday situations in life this is no different, and it undoubtedly comes as no surprise that emotional understanding is a rather fundamental human ability. For example, people base rapid inferences on facial information (e.g., Todorov, Olivola, Dotsch & Mende-Siedlecki, 2015) and can produce thousands of different combinations of contractions of facial muscles (e.g., Ekman & Friesen, 1976). Furthermore, even newborn infants already show a preference for faces and stimuli that look like faces (Johnson, 2005), suggesting that the expressive elements of the human face have evolved in a manner that facilitates emotion transmission (e.g., Kret, 2015; Kret, Prochazkova, Sterck & Clay, 2020). The ability to engage in such a wide diversity of emotional processing underlines the importance of the human face in emotional expression and social interaction.

Interestingly, emotion research suggests that the face serves a dual function: We not only use our facial movements to express what we feel, but also to *simulate* emotional information we perceive, a process which is often also referred to as facial simulation or facial mimicry. Numerous studies have shown that perceiving and processing of various types of emotional stimuli (e.g., facial expressions) can activate the observer's own facial muscles (e.g., Dimberg, Thunberg & Grunedal, 2002), often in line with the valence of the observed emotion.

The role of facial mimicry in social interaction has been explained in two main ways. One explanation addresses the social-affective nature of emotions and centers around the idea that facial mimicry reflects the process of mutual liking that promotes affiliation and social bonding (cf. Chartrand & Bargh, 1999; Hatfield, Cacioppo, & Rapson, 1992; Hess & Fischer, 2014; Lakin & Chartrand, 2003; Stel & Vonk, 2010). Specifically, it has been argued that observation of another's emotional expressions either triggers the subjective experience of the corresponding emotion in the observer which then elicits facial mimicry, or that it elicits facial

mimicry in the observer, which in turn triggers the corresponding emotion (cf. Lundqvist & Dimberg, 1995). Another general explanation for facial mimicry takes a more social cognitive account, according to which facial mimicry reflects an internal simulation of the perceived facial expression to facilitate understanding of others' emotion (Atkinson & Adolphs, 2005; Niedenthal, 2007; Niedenthal, Brauer, Halberstadt, & Innes-Ker, 2001; Wallbott, 1991).

The present thesis addresses the question of whether and when facial mimicry occurs and serves as input for emotion understanding. Research has treated facial mimicry as a rather natural and automatic process, that seems to inform observers about the emotional state of others in a rather straightforward way. The present research aims to scrutinize this issue in more detail. I therefore examined the role of facial mimicry in emotion understanding by not only examining individuals with normal facial functioning, but also by examining individuals who are impaired in their facial functioning, either due to temporal (e.g., Botox injections) or more chronic (e.g., facial palsy) conditions. This way, I attempt to contribute to a better understanding and examination of the importance of facial mimicry in social interaction and well-being. Before I outline the remaining part of the dissertation, I shall briefly introduce the theoretical and empirical background that forms the basis for the present thesis.

From facial mimicry to emotion understanding: An embodied cognition perspective

Understanding the emotions of others often requires some conceptual knowledge about internal states underlying facial expressions (e.g., Castro, Cheng, Halberstadt & Grühn, 2016; Ekman & Keltner, 1997; Izard, 1992; Oatley & Johnson-Laird, 1987). For instance, seeing an uplifted position of the zygomaticus major in the face -the muscle used for smiling- is associated with happiness, and a downward position of the corrugator supercilii -the muscle used for frowning- is associated with negative emotions such as anger. While observing specific facial expressions might frequently go together with specific mental representations and emotional meaning, a pure cognitive account for such concept learning has been challenged (e.g., Barsalou, 1999; 2008; Feldman Barrett & Lindquist, 2008; Niedenthal, 2007). One specific challenge concerns the question how concepts (including emotional meaning) are learned and represented.

Earlier cognitive accounts consider concepts to emerge from the existence of discrete, internal representations realized by underlying, sharply distinct and highly specified mechanisms in the brain. Whereas the initial cognitive account of concept learning has

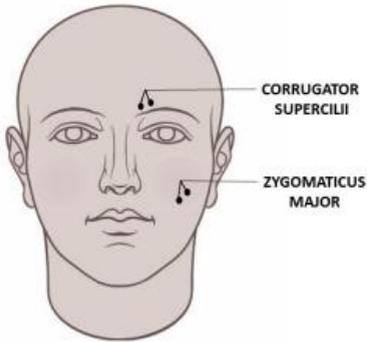
produced substantial advances in the study of the mind (e.g., symbolic processing, reasoning, language comprehension and production), some researchers questioned how conceptual knowledge can emerge within the confines of biological processes and how they are grounded in the body (including the brain). Consequently, several streams of theories and research proposed an alternative view to conceptual representations that acknowledges the importance of the relation between body and environment in shaping knowledge about and evaluating the world, a framework generally known as embodied cognition. According to embodied cognition theories, the brain and body coevolved in an adaptation to the environment, such that people utilize their body and perceive the resulting consequences to make sense of the world and the people surrounding them (e.g., Clark, 1999; Matheson & Barsalou, 2018; Semin & Smith, 2008). Therefore, the sensorimotor and perceptual processes involved in action execution and observation share common representational codes and underlying neural substrates. This notion has been advanced in research on the acquisition of metaphors (Lakoff & Johnson, 1999), language (Fischer & Zwaan, 2008; Pulvermüller, Hauk, Nikulin & Ilmoniemi, 2005), action concepts (Aarts & Veling, 2009; De Lange, Spronk, Willems, Toni, & Bekkering, 2008), desire (Keesman, Aarts, Vermeent, Häfner & Papies, 2016) and emotions (Arnold & Winkielman, 2019; Niedenthal, 2007).

According to the embodied cognition view on emotion understanding, perceiving another person expressing an emotion activates to a certain extent in the observer much of the same brain areas as it does in the actor. The embodiment framework has been shown to be especially fruitful in emotion research, revealing how the sensorimotor system can become activated during emotion perception, partially re-enacting or simulating bodily changes involved in earlier emotional experiences (e.g., Arnold & Winkielman, 2019; Niedenthal, 2007). Importantly, sensorimotor simulation can spill over into actual facial muscle activity: Facial simulation or facial mimicry. It is thought that facial mimicry occurs in a relatively automatic manner when one perceives an emotional expression (e.g., Dimberg et al., 2002). Furthermore, facial mimicry is argued to provide feedback about the emotion of the others to the simulator, and as such support a quick understanding of others' internal states and concerns (e.g., Niedenthal, 2007; Stel, 2016). This way, people can feel what others feel (empathizing), and believe and intend what others think and want (mentalizing).

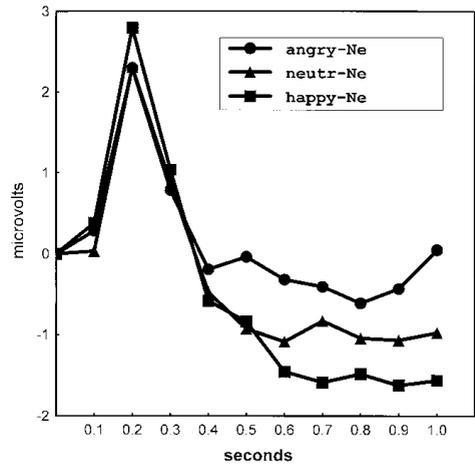
Methodology for examining the role of facial mimicry in emotion understanding

Research on emotional information processing in humans has examined a set of questions that are central to the embodied cognition perspective on emotion. Specifically, a variety of studies have been designed to validate the claim that facial mimicry occurs automatically upon perceiving emotions in others, and that such facial mimicry plays a crucial role in emotion understanding. Below I summarize the three main procedures that have been used.

Facial Electromyography. An important step in the measurement of facial mimicry in response to emotional stimuli, such as faces and words, is the method of electromyography (EMG). EMG can be applied to the face and allows researchers to pick up spontaneous and subtle changes in specific muscles in the face (see Figure 1A and B). In one of the first proof of concept studies of this method, Dimberg (1982) showed that exposure to happy and angry facial expressions elicits differential EMG patterns in the observer. Happy facial expressions increased activation of the zygomaticus muscle -the muscle used for smiling- whereas angry facial expressions increased activation of the corrugator muscle -the muscle used for frowning. Subsequent studies revealed that EMG can assess the automatic triggering of facial mimicry during emotion understanding tasks, such as inferring the emotional state of a target (e.g., Murata, Saito, Schug, Ogawa & Kameda, 2016) or evaluating the emotionality of faces (e.g., Blom, Aarts & Semin, 2019). By and large, research has shown that observing a positive facial expression activates the zygomaticus major and that observing a negative facial expression activates the corrugator supercilia (cf. Cacioppo, Petty, Losch, & Kim, 1986; Hess & Fischer, 2014), suggesting that emotion understanding is rooted in the natural tendency of facial emotional simulation.



1.A



1.B

Figure 1. (A) Illustration of EMG electrode placement to assess EMG signals of the Corrugator supercilii and the Zygomaticus major muscles. (B) Example of the EMG pattern of the Corrugator supercilii elicited in response to observing identical neutral faces (“Ne”), preceded by short (30ms) exposure of angry, neutral, or happy faces. Image adapted based on: Dimberg, Thunberg & Elmehed, (2000).

Temporal blocking of facial muscle activity. Another way to examine whether facial mimicry plays a role in emotion understanding builds on the notion that causally ruling out facial mimicry (e.g., by blocking facial muscle movement) should impair emotion understanding. This hypothesized effect has been examined by using noninvasive (e.g., having participants hold a pen in their mouth) or more invasive (e.g., Botox injections) methods.

One of the first examinations of the role of facial muscle manipulations in emotional processing comes from Strack, Martin, and Stepper (1988). They asked participants to hold a pen between their teeth (inducing either a ‘smile’ or a ‘pout’), which was shown to influence participants’ judgment of an emotional stimulus, also known as the so-called facial feedback hypothesis (for the reliability of testing the facial-feedback hypothesis see Wagenmakers et al., 2016; and Strack, 2016).

Strack et al.'s study inspired researchers to examine whether *blocking* facial movement might also affect *emotion understanding*. Noninvasive methods used to block facial mimicry range from instructing participants to hold a chopstick or pen sideways in the mouth (e.g., Davis, Winkielman & Coulson, 2017), touching it with ones' lips and teeth, while the upper and lower lips touch each other softly in front of the utensil, a method that has been shown to interfere with facial simulation (see Figure 2A), to asking participants to wear a mouthguard, a method that has been shown to disrupt facial mimicry (cf. Rychlowska, Cañadas, Wood, Krumhuber, Fischer & Niedenthal, 2014). A more invasive method to rule out facial mimicry is by injecting Botox in individuals' facial muscles, temporarily paralyzing these muscles (for example, see Figure 2B). Overall, studies employing (noninvasive or more invasive) facial blocking manipulations so far show that temporarily ruling out facial mimicry only impairs the more subtle elements of emotion understanding.



Interference

Control

2.A



Before Botox



After Botox

2.B

Figure 2. (A) Illustration of the utensil-manipulation interfering with facial simulation -holding the utensil with the teeth and lips- on the left, and the control condition -touching the utensil with the lips only- on the right. Image adapted based on Davis, Winkielman & Coulson (2017). (B) Before and after Botox injections in the “frown lines”. Image adapted based on: Myint (2018).

Chronic impairment of facial muscle activity. A final approach to study the importance of facial mimicry for emotion understanding is research with patients that suffer from diseases that render facial muscle activity impossible, such as in facial paresis. However, due to the complexity of such patient studies, experiments on emotion understanding in patients with a

facial paresis are rare. A specific group of patients that can experience a facial paresis are individuals with a Vestibular Schwannoma (VS), also known as Acoustic Neuromas, see Figure 3A. VS patients have benign unilateral tumors (e.g., Johnson & Lalwani, 2012; Weinberger & Terris, 2015), VS's are localized near the facial nerve. Their surgical removal can cause injury to the facial nerve (see Figure 3B), and lead to a unilateral facial paresis (see Figure 3C). The relationship between chronic impairment of facial muscle activity and emotion understanding has recently been examined (see Chapters 6-8) in this patient group by comparing VS patients with facial paresis to a matched (control) group of VS patients without facial paresis.

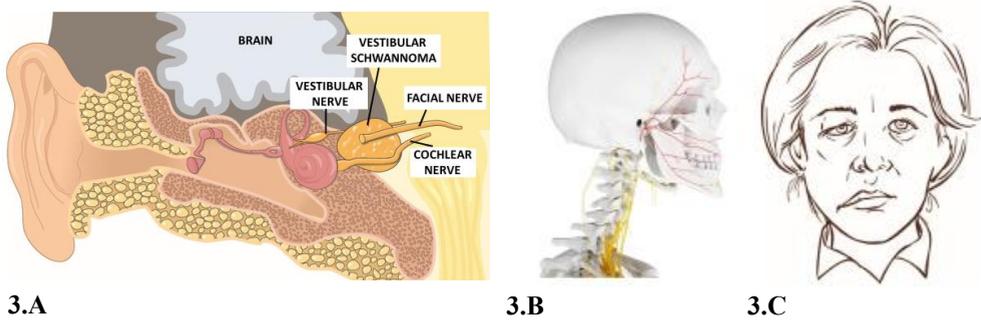


Figure 3. (A) Illustration of the localization of a Vestibular Schwannoma near the Facial nerve. (B) Localization of the Facial nerve. (C) Illustration of the impact of a facial nerve injury: Unilateral facial paresis.

Overview of the remaining part of the present dissertation

In an effort to study the role of facial muscle activity in social emotion processing, I build on the embodied cognition view of action concepts (Clark, 1999; Matheson & Barsalou, 2018). In particular, I investigated the role of facial mimicry in understanding the emotions of others such as displayed in their facial expressions or the words they say. As it turns out (see Chapter 2), so far findings from several studies provide a rather ambiguous picture as to the relation between facial mimicry and emotion understanding. The present thesis therefore presents a set of studies to shed more light on this issue. The remaining part of the thesis consists of seven chapters. Chapter 2 will present an overview of the literature on the role of facial mimicry in emotion understanding. Chapters 3-5 (Part 1 of the conducted empirical research) form a set of studies

that examine the role of body movements in general, and facial mimicry in particular in shaping knowledge about social constructs and emotions. Chapters 6-8 (Part 2 of the conducted empirical research) form a coherent set of studies that address the role of facial mimicry in emotion understanding by examining conditions that cause impairment in facial muscle movement. Thus, we were able to examine a unique sample of patients who suffer from Vestibular Schwannoma, a nerve tumor the removal of which can cause a chronic facial paresis. Below I briefly introduce and summarize the chapters of this thesis.

Chapter 2 presents a more in-depth analysis of the relationship between facial mimicry and emotion understanding. It thus addresses the embodied cognition framework in the context of processing social information by scrutinizing how muscle activity is related to abstract knowledge processing and emotion understanding. This chapter also aims to integrate and discuss the empirical data of the present dissertation and addresses a few unresolved issues, and directions for future research. To that end, we first of all examine evidence from emotion understanding studies in which participants' facial muscle activity is measured by use of EMG. These findings suggest that the occurrence of facial mimicry is moderated by various factors such as the relationship between the target and the observer, as well as the quality of emotion information. Furthermore, facial mimicry shows to not always mediate emotion understanding. We then examine the role of facial mimicry in emotion understanding by reviewing studies in which facial muscle movement was temporarily (manipulated) or chronically (disease-related) impaired. Findings indicate that being impaired in facial mimicry affects the more subtle elements of emotion understanding, such as impaired recognition of less intense or visually unclear emotional expressions, or in an impaired ability to dissociate between genuine and false smiles.

Part 1: Muscle activity and understanding of concepts

Chapter 3 presents an empirical study to explore the embodied cognition perspective and examines the importance of bodily movements, i.e., sensorimotor processes, in social information processing pertaining to abstract concepts. It has as such been suggested that in order to represent abstract concepts, people make use of bodily experience with the world (Lakoff & Johnson, 1980; 1999). In this chapter, we examined the abstract concept of time by

studying the effect of manipulating bodily movements on individuals' perception of time. In western cultures time is typically *mapped* onto a back-to-front (e.g., 'looking forward to something') or a left-to-right spatial axis (Boroditsky, 2011; 2018; Casasanto & Boroditsky, 2008). Accordingly, participants were induced to make left (right) hand-arm movements while thinking about a past event. It was found that left (right) spatial hand-arm movements increase (decrease) the perceived temporal distance to the event. These findings thus provide initial support from our laboratory that sensorimotor processes in general, and hand movements in particular are involved in shaping social knowledge about abstract concepts.

Chapter 4 takes the embodiment cognition perspective to emotion understanding. Specifically, whereas Chapter 3 addresses whether bodily movements in the form of hand-arm gestures can influence abstract concept processing of time, in Chapter 4 we focus on facial muscle movement and the relationship with processing information about emotions of others. In a study, we measured individuals' facial muscle movement while they participated in a well-designed task assessing hemispheric lateralization of facial emotion processing. It is commonly established that when individuals perceive an emotional facial expression in the left (vs. right) visual field, they tend to consider this facial expression as more emotive (e.g., Bourne, 2010; Meletti et al., 2015). Considering that information from the left visual field first arrives to the right hemisphere, this finding is interpreted as evidence for the right hemisphere hypothesis, which states that the right (vs. left) hemisphere plays a more prominent role in emotion processing.

In our study, individuals had to judge the emotionality of faces showing an emotional expression in the left vs. right visual field, while we simultaneously recorded their facial muscle response by means of EMG. This study replicated this left visual field bias: Participants judged emotional facial expressions shown in the left visual field as more emotional than those shown in the right visual field. Importantly, even though facial mimicry showed to occur -relating to the valence of the observed emotional expression-, these simulation effects did not show a difference based on the visual field in which the emotional expression was shown. The findings of this study therefore suggest that encoding the emotionality of another person's facial expression might occur independent from the mere simulation of the facial expression itself, suggesting that facial mimicry might not be directly important in understanding others' emotion as they are expressed by their faces.

Chapter 5 reports a study that assessed whether adding contextually supportive information - a voice that produces valence-related words and intonation - facilitates the detection of emotion in text and in faces. To examine whether such context supporting emotion detection effect is accompanied by facial mimicry we furthermore measured facial muscle responses to the target information by means of EMG. Participants were presented with visual target information (written words or images of faces), which were systematically accompanied by different levels of contextually supporting information (e.g., while seeing a happy face on the computer screen, a voice says the word “nice” in a neutral or positive way). They were asked to decide whether the target was an emotional or a non-emotional one.

Results showed that emotion detection was highest when the visual target was accompanied by the verbal expression of a valence-related word pronounced in an emotionally matched intonation. This context-supporting effect was more pronounced for written emotional words than for facial emotional expressions. While facial simulation emerged for the emotional stimuli -based on the valence of the visual stimuli- the level of contextual supporting information did not show to qualify this facial mimicry effect. The findings of this study indicate that contextually supporting voice elements can indeed facilitate the detection of emotion-related information. However, facial mimicry in this case thus did not show to be involved in linking this contextual information to the detection of emotion stimuli.

Part 2: Vestibular Schwannoma patients and emotion understanding

Chapters 6 – 8 present the findings from a set of studies that tested emotion understanding of facial expressions among patients who have a permanent condition of unilateral facial paresis. An alternative (and compelling) test of the relationship between facial mimicry and emotion understanding would be to show that emotion understanding is impaired when facial functioning is impaired. Examining emotion understanding in patients with facial paresis, however, is not only of scientific importance. Knowledge about potential disturbances in social and emotional life of patients has also practical significance. For example, physicians working with Vestibular Schwannoma patients could take the possible impact of a facial paresis on emotion understanding into account when deciding between treatment options, and in case of surgery the type of resection. Furthermore, a better grasp of the negative impact on patients’ social and emotional life might help to align specific needs with proper guidance and help.

In the last three chapters of this dissertation, we report a series of studies that include a unique sample of patients with a Vestibular Schwannoma (VS), and we compared patients with unilateral facial paresis to a matched (control) sample of VS patients without a facial paresis. The fact that both patient groups suffer from VS rules out possible differences between facial paresis and no facial paresis that may result from having the disease itself. The idea being tested, then, is whether being chronically impaired in facial muscle movement is related to impaired emotion understanding.

Chapter 6 presents the analysis of a survey study that assessed the possible negative impact of impaired facial functioning on emotion understanding. This study formed the basis for the research reported in Chapters 7 and 8, and included forty-seven patients previously diagnosed with VS. They filled out a questionnaire including measures of patients' quality of life, social function, and emotion. Twenty-four of these patients had a unilateral facial paresis after removal of their VS, while twenty-three patients had a VS but no facial paresis and thus served as a matched control group. Forty-four of the patients who participated in the questionnaire study, also decided to participate in the experimental studies examining emotion understanding (presented in Chapters 7-8). The findings of the survey study showed that VS patients with a facial paresis experienced lower health-related quality of life compared to VS patients without a facial paresis. Moreover, VS patients with a facial paresis experienced lower overall satisfaction with life, more characteristic symptoms of depression, and more fear of being evaluated negatively by others than VS patients without a facial paresis. This was further supported by analyses considering VS patients' degree of facial dysfunction as measured by the House Brackman Grade (HBG) (House, 1985), showing increased negative impact for patients with higher degrees of facial dysfunction. Our findings thus confirmed a clear negative association between impaired facial functioning in VS patients and health-related quality of life and well-being, including their experienced quality of social function and emotional life.

In order to reduce possible constraints that our sample of patients might have had to further participate in the following two experimental studies (e.g. due to time, travelling costs, inability to travel, or for example health reasons), they were visited at their home by the researcher (S. Blom). This also allowed us to carefully provide them with instructions and to support them in

completing these studies conducted on a portable computer.

Chapter 7 examined the relationship between impaired facial muscle movement in VS patients and emotion by conducting an experiment that employed the test of hemispheric processing of facial emotional expressions as described in Chapter 4. Results showed that VS patients judged emotional expressions shown in the left visual field as more emotive than those shown in the right visual field. This visual field bias replicated the effect reported in Chapter 4. Importantly, this effect was not moderated by facial paresis, nor by patients' degree of facial dysfunction (as measured by the HBG). Moreover, the visual field bias of the two VS patient groups did not differ from a healthy control sample of university students (reported in Blom, Aarts & Semin, 2019; Chapter 4). In short, these results suggest that being impaired in facial muscle movement does not affect the lateralization of facial emotion understanding in patients with VS.

Chapter 8 reports a patient study that builds on the findings reported in Chapter 7. Specifically, considering the absence of a facial paresis effect on the visual field bias of emotion understanding, it could be the case that other processes underlying emotion understanding might be affected. One such process pertains to the ease of detecting emotional facial expressions, especially considering the recently proposed hypothesis that facial mimicry becomes more relevant as input for emotion understanding when the perceived emotional information is more ambiguous (Arnold & Winkielman, 2019). We therefore conducted a new experiment with the same VS patient sample to examine emotion detection in (happy and angry) facial expressions with different levels of visibility. For this purpose, we designed a new emotion processing task that used different levels of noise patterns (10-80% noise) to systematically mask facial expression images that were presented on a computer. Patients had to indicate whether the face displayed an emotion or not (hence 50% chance when merely guessing).

Results showed that the level of emotion detection was generally high for happy faces and somewhat lower for angry faces, concurring with the common view that happiness is more readily detected than anger. Surprisingly, no general differences between VS patients with and without facial paresis turned up. Exploratory analysis, however, revealed that only the VS patients with a facial paresis were somewhat less able to detect angry faces as emotional,

especially when the visibility dropped to 80% due to noise pattern masking. The results of this study thus show that patients suffering from facial paralysis have some troubles to understand angry faces that are less clearly visible. This supports the notion that the ability to simulate and mimic facial expressions might become more relevant for emotion understanding when one perceives a facial expression for which it is not directly clear or more ambiguous as to the type of emotion it conveys.

To summarize: The reported work in this dissertation advances the understanding of facial mimicry's function in emotion understanding, and as such also provides new insights relating to the embodied cognition research framework of social information processes and emotion. Our findings generally suggest that facial mimicry responds to the valence of emotional information, but that it might be less relevant for emotion understanding than has been generally argued before. More specifically, the present thesis gives reason to suggest that facial mimicry mainly becomes relevant for emotion understanding, when emotion understanding cannot readily rely on other sources that can give a crystal clear and unequivocal picture of the emotion that is at stake. Such a role of facial simulation would fit well with an embodied cognition view on conceptual learning of emotions, according to which the internal reenactment of the perceived emotional facial expression -- either through generation of peripheral feedback (e.g., facial muscles) or engagement of the somatosensory and motor cortices -- provides useful information when a face representation cannot be easily constructed to understand others' emotions in the situation at hand.

As a final note, I wish to stress that the empirical chapters (3-8) in this thesis have been written as separate articles for scientific journals. This means that these chapters can be read separately and on their own, and that there is some overlap in content across the chapters

Chapter 2

Embodied cognition in emotion processing:

An examination of the role of facial mimicry in emotion understanding.

Based on: Blom, S.S.A.H., Aarts, H., Semin, G.R. Embodied cognition in emotion processing: An examination of the role of facial mimicry in emotion understanding. Manuscript in preparation for submission.

Abstract:

Understanding emotions is crucial for social interaction. One important process that is argued to support the understanding of emotion is the simulation of the emotion one observes. Building on the embodied cognition perspective of social information processing, facial emotional expressions have been argued to automatically evoke sensorimotor processes that cause a person to mimic the perceived facial expression. Once simulated, the person can quickly grasp the emotion of others and act accordingly. This review addresses the automatic nature of facial mimicry and its role in understanding others' emotion. Several streams of research on facial muscle activity and emotional processing indicate that (1) facial mimicry is moderated by motivational and cognitive aspects that are pertinent to emotional understanding; (2) understanding emotion is not always related to facial mimicry; and (3) emotion understanding can occur when observers suffer from impairment in facial muscle activity due to temporal (e.g., restraining facial activity by holding a pen between one's lips and teeth) or chronic (disease-related facial paresis) conditions. Our analysis thus suggests that facial mimicry is not fully automatic and critical to emotion understanding. We discuss these findings in the context of embodied cognition of emotion processing and address a few avenues for future research that might shed new light on the role of facial mimicry in emotion understanding and social interaction.

Introduction

The ability to understand and recognize the emotions of others is a key social cognitive skill for successful social interaction and communication. Grasping others' emotions and empathizing with them serves important socioemotional goals, fosters social care and wellbeing and facilitates prosocial behavior (Castro, Cheng, Halberstadt & Grühn, 2016). One important process that is argued to support the understanding of emotion of others is by simulating the emotion one observes. Building on the embodied cognition perspective of social information processing, observing facial emotional expressions has been argued to automatically evoke sensorimotor processes that can cause a person to mimic the perceived facial expression with their own facial muscles (e.g., Niedenthal, 2007). This simulation is reasoned to facilitate a quick grasp of the emotion of others, such that one can act accordingly.

Whereas the importance of facial mimicry for emotional processing is well recognized, there is no up to date analysis that addresses the evidence for its automaticity and mediating role in emotion understanding. The present paper aims to fill this void. We will discuss the recent literature and address research that (a) examined conditions that moderate facial mimicry and emotion understanding in observers and (b) studied whether observers can understand others' emotion when they suffer from impairment in facial muscle activity due to temporal (e.g., Botox injection) or chronic (disease-related: Facial palsy) conditions. Before we discuss this literature, we will first briefly address the embodied cognition perspective to social information processing, as this perspective forms the basis for the explaining role of facial mimicry in emotion understanding.

The embodied cognition perspective on emotion understanding

The concept of embodied cognition stems from critique on the conventional cognition approach to human information processing and behavior that emerged during the cognitive revolution. That is, while the more classic cognition theories assume the existence of discrete, internal representations realized by underlying, sharply distinct and highly specified mechanisms in the brain, the embodied cognition framework proposes a more prominent role for bodily experience in human cognition (e.g., Barrett & Lindquist, 2008; Barsalou, 1999; 2008; Clark, 1999; Glenberg, 2010; Niedenthal, 2007; Wilson, 2002). Though various perspectives exist within the embodiment framework, the common and unique suggestion of embodiment theories is that

human cognition and emotion are grounded in individuals' perceptual somatosensory and motor resources (e.g., Arnold & Winkielman, 2019; Barsalou, 2008; Hoemann & Feldman Barrett, 2019; Semin & Smith, 2008).

The embodiment framework developed from precursors such as -amongst others- the ideomotor theory of action by James (1890), the developmental psychology perspective of Piaget (1954) and Gibson's (1979) ecological approach to visual perception considering the notion of affordances. It has since developed into a prominent framework applied in various scientific fields. For instance, linguists Lakoff and Johnson (1980; 1999) developed the conceptual metaphor theory positing that the human conceptual system makes use of more concrete knowledge, metaphors, and bodily experience with the world in order to represent abstract concepts. One important abstract concept that has been studied recently is that of time. In western cultures time is typically *mapped* onto a back-to-front (e.g., 'looking forward to something') or a left-to-right spatial axis. Spatial experience is thus used to understand time (Boroditsky, 2011; 2018; Casasanto & Boroditsky, 2008). In a recent demonstration of the embodied cognition of the concept of time (Blom & Semin, 2013), participants were induced to make left (right) hand-arm movements while thinking about a past event. It was found that left (right) spatial hand-arm movements increase (decrease) the perceived temporal distance to the event, thus providing support for the concept of "the left is associated with earlier times, and the right is associated with later times". These, and various other findings (Fuhrman & Boroditsky, 2010; Ouellet, Santiago, Funes, & Lupiáñez, 2010) provide support for the relevance of sensorimotor processes in general, and hand movements in particular, in shaping social knowledge about abstract concepts.

The embodied cognition perspective has similarly developed into an important framework for emotion research. The application of the embodiment perspective to emotion research was inspired by the discovery of mirror neurons in monkeys; neurons in sensorimotor areas that automatically activate when a monkey acts as well as when it observes another engaging in a similar action (e.g., Di Pellegrino, Fadiga, Fogassi, Gallese & Rizzolatti, 1992; Rizzolatti, Fadiga, Gallese & Fogassi, 1996). One of the supposed functions of mirror neurons is to facilitate the understanding of others' behavior by means of simulation of others' actions in oneself (e.g., Iacoboni et al., 2005; Keysers & Gazzola, 2007). The concept of mirror neurons has been extrapolated to the embodied cognition perspective on emotion, according to which

the sensorimotor simulation of other's emotions can facilitate understanding of this emotion (e.g., Arnold & Winkielman, 2019; Niedenthal, 2007).

There are several models that address how embodied cognition could affect emotion perception and understanding (Goldman & Sripada, 2005). Central to these models is that action execution and action observation share a common representational code (Sebanz, Knoblich & Prinz, 2003) and neural substrates (Grezes & Decety, 2001). The internal reenactment of the perceived emotion thus provides useful information either through generation of peripheral feedback (e.g., facial muscle activity) or engagement of the somatosensory and motor cortices. In short, observing emotion expressions in another person can evoke facial mimicry in the observer, which in turn is argued to facilitate the understanding of the emotion of the other. This way, people can feel what others feel (empathizing), intend what others intend (mentalizing), and adopt a goal that serves personal and shared interest. Figure 1 depicts a simplistic version of this emotional imitation process.

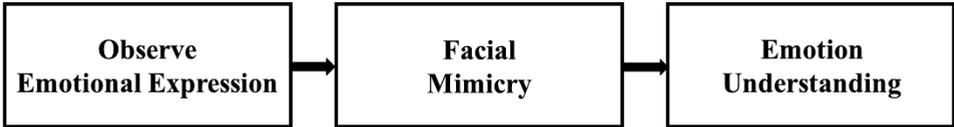


Figure 1. A simple model of the role of facial mimicry in emotion understanding

In the remaining part of this paper we will address the evidence for this process. First, we will examine research that administers measures of facial muscle activity in tasks that expose participants to emotional information, and tests the hypothesis whether facial mimicry occurs automatically, or is conditional on specific aspects that are pertinent to emotion understanding. Next, we examine research that addresses the question whether individuals are able to understand emotions of others when their facial muscle activity is impaired during exposure to others' emotional facial expression. Here, we will discuss work that examines facial activity impairment as a function of temporal blocking of facial muscles or chronic conditions due to facial nerve paresis.

1. Emotion understanding and facial mimicry: Electromyography data

An important area of research that considers the fundamental role of facial mimicry in emotion understanding consists of studies that measures facial electromyography (EMG) to pick up

muscle activity in response to exposure to others' faces. Some of the most highly cited articles studying the automatic nature of facial mimicry come from Dimberg and colleagues. They tested and showed that seeing a happy face activates the zygomaticus major -the muscle used for smiling- and that seeing an angry face activates the corrugator supercilii -the muscle used for frowning- and argued that these emotional imitation effects occur automatically and unconsciously (Dimberg, 1982; Dimberg, Thunberg & Elmehed, 2000; Dimberg, Thunberg & Grunedal, 2002). That is, involuntary, and without intention.

Does facial mimicry occur automatically?

Since the first studies by Dimberg and colleagues, several other studies have shown that facial mimicry in observers of emotional information tends to reflect the overall valence of emotional stimuli -e.g., zygomaticus activation to a positive stimulus- or the perceived *emotional intention* of others (Hess & Fischer, 2014; Seibt, Mühlberger, Likowski & Weyers, 2015). Furthermore, there is research to suggest that facial mimicry provides feedback to the observer about the perceived emotion (e.g., Niedenthal, 2007; Stel, 2016), which facilitates understanding of the other (Niedenthal, 2007). Whereas facial mimicry has been originally explained in terms of a natural tendency that occurs automatically, recent research has started to explore potential moderators that might question the automatic nature of facial mimicry.

One moderator that seems to be highly relevant for emotion processing in social interaction pertains the **observer's relationship with others** (e.g., Duffy & Chartrand, 2015; Korb, Goldman, Davidson & Niedenthal, 2019; Seibt et al., 2015; Stel, 2016). For example, studies on group membership show that facial mimicry in response to another person's emotional facial expression is more likely to occur when participants consider the other person as being an ingroup (vs outgroup) member. Also, people tend to mimic faces of others more strongly when they have to goal to cooperate versus to compete with others, or when they have a positive versus negative attitude towards the other, suggesting that facial mimicry can be facilitated or inhibited by positive or negative features of the relationship, respectively. Furthermore, specific social considerations have been found to influence facial mimicry. For instance, when a task requires one to understand the emotion of the other more thoroughly, more facial mimicry occurs compared to when one solely has to make inferences about non-emotion related traits of the target such as their age or gender (e.g., Murata, Saito, Schug,

Ogawa & Kameda, 2016). Similarly, encoding ambiguous facial expressions with emotional conceptual information induces facial mimicry congruent with the valence of emotional conceptual information (Halberstadt, Winkielman, Niedenthal & Dalle, 2009). Importantly, EMG activity to ambiguous facial expressions paired with non-emotional concepts did not induce specific facial mimicry. Thus, further underlining the notion that facial mimicry relates to the task of emotion understanding, and that solely seeing a face does not necessarily elicit facial mimicry.

Taken together, then, these findings demonstrate that facial mimicry is not necessarily automatic, but relies on social motives or goals in order to be enacted. This is in line with a recent study that found that facial mimicry indeed appears to arise automatically and spontaneously, but that top-down processes can inhibit or change it via activity of the medial prefrontal cortex (Korb et al., 2019).

Furthermore, it is important to note that most research on facial mimicry builds on stimulus materials that are designed for full emotion understanding. In such cases, emotional stimuli are well perceived and, as the role of social motives discussed above suggests, facial mimicry might provide an additional information signal during social interaction. However, the importance of facial mimicry as a signal for emotional understanding has also been studied in the context of **the quality of emotional information**, addressing that various information channels can contribute in emotion understanding. For instance, when a facial expression is less clearly visible, facial mimicry is more likely to serve as information source to the observer (e.g., Arnold & Winkielman, 2019; Winkielman, Coulson & Niedenthal, 2018; Winkielman, Niedenthal, Wielgosz, Eelen & Kavanagh, 2015). These findings are taken as evidence for the notion that facial mimicry supports emotion understanding in situations where emotional information is more ambiguous, whereas when emotional information is very clear, such facial mimicry is less important to arrive at the understanding of emotion. In a related vein, it has been shown that facial emotion recognition can be achieved via two routes: By relying on visual information as well as by relying on sensorimotor information such as facial mimicry (de la Rosa, Fadernrecht, Bülthoff, Giese & Curio, 2018).

In sum, facial mimicry is moderated by social needs or goals, as well as the clarity of emotional information. Whereas social needs might render facial mimicry goal-directed and more strategic in order to foster social bonding (Hatfield, Cacioppo, & Rapson, 1992; Hess &

Fischer, 2013; Lakin & Chartrand, 2003; Stel & Vonk, 2010), the effects of ambiguous emotional information on facial mimicry might result from increased attention as a result of a person's need to produce a better grasp of others' emotions that otherwise might go unnoticed (e.g., Arnold & Winkielman, 2019; Winkielman et al., 2018). While initial research suggests that facial mimicry is a bottom-up process that is automatically evoked in response to emotional facial expressions, the recent literature indicates that this process is not fully automatic. For facial mimicry to occur specific conditions need to be in place that are pertinent to understanding the others' emotions in the social context at hand (e.g., Hess & Fischer, 2013; Winkielman et al., 2018). We now turn to the relationship between facial mimicry and emotion understanding.

Is facial mimicry necessary for emotion understanding?

Just because facial mimicry takes place does not mean it is a prerequisite for emotion understanding. One area of research that has looked into the relationship between facial mimicry and emotion understanding assesses the correlation between facial mimicry and emotion recognition (e.g., Blairy, Herrera & Hess, 1999; Fischer, Becker & Veenstra, 2012; Hess & Blairy, 2001). However, these studies do not unequivocally show a link between facial mimicry and emotion understanding.

Some studies failed to establish a relation at all; others found some association between facial mimicry and emotion understanding. For instance, research on the recognition of complex contextually embedded emotional expressions as well as research on individuals' emotion perception ability as measured by a battery of complex facial emotion perception tasks suggest that facial mimicry and emotion understanding are positively correlated (Drimalla, Landwehr, Hess & Dziobek, 2019; Künecke, Hildebrandt, Recio, Sommer & Wilhelm, 2014). Furthermore, a positive association between facial mimicry and the perceived authenticity of smiles has also been reported, but facial mimicry however did not show to mediate the association between the type of smile of the expressor and said authenticity judgments of the observer (Korb, With, Niedenthal, Kaiser & Grandjean, 2014). Furthermore, the facial mimicry that participants showed when exposed to ambiguous facial expression that were previously encoded with an emotion-concept ("happy" or "angry") has been shown to predict how happy the participant remembered the encoded face to have been (Halberstadt et al., 2009). Lastly,

facial mimicry has also been shown to predict individuals' experienced emotion (i.e., the emotion an individual felt upon perceiving a target face, ranging from positive to negative), which in turn predicted recognition of valence in dynamic facial emotional expressions (Sato, Fujimura, Kochiyama & Suzuki, 2013).

Whereas the studies alluded to above offer some support that facial mimicry is associated with emotion understanding, other recent experimental studies consider the relationship between facial mimicry and emotion understanding by examining whether participants' facial mimicry is in line with their emotion understanding in tasks that require them to process emotional information (such as facial expressions or emotional words) under different circumstances. In a recent set of studies, Blom and colleagues examined this issue in more detail by designing tasks that allowed them to separate emotion understanding from facial mimicry. In a first study (Blom, Aarts & Semin, 2019), facial mimicry was tested in an emotion understanding task building on lateralization effects in emotional facial processing. A commonly reported finding in emotion research is that facial expressions are perceived as more emotive when portrayed in the left vs. right visual field, also known as the left visual field bias. A well-known method to examine individuals' visual field bias in emotion processing is the chimeric faces test, in which participants are presented with an emotional facial expression in the left vs the right visual field (e.g., Bourne, 2010). This test builds on the overall finding of more right (vs. left) cortical hemisphere involvement in emotion processing (e.g., Bourne, 2010; Meletti et al., 2015; Murray, Krause, Stafford, Bono, Meltzer, & Borod, 2015). Blom et al. (2019) found clear evidence for the left visual field bias. Surprisingly, the visual field bias did not show up in the facial EMG data. However, facial mimicry occurred in response to the emotional facial expressions, but the pattern only reflected the valence of the perceived facial emotional expression. These findings indicate that emotional chimeric faces can produce two separate, unrelated effects: an emotion understanding effect relying on the left visual field bias, and a facial mimicry effects resulting from the valence of the emotional expression.

In another study, Blom, Aarts & Semin (2020b) designed an emotional processing task that enabled them to study the contribution of different levels of emotion-supporting context in emotion understanding and facial mimicry. Previous work has shown that contextual information, such as gestures and body postures, can have a strong impact on emotion processing (Aviezer et al., 2017; Feldman Barrett, Mesquita & Gendron, 2011; Halberstadt &

Niedenthal, 2001; Holler & Levinson, 2019; Mermillod et al., 2018; Mumenthaler & Sander, 2015; Sendra, Kaland, Swerts & Prieto, 2013). Building on this research, Blom et al. reasoned that emotional understanding might be facilitated by emotion-supporting auditory information conveyed by voices. For instance, in face-to-face communication, people not only see another person's emotional facial expression; they commonly also hear what the other person says and the intonation with which their message is being articulated. Thus, a happy (or angry) face is more likely to be detected as an emotional expression when the face is accompanied by positive (or negative) words that are expressed with a positive (or negative) intonation. Indeed, Blom et al. established that accuracy of emotion detection increased when emotional information (words or faces) was accompanied by emotion-supporting verbal context. Interesting, and in line with Blom et al. (2019), emotional information evoked facial mimicry, but these facial EMG effects only reflected the valence of the stimuli, independent of the emotion-supporting verbal context. Facial mimicry in this case thus did not co-occur with emotion understanding, because only in the latter case emotion-supporting contextual information was linked to the detection of emotional stimuli.

All in all, the findings discussed above do provide some evidence for an association between facial mimicry and emotion understanding, especially when it entails more complex emotion understanding. However, some recent studies indicate that facial mimicry and emotional understanding can occur separately, relying on different sources of information during processing of emotional stimuli, such as facial expressions and words.

So far, we reviewed studies that examined facial muscle activity in emotion processing tasks, and observed that facial mimicry is sometimes related to emotion understanding. Although informative, a more direct test would be to show that emotion understanding is impaired when facial mimicry is blocked or impossible. If blocking of facial mimicry hampers emotion understanding, then this would provide compelling evidence for the notion that facial mimicry is a crucial part of emotion concept processing. The next two sections address this important and intriguing issue. We start off with studies that tested people's ability to understand emotions when their facial muscles are temporally blocked, which will be followed by discussing studies that involve patients that suffer from chronic impairment of facial muscle activity due to facial nerve paralysis.

2. Emotion understanding when facial muscle activity is temporarily blocked

The embodied cognition view of emotion understanding builds on the idea of action understanding, according to which performance or simulation of a compatible action tends to facilitate action recognition whereas performance of incompatible or constraint actions tends to interfere with it (Reed & Farah, 1995; Tucker & Ellis, 1998; see Pulvermüller, Hauk, Nikulin & Ilmoniemi, 2005; for an embodied cognition view on action and language). These findings suggest that emotion understanding is hampered when facial mimicry is constrained by blocking or disturbing facial muscle activity during emotion processing. This hypothesized facial muscle constraint effect on emotion understanding has been explored in several studies that use manipulations to temporarily block facial movement by noninvasive (e.g., inhibiting facial simulation by having participants hold a pen in their mouth) as well as more invasive (e.g., Botox injections) methods.

Blocking facial mimicry - pen manipulation

A by now classic and famous experiment in which facial muscle movement was temporarily manipulated, is the so called ‘pen-study’ by Strack, Martin, and Stepper (1988). In this study, participants who were holding a pen between their lips (inducing a “pout”) when reading a cartoon judged the cartoon to be less funny compared to participants who were holding a pen between their teeth (inducing a “smile”). Manipulating facial activity thus influenced participants’ judgment of an emotional stimulus, also known as the “facial feedback” effect. A recent large project including 17 independent direct replications (Wagenmakers et al., 2016) failed to replicate the findings of this study, suggesting that the facial feedback effect might be unreliable or sensitive to context factors (see the comment by Strack, 2016). While the Strack et al. (1988) study did not examine *emotion understanding* per se, its’ findings did (and still do) inspire researchers to examine whether blocking facial movement might affect emotion understanding.

Other studies have since used variations of the pen-manipulation that prevents the occurrence of a facial signal; preventing facial mimicry. Manipulations range from instructing participants to simply bite in a pen, to more sophisticated procedure, such as asking participants to hold a pen sideways in the mouth, touching it gently with ones’ lips and teeth, while the upper and lower lips touch each other softly in front of the pen. The application of such

manipulations has shown to undermine the recognition of happy faces (Oberman, Winkielman, & Ramachandran, 2007), and the differentiation between the genuineness of true and false smiles (Maringer, Krumhuber, Fischer & Niedenthal, 2011); effects that do occur when participants are free in facial movement. A different study reported that inhibiting facial simulation in this manner slowed down participants' detection of change in an emotional facial expression (Niedenthal, Brauer, Halberstadt & Innes-Ker, 2001). Interestingly, recent evidence from a combined EMG and EEG showed that preventing facial mimicry by use of this pen-manipulation increases semantic retrieval demands (Davis, Winkielman & Coulson, 2017). Hence, providing support for the notion that facial mimicry is one of the sources individuals can rely on during emotion understanding, such that interrupting this information source increases reliance on other sources.

These findings together suggest that temporarily blocking facial mimicry indeed negatively impacts emotion understanding, and support the idea that facial mimicry can become a more important source of information when considering more subtle elements of emotion understanding (e.g., Arnold & Winkielman, 2019).

Blocking facial mimicry - mouthguard manipulation

A different method to temporarily block facial mimicry is wearing a mouthguard, a manipulation that disrupts facial simulation (Rychlowska, Cañadas, Wood, Krumhuber, Fischer & Niedenthal, 2014). In line with previous findings (Maringer et al., 2011) this method of blocking facial mimicry was also found to diminish participants' ability to differentiate between the genuineness of true and false smiles (Rychlowska et al., 2014).

In another study, participants viewed videos of actors who simultaneously produced valence congruent or incongruent facial expressions and hand gestures (e.g., happy face with thumb down). Participants were asked to report the valence of either the face or hand. It was found that valence congruency (vs. incongruency) positively (vs. negatively) affected speed and accuracy of classifying facial expressions and hand gestures. Interestingly, blocking facial mimicry by use of the mouthguard while additionally applying face tape over the forehead muscles did not affect the face-hand congruency effect, but it negatively influenced speed and accuracy of classifying isolated (i.e., without a hand gesture) facial expressions in isolation for men, but not women (Wood, Martin, Alibali & Niedenthal, 2019). According to the authors, an

explanation for these unexpected results could be that men (vs. women) generally perform worse on emotion recognition tasks, and therefore their emotion recognition could be more vulnerable to disturbance. Thus, while facial muscles blocking does seem to affect emotion understanding, it only does so for those that have poor abilities to recognize emotion in the first place.

Blocking facial mimicry - Botox injections

Lastly, a more invasive manner to examine the impact of blocking facial movement on emotion understanding is by use of Botox injections, temporarily paralyzing facial muscles. One of the first of such studies showed a negative impact on emotional language comprehension in individuals after receiving Botox injections (Havas, Glenberg, Gutowski, Lucarelli, & Davidson, 2009). Studies on facial emotion recognition have since also shown a negative effect of temporarily paralyzing facial muscles; individuals who received Botox injections performed worse on facial emotion recognition compared to individuals who received non-paralyzing filler injections (Neal & Chartrand, 2011), as well as compared to matched control participants (Lewis, 2018).

Other studies have specifically found support for the hypothesis that receiving Botox injections in the facial muscles negatively affects more subtle elements of emotion understanding (e.g., Bulnes, Mariën, Vandekerckhove & Cleeremans, 2019; Davis, Senghas, Brandt & Ochsner, 2010). For instance, in a study examining differences in understanding emotions expressed in a less intense or more intense fashion (e.g., a slightly happy vs a very happy facial expression), Botox injections caused individuals to take more time to categorize less intense -but not the more intense- facial emotional expressions (Baumeister, Papa, Foroni, 2016). Relatedly, less intense emotional sentences and facial expressions were rated as being less emotive after individuals received Botox injections, an effect that did not occur for neutral or more intense emotional stimuli (Baumeister et al., 2016). Temporarily blocking facial mimicry by use of Botox injections thus appears to negatively affect -more subtle elements of- emotion understanding.

Emotion understanding and blocking facial mimicry: Meta-analysis

A recent meta-analysis (Coles, Larsen & Lench, 2019) aimed to estimate the effect of manipulating facial muscle movement on affective judgments and emotional experience. Considering the effect of *facial blocking* showed an averaged effect size of $d = .15$ (95% CI [0.04, 0.25], $p = .006$) - based on 57 studies, and 96 effect size estimates ($n = 5899.69$ observations). While this effect size is rather small (Cohen, 1988), a relatively large effect of Botox injections was reported, $d = .71$ (Coles et al., 2019), suggesting that Botox injections disturb emotion understanding substantially. It should be noted that this effect size was based on only 3 studies and 6 effect size estimates ($n = 224$ observations, and $n = 103$ unique subjects) thus some caution might be taken when considering the robustness of the effect.

In short, in line with the EMG evidence reviewed previously, evidence from studies temporarily blocking facial mimicry support the notion that facial mimicry is one of various emotion sources utilized in emotion understanding, becoming more relevant for more demanding, complex, and subtle elements of emotion understanding. We now turn to address evidence from emotion research with patients suffering from chronic impairment of facial muscle activity.

3. Emotion understanding in individuals with facial paresis

While temporal facial muscle blocking can hamper emotion understanding at the task at hand, a more severe effect might be in place when such facial muscle impairment has a chronic condition, such as in patients suffering from facial paresis. Indeed, recent research shows that patients with a facial paresis experience lower quality of life (e.g., Blom, Aarts, Wever, Kunst & Semin, in press^b; Leong & Lesser, 2015; Soulier et al., 2017), as well as lower satisfaction with life, more fear of being judged negatively by others and more characteristics and symptoms of depression compared to individuals without facial paresis (Blom, et al., in press^b). Impaired facial functioning has furthermore been associated with anxiety, distress (Fu, Bundy & Sadiq, 2011), social avoidance and isolation (Nellis, Ishii, Byrne, Boahene, Dey & Ishii, 2017). These patient studies suggest that social communication can be severely disturbed when suffering from a facial paresis, and such social life problems might be related to poor emotion understanding.

Experimental studies on emotion understanding in patients with a facial paresis are rare and typically have small sample sizes, due to the complexity of such patient studies. We will

summarize the available literature and findings of studies that examined emotion understanding in different patient groups experiencing facial paresis, and will focus especially on individuals with a Vestibular Schwannoma, as recent studies examined their possible affected emotion understanding.

Moebius Syndrome patients

A few experimental studies on emotion processing have been conducted with individuals with Moebius syndrome (for a review, see: De Stefani, Nicolini, Belluardo & Ferrari, 2019). The Moebius syndrome is a congenital, nonprogressive condition resulting in facial paresis and impaired abduction of the eyes. Findings of two studies with Moebius syndrome patients ($n = 6$ and $n = 2$) suggest that some -but not all- adults with Moebius syndrome show impairments in recognition of more complex emotion recognition tasks, such as the recognition of more ambiguous facial expressions (Bate, Cook, Mole & Cole, 2013; Calder, Keane, Cole, Campbell & Young, 2000), while recognition of more straightforward and visually clear facial expressions is often unimpaired or less impaired (Bate et al., 2013; Calder et al., 2000).

However, it should be taken into account that such impairments could be -partly- due to visual impairments, as they have also showed deficits in other visual processing, facial identity, and object recognition tasks (Bate et al., 2013). Interestingly, the one patient that showed normal performance on all emotion recognition tests indicated to have been always highly interested in, and attentive to faces. Hence, though based on only one case, this does provide some support for the suggestion that -some- Moebius patients develop compensatory or alternative strategies for emotion understanding, while also relying on the other emotion information channels available (as is also suggested by Nicolini et al., 2019; Krueger & Michael, 2012). Overall, patients showed to perform normally on an imagery task, during which they had to imagine an emotional expression and answer questions regarding common visual elements of this expression (Bate et al., 2013), suggesting that visual representations of emotional expressions are not necessarily impaired in these patients. An online study with a larger group of adults however, showed no difference in facial emotion recognition when comparing individuals Moebius syndrome to a matched healthy control group (Rives Bogart &

Matsumoto, 2010). These studies thus show inconclusive results regarding the association between chronically impaired facial movement and emotion understanding.

Bell's Palsy patients

Bell's Palsy is a condition that causes sudden unilateral weakness or paresis in the facial muscles, the cause of which is unknown (e.g., Holland & Weimer, 2004). A recent study showed that facial emotion recognition was slower -but not less accurate- in individuals with Bell's Palsy compared to a matched healthy control group. Unexpectedly, testing both groups again approximately 55 days later, when the paralysis symptoms of the patients were mostly gone, patients' emotion recognition was still slower compared to that of the control group (Storbeck, Schlegelmilch, Streitberger, Sommer & Ploner, 2019). This Bell's Palsy study findings are somewhat puzzling, as they show an initial impairment in emotion understanding, that seem to sustain even in the absence of facial paresis.

Vestibular Schwannoma patients

A different group of patients that can experience a facial paresis are individuals with a Vestibular Schwannoma (VS). VS patients have benign unilateral tumors (e.g., Johnson & Lalwani, 2012; Weinberger & Terris, 2015). Surgical removal of a VS can cause injury to the facial nerve, and therefore unilateral facial paresis. The relationship between facial paresis and emotion processing has recently been explored by comparing VS patients with facial paresis to a matched (control) group of VS patients without facial paresis.

First, a study testing patients with acute, subacute or chronic unilateral facial paresis found that patients with a left vs. right facial paresis processed emotional expression of happiness and anger equally (Korb, Wood, Banks, Agoulnik, Hadlock & Niedenthal, 2016). Interestingly, patients with a left facial paresis processed happy expressions more accurately when presented in the right vs. left visual field, indicating a somewhat complicated relationship between facial paresis and emotional processing of others' expressions.

A more recent experimental study (Blom, Aarts, Kunst, Wever & Semin, in press^a) asked VS patients with and without a facial paresis to perform a chimeric faces test. Both groups of patients judged emotional expressions shown in the left vs. right visual field as more emotive, in line with the right hemisphere hypothesis of emotion processing established in healthy

individuals (e.g., Blom et al., 2019; Bourne, 2010). Interestingly, and somewhat surprisingly, the visual field bias was also not related to patients' degree of facial dysfunction. Furthermore, the patients' visual field bias was not different from that of a healthy control sample of university students. Thus, the findings of this study suggest that facial mimicry does not directly relate to the lateralization of emotion processing. This concurs with other recent findings, showing typical left visual field bias effects on perceived emotionality in healthy individuals (Blom et al., 2019), but no direct effects on facial muscle activation.

Considering the absence of a facial paralysis effect on the visual field bias effect on emotion understanding, it might be the case that other processes underlying emotion understanding might be affected. One such process pertains to the ease of detecting emotional facial expressions, especially considering the hypothesis that facial mimicry becomes more relevant when emotional information is more ambiguous (Arnold & Winkielman, 2019; Winkielman et al., 2018). Therefore, Blom and colleagues conducted a different experiment with the same VS patient sample to examine emotion detection in (happy and angry) facial expressions with different levels of visibility (Blom, Aarts, Kunst, Wever & Semin, 2020a). The visibility of images on a computer screen was systematically manipulated by a masking noise pattern, and varied from 20% to 80%, in steps of 10%, and patients had to indicate whether the face display an emotion or not (50% chance when merely guessing). While the level of emotion detection was generally high (up to 90% or higher) for happy faces and somewhat lower for angry faces, no differences between VS patients with and without facial paresis turned up. Exploratory analysis, however, revealed that only the Vs patients with a facial paresis perceived angry faces displayed with high levels (80%) of visual noise as non-emotional, i.e. below chance: They thus consistently failed to detect the emotion in images of angry facial expressions with the least amount of visual information. Findings with VS patients with facial paresis thus support the notion that facial mimicry becomes relevant for emotion understanding when an emotional facial expression is more ambiguous.

Conclusion: Emotion understanding in facial paresis patients

Due to the limited number of experimental studies examining emotion understanding in individuals with facial paresis, interpretations remain speculative. Though findings are somewhat inconclusive, the general gist of the reviewed studies -in line with the previously

discussed studies- does support the notion that when facial mimicry is chronically impaired, this can negatively affect understanding of more ambiguous and less clear emotion information.

Discussion

This literature review aimed to provide an up to date analysis addressing the automatic nature of facial mimicry and its mediating role in emotion understanding. Our analysis indicates that the occurrence of facial mimicry in response to emotional information is rather strategic and not so automatic, suggesting a prominent role of top-down processes in emotion understanding. Recent research suggests that mimicry in general might not be fully automatic and is more flexible than suggested before (Cracco et al., 2018).

Moreover, the role of facial mimicry in emotion understanding seems to be limited to situations whether processing of emotional information becomes more ambiguous and demanding. In the following, we will briefly discuss these findings in the context of embodied cognition in emotion processing and address a few avenues for future research that might shed new light on the importance of facial mimicry for emotion understanding and social interaction.

Facial mimicry, valence and emotion understanding

An interesting recurring finding reported in the literature discussed in the present paper is that even though a facial mimicry effect reflecting the valence of the stimuli occurred, such EMG measures do not always relate to emotion understanding. This is not completely surprising, considering that facial simulation is just one of various information sources used in emotion understanding (e.g., Arnold & Winkielman, 2019; de la Rosa et al., 2018; Winkielman et al., 2018). Hence, though facial mimicry might show to occur, this does not per definition mean that this muscle activation is subsequently involved in the understanding of emotions of others. While some situations could require sensorimotor simulation -and possibly facial mimicry- in order to understand others' emotion, other situations can be relatively straightforward and highly overlearned such that one does not need to rely on facial mimicry. For instance, it might be the case that the meaning of an emotion has been (physically) simulated over and over again in the past, and hence, a representation of the emotion concept can be readily constructed or retrieved from memory on the spot to explicitly assess the emotions of others.

Variations in facial mimicry's necessity relating to the task at hand are thus one possible explanation for the finding that facial mimicry is not always related to emotion understanding. Furthermore, it should be noted that facial mimicry generally reflects the valence of stimuli (e.g., Blom et al., 2019; for a review, see Hess & Fischer, 2013), not discrete emotional expressions per se. The information that a person could hypothetically deduce from facial muscle activation based on a stimuli's valence could appear somewhat limited. However, when the emotions one observed in others are more complex, ambiguous, or unclear, it could indeed provide relevant information to the person (e.g., Arnold & Winkielman, 2019; Barsalou, 2008; Winkielman et al., 2018).

Impaired facial muscle activity and emotion understanding

Although facial mimicry is not always related to emotion understanding, being (temporarily or chronically) impaired in facial mimicry similarly does not always impair emotion understanding. This raises the question regarding how individuals reach emotion understanding when facial simulation is impaired.

Regarding the discussed research on patients with unilateral facial paresis (VS and Bell's palsy patients), we cannot exclude the possibility that these patients still -partially-simulate emotion with their non-paralyzed hemiface, and that this partial simulation facilitates their emotion understanding. However, we consider this unlikely due to similar findings with Moebius syndrome patients -who have a bilateral facial paresis, as well as with patients with Locked-in-Syndrome (LIS) -who typically show a complete paralysis of voluntary facial movements due to lesions of the ventral pons. For instance, LIS patients have shown an impaired ability to consciously recognize negative facial expressions, but no impairment in recognition of expressions of happiness and surprise (Pistoia et al., 2010). Thus, these rather extreme conditions of full facial paralysis further confirm that being impaired in facial muscle movement does not impair all emotion understanding.

While this could be interpreted as undermining the importance of embodied processes and simulation in emotion understanding, this does not necessarily have to be the case. First of all, whereas the present review particularly focused on the role of facial mimicry in emotion understanding, it should be noted that the absence of observable (overt) facial mimicry does not mean that embodied emotion simulation is completely absent. Neurobiological research shows

that somatosensory-related regions, motor regions and other neural networks related to emotion processing and expressing emotion with the facial muscles indeed are important for emotion understanding (Adolphs, Damasio, Tranel, Cooper & Damasio, 2000; Kircher et al., 2013; Rymarczyk, Żurawski, Jankowiak-Siuda & Szatkowska, 2018). Thus, when individuals are impaired in facial muscle movement, they most probably can still engage in perception and sensory simulation processes to build an embodied representation when needed, such as by involving emotion related regions in the brain.

Furthermore, studies showing that emotion understanding is impacted negatively in individuals with damage in basic emotion-related brain areas, support this notion that the cortical simulation of emotion is yet another important route of embodied social cognition (e.g., Adolphs et al., 2000). For instance, patients with bilateral lesions in the amygdala - a brain region important for social signal processing- tend to show impaired recognition of fearful facial expressions (Mihoy et al., 2013). Interestingly however, this subcortical impairment in the limbic brain can be taken over by cortical processes to guide of emotion understanding. For example, other brain regions related to the mirror-neuron system (also implicated in embodied cognition processes) can sometimes compensate for the effects of this lesion (Mihoy et al., 2013). These findings suggest that impaired abilities to simulate emotion can impair emotion understanding, but that the brain allows for some plasticity to deal with emotion understanding in social situations (Becker et al., 2012; De Gelder, Terburg, Morgan, Hortensius, Stein & van Honk, 2014; van Honk, Terburg, Thornton, Stein & Morgan, 2016; Hortensius, Terburg, Morgan, Stein, van Honk & de Gelder, 2016). While such brain plasticity is often considered to take time and practice (Kelly & Garavan, 2005; Kolb & Wishaw, 1998), as well as motivation and attention (Cramer et al., 2011), it is not yet clear how much learning is required to compensate for basic subcortical losses in emotion processing and understanding.

In short, even when individuals are impaired in facial muscle movement, an embodied representation of emotion can still inform emotion understanding. Furthermore, in line with research showing impairments in more complex or demanding emotion understanding, full and overt simulation is not always necessary for emotion understanding to take place when the emotions of others are clear and do not need any additional context in order to be understood (Arnold & Winkielman, 2019; Blom et al., 2020b; Winkielman et al., 2018).

Future avenues for research

The current analysis suggests that facial mimicry is not crucial for emotion understanding, hereby questioning a more radical embodied cognition view on emotion understanding (for recent reviews discussing more vs. less radical embodied cognition approaches, see e.g., Wilson & Golonka, 2013; Raab & Araujo, 2019). Nevertheless, this does not exclude the possibility that embodied processes might have a vital role in different phases of emotion processing, namely during the learning and development of emotion concepts.

Indeed, embodied processes have been shown to facilitate learning of new concepts (e.g., Black, Segal, Vitale & Fadjo, 2012; Lindgren, Tscholl, Wang & Johnson, 2016), and to reveal differences in the representation of emotion (Kitayama & Salvador, 2017). This would concur with the notion of flexible and adaptive emotion concepts. It has been reasoned and shown that individuals develop more complex emotion concepts during childhood, and that these are continuously updated based on new relevant experiences (Hoemann & Feldman Barrett, 2019). This fits well with the embodied cognition framework positing that individuals form representations of concepts based on their -bodily- experiences and their interaction with the environment (e.g., Barsalou, 2008; Semin & Smith, 2008). Furthermore, it would also explain why facial mimicry appears to become more relevant during understanding of more ambiguous emotion information, as individuals might not have stored previous experiences where they can otherwise readily rely on to arrive at a judgment of others' emotions.

The link between practice and repetition of bodily experiences with emotion on the one hand, and emotion understanding on the other hand, has not received full attention so far. It would suggest that when an individual has more bodily experiences with an emotion concept, that facial mimicry would become less crucial for emotion understanding. Studying the role of learning and past experiences, therefore, might be an important and fruitful step for future research to examine boundary conditions of the embodied cognition model of emotion understanding.

First, in the context of learning and past experiences, the absence of an association between facial mimicry and emotion understanding might result from lack of facial activity in response to facial expressions or the translation of facial mimicry into emotion understanding (see also Figure 1). For example, Blom and colleagues (2019, 2020) showed that facial activity was sensitive to the valence of facial emotional expression, but not to the emotional expression

itself, suggesting that facial mimicry did not emerge in the first place. Based on such findings, it is possible that facial mimicry is more relevant for processing specific or novel emotional expressions, while after sufficient practice the mere valence effect remains as a part of a more rudimentary process that links basic affect to sensorimotor activity (see also the distinction between liking and wanting in behavioral effects, Berridge, Robinson & Alridge, 2009). Following this line of reasoning suggests that embodied processes are more crucial in emotion learning and when an emotion concept is not fully or clearly formed. Previous research supports this notion. Facial activity during encoding of an ambiguous facial expression affects how each particular face is eventually represented and understood (Halberstadt et al., 2009). In addition, facial mimicry has been shown to play an important role in social learning (e.g., Buchsbaum, Blumberg, Breazeal & Meltzoff, 2005; Hess, Philippot & Blairy, 1999; McIntosh, Reichmann, Decker, Winkielman & Wilbarger, 2006).

Furthermore, research on the effect of blocking facial mimicry shows rather mixed evidence for an embodied cognition view on emotion understanding. In most research on facial blocking effects, the role of learning is generally not explicitly taken into account. If facial mimicry plays a more important role during learning, then more experienced individuals would experience less impairment in emotion understanding when facial mimicry is blocked compared to individuals with less experience. Findings that illustrate this idea come from research showing that individuals with supposedly poor (vs. good) emotion recognition abilities have impaired emotion recognition when facial mimicry was blocked (Wood et al., 2019). Additionally, Botox injections did not seem to speed up the categorization of less intense facial emotion expressions from pre- to post-test, while individuals who did not receive Botox injections did become faster (Baumeister et al., 2016). Hence, facial mimicry blocking studies could specifically study the role of learning by examining unlearned emotion understanding, or learning effects as reported in Baumeister et al. (2016).

Another, important area of future examination concerns patients suffering from a facial paresis. These patients tend to show rather intact emotion understanding abilities, even though some elements of more complex emotion understanding might be impaired. Whereas earlier research cannot completely rule out that facial mimicry did occur (e.g., in case of unilateral side paralysis in VS patients; Blom et al., 2020a, 2020b), in more extreme cases of paralysis -such as LIS patients- emotional understanding still appears without facial mimicry. However,

emotion understanding in these patients could be relatively established and developed due to previous -bodily- experience with emotion, as well as due to established conceptual emotion knowledge or other compensatory emotion understanding routes (e.g., Bate et al., 2013). Especially when the facial paresis is acquired at a later age, after the individual has been able to develop complex emotion concept representations. If the role of facial mimicry is mainly relevant during facial emotional expression learning, then one would expect for individuals who had more (vs. less) learning opportunities to show less (vs. more) impairments in emotion understanding after developing a facial paresis.

Finally, taking the role of experiences one step further would suggest that facial paresis present since birth (i.e., congenital facial palsy, such as in Moebius syndrome) renders emotion understanding might be rather problematic, due to the full absence of producing facial emotional expressions nor any opportunity to facially mimic emotion in life. Studying emotion understanding in congenital facial palsy would thus constitute a strong test of the importance of facial mimicry for embodied emotion understanding. A recent study suggests that children with Moebius syndrome (with an average age of 5.7) encounter more difficulties in facial emotion recognition based on simple cartoon illustrations of emotional expressions compared to a control group (Nicolini et al., 2019). It is important to note, though, that these children were not completely impaired in emotion understanding, which suggests that emotion understanding can be -at least partly- compensated for by other routes. Further examining the development of, as well as possible impairments in, emotion understanding in children suffering from permanent conditions of facial paralysis from birth (such as Moebius syndrome) would especially advance the understanding of the role of embodied processes and experience in emotion understanding.

To conclude, the present paper indicates that the role of facial mimicry in emotion understanding remains elusive, and calls for a research agenda that addresses in more detail when facial simulation, in particular, and embodied processes in general, are vital for knowledge representations and cognition. As the present analysis suggests, sensorimotor and perception processes might be especially relevant during the learning and development of emotion concepts, that is, when a person had less previous -bodily- experience with the concept in order to form representations of emotions. While the essence of learning and practice has been addressed before, it might provide an interesting and important window to more fully

understand, from a theoretical, empirical and practical point of view, when people rely on their own face to understand the faces and emotions of others

Chapter 3

Moving events in time: Time-referent hand–arm movements influence perceived temporal distance to past events.

Based on: Blom, S.S.A.H., & Semin, G. R. (2013). Moving events in time: Time-referent hand–arm movements influence perceived temporal distance to past events. *Journal of Experimental Psychology: General*, 142(2), 319-322.

Abstract:

We examine and find support for the hypothesis that time-referent hand-arm movements influence temporal judgments. In line with the concept of "left is associated with earlier times, and right is associated with later times," we show that performing left (right) hand-arm movements while thinking about a past event increases (decreases) the perceived temporal distance to the event. These findings show for the first time that hand-arm movements can influence the perceived temporal distance to events.

INTRODUCTION

Sometimes past events can feel very close in time, and on other occasions recent events can feel as if they took place a long time ago. We report an experiment revealing that systematically controlled hand-arm movements on a horizontal plane can influence how past events are anchored in time. The argument driving this research was derived from conceptual metaphor theory (Lakoff & Johnson, 1999), which presents a framework to understand how concepts that we cannot touch or see are grounded and processed. The general idea behind conceptual metaphor theory is that we make sense of abstract concepts by grounding them on our knowledge and experience with more concrete experiences. Thus, abstract concepts are "mapped" onto concrete concepts. Such abstract-concrete mapping can be revealed in metaphors representing abstract concepts. For example, metaphors about time rely on spatial references, as in the case of "leaving one's past behind oneself" or "looking forward to tomorrow's party". The spatial grounding of time facilitates our understanding and processing of time (e.g., Boroditsky, 2000; Casasanto, 2010). Notably, referring to leaving the past behind or looking forward to the future is accompanied by gestures, respectively pointing behind oneself or ahead (Cienki & Muller, 2008; Nunez & Sweetser, 2006). Aside from their communicative function, such gestures also facilitate the expression of thought (e.g., McNeill, 1992), and they influence cognition (e.g., Goldin-Meadow & Beilock, 2010). These considerations led to a novel line of inquiry connecting spatial hand-arm movements (HAMs) and the spatial grounding of time in order to examine the influence of systematically controlled HAMs upon the perceived temporal distance to events.

Although the spatial grounding of time (Lakoff & Johnson, 1999) can be noted in the everyday language we use when talking about time (Boroditsky, 2000; Boroditsky & Gaby, 2010; Boroditsky & Ramscar, 2002; Casasanto & Boroditsky, 2008; Matlock, Ramscar, & Boroditsky, 2005), its directionality seems to be influenced by writing direction (e.g., Boroditsky, 2001, 2011; Boroditsky, Fuhrman, & McCormick, 2011; Chan & Bergen, 2005). For example, whereas English speakers were faster in classifying events as having occurred "earlier" by pressing a left compared to a right response key, Hebrew speakers-writing from right to left-were faster in classifying earlier events with a right compared to a left response key (Fuhrman & Boroditsky, 2010). In line with these findings, a study on the relation between

writing direction and classifying auditory presented time-related words found that responses of Spanish and English participants (left-to-right writing cultures) were faster to past (future) words with the left (right) hand, whereas the opposite held for Hebrew participants (Ouellet, Santiago, Israeli, & Gabay, 2010). Moreover, categorization of past and future words is faster when the key to be pressed and the position of the words on the screen are congruent with the left-to-right timeline (Santiago, Lupianez, Perez, & Funes, 2007). Another study found that activating past or future words primes attention and motor responses to the left and right, respectively (Ouellet, Santiago, Funes, & Lupianez, 2010). HAMs may therefore both influence and reflect our spatial grounding of time.

In general, a spatial left-to-right mental timeline is thus commonly used in the West (Ouellet, Santiago, Israeli, & Gabay, 2010; Weger & Pratt, 2008), where "the left" is associated with earlier times and "the right" with later times. Hand-arm gestures accompanying speech about time reveal that this timeline is often used in one of two ways. One way is with the ego as a reference point, such that pointing to the left (right) refers to the past (future). Another manner to use the left-to-right timeline is without the ego as a reference point. The position of events in time are then expressed relative to one another, such that earlier (later) events are referred to by pointing more toward the left (right; Cooperrider & Nunez, 2009). In line with the use of the mental timeline with reference to the ego, Casasanto and Jasmin (2012) have observed that when participants were speaking about past events, they spontaneously gestured more to the left compared to when they were speaking about future events. Additionally, the influence of gestures on thinking, and the gestural expression of abstract as well as spatial concepts, are well documented (e.g., Alibali, 2005; Goldin-Meadow & Beilock, 2010; Kinsbourne, 2006).

HAMs Can Influence Perceived Temporal Distance

The research reviewed above leads cumulatively to the conclusion that if participants' HAMs were controlled such that if they were making left HAMs while thinking of an event from

memory, then the event should feel temporally more distant compared to when they make right HAMS.¹

Although this general conclusion may be derived from the research cited above, there are three plausible accounts embedded in this general observation. The first is that it is not the movement per se but the spatial position of the movement relative to the body, namely with the ego as the reference point. So, it is possible that a movement on the left side of the body results in events being perceived as more distant and the reverse for performing HAMS on the right of the body. The second account is that it is HAMS with the left or right hand that may be responsible. Finally, the third possibility is that the goal of the movement is an important anchor for perceived temporal distance, such that movements with a left (right) directionality lead to events being perceived as more distant (close).

In order to be able to differentiate between these three alternatives, we designed an experiment whereby left HAMS and right HAMS were varied across three factors in order to disentangle the influence of (a) the spatial position, namely the side on which HAMS are performed (on the left vs. the right side of the participant); (b) the hand with which HAMS are performed (with the left vs. the right hand); and (c) the goal of movement of HAMS (toward the left vs. toward the right) on the perceived temporal distance to an event.

We conducted an experiment in which we experimentally controlled HAMS to examine whether they systematically influence the perceived temporal distance to an event. HAMS were manipulated by asking participants to manually move marbles from one box into a second box (cf. Casasanto & Dijkstra, 2010). Congruency with the concept of "left is an earlier moment in time, and right is a later moment in time" in spatial position, hand, and goal of movement was controlled for as between-subjects variables with two levels in each case. This resulted in an experiment with spatial position (left vs. right), hand (left vs. right), and goal (left vs. right) as the three between-subjects variables.

¹ The judgment of perceived temporal distance to an event after producing HAMS should be classified as a retrospective temporal judgment (e.g., Block & Zakay, 1997) because participants were not aware that they had to make temporal judgments about the event prior to retrieving the event from memory and prior to engaging in left or right HAMS.

Participants were asked to retrieve an event from memory. After retrieving the event from memory, participants were asked to move the marbles manually from one box into a second box repeatedly for 3 min. They performed this marble-moving task while keeping the event in mind and were subsequently asked to indicate how temporally close or distant they felt to the event they had retrieved.

METHOD

Participants

One hundred ninety-two students (137 female, 55 male; $M_{age} = 21.33$, $SD = 2.96$) participated in this experiment. Five participants were excluded from analysis beforehand, as they failed to retrieve an event from memory with the specified temporal distance, and one participant was excluded, as he did not follow the instructions.

Independent Variables

Time of past event was controlled by asking the participants to retrieve an event from memory that had occurred a year ago. To induce HAMs, we asked participants to move marbles from one box to a second box. There were always three boxes present: one positioned to the left, one directly in front, and one to the right of the participant. Only two boxes were assigned in each condition, one containing marbles and the other being empty. Participants had to move one marble at a time from the box that contained marbles into the empty box. They heard a beep every 3 s, which was their signal to move a marble. The same movement was carried out during three 1-min rounds, resulting in a total of 60 HAMs per participant: This resulted in a full factorial design with the above three factors as between-subjects variables.

* Factor 1: Spatial position of movement: Participants had to move marbles either on their left side (moving marbles between the left and center box) or their right side (moving marbles between the center and right box).

* Factor 2: Hand used to produce the movement: Participants had to carry out the marble moving-task either with their left hand or with their right hand.

* Factor 3: Goal of movement: Participants had to move marbles either to the left (e.g., from the center box to the left box, or from the right box to the center box) or to the right (e.g., from the left box to the center box, or from the center box to the right box).

Dependent Variable

The perceived temporal distance to the event was assessed by asking "How far in time do you feel the event that you described is?" (1 = *very close*, 9 = *very far*) and "How long ago does it feel that this event took place?" (1 = *shorter than in actuality*, 9 = *longer than in actuality*). These two measures were correlated ($r = .61, p < .001$), and were averaged to form one score for perceived temporal distance (1 = *very close*, 9 = *very distant*).

Procedure

After introducing the general background, participants were asked to retrieve an event from memory that was approximately a year old. They were also asked to write down the day, month, and year on which the retrieved event occurred. Subsequently, participants carried out the marble-moving task while keeping the event in mind. After completing this task, the two questions of perceived temporal distance were assessed. Participants then rated the event on five 9-point scales measuring various features of the event (emotionality, importance, valence, vividness, and degree of rehearsal of the event, adapted from Semin & Smith, 1999) to assess possible qualitative differences between the retrieved events.

RESULTS

Manipulation Check

The event retrieval manipulation was successful. The retrieved events were approximately a year old ($M_{days} = 369.10, SD = 21.81$).

Perceived Temporal Distance

To check whether any of the qualitative features of events retrieved from memory revealed a systematic effect as a function of HAMs, we performed a multivariate analysis of variance with spatial position (left vs. right), hand (left vs. right), and goal (left vs. right) as the three

between-subjects variables and emotionality, importance, valence, vividness, and degree of rehearsal as the dependent variables. This revealed that these features did not differ as a function of side, hand, and goal of movement (all $F_s > 2.06$). The main prediction that producing left (right) HAMs while keeping an event in mind would increase (decrease) the perceived temporal distance to the event was analyzed in a 2 X 2 X 2 analysis of variance, with spatial position (left vs. right), hand (left vs. right), and goal of movement (left vs. right) as between-subjects factors. This analysis revealed a main effect for spatial position, $F(1, 184) = 7.84, p = .006, \eta_p^2 = .034$. In line with expectations, producing HAMs on the left side increased the felt distance to the retrieved event ($M = 5.51, SD = 1.98$) compared to producing HAMs on the right side ($M = 4.82, SD = 2.04$). A main effect of hand was also found, $F(1, 184) = 4.32, p = .04, \eta_p^2 = .023$, revealing that using the left hand to produce HAMs increased the felt distance to the retrieved event ($M = 5.52, SD = 2.10$) compared to using the right hand to produce HAMs ($M = 4.90, SD = 1.94$). There was no effect of goal of movement, nor were there any interactions.

This indicates that in line with the concept of “left is an earlier moment in time, and right is a later moment in time,” making HAMs on the left spatial position as well as making them with one’s left hand can make an event feel more distant compared to making HAMs on the right spatial position and with the right hand.

To further explore this effect, we carried out a linear trend analysis with spatial position and hand as factors. Because the reported three-way analysis of variance showed that spatial position had a somewhat stronger effect than hand, spatial position was chosen as the main factor in determining the congruency with “left is an earlier moment in time, and right is a later moment in time,” with hand being the additional factor. This leads to the following four combinations of the two factors: (a) both spatial position and hand are left (most congruent with “left is earlier”), (b) spatial position is left and hand is right (less congruent with “left is earlier”), (c) spatial position is right and hand is left (more congruent with “right is later”), and (d) both spatial position and hand are right (most congruent with “right is later”). The linear effect was significant, $t(188) = 2.92, p = .004$, Cohen’s $d = 0.43$, whereas both the quadratic and cubic effect were not (both $t_s < 1$).

These findings reveal that when spatial position and hand used are congruent with each other in producing HAMs (i.e., left–left vs. right–right), then the highest difference reveals;

participants in the left spatial position–left hand condition judged the event to feel the furthest in time ($M = 5.88$, $SD = 2.13$), and participants who produced HAMs in the right spatial position–right hand condition judged the event to feel the closest ($M = 4.50$, $SD = 2.03$), with the two other conditions—left spatial position–right hand ($M = 5.22$, $SD = 1.81$) and right spatial position–left hand ($M = 5.06$, $SD = 2.03$)—falling precisely in between.

DISCUSSION

The experiment reported here was designed as a contribution to elucidate the relationship between the grounding of time, space, and gestures by examining the effect of time-referent HAMs on the retrospective memory judgments and temporal anchors for those judgments. The experiment revealed that time-referent HAMs influenced the perceived temporal distance to events. Producing HAMs on the left (right) spatial position with the left (right) hand while thinking about a past event increased (decreased) the perceived temporal distance to the event.

To our knowledge, this is the first time that a systematic analysis of the differential contribution of spatial position, hand, and movement goal on retrospective memory judgments and temporal anchors for those judgments has been examined. The present findings suggest that the left-to-right spatial representation of time in the West (Boroditsky, 2000, 2001, 2011; Boroditsky & Ramscar, 2002; Casasanto & Boroditsky, 2008; Matlock et al., 2005) is integrally represented and that the perceived temporal distance to events is influenced by left or right HAMs that map and prime corresponding temporal anchors and references.

Our findings are clearly in line with the idea of the left being associated with an earlier point in time and the right with a later point. The results support the argument that the mental timeline is constituted by the vertical body axis of left and right with the ego in the middle. The division of space to left and right with reference to the ego constitutes the constraint within which HAMs congruent with the spatial position influence the temporal anchoring of the same event. Thus, left HAMs to the left side of the vertical body axis move the felt temporal anchor of the event further to the past, whereas right HAMs to the right side of the vertical body axis move the felt temporal anchor of the event to a closer point in time.

Interestingly, the goal of the movement did not produce any systematic effects. This provides some support for the argument that the ego serves as a reference point of the mental

timeline. If the goal of the HAMS was a driving factor, then one should have observed movements to the right (left) to induce a closer (more distant) perceived temporal distance to the event in time, irrespective of which hand was performing the movement and on which side of the body the movement was. This in fact turns out to be not the case. The goal of HAMS shows no main effect or higher order ones.

One may raise the argument that the valence implied by the spatial position involved in movements provides a possible alternative account for the results reported here. Research on the body specificity hypothesis has shown that right-handed people are more likely to associate the right horizontal space with positivity and the left horizontal space with negativity (e.g., Casasanto, 2009). Independently, earlier research (e.g., Ross & Wilson, 2002; Semin & Smith, 1999; Wilson & Ross, 2001) has revealed that negative events retrieved from memory are anchored earlier in time than positive events.

If the left horizontal space is associated with negativity and the right horizontal space with positivity for right-handed people (e.g., Casasanto, 2009), as our participants were, then it is possible to argue that left HAMS induce negativity and thus shift the anchor of the event further away, whereas right HAMS induce positivity and shift the anchor of the event closer. However, our data show that there are no systematic differences in valence for the retrieved events. Moreover, the events were retrieved prior to HAMS. We therefore think that this account is implausible and that the present findings are best explained by conceptual metaphors about time that rely on spatial references and support the general view that the spatial grounding of time facilitates our understanding and processing of time.

Although time-referent gestures have been observed, experimentally controlled HAMS have never been shown to influence perceived temporal anchors of events. This contribution opens ways to examine which temporal anchors can be shifted in a variety of everyday contexts, as well as issues related to their generalizability across cultures where it is known that the timeline is the reverse or orthogonal to the Western left-right timeline.

Chapter 4

Lateralization of facial emotion processing and facial mimicry

Based on: Blom, S.S.A.H., Aarts, H., Semin, G.R. (2019). Lateralization of facial emotion processing and facial mimicry. *Laterality: Asymmetries of Body, Brain and Cognition*, Advance online publication. DOI: 10.1080/1357650X.2019.1657127

Abstract:

The two halves of the brain are believed to play different roles in emotional processing. In studies involving chimeric faces, emotional expressions in the left visual field are more strongly perceived as emotional than those in the right visual field. Notably, the role of facial mimicry has not been studied in relation to hemispheric lateralization. In the current study, which used a novel stimulus set of chimeric faces, we proposed and found that emotional intensity judgments replicate the left visual field bias for facial expressions of emotions. While a general facial mimicry effect to the chimeric faces occurred for the corrugator muscle, these mimicry effects were not related to the visual field bias. The results suggest that encoding the emotionality of another person's facial expression might occur independent from the mere mimicry of the facial expression itself.

INTRODUCTION

Social interaction and our connections with other people are a vital part of human life. In order for these social interactions to work smoothly, it is crucial that we understand what our communication partner feels. One of the most important manners in which people express their feelings in social interactions is by facial expressions. Facial expressions thus play a crucial role in the understanding of the other. There is a fair amount of evidence showing that the facial expression of an emotional state can lead observers' corresponding facial muscles to be directly activated, often referred to as 'facial mimicry' (e.g., Dimberg, Thunberg, & Grunedal, 2002). The automatic nature of facial mimicry suggests the existence of a process that supports the interpretation and encoding of emotions during social interactions with other people (e.g. Niedenthal, 2007).

An interesting finding in research on the encoding of emotional expressions concerns the observation that when people attend more to the left visual field, rather than the right visual field, emotional facial expressions are perceived as more intense. This bias of perceiving an expression seen in the left (vs. right) visual field as more emotional is interpreted as supporting evidence for the idea that the right-brain hemisphere is involved more strongly in emotion processing than the left-brain hemisphere (e.g., Bourne, 2010). Hemispheric processing is often studied by using the chimeric faces test, a behavioral test of lateralization in which an emotional facial expression is presented in either the left or right visual field.

The relation between right hemispheric processing of emotional expressions and perceptions of emotional intensity raises the intriguing question of whether this relation might be modulated by facial mimicking processes. The role of the facial muscles of the observer in relation to hemispheric lateralization has been partly in studies with patients with unilateral facial paralysis (Korb, Wood, Banks, Agoulnik, Hadlock & Niedenthal, 2016). While some tasks showed no difference between patients with a left vs. right facial paralysis, one difference that was found in these studies was that left sided paralysis patients showed more errors for onset of happiness on left vs. the right visual field. Though the current study focuses on perceived emotionality of facial emotional expressions on the left vs. right visual field and not on accuracy in judging the onset of facial emotional expressions on the left vs. right visual field, the finding of this study does suggest that there might be an association between facial mimicry

and lateralization of emotion processing. Surprisingly, the role of facial mimicry has not been studied in relation to hemispheric lateralization directly.

Accordingly, the present study serves two main goals. First of all, we aim at replicating the results of the chimeric faces test. Secondly, we aim to examine whether facial mimicry occurs for chimeric faces –e.g., faces showing an emotional expression only in one half of the face–, something which has not been tested before.

Hemispheric lateralization of emotion processing

Theories concerning the hemispheric lateralization of emotion processing often consider the viewpoint that 1) all emotions are, by and large, processed in the right hemisphere –the right hemisphere hypothesis, or that 2) positive emotions are processed in the left hemisphere, and negative emotions in the right hemisphere –the valence hypothesis¹ (e.g., Bourne, 2010). Each of these viewpoints is partially supported empirically, suggesting that neither hypothesis has unambiguous evidence (cf. Fridlund, 1988). However, in general the predominant evidence suggests that the right hemisphere plays a more important role in emotion processing than the left hemisphere (Murray, Krause, Stafford, Bono, Meltzer, & Borod, 2015). For example, right hemispheric processing of emotional facial expressions often leads to better recognition, discrimination, as well as a stronger perceived emotionality of these expressions compared to left hemispheric processing and has been reported for facial expressions of various emotions (e.g., Bourne, 2010). Research has also shown that left hemiface composites of faces tend to be rated as more similar to the full face as well as being perceived as more expressive than right hemiface composites (e.g., e.g., Sackeim & Gur, 1978). This relates to the expressiveness of the poser, and is in line with the right hemisphere hypothesis as it suggests that our left hemiface (which is primarily controlled by the right hemisphere) is more expressive than our right hemiface (e.g., Bourne, 2010). Moreover, deficiencies in right hemispheric areas have been associated with difficulties in recognition of emotional facial expressions, and with social and emotional functioning in general (e.g., Meletti et al., 2003, Murray et al., 2015). In line with

¹ A third hypothesis, which is less frequently stated, suggests that lateralization of emotion processing is based upon approach and avoidance, where the left hemisphere is said to be specialized in approach emotions, and the right hemisphere in avoidance emotions.

this, the left visual field bias tends to be reduced or reversed for people with right brain damage (e.g., Kucharska-Pietura & David, 2003), further supporting the role of the right hemisphere in processing emotional facial expressions.

The current's study's focus is not on lateralization in expressiveness of a poser but on lateralization of perceived emotionality and emotion processing in the observer.

A great deal of evidence for the lateralization of emotion processing is derived from the chimeric faces test. This test measures the possible bias in the observer relating to the perception of emotional expressions presented in the left vs. the right visual field (e.g., Bourne, 2010; Bourne & Gray, 2011; Levy, Heller, Banich & Burton, 1983). In studies using the chimeric faces test, the classic and repeatedly reported finding is that expressions shown in the left visual field are perceived and judged as more emotive than expressions shown in the right visual field, in line with the right-hemisphere hypothesis². Different versions of this test exist. For example, participants can be presented with two faces at a time, one above the other, with one face depicting an emotional expression in the left visual field while the other depicts it in the right visual field (e.g., Bourne & Vladeanu, 2011), after which participants are asked to choose which of the two faces they find more emotive. Another option is to present one chimeric face at a time, at fixation, with an emotional expression depicted in the part of the face that falls in either the left or right visual field. The participant is asked how emotive they find each face, and comparisons can be made across faces depicting the expression in the left vs. right visual field (e.g., Bourne & Gray, 2011).

Facial mimicry and emotion processing

People's facial muscles often automatically respond when processing emotional facial expressions. Seeing a negative emotional expression for example tends to increase activity of the frowning muscle – corrugator supercilii–, and seeing a positive emotional expression tends to increase activity of the smiling muscle –zygomaticus major. This process of facial mimicry (e.g., Dimberg, Thunberg, & Grunedal, 2002) is suggested to relate to the valence of the facial

² While sometimes differences are reported based on the valence of the emotion or the type of emotion, the strongest overall effects reported support the left visual field/right-hemisphere bias (e.g., Bourne, 2010).

expression one sees (Hess & Fischer, 2013). Facial mimicry is one way in which bodily processes that are active when people experience a state can also become activated to a certain extent when people perceive and process a similar state in the environment (e.g., Winkielman, Niedenthal, Wielgosz, Eelen, & Kavanagh, 2015). Facial mimicry is thought to play a functional role, supporting our recognition, processing, understanding and encoding of emotional information (e.g., Niedenthal, 2007).

Lateralization and facial mimicry

While voluntarily induced movements of the face stem from the cortical motor strip—a pathway called the pyramidal tract—and are likely to be lateralized, emotionally induced facial movements are thought to arise from an older motor system—the extrapyramidal tract—for a review, see: Rinn, 1984) and are thus unlikely to be lateralized. Evidence for this double dissociation shows that neurological damage can disrupt either one of these systems (Blair, 2003; Rinn, 1984). Furthermore, little asymmetry is reported in studies using spontaneous emotional expressions, with any present asymmetry divided equally over the two sides of the face (cf. Ekman, Hager, & Friesen, 1981, Gazzaniga & Smylie, 1990). Only one study, to our knowledge, reported facial mimicry to be somewhat stronger in the left than the right side of the perceiver's face (Dimberg & Petterson, 2000). Another study did not find differences based on the side of the muscles but did show a relationship between stronger facial mimicry and right-brain activity (Achaibou, Pourtois, Schwartz, & Vuilleumier, 2008), suggesting that the strength of facial mimicry and hemispheric emotion processing could be related. Taken together, it can be argued that right hemispheric processing of emotional expressions can be expected to be related to stronger facial mimicry, but facial mimicry itself will likely not differ between the left or right side of the observer's face.

Current study

While many effects reported in psychology have been difficult to replicate, the chimeric faces test seems to show a reliable and medium to large effect. Most of the previous tests of hemispheric processing of emotional expressions used chimeric faces that are based on the database developed by Ekman and Friesen (1976) or the Karolinska Directed Emotional Faces database (Lundqvist, Flykt, & Ohman 1998). In the current study we firstly aim to further

generalize these effects by replicating the previous findings of hemispheric processing with a more recently developed stimulus set based on the Dutch Radboud Faces Database (Langner, Dotsch, Bijlstra, Wigboldus, Hawk, & van Knippenberg, 2010). Validation of this database revealed that the overall agreement rate between intended and chosen expression was around 11% higher than reported in a recent validation study of the Karolinska database (Langner et al., 2010).

Secondly, we aim to examine whether facial mimicry occurs for chimeric faces. Lastly, if facial mimicry occurs to chimeric faces, we will further examine whether an individual's facial muscles react differently to faces showing the emotional expression in the left vs. the right visual field. If such lateralization of emotion processing shows differential effects in facial mimicry, then this would allow for a test of the mediating role of facial muscle activity in the effects of hemispheric processing and perceptions of emotionality.

The relationship between lateralization of processing emotional facial expressions and emotional facial mimicry has not been studied directly. In the study reported here, this relationship is examined with the aid of the chimeric faces test of angry and happy facial expressions. The one-face chimeric faces test (see Bourne & Gray, 2011 for a similar procedure) was chosen in order to allow for informative facial EMG measurements per type of stimulus. Faces were presented at fixation. Participants were shown one chimeric face at a time –with the emotional expression depicted either in the left or the right visual field– and had to indicate the emotionality of the face³ while both left and right facial muscle activity of the corrugator and zygomaticus were measured. Attempting to replicate previous findings with a new stimulus set, we first tested whether there would be stronger emotionality judgments when emotional expressions are shown in the left vs. the right visual field. Furthermore, we examined whether a general emotional facial mimicry effect would show despite the fact that the stimuli consist of chimeric faces. If facial mimicry occurred, we would examine if emotional facial mimicry would be stronger for left vs. right visual field facial emotional expressions.

Study overview

The study had a within participants' design with emotional expression (angry vs. happy) and

³ see Bourne & Gray (2011) for a similar procedure.

emotional half (left vs. right visual field) of the stimulus as repeated measures.

METHOD

Participants

A sample of 23 right-handed University students (12 female, $M_{\text{age}} = 24.74$, $SD_{\text{age}} = 3.59$) participated in this experiment.⁴

Stimuli

Chimeric faces were created using images of four male and four female faces from the Dutch Radboud Faces Database (Langner et al., 2010). Chimeric faces were created by slightly blending the faces at the midline. This is in line with the approach of a recent study (Innes, Burt, Birch, & Hausmann, 2016) which showed that chimeric faces blended at the midline are equally effective as previous versions while providing the advantage of avoiding possibly inducing atypical emotion processing because of a visible midline. Each chimeric face was composed of an emotional (angry or happy) half face and a neutral half face (see Figure 1 for an example). We made use of both the original pictures, and the mirrored picture.⁵ The final stimulus set consisted of 64 unique chimeric faces, differing in gender (4 male, 4 female), emotion (happy vs. angry), emotional half (left vs. right visual field), and version (original vs. mirrored). The images of faces had a resolution of 462 x 562 pixels and an absolute size of 11.3 x 15.0 cm, and were presented in grayscale on a grey background.⁶

⁴ We wish to stress here that data for this study was collected in 2012, and while ideally the sample size would have been calculated based on an a-priori power analysis, this was not done. However, given the medium to large effect sizes reported for the chimeric faces test (e.g. Cohen's d of .82 (Bourne & Gray, 2011), and Cohen's d of .50 for angry and .60 for happy chimeric faces (Bourne & Vladeanu, 2011), and the full within participant design, we aimed for a convenience sample of 20-25 participants.

⁵ This ensured us that the effects that we might find would be due to a true visual field bias, and not to a difference in expressiveness of the left or right side of the poser's face.

⁶ These chimeric face stimuli are available upon request from author SB.

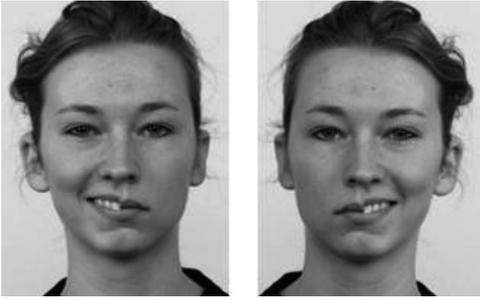


Figure 1. Examples of a chimeric face showing a happy facial expression in the left visual field (left) and in the right visual field (right).

Procedure

Participants were told that the study involved measurement of facial EMG to assess muscle activity during exposure to visual stimuli on the computer screen. The EMG procedure followed the typical protocol of facial muscle activity assessment that had received approval from the ethics commission at Utrecht University. The study was conducted and written informed consent of each participant was obtained in compliance with the principles contained in the Declaration of Helsinki.

Electrodes to measure facial muscle activity were placed on the participant's face, after which they were seated in an individual cubicle in which the experiment was completed. Participants were told that they were to rate pictures of faces presented on the screen on a 9-point scale regarding how emotional they found each face. They were asked to trust their first impression and to not think too long about their rating. Mean ratings of emotionality were calculated per stimulus type.

The experimental task was presented in two blocks, each consisting of the same 64 trials, randomly presented. A trial started with a blank screen (2s), after which a fixation point appeared (1s), followed by the chimeric face (3s). After 3 seconds the rating scale appeared below the chimeric face and the scale remained on screen until participants rated the emotionality of the face.

Facial EMG

Facial muscle activity at the corrugator supercilii and zygomaticus major sites was measured

using bipolar placements of Ag/AgCl miniature surface electrodes filled with electrode gel attached on the left and right side of the face. The skin was cleansed and prepared with alcohol prep pads and semi abrasive lotion. The electrodes were placed following the methods described by Fridlund and Cacioppo (1986), and all pairs were referenced to a forehead electrode placed near the midline. The raw EMG signal was measured with a BioNex Bio-Potential amplifier and stored with a sampling frequency of 1000 Hz. Raw data were filtered with a 30–300 Hz band pass filter and a 50 Hz notch filter and then rectified. Facial muscle activity recorded during the last 500 milliseconds of each blank screen at the start of a trial was used as baseline. Difference scores were calculated using this baseline. Prior to statistical analysis, data were collapsed over trials with the same emotional expression shown in the same half face and averaged over steps of 200 ms for a total of 1000ms.⁷

Equivalence testing in analyses

Reported non-significant effects for this study were further explored by equivalence testing based on the confidence interval approach (see Lakens, 2016⁸). This meant that if the range of the confidence interval of the effect size fell completely within the range of indifference –the equivalence range–, the reported effect was considered not meaningful. If the range of the confidence interval of the effect size fell partly, but not completely, within the range of indifference, it was concluded that it was undetermined if there was or was not a meaningful effect. The range of indifference for this study was defined by a medium effect d_z of .5 (range of -.5 until .5), and a medium effect η_p^2 of .06 (range of .00 until .06)⁹. Bayesian tests were also

⁷ The first second of seeing the stimulus is chosen as it can be assumed that facial muscle activity during this time window is considered to be spontaneous, while after the first second more deliberate processes can occur (Häfner & IJzerman, 2011).

⁸ In line with recommendations by Lakens (2014), 90% CI is reported for eta-squared.

⁹ As reported earlier, the data for this study was collected in 2012. At that time equivalence testing for effect sizes were not common practice yet in psychological research, therefore the range of indifference for the effect sizes was set after obtaining the data. The effect sizes for the equivalence bounds are based on Cohen (1988).

performed for non-significant effects in order to assess the weight of evidence in the data set for the null hypothesis.

RESULTS

1. Behavioral data: Visual field bias

A left visual field bias was expected and confirmed. An analysis of variance of the emotionality ratings as a function of emotional expression (angry vs. happy), emotional half (left vs. right visual field), and block of presentation (first vs. second block) as repeated measures revealed a considerable main effect of emotional half. Participants rated faces showing emotion in the left half face as more emotional ($M = 5.91$, $SD = .85$) than those showing emotion in the right half face ($M = 5.53$, $SD = .82$). The mean difference 0.38 , $CI [0.11, 0.65]$ was significant, $F(1,22) = 15.63$, $p < .001$, $d_z = .82$, $\eta_p^2 = .42$, $90\% CI \eta_p^2 [.14-.59]$. The basic finding of the chimeric faces test was thus replicated, showing in a large and reliable effect of the emotional half of the face.

If the visual field bias would be different based on the emotional expression (happy vs. angry chimeric faces), this should show in an interaction between emotional expression and emotional half. This interaction was not close to significant; $F(1,22) = .90$, $p = .35$, $\eta_p^2 = .04$, $90\% CI \eta_p^2 [.00-.22]$. Equivalence testing revealed that the range of this confidence interval lies partly, but not completely, within the zone of indifference defined by a medium (η_p^2 of $.06$) effect size. This indicates that it is undetermined if there was or was not a difference in visual field bias based on the type of emotional expression being a happy or an angry one. Therefore, Bayesian paired samples t-tests were performed in order to assess the weight of evidence of the non-significant interaction effect (emotional expression x emotional half) provided by the set of data. Comparing emotionality ratings for chimeric faces showing anger in the left versus in the right visual field, showed that the data were 6.24 times more likely to reflect a null effect than to reflect a difference ($BF_{01} = 6.24$). Comparing emotionality ratings for chimeric faces showing happiness in the left versus in the right visual field, showed that the data were 5.71 times more likely to reflect a null effect than to reflect a difference ($BF_{01} = 5.71$).

2. Physiological data: Facial muscle activity

Two separate repeated measures analyses were executed to examine the facial muscle activity

data, one for the corrugator muscles (left and right), and one for the zygomaticus muscles (left and right) with the following repeated measures: emotional expression (happy vs. angry), emotional half (left vs. right visual field), block of presentation (first vs. second block), and time (5 steps of 200 ms).

2.1. Emotional facial mimicry: Corrugator muscles

We first examined whether participants would show emotional facial mimicry to the chimeric faces, expecting stronger activation of the corrugator to angry compared to happy chimeric faces. The interaction between emotional expression and time was indeed significant, $F(1.97, 41.96) = 14.97, p < .001, \eta_p^2 = .40, 90\% \text{ CI } \eta_p^2 [.20-.54]$.¹⁰ This interaction revealed increasing reactivity of the corrugator to the differential emotional expressions at later time points. Stronger corrugator activation to angry than to happy chimeric faces showed (see Figure 2), revealing that an emotional facial mimicry effect indeed occurred even for chimeric faces showing an emotional expression in only one half of the face. In line with expectations, no differences in emotional mimicry revealed based on the side of the corrugator muscle.

¹⁰ Greenhouse Geisser correction was used because of Sphericity violation for this interaction effect.

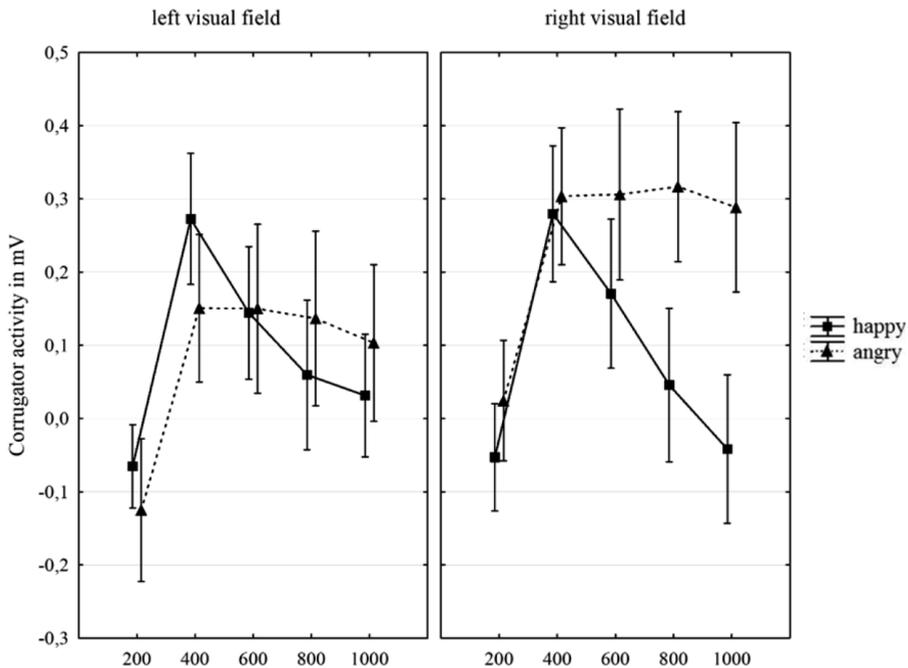


Figure 2: Corrugator activity (in mV, as compared to baseline activation) to happy and angry chimeric faces over time per visual field. Error bars indicate the standard error. The x-axis shows time in ms.

Because emotional facial mimicry occurred to the chimeric faces for the corrugator muscle, we continued analyses checking if the process of facial mimicry were related to hemispheric processing of emotional expressions. If so, then emotional facial mimicry should be stronger to emotional expressions shown in the left vs. right half face. This was not confirmed; the interaction between emotional half and emotional expression was not significant for the corrugator muscle, $F(1,22) = 3.97, p = .06, \eta_p^2 = .15, 90\% \text{ CI } \eta_p^2 [.00-.36]$. Equivalence testing by use of the confidence intervals revealed that the range of this confidence interval lies partly, but not completely, within the zone of indifference defined by a medium (η_p^2 of .06) effect size.

The fact that no interaction showed for the corrugator based on the emotional facial expression being shown in the left vs. right visual field could either reflect that 1) no such interaction existed and that lateralization of emotion processing and facial mimicry are in fact

not related, or 2) that said interaction would be relatively small meaning we did not have enough power to detect its occurrence.

Bayesian paired samples *t*-tests were performed in order to assess the weight of evidence of the interaction effect (visual field of emotion \times emotional expression) provided by the set of data. Comparing corrugator activity for chimeric faces showing happiness in the left versus in the right visual field, it showed that the data were 6.22 times more likely to reflect a null effect than to reflect a difference ($BF_{01} = 6.22$). Comparing corrugator activity for chimeric faces showing anger in the left versus in the right visual field, revealed that the data were 1.87 times more likely to reflect a null effect than to reflect a difference ($BF_{01} = 1.87$).

2.2. Emotional facial mimicry: Zygomaticus muscles

We again first examined whether participants would show emotional facial mimicry to the chimeric faces, with stronger zygomaticus activity to happy compared to angry chimeric faces. This was not confirmed. No interaction between emotional expression and time emerged for the zygomaticus, $F(4,88) = .18, p = .95, \eta_p^2 = .01, 90\% \text{ CI } \eta_p^2 [.00-.01]$. Equivalence testing by use of the confidence intervals revealed that the entire range of this confidence interval is completely contained within the zone of indifference that we defined by a medium (η_p^2 of .06) effect size, indicating that the zygomaticus muscle indeed did not show a meaningful facial mimicry effect of increasing reactivity to the differential emotional expressions at later time points. A Bayesian paired samples *t*-test comparing zygomaticus activity to happy and angry chimeric faces revealed that the data were indeed 3.46 times more likely to be observed under the null hypothesis ($BF_{01} = 3.46$). In line with expectations, no differences in emotional mimicry revealed based on the side of the zygomaticus muscle.

While no emotional facial mimicry occurred to the chimeric faces for the zygomaticus muscle, we did check if there might be a differentiation in facial mimicry related to hemispheric processing of emotional expressions (see Figure 3). If so, then emotional facial mimicry should be stronger to emotional expressions shown in the left vs. right visual field. This was not confirmed; the interaction between emotional half and emotional expression was not significant for the zygomaticus muscle, $F(1,22) = 1.02, p = .323, \eta_p^2 = .04, 90\% \text{ CI } \eta_p^2 [.00-.23]$. Equivalence testing by use of the confidence intervals revealed that the range of this confidence

interval lies partly, but not completely, within the zone of indifference defined by a medium (η_p^2 of .06) effect size.

Bayesian paired samples t-tests were performed in order to assess the weight of evidence of the non-significant interaction effect (emotional expression x emotional half) provided by the set of data for the zygomaticus. Comparing zygomaticus activity for chimeric faces showing happiness in the left versus in the right visual field, showed that the data were 5.32 times more likely to reflect a null effect than to reflect a difference ($BF_{01} = 5.32$). Comparing zygomaticus activity for chimeric faces showing anger in the left versus in the right visual field, revealed that the data were 4.63 times more likely to reflect a null effect than to reflect a difference ($BF_{01} = 4.63$).

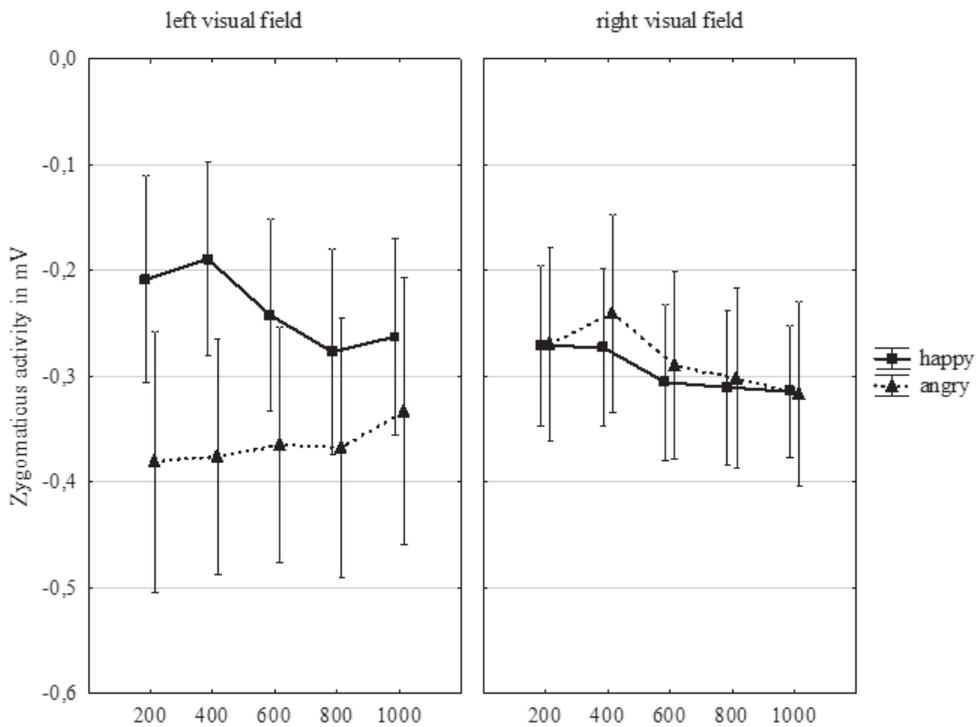


Figure 3: Zygomaticus activity (in MV, as compared to baseline activation) to happy and angry chimeric faces over time per visual field. Error bars indicate the standard error. The x-axis shows time in ms.

DISCUSSION

The present study had two main goals: First, replicating the findings of the chimeric faces test by use of images created with a more recent facial stimulus set (Lagner et al., 2010); and second, examining the role of facial muscle activity (i.e., facial mimicry) in these effects. In line with the idea that the right hemisphere is more involved in processing emotional information, we replicated previous findings of the chimeric faces test and found that participants indeed perceived emotional expressions presented in the left visual field –processed first in the right hemisphere– to be more emotional than those presented in the right visual field. This further generalizes the effects the chimeric faces test, showing that the newly developed stimulus set can be used to measure hemispheric processing of emotional facial expressions.

Moreover, a general emotional facial mimicry effect to the chimeric faces was found for the corrugator muscles, which were activated more in response to angry than to happy chimeric faces. This suggests that even for faces that only show an emotional expression in one half of the face, participants' frowning muscle activity responded in line with the emotional expression shown, showing stronger activation to angry than to happy chimeric faces. Unfortunately, with the current data we were unable to determine if facial mimicry for the corrugator was due to the visual field in which the emotional expression was shown. The zygomaticus muscle did not show any emotional facial mimicry effect. Lastly, as expected, we observed no differences in emotional facial mimicry between the left and right side of the facial muscles.

While the corrugator revealed the expected emotional facial mimicry effect, the zygomaticus did not show any meaningful facial mimicry effect. One possible reason for the absence of the zygomaticus activity effect concerns the notion that the faces in this study were not full emotional faces, only showing an emotional expression in one half of the face. It could thus be the case that the general emotional facial mimicry effect for the zygomaticus could be weaker than when people view full emotional facial expressions. Indeed, emotional stimuli that are less straightforward or intense have been found to induce weaker emotional facial mimicry effects, in particular for the zygomaticus (e.g., Larsen, Norris, & Cacioppo, 2003). Furthermore, it has been found that the zygomaticus shows increased activity to positively valenced stimuli only when these stimuli are strongly positive, while the corrugator shows differences in activity

to emotional stimuli at various levels of intensity (Larsen et al., 2003). The absence of facial mimicry effects for the zygomaticus in the current study is thus in line with previously observed differences between the zygomaticus and the corrugator in sensitivity to emotional stimuli.

While the facial mimicry effect observed in the present study was found for the corrugator, the current data did not reveal if this mimicry effect was different for faces with the emotional expression shown in the right vs. left visual field. While this study is the first to examine the relationship between hemispheric processing of chimeric faces and facial mimicry, we do realize that leaving this undetermined leaves an open question. However, we hope that by providing information on this effect, future studies can provide further insight into the possible connection between facial mimicry and lateralization of emotion processing.

A limitation of the current study is that the facial expression stimuli were of static nature. Use of static stimuli keeps in line with the common chimeric faces test as used by Bourne (2010), hence providing the opportunity to first replicate the basic finding of visual field bias while simultaneously adding the measure of facial muscle activity. However, dynamic facial stimuli (as for example addressed in Carr, Korb, Niedenthal, & Winkielman, 2014) have the obvious advantage of being more representative of real-life situations. Future research could - in line with the study by Korb and colleagues (2016)- further extend the current study by employing dynamic facial stimuli and measures of facial muscle activity in order to provide more insight into the working of lateralization and facial mimicry.

The general gist of our findings suggests that the chimeric faces test is a reliable measure of hemispheric processing and our replication with a newly developed stimulus set further generalizes its findings. Moreover, our study shows that, for the corrugator, a reliable emotional facial mimicry effect was found, revealing that the corrugator responds sensitively to perceived facial hemi-expressions. This opens up possibilities for further investigation into the relationship between facial mimicry and hemispheric processing. The zygomaticus muscle however, did not show a facial mimicry effect in the current study, further supporting the differences between the corrugator and zygomaticus muscle in sensitivity to intensity of emotional information.

In closing, we would like to stress that the present study provides a first test for the relationship between the perception of chimeric faces and facial muscle activity measures. In

our view, the combined methods of hemispheric encoding of facial emotional expressions and the ability of displaying muscle activity in response to these facial expressions presents an interesting avenue for future scientific exploration.

Chapter 5

When social verbal context facilitates emotional processing of visual stimuli

Based on: Blom, S.S.A.H., Aarts, H., Semin, G.R. (Revise and Resubmit). When social verbal context facilitates emotional processing of visual stimuli.

Abstract:

Building on the notion that processing of emotional stimuli is sensitive to context, in two experimental tasks we explored whether the detection of emotion in text and in faces is facilitated by emotional contextual information in the form of verbal audio. In the first task we examined emotion detection in emotion-loaded written words by adding different levels of contextual supporting auditory information. We found that increasing levels of supporting contextual information enhanced emotion detection: Emotion detection in a written emotional word (e.g., nice) was highest when accompanied by the verbal expression of this word pronounced in an emotionally matched (e.g., positive) intonation. In the second experimental task, we added the same contextual supporting auditory information to images of facial emotional expressions, and established that emotion detection was not influenced by contextual supporting information. Furthermore, in both tasks we measured activity of the corrugator and zygomaticus muscle to assess facial simulation in response to the target information. While facial simulation emerged for written words and facial expressions, showing differentiation based on positive vs. negative valence of the visual stimuli, the level of contextual supporting information did not qualify this mimicry effect.

INTRODUCTION

A considerable part of peoples' everyday lives consists of grasping emotion-related information. In social interactions, emotion-related information can come in different forms and shapes. People might use language to convey affective information or to communicate their emotional states, such that emotion processing is directed at verbally expressed or written words. In addition, social interaction involves emotional facial expressions that can reveal the emotional states of interaction partners.

Understanding the emotionality of communicated information that is targeted in social interaction does rarely happen in isolation. Often, emotional processing is accompanied by context (e.g. Arnold & Winkielman, 2019; Aviezer, Ensenberg & Hassin, 2017; Feldman Barrett, Mesquita & Gendron, 2011; Mermillod et al., 2018) that can support the identification of emotionality of target information. For instance, consider a common read-aloud setting in which a child is taught to read a book. In such a situation, the child not only sees the words, but also might hear the very same words and intonation with which these words are being articulated by a caregiver or teacher. Recent research has shown that such reading aloud to young children actually positively affects their social-emotional development (Mendelsohn et al., 2018). Also, in face-to-face communication, people not only see another person's emotional facial expression; they commonly also hear what the other person says and how they say it (e.g., Aviezer et al., 2017; Holler & Levinson, 2019; Sendra, Kaland, Swerts & Prieto, 2013). In both cases, the emotional context includes different sources of input that can support the processing of emotion-related information.

The importance of emotion-supporting context in social interaction raises the question of whether such a context offers a setting for improved emotional understanding of emotion-related target information, such as words and faces. The present study aims to address this issue. Specifically, we examined how emotional supporting context affects the identification of the emotionality of written words and facial expressions.

Previous research showed that contextual factors are -to a certain extent- automatically taken into account in emotion perception. Seemingly minimal signals such as someone's gaze direction can -automatically- influence how emotions are perceived (Feldman Barrett, Mesquita & Gendron, 2011; Mumenthaler & Sander, 2015). Relatedly, voice, body posture, and a visual

setting (e.g., Aviezer et al., 2017) all have been shown to affect emotion perception. More directly relevant for the present study, research supports the notion that language as well as affective voice is important contextual elements in emotion processing. Emotion words (Halberstadt & Niedenthal, 2001) as well as written social labels (Mermillod et al., 2018) have been shown to affect face perception, and it is reasoned that emotion words support facial emotion processing by inducing certainty about the emotionality of such facial expressions (Gendron, Lindquist, Barsalou & Feldman Barrett, 2012). Relatedly, not having access to an emotion word has been found to impair perception accuracy of facial expressions (Gendron et al., 2012).

Studies have also revealed the influence of voice and intonation on emotion processing. For example, vocal emotion cues influence the way in which people visually scan and process facial expressions (e.g., Rigoulot & Pell, 2014). Furthermore, affective tone of voice was found to influence facial emotion identification, while the opposite also held; emotion in a face can influence judgment of emotion in a voice (De Gelder & Vroomen, 2000b). It has been suggested that humans automatically and naturally pair affective voice and face in a successful manner (De Gelder, Pourtois, Weiskrantz, 2002), suggesting that affective voice is a natural contextual element in emotion processing.

Previous work on the influence of contextual information on emotion processing explored setting that employed combinations of affective information from multiple modalities (e.g., De Gelder, Pourtois & Weiskrantz, 2002; Rigoulot & Pell, 2014), which constitutes a realistic and ecologically valid situation (e.g., De Gelder & Vroomen, 2000a). It is important to note that most of these studies often compare congruent vs. incongruent situations, and demonstrate that congruent (or incongruent) settings facilitate (or undermine) emotional processing. Whereas important and informative, these studies do not clearly reveal how emotion-supporting context improves the understanding of emotion-related information. In the case of visual perception of target information pertaining to written words and facial expressions in the presence of others, it is important to examine how auditory verbal cues, such as emotion-matched words and intonation of an accompanying voice enhance the detection of the emotionality of the target information.

Accordingly, the present study was set out to test this systematically by assessing the contribution of each contextually supporting element of a voice (word and intonation) to the

identification of emotion-related target information. To increase the generalizability of our test for different modes of communication to which people are exposed in everyday life we designed two different tasks. In both task, emotion-supporting context was induced in the form of spoken audio. The first task compared emotion detection in written emotion-related (positive and negative) words without any contextual information to trials in which we stepwise added a pronunciation of the words and intonation that matched the valence of the written words. In the second task we focused on the influence of emotion-supporting context on emotion detection in images of emotion-related (happy and angry) facial expressions. Thus, in both tasks supporting information consisted of spoken emotional-matched words with a neutral intonation (words only), or of spoken emotional-matched words with an emotionally-matched intonation (words and intonation). Based on previous research, we expected that the emotion-supporting context facilitates the identification of emotion-related information.

A proper identification of emotion-related information is an important ability for successful human interaction. Grounded in the embodied cognition view of social information processing (e.g., Arnold & Winkielman, 2019; Niedenthal, 2007; Niedenthal, Barsalou, Winkielman, Krauth-Gruber, & Ric, 2005), in numerous emotion processing studies, both written words as well as facial expressions have been shown to trigger a simulation process that sometimes is reflected in facial muscle activity (e.g., Foroni & Semin, 2009; Niedenthal, 2007). Especially the simulation of facial expressions involves cortical processing related to motor simulation of facial expressions, the posterior cingulate cortex, and medial temporal lobe structures (Schilbach, Eickhoff, Mojzisch & Vogeley, 2008). For example, the smiling muscle -zygomaticus major- tends to show more activity when people perceive positive emotional information, and less activity to negative emotional information. Similarly, the frowning muscle – corrugator supercilii- tends to become activated when people perceive negative information, while showing less activity to positively valenced information (e.g., Dimberg, Thunberg & Elmehed, 2000; Dimberg, Thunberg & Grunedal, 2002). This process is also referred to as facial mimicry. One of the main current ideas about the occurrence of facial mimicry is that it serves a social function and that it depends on the social context (e.g., Hess & Fischer, 2014). In the current study we therefore also explored whether this simulation process might depend on the amount of emotion supporting contextual information one has when processing emotion words and emotional facial expressions.

METHOD

Participants and Study Design

A sample of 28 students participated in this study (23 female, $M_{\text{age}} = 21.5$, $SD_{\text{age}} = 2.41$). The study had a within participants design, employing three levels of contextual auditory support: no contextual support, partial support or full support. Running a sensitivity analysis in G*Power 3.1 ($\alpha = .05$, power = 80%, $N = 28$, nonsphericity correction $\epsilon = 1$ and $r = 0.5$) for an ANOVA: Repeated measures indicated that we were able to detect a difference of moderate effect size between the three conditions in our experimental design, effect size $f = .25$. The study received approval from the ethics committee at Utrecht University in accordance with the ethical standards of the Declaration of Helsinki. Written informed consent of each participant was obtained before participating in the study.

Experimental tasks

Experimental task 1: classifying written words as emotional vs. non-emotional

In the first experimental task, we measured classification of written words, with different levels of contextual auditory support. Written emotional (of positive or negative valence) and neutral words were presented on screen in each trial, neutral words served as fillers. There were three levels of contextual support: A) No contextual support (visual stimulus only), B) Partial support by contextual information (the word presented on screen is pronounced over the headphones, with a neutral intonation), and C) Full support (the word presented on screen was pronounced over the headphones, with emotionally matched intonation), see Table 1.

Experimental task 2: classifying images of facial expressions as emotional vs. non-emotional

The second task had a similar design as task 1, the difference being that the visual stimuli to be classified were images of facial expressions. An emotional (happy or angry) or neutral facial expression was presented on the screen in each trial, neutral expressions served as fillers. Again, three levels of contextual auditory support were used, see table 1. For example, considering happy facial expressions, a facial expression would either A) appear without any audio, B) appear with the audio of a semantically positive word with neutral pronunciation, or C) appear with the audio of a semantically positive word pronounced in a positive intonation.

Table 1

The different stimulus combinations in the two tasks that apply to for both experimental task 1 (with visual targets being written words) and task 2 (with visual targets being facial expressions).

Contextual support level	Visual target valence	Audio information	Number of trials
A) None	Positive	NA	12
A) None	Negative	NA	12
B) Partial	Positive	Positive word /Neutral intonation	12
B) Partial	Negative	Negative word /Neutral intonation	12
C) Full	Positive	Positive word /Positive intonation	12
C) Full	Negative	Negative word /Negative intonation	12
			Total: 72
A) None	Neutral (filler)	NA	24
B/C) Partial/full	Neutral (filler)	Neutral word - Neutral intonation	48
			Total: 72

NA = not applicable

Stimuli

Words.

Words used and tested in previous studies were selected as stimulus material¹. In total, 24 positive, 24 negative, and 48 neutral words were selected for the current study. Splitting these up into two separate lists enabled us to present participants with unique words in each of the

¹ Six positive and six negative Dutch words previously used in a study by Foroni & Semin (2009), and 9 positive, 9 negative, and 18 neutral Dutch words from a study reporting their emotional meaning and perceived valence (Hermanns & De Houwer, 1994) were selected. Lastly, selected words from a study reporting affective norms of English words (Bradley & Lang, 1999) were translated into Dutch and pilot tested for the current study on their valence and emotionality. Of these words 9 positive, 9 negative, and 30 neutral rated words were selected. See Appendix I for the complete list of words selected for this study.

two experimental tasks. Matching the 2 wordlists with the 2 experimental tasks was counterbalanced across participants.

Faces.

Images of 6 female and 6 male actors were selected from the Dutch Radboud Faces Database (Langner, Dotsch, Bijlstra, Wigboldus, Hawk & Knippenberg, 2010) for task 2. Of each actor, images with a happy, negative, and neutral facial expression were used, meaning a total of 12 happy, 12 angry, and 12 unique neutral faces were used.

Audio.

All words were read out by a professional female actor and recorded with Audacity (version 2.0.3). Positive words were recorded in a neutral and in a positive intonation, negative words were recorded in a neutral and in a negative intonation, while the neutral words were only recorded in a neutral intonation. Pretests confirmed that the intonation of these audio recordings were in line with the intended emotional intonation.

Procedure

Upon arrival at the lab, participants were told that the study involved measurement of facial EMG to assess muscle activity during exposure to visual and audio stimuli. The EMG procedure followed the typical protocol of facial muscle activity assessment and adhered to the typical procedure and guidelines that had received approval from the ethics commission at Utrecht University. Written informed consent of each participant was obtained.

Electrodes to measure facial muscle activity were placed on the participant's face, after which participants were seated in an individual soundproof cubicle in which the experiment took place. Participants were informed that the experiment consisted of two tasks, one in which they would be seeing words and the other in which they would be seeing faces, and that these visual stimuli would sometimes also be accompanied by audio. The two tasks were presented consecutively; the order of the tasks was counterbalanced across participants.

Participants were asked to indicate whether the stimulus on the screen was an emotional or a non-emotional one. They were instructed to be accurate and fast. Neutral stimuli served as

fillers and are thus not reported in the analyses². Because each task includes an equal number of emotional and neutral targets the responses could be accurate (coded 1) or not (coded 0). Accordingly, participant's emotion detection level was assessed and served as dependent variable. Furthermore, activity of the corrugator and the zygomaticus muscles were recorded and processed for further analyses (see below at Data preparation and analysis). All visual stimuli were shown 3 times during the same task, once for each level of contextual support. Each task consisted of 144 trials, presented randomly without replacement. Written words (task 1) in partial or full contextual support were always presented with an audio pronouncing the same word, each image of a facial expression (task 2) in partial or full contextual support was presented with the audio of a word randomly chosen from the wordlist, but always semantically supporting of the valence of the facial expression.

As can be seen in Figure 1, in each task a trial started with a blank screen (3s), after which a fixation point appeared (1s), followed by the visual stimulus, which remained on screen until participants classified the stimulus as being emotional or non-emotional. In the trials with partial or full contextual support, audio stimulus presentation directly followed visual stimulus presentation. Before starting each task, participants completed 4 practice trials during which participants received feedback on screen regarding their performance.

² For task 1 (visual stimuli written words), average accuracy levels for written words supported by contextual information -audio with neutral intonation- was 96.6% ($SD = 3.3$), and for words not supported by any contextual information accuracy was 95.3% ($SD = 2.6$). For task 2 (visual stimuli facial expressions), average accuracy levels for faces supported by contextual information -audio with neutral intonation- was 91.2% ($SD = 11.4$), and for faces not supported by any contextual information accuracy was 94.6% ($SD = 11.3$).

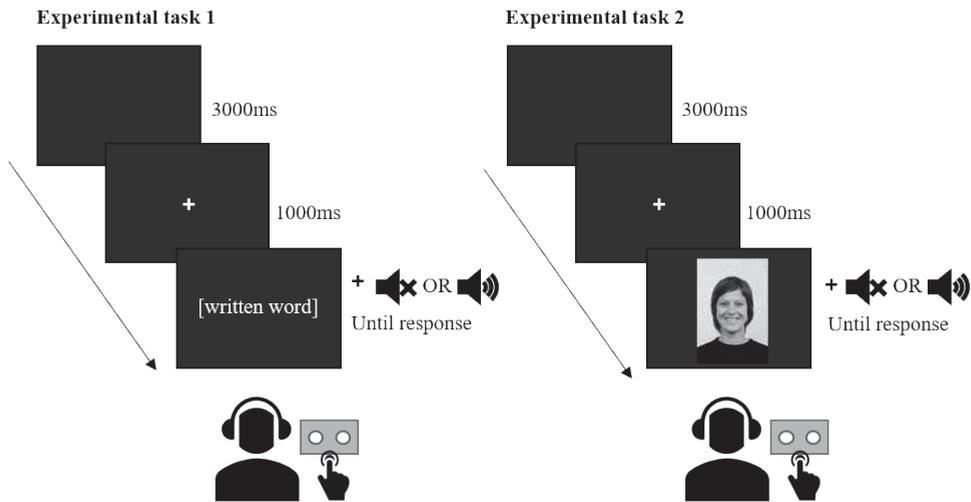


Figure 1. Visual overview of stimulus presentation in experimental task 1 (words) and experimental task 2 (faces).

Equipment

Participants responses when classifying the stimuli were recorded by use of a response box. The experiment ran on a computer with a 19-inch screen and 1280 x 1024 screen resolution. The experimental task was programmed in E-prime 2.0. Facial muscle activity was recorded and processed with MindWare Technologies EMG Application software (version 2.5).

Data preparation and analysis

Behavioral measures.

Emotion detection levels in percentages were calculated in percentages per stimulus type for both tasks. Positive and negative words (task 1) and happy and angry facial expressions (task 2) served as target stimuli, classifying these stimuli as emotional was considered accurate, while classifying these stimuli as non-emotional was considered inaccurate.

Facial EMG.

Facial muscle activity at the corrugator and zygomaticus sites was measured using bipolar placements of Ag/AgCl miniature surface electrodes filled with electrode gel attached on the left side of the face. The skin was cleansed and prepared with alcohol prep pads and semi

abrasive lotion. The electrodes were placed following the methods described by Fridlund and Cacioppo (1986), and all pairs were referenced to a forehead electrode placed near the midline. The raw EMG signal was measured with a BioNex Bio-Potential amplifier and stored with a sampling frequency of 1000 Hz. Raw data were filtered with a 30–300 Hz band pass filter and a 50 Hz notch filter and then rectified. Facial muscle activity recorded during the last 500 milliseconds of each blank screen that was shown before the fixation point was used as baseline measure for that specific trial. Difference scores were calculated by using these measures as a baseline. Prior to statistical analysis, data were collapsed per type of trial and averaged over the first 1000ms of stimulus presentation.³ One participant's data was not included because of too many irrelevant facial movements due to tiredness, leading to unusable EMG measures.

Statistical Analyses

Because, in principle, the two tasks used different visual targets (words or faces), we first examined the behavioural data of each task separately by subjecting emotion detection levels to a repeated measures ANOVA's with contextual support level and valence of targets as within subject variables. We also examined the physiological (facial EMG with respect to the zygomaticus muscle and the corrugator muscle) data for each task separately. in the same experimental design. Here the effects of interest were a main effect of valence, and a possible interaction between valence and contextual support level. As a second step, with combined the data of the two tasks to explore whether effects of word targets are different from face target. Combining the two tasks also increased the number of trials for a more sensitive test. In addition to the frequentist statistical tests, Bayesian analyses are performed to quantify the evidence of the hypotheses under investigation (main effect of contextual support) given the data. Bayesian Factors (BF) are reported; a larger BF represents more evidence in the data set for the hypothesis under consideration. In case sphericity was violated for any of the reported results, Greenhouse-Geisser corrections were applied and adjusted degrees of freedom were reported.

³ The first second of seeing the stimulus is chosen as it can be assumed that facial muscle activity during this time window is considered to be spontaneous, while after the first second more deliberate processes can occur (Häfner & IJzerman, 2011).

RESULTS

Experimental task 1: Classifying written words

Classification of written words.

Participants emotion detection levels when classifying written words was analyzed by use of a repeated measures ANOVA with contextual support level (none, partial, or full) and valence of the written word (positive vs. negative) as within participants factors.

The main effect of contextual support level showed to be significant, $F(2, 52) = 4.25$, $p = .020$, $\eta_p^2 = .14$. As can be seen in Figure 2, highest emotion detection levels showed for fully supported written words ($M = 90.1\%$, $SD = 16.6$), while partially supported ($M = 86.0\%$, $SD = 16.2$) and contextually unsupported written words ($M = 86.3\%$, $SD = 15.1$) had lower detection levels. A Bayesian analysis of variance showed that the data was 2.50 times more likely to reflect a main effect of contextual support level than for it not to reflect such an effect ($BF_{10} = 2.50$). No main effect showed for valence, $F(1,26) = 2.32$, $p = .140$, $\eta_p^2 = .08$. Lastly, no interaction showed between valence and contextual information $F(2, 52) = 1.07$, $p = .349$, $\eta_p^2 = .04$.

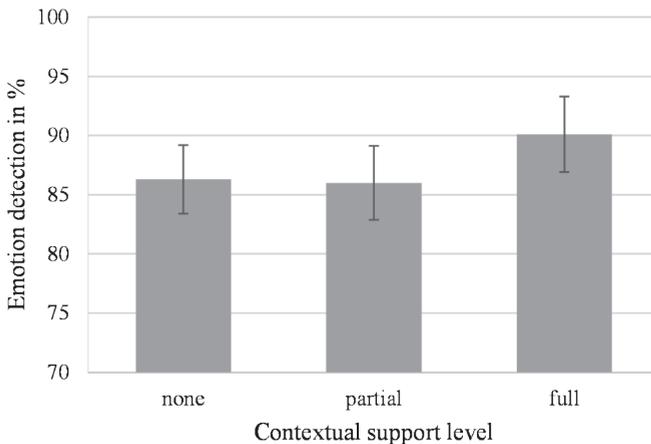


Figure 2. Emotion detection levels when classifying written words based on the different levels of contextual support. Error bars represent standard error.

Zygomaticus activity to written words

Zygomaticus activity during the first 1000ms of stimulus presentation was analyzed with a repeated measures ANOVA whereby contextual support level (none, partial, or full) and valence of the written word (positive vs. negative) were the within participants factors.

The main effect of valence on zygomaticus activity did not reach significance, $F(1,26) = 2.92, p = .099, \eta_p^2 = .10$. A Bayesian paired samples t-test showed that the data were 1.37 times more likely to reflect a null effect than to reflect a difference based on valence ($BF_{01} = 1.37$). Furthermore, the interaction between valence of the written word and level of contextual support was not significant, $F(1.63, 42.24) = 0.54, p = .551, \eta_p^2 = .02$.

Corrugator activity to written words

Corrugator activity during the first 1000ms of stimulus presentation was analyzed with a repeated measures ANOVA with contextual support level (none, partial, or full) and valence of the written word (positive vs. negative) as the within participants factors.

This analysis revealed no significant main effect of valence of the written word on corrugator activity, $F(1,26) = 3.02, p = .094, \eta_p^2 = .10$. A Bayesian paired samples t-test showed that the data were 1.30 times more likely to reflect a null effect than to reflect a difference based on valence ($BF_{01} = 1.30$). No interaction was found between valence of written word and level of contextual support, $F(1.31, 35.10) = 0.62, p = .542, \eta_p^2 = .02$.

Experimental task 2: Classifying facial expressions

Classification of facial expressions.

Participants emotion detection levels when classifying the facial expressions was analyzed with a repeated measures ANOVA. Contextual support level (none, partial, or full) and valence of the facial expression (positive vs. negative) were the within participants factors.

This analysis revealed no main effect of contextual support level, $F(2, 52) = 1.20, p = .309, \eta_p^2 = .04, f = .20$, see Figure 3. A Bayesian analysis of variance showed that the data was 3.66 times more likely to reflect a null effect than for it to reflect a main effect of contextual support level ($BF_{01} = 3.66$). Furthermore, no main effect showed for valence, $F(1,26) = 0.18, p = .671, \eta_p^2 = .01$. Lastly, there was no interaction between valence and contextual support level, $F(2,52) = 0.59, p = .559, \eta_p^2 = .02$.

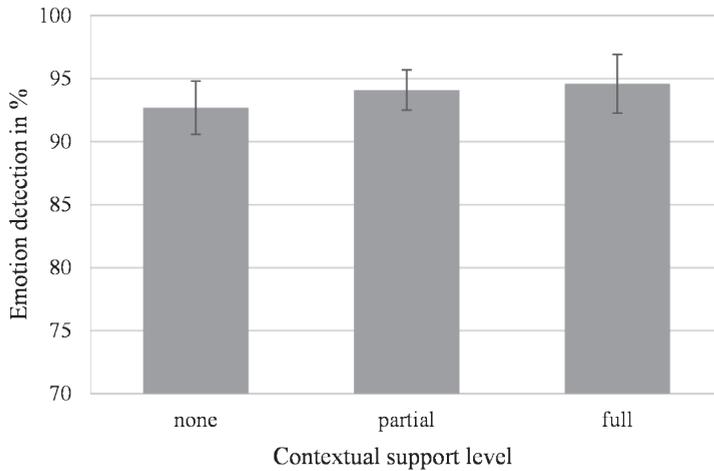


Figure 3. Emotion detection levels when classifying facial expressions based on the different levels of contextual support. Error bars represent standard error.

Zygomaticus activity to facial expressions

Zygomaticus activity during the first 1000ms of stimulus presentation was analyzed with a repeated measures ANOVA. Contextual support level (none, partial, or full) and valence of the facial expression (positive vs. negative) were the within participants factors.

This analysis revealed a main effect of valence of the facial expression, $F(1,26) = 4.56$, $p = .042$, $\eta_p^2 = .15$, see Figure 4. In line with expectations, zygomaticus activity was stronger when participants saw positive ($M = -.20$ mV, $SD = .65$) than when they saw negative facial expressions ($M = -.37$ mV, $SD = .75$). A Bayesian paired samples t-test showed that the data were 1.43 times more likely to reflect such difference than to reflect a null effect ($BF_{10} = 1.43$). No interaction was found between valence of the facial expression and level of contextual support $F(1.19, 30.94) = 2.95$, $p = .090$, $\eta_p^2 = .10$.

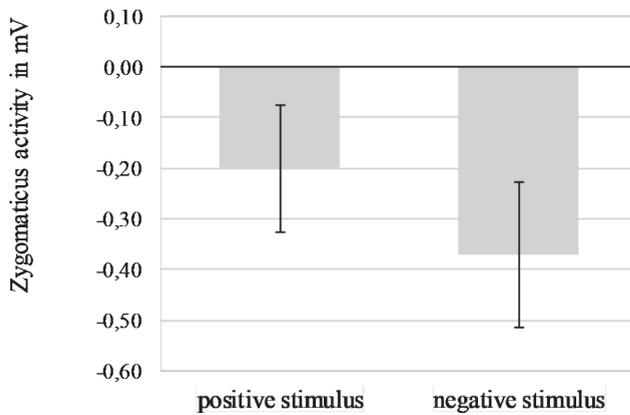


Figure 4. Zygomaticus activity to positive and negative facial expressions. Error bars represent standard error.

Corrugator activity to facial expressions

Corrugator activity during the first 1000ms of stimulus presentation was analyzed with a repeated measures ANOVA. Contextual support level (none, partial, or full) and valence of the facial expression (positive vs. negative) were the within participants factors.

No main effect of valence of the facial expression was found for the corrugator; $F(1,26) = 2.83, p = .105, \eta_p^2 = .10$. A Bayesian paired samples t-test showed that the data were 1.42 times more likely to reflect a null effect than to reflect a difference based on valence ($BF_{01} = 1.42$). No interaction between valence of the facial expression and level of contextual support was found, $F(1.17, 30.45) = 0.04, p = .877, \eta_p^2 = .00$.

Combining data of experimental task 1 and 2: written words and facial expressions

Emotion detection levels

A repeated measures ANOVA examining emotion detection levels for written words and facial expressions was performed in order to explore possible effects taking into account both types of visual stimuli at once. Visual stimulus (written word vs. facial expression), contextual

support level (none, partial, or full) and valence of the visual stimulus (positive vs. negative) served as within participants factors.

Considering participants emotion detection levels when classifying the visual stimuli, the main effect of contextual support level showed to be significant, $F(1,26) = 5.47, p = .007, \eta_p^2 = .17$, see Figure 5. Highest emotion detection levels showed for fully supported visual stimuli ($M = 92.4\%, SD = 10.9$), while partially supported ($M = 90.1\%, SD = 8.9$) and contextually unsupported visual stimuli ($M = 89.5\%, SD = 10.4$) had lower detection levels. A Bayesian analysis of variance showed that the data was 5.88 times more likely to reflect a main effect of contextual support level than for it not to reflect such an effect ($BF_{10} = 5.88$). No main effect showed for valence ($F(1,26) = 1.18, p = .288, \eta_p^2 = .04$), nor for type of visual stimulus ($F(1,26) = 3.89, p = .059, \eta_p^2 = .13$).

None of the two-way interactions were significant; valence X contextual support level ($F(2,52) = 0.26, p = .773, \eta_p^2 = .01$), visual stimulus type X contextual support level ($F(2,52) = 1.43, p = .248, \eta_p^2 = .05$), valence X visual stimulus type ($F(1,26) = 1.33, p = .259, \eta_p^2 = .05$). Lastly, no three-way interaction revealed; valence X contextual support level X visual stimulus type, $F(2,52) = 0.98, p = .148, \eta_p^2 = .07$.

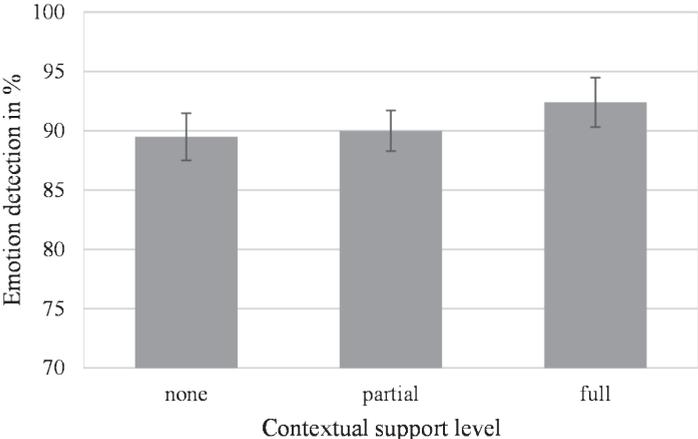


Figure 5. Emotion detection levels when classifying the visual stimuli based on the different levels of contextual support. Error bars represent standard error.

Zygomaticus activity

Zygomatous activity during the first 1000ms of stimulus presentation of written words and facial expressions was analyzed with a repeated measures ANOVA. Visual stimulus (written word vs. facial expression), contextual support level (none, partial, or full) and valence of the visual stimulus (positive vs. negative) were within participants factors.

A main effect of valence showed that zygomatous activation was higher when participants were exposed to positive ($M = -.14$ mV) compared to negative stimuli ($M = -.26$ mV), $F(1,26) = 6.95, p = .014, \eta_p^2 = .21$, see Figure 6. A Bayesian paired samples t-test showed that the data were 3.51 times more likely to reflect this difference than to reflect a null effect ($BF_{10} = 3.51$). A main effect showed for contextual support level ($F(1.52, 39.59) = 4.47, p = .026, \eta_p^2 = .15$). Zygomatous activation was highest when visual stimuli were fully supported by contextual information ($M = -.11$ mV), followed by no contextual support ($M = -.20$ mV), while zygomatous activity was weakest when visual stimuli were partially supported by contextual information ($-.29$ mV). No main effect showed based on type of visual stimulus ($F(1,26) = 1.36, p = .255, \eta_p^2 = .05$).

None of the two-way interactions were significant; valence X contextual support level ($F(1.19, 30.94) = 2.95, p = .090, \eta_p^2 = .10$), visual stimulus type X contextual support level ($F(1.53, 39.80) = 1.09, p = .330, \eta_p^2 = .04$), valence X visual stimulus type ($F(1.20, 31.21) = 2.35, p = .131, \eta_p^2 = .08$). Lastly, no three-way interaction revealed; valence X contextual support level X visual stimulus type, $F(1.32, 34.43) = 3.02, p = .071, \eta_p^2 = .11$.

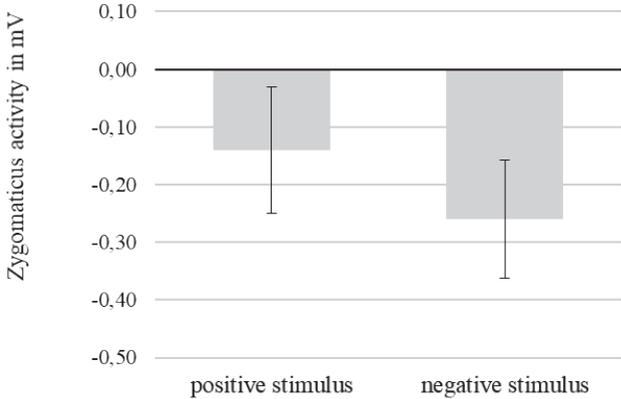


Figure 6. Zygomatous activity to positive and negative words and faces. Error bars represent standard error.

Corrugator activity

Corrugator activity during the first 1000ms of stimulus presentation of written words and facial expressions was analyzed with a repeated measure ANOVA with visual stimulus (written word vs. facial expression), contextual support level (none, partial, or full) and valence of the visual stimulus (positive vs. negative) as within participants factors.

The analysis showed that corrugator activity was somewhat stronger when participants saw negative visual stimuli ($M = 2.09$ mV) compared to positive visual stimuli ($M = 1.80$ mV), but this effect did not reach the conventional level of significance, $F(1,26) = 4.01, p = .056, \eta_p^2 = .13$, see Figure 7. A Bayesian paired samples t-test showed that the data were 1.15 times more likely to reflect such difference than to reflect a null effect ($BF_{10} = 1.15$). Furthermore, a main effect for type of visual stimulus revealed that corrugator activity to written words was higher ($M = 2.43$ mV) compared to facial expressions ($M = 1.46$ mV), $F(1,26) = 7.73, p = .010, \eta_p^2 = .23$. No main effect showed for contextual support level ($F(1.50, 39.08) = 0.71, p = .461, \eta_p^2 = .03$).

None of the two-way interactions were significant; valence X contextual support level ($F(1.38, 35.90) = 0.29, p = .667, \eta_p^2 = .01$), visual stimulus type X contextual support level ($F(1.99, 31.18) = 0.57, p = .486, \eta_p^2 = .02$), valence X visual stimulus type ($F(1,26) = 0.81, p = .376, \eta_p^2 = .03$). Lastly, no three-way interaction revealed; valence X contextual support level X visual stimulus type, $F(1.34, 34.72) = 0.03, p = .918, \eta_p^2 = .00$.

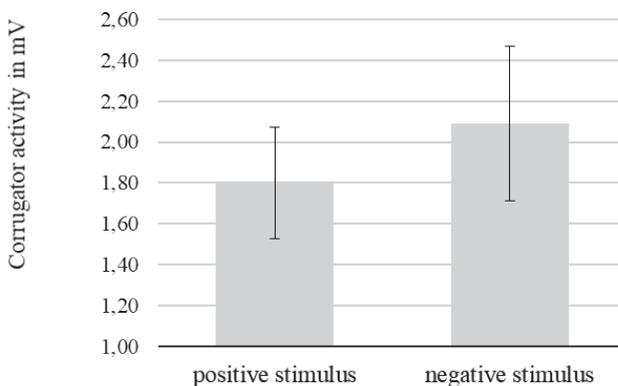


Figure 7. Corrugator activity to positive and negative words and faces. Error bars represent standard error.

DISCUSSION

The current study included two tasks to assess the role of contextually supportive elements of a voice - word and intonation- in identifying emotion-related information in written emotion-related words and in facial expressions, relating to two common forms in which people encounter affective information in everyday life. Furthermore, we explored whether adding contextually supportive elements of a voice would relate to differences in facial simulation. Our results showed increased emotion detection levels when adding contextually supporting voice elements. However, this effect was more pronounced for written words than for facial expressions. Furthermore, we found some evidence for facial simulation effects, but this was mainly the case for activation of the zygomaticus muscle in response to observing facial expressions, an effect that was not qualified by contextually supporting voice elements. Combining the data of the two tasks - thereby increasing the sensitivity of the test – yielded more convincing evidence for the contribution of contextual information in emotion detection.

Our findings support previous work on the relevance of contextual information for emotion processing (e.g., Feldman Barrett, Mesquita & Gendron, 2011; Mumenthaler & Sander, 2015). Specifically, the observation that different elements of supporting contextual voice elements affect the detection of emotion-related information concurs well with the informative element of the human voice (e.g., Aviezer et al., 2017); semantical information and intonation elements improved emotion detection, underlining the advantage of multimodal information in emotion processing (e.g., Paulmann & Pell, 2011). This is central to an embodied cognition perspective to social information processing according to which sensorimotor processes in dedicated cortical areas are involved in simulating the emotional meaning of such information (e.g., Niedenthal, 2007; Niedenthal, et al., 2005). Interestingly, while facial simulation did reflect the valence of the visual stimuli, it did not interact with the differences in level of contextual support. Whereas this might appear to contradict the view that cognition and emotional meaning is grounded in sensorimotor processes, there is research suggesting that facial simulation does not always relate to or occur in emotion processing tasks (e.g., Arnold & Winkielman, 2019). Various routes to emotion processing have been shown to play a role in detecting and grasping emotional concepts (e.g., e.g., Arnold & Winkielman, 2019; de la Rosa, Fademrecht, Bühlhoff, Giese & Curio, 2018; Stel, 2016). In the present study

such routes pertain to visual information, auditory information, semantic information as well as previous knowledge on emotion concepts. Our findings, then, suggests that facial simulation in general, and mimicry in particular, is likely to be more implicated in the valence of the stimulus, but not necessarily involved when linking contextual information to the valence of visual stimuli in the task at hand.

The present study indicates that contextually supporting voice elements facilitate the detection of emotion-related information, as is revealed by higher accuracy of classifying emotional stimuli as actually being emotional. However, it is important to note that, in the present task, contextual supporting information might also have increased the intensity of the emotional target information and therefore participants were better in detecting the emotional meaning (e.g., Montagne, Kessels, De Haan & Perrett, 2007). In that case, accuracy does not represent detection quality, but strength of emotional experiences. Whereas we cannot rule out this alternative account empirically, our general findings suggest that strength of emotional experiences is not the sole cause of our effects. First, we only observed context supporting advantage for emotion detection accuracy in the case of written words, and not for facial expressions. Furthermore, our results showed that facial mimicry only depended on the valence of the stimuli, and thus was not further enhanced by adding contextual supporting emotional information. Together, these findings are not easy to explain with a general strengthening account of emotional experiences of the target stimuli. Whereas detection of emotional stimuli and intensity of emotional experiences have been linked to neural networks that play a different role in social cognition and behavior (e.g., Rapport, Friedman, Tzelepis & Van Voorhis, 2002), it is important for future research to more clearly examine how contextual supporting information impinges on the perception of emotions when processing words during reading and facial expressions of others in interactions.

Ruling out this issue is particularly important, because it bears on real-life situations where one sees someone's facial expression while also hearing her speak, or a caregiver or teacher read aloud to a child with supporting intonation hereby aiding in detecting emotion. In such cases, being able to correctly detect and respond to emotions can make the difference between a smooth and stiff social interaction (e.g., van Kleef, 2016). For example, the role of supporting voice elements could relate more to signaling the fact that one should pay attention (e.g., Brosch, Grandjean, Sander & Scherer, 2008; Sander et al., 2005; Vuilleumier, 2005;

Wegrzyn, Herbert, Ethofer, Flaisch & Kissler, 2017), which could also positively influence interaction and communication by taking notice when the other person is portraying positive or negative emotions with different intensity. Thus, while we reason that added voice elements could be argued to positively influence daily life interactions, we need more research to further explore the mechanism that allow people to include auditory context in processing emotional information conveyed by interaction partners.

Chapter 6

Quality of life, social function, emotion and facial paresis in Dutch Vestibular Schwannoma patients.

Based on: Blom, S.S.A.H., Aarts, H., Wever, C.C., Kunst, H.P.M., & Semin, G.R. (in press) Quality of life, social function, emotion and facial paresis in Dutch Vestibular Schwannoma patients. *Laryngoscope Investigative Otolaryngology*, <https://doi.org/10.1002/lio2.371>.

Abstract:

The present study aimed to replicate the finding that Vestibular Schwannoma (VS) patients with facial paresis experience lower health related quality of life (QoL) than those without facial paresis in a Dutch sample, and to extend these findings by measuring VS patients' overall satisfaction with life, social function and emotion. Forty-seven VS patients, differing in degree of facial functioning, half of them with and half of them without a facial paresis, answered questionnaires about health related QoL (SF-36 and PANQOL), overall satisfaction with life, fear of being evaluated negatively by others, social avoidance and distress, and characteristics and symptoms of depression. We observed that VS patients with facial paresis experience lower health related QoL as well negatively impacted social function and emotion compared to VS patients without facial paresis. VS patients with facial paresis experienced lower overall satisfaction with life, more characteristic symptoms of depression, and more fear of being evaluated negatively by others than VS patients without facial paresis. These findings corroborate previous research showing an association between impaired facial functioning and lower QoL, but also extend them by showing differences on the quality of social function and emotion. Being aware of this difference between VS patients with and without facial paresis informs health practitioners regarding the specific support these patients might need. Moreover, it is also relevant to consider the influence of a facial paresis on patients' life when deciding between treatment options and in case of surgery the type of resection.

INTRODUCTION

In human social interaction our facial expressions are an important element in conveying our message and feelings to each other. Considering this importance of facial expressions, it is likely that impairment in producing facial expressions would have a negative impact on a person's social and emotional life. A specific medical condition that can bring about such impairment in facial functioning is Vestibular Schwannoma (VS). VS is a benign unilateral tumor also known as acoustic neuroma. Different treatment strategies exist for VS depending on its stage, such as observation, irradiation, or surgical removal (Johnson & Lalwani, 2012). Due to its location near the facial nerve, surgical removal can cause damage to the facial nerve and impact facial functioning.

Studies in various countries have shown an association between impaired facial functioning in individuals with VS and health-related quality of life (QoL). For example, in Italy (Tufarelli et al., 2006), and the UK (da Cruz, Moffat & Hardy, 2000) studies reported that VS patients who have undergone surgery experience lower health related QoL compared to healthy standards, on all domains (Tufarelli et al., 2006) or most domains (da Cruz et al., 2000). Furthermore, patients with VS and facial paresis report low levels of health related QoL in the UK (Leong & Lesser, 2015), though in this particular study there is no control group, and no effect size is reported. Though not specifically comparing health-related QoL between VS patients with and without facial dysfunction, a study in the Netherlands (Soulier et al., 2017) showed that self-reported facial weakness as scored on one item by a large sample of VS patients¹ was associated with health related QoL, an effect that showed to be of moderate size. However, a study with VS patients conducted in Spain (Lassaletta, Alfonso, Del Rio, Roda & Gavilan, 2006) reported no difference in health-related QoL based on the degree of facial dysfunction as measured by the HBG nor when comparing patients with and without facial dysfunction. In short, while results and methods vary, most studies conducted so far support the expectation that impaired facial functioning in VS patients relates to lower health related QoL.

Importantly, besides health related QoL, impaired facial functioning in VS patients might also negatively impact patients' experienced social and emotional life. Firstly, because

¹ Measured on a scale from 1 (best imaginable) to 5 (worst).

limitations in facial expression could lead to encountered difficulties in interpersonal interactions as mentioned previously. For instance, a study showed that people with a facial paralysis were perceived as expressing a negative emotion most of the time when they were in repose but even when they were smiling (Ishii, Godoy, Encarnacion, Byrne, Boahene & Ishii, 2011). Moreover, having a visible condition in general can be experienced as highly distressing and disfiguring (Ishii et al., 2011), and is associated with low self-esteem, negative self-image, social isolation as well as a fear of rejection by others (Valente, 2004). Studies with individuals with impaired facial functioning indeed suggest that a facial paralysis negatively impacts social function and emotional life showing in depression symptoms (Van Swearingen, Cohn, Turnbull, Mirzai & Johnson, 1998), lower mood (Ryzenman, Pensak, Tew Jr, 2005), anxiety and distress (Fu, Bundy & Sadiq, 2011; Ishii et al., 2011), patterns of social avoidance and social isolation (Nellis, Ishii, Byrne, Boahene, Dey & Ishii, 2017), and psychological distress (Cross, Sheard, Garrud, Nikolopoulos & O'Donoghue, 2000). Thus, we consider it important to not only examine the impact of facial paresis on VS patients' health related QoL, but also on their social function and emotional life.

The current study therefore focuses on facial paresis in VS patients, comparing them on several measures to a matched control group of VS patients without facial paresis. Our study was conducted in the Netherlands, where on a yearly basis at least one case of VS seems to be discovered every day (Brughoektumor, n.d.). However, while one study examined health related QoL in Dutch VS patients, no information is available about the relation between VS, facial paresis, and the quality of life relating to social function and emotion specifically.

We wish to stress here that the current questionnaire study is part of a larger project that examined possible differences in *emotion processing* of facial expressions between VS patients with and without facial paresis. In this project, we used several experimental tasks (see Blom, Aarts, Kunst, Wever & Semin, in press^b; Blom, Aarts & Semin, 2019) that require participants to work on a computer and that make an appeal to them to invest much time and effort in order to complete the project. Because of this practical burden, we were able to recruit a convenient, but much smaller patient sample than for example the one reported in Soulier et al (2017). However, we deemed it important to report whether the finding that impaired facial functioning is related to lower health related QoL in VS patients is replicated in our smaller sample. Specifically, we compared VS patient with and without facial paresis in order to directly assess

the impact of a facial paresis on health related QoL, as well as examining the association between health related QoL and the degree of facial dysfunction (as measured by the HBG). Moreover, our second goal was to extend these findings by examining patients' social function and emotional life. Although various studies on health related QoL of VS patients already exist, this is the first study to extend such findings by particularly examining possible differences on subjective experiences about social function and emotion between VS patients with and without facial paresis.

In line with previous research, we administered a widely used general health related QoL measure (the SF-36, see: Ware, 1993) and a VS disease specific measure (PANQOL, see: Shaffer, Cohen, Bigelow & Ruckenstein, 2010) to assess experiences of health. Furthermore, we explored whether VS patients with facial paresis would experience less overall –thus not necessarily health-related– satisfaction with life, more fear of being evaluated negatively by others, social avoidance and distress, and more depressive symptoms compared to VS patients without facial paresis. Having knowledge of these possible differences between VS patients with and without facial paresis would inform health practitioners regarding the specific support these patients could need. Moreover, considering that some treatment options for VS have higher chances of causing facial dysfunction than others, it is also relevant to consider the influence of a facial paresis on patients' life when deciding between treatment options.

MATERIALS & METHODS

Patient population and the current patient sample

Vestibular Schwannomas are rare, and incidence rates to date are limited. In Denmark, where registration of VS cases is assumed to be most accurate, the incidence rate in 2011 was 30.7 persons per million (Stepanidis, Kessel, Caye-Thomasen & Stangerup, 2014). Currently the estimated incidence rate is 19 persons per million in the Netherlands (Brughoektumor, n.d.). However, in one specific region of the Netherlands it was 33.2 from 2009 to 2012 (Kleijwegt, Ho, Visser, Godefroy & van der Mey, 2016). The Dutch incidence rate might thus be comparable to the one of Denmark. As the current study aimed to examine the difference between VS patients with and without facial paresis, we deliberately oversampled the number of VS patients experiencing facial paresis.

Participants

Forty-seven patients, all with VS, participated in the current study (mean age = 53.98, $SD = 7.88$). Average patient age at diagnosis was 47.93 years ($SD = 8.59$). Twenty-four patients had a facial paresis after surgical removal of their VS, while twenty-three patients had a VS but no facial paresis and served as a matched control group.² Facial functioning (focusing on the side of the VS) was graded by the first author and the participant by means of the House Brackman Grading scale (HBG) (House, 1985). A HBG of 1 reflects normal facial functioning, a HBG of 6 reflects complete facial paralysis. Inter-rater reliability showed to be high: Pearson's $r = .86$, therefore the average of these two HBG scores was used in this study.

Demographics: Participants answered questions on various sociodemographic characteristics (see Tables 1 and 2). Participants with and without facial paralysis only significantly differed on their HBG.

Table 1.

Descriptives of patient sample and t-tests comparing VS patients with and without facial paresis.

	Patients without facial paresis <i>M</i> (<i>SD</i>)	Patients with facial paresis <i>M</i> (<i>SD</i>)	<i>M</i> difference [95% CI]	<i>t</i>	<i>p</i>
HBG	1.32 (.57)	3.88 (1.13)	2.56 [2.03, 3.09]	9.88	<.001
Time since diagnosis	5.22 (3.56)	6.85 (5.40)	1.63 [-1.07, 4.33]	1.22	.230
Age	54.61 (8.31)	53.38 (7.55)	1.23 [-3.43, 5.89]	.53	.931
Education level EQF	5 (1.98)	4.95 (1.50)	.05 [-1.01, 1.10]	.09	.931

Note. HBG = House Brackman Grade, EQF = European Qualifications Framework.

² Of the VS patients with a facial paresis, 4 patients also underwent Gamma Knife radiosurgery after having (part of) their tumor removed. Of the VS patients without facial paresis, 2 patients underwent surgery in which (part of) their tumor was removed, and 7 patients underwent Gamma Knife radiosurgery.

Table 2.

Descriptives of patient sample and Chi square tests comparing VS patients with and without facial paresis.

	Patients without facial paresis		Patients with facial paresis		Chi square test
Localization VS	Left CPA (14)	Right CPA (9)	Left CPA (13)	Right CPA (11)	$p = .642$
Sex	Female (15)	Male (8)	Female (16)	Male (8)	$p = .917$
Working	Yes (16)	No (7)	Yes (13)	No (11)	$p = .278$

Note. CPA = Cerebellopontine angle.

The number of patients in each category is reported between brackets.

Participant recruitment and response rate

Patients applied for participation either via responding to a call for participants on the Dutch website for people with VS (www.brughoektumor.nl), or by responding to an invitation by a letter from their treating physician. Participants were then called to further inform them about the study and to answer possible questions. In case they confirmed their willingness to participate the questionnaire was sent on paper or via email, depending on the participants' preference. In total, sixty-two patients either applied via the online forum or were invited by their physician, forty-seven (75.81%) of these patients decided to participate in the current study. A majority of patients were recruited via their physician ($n = 32$) and a lower number of participants ($n = 15$) entered the study via the online forum website).

Forty-four of the patients who participated in the current study, also decided to participate in the experimental studies described in Chapters 7 and 8. On the day of participation in the experimental studies, patients were visited at their home by the researcher (S. Blom) so that they could receive thorough instructions and could complete the experiments on a laptop. This was done in order to reduce any possible constraints patients might have to participate (e.g. due to time, travelling costs, inability to travel, or for example health reasons).

Our VS patient sample and it's representation of the VS patient population

When comparing the current total patient sample to the reported statistics describing VS patients in general, our patient sample is representative of the Dutch VS patient population (as described in Kleijwegt et al., 2016) in most regards. VS normally is reported to occur equally often amongst males and females (e.g., for the Netherlands the distribution was 49.8% males and 50.2% females from 2001-2011). Females were slightly overrepresented in our studies, considering that our distribution was 37% males and 66.0% females. The average age at time of diagnosis in the Netherlands is 56.5 years. In our studies, the average patient age at time of diagnosis was 47.93 years ($SD = 8.59$). Regarding the localization of the VS, in our studies 57.5% of the patients had a VS on the left CPA, while 42.5% had it on the right CPA. This is in line with the percentages reported for the region of Leiden in the Netherlands (left CPA: 54.7%, right CPA: 45.3%, not including cases in which localization was unreported). Figure 1 shows the geographical distribution of the current patient sample.

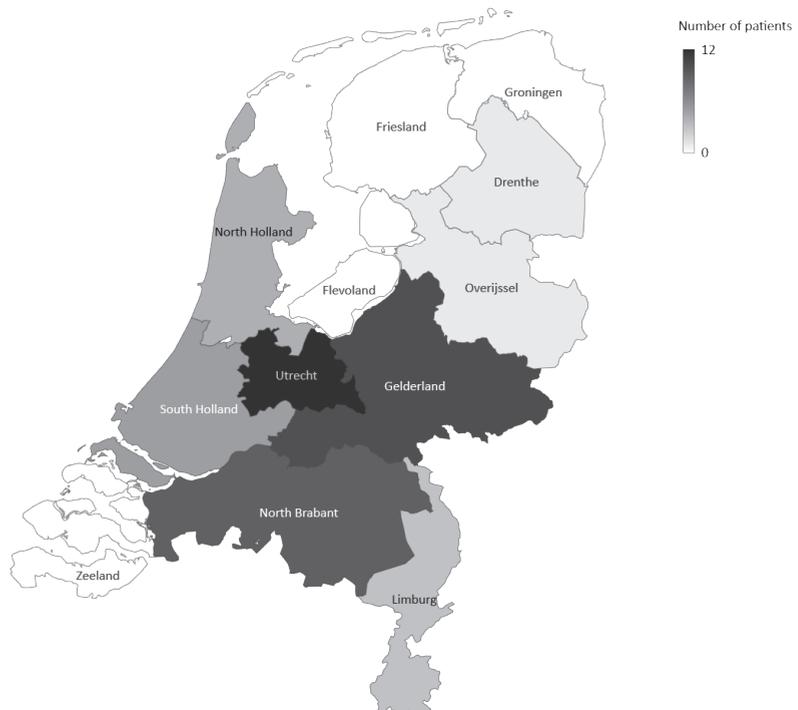


Figure 1. Participants' geographic distribution ($n = 45$, province of residence of 2 participants was not provided).

Materials

Health-related Quality of Life questionnaires

Short Form Questionnaire (SF-36). The SF-36 is a 36-item validated questionnaire to assess generic health-related QoL. It is divided into eight subscales; physical functioning, social functioning, role limitations due to physical problem, role limitations due to emotional problems, mental health, vitality and energy, bodily pain, and general health perceptions (Ware, 1993). Additionally, a total instrument score (unweighted average of all domain scores) was calculated. All scores had a scale ranging from 0 (worst) to 100 (best).

Penn Acoustic Neuroma Questionnaire of Life (PANQOL) Scale. The PANQOL is a VS disease-specific QoL questionnaire (Shaffer et al., 2010) (Dutch version, see: van Leeuwen, Herruer, Putter, Jansen, van der Mey & Kaptein, 2013). Its' 26 items measure seven subscales; anxiety, facial functioning, general health, balance, hearing loss, energy and pain. Additionally, a total instrument score (unweighted average of all domain scores) was calculated. All scores had a scale ranging 0 (worst) to 100 (best).

Overall satisfaction with life questionnaire

Satisfaction with Life Scale (SWLS). The widely used and validated 5-item SWLS (Diener, Emmons, Larsen & Griffin, 1985) was used to measure patient's overall satisfaction with life. A sum score (ranging from 5-35) was calculated, with a higher score reflecting more satisfaction with life.

Quality of emotional life and social function questionnaires

Beck Depression Inventory (BDI-II). The BDI-II (Beck, Steer & Brown, 1996) (Dutch version, see: Van der Does, 2002) is a 21-item self-report inventory measuring characteristic attitudes and symptoms of depression. A sum score (ranging from 0-63) was calculated, with a higher score representing more characteristic attitudes and symptoms of depression.

Brief version of the Fear of Negative Evaluation Scale (BFNE). The 12-item BFNE (Leary, 1983) (Dutch version, see: van Wees-Cieraad R & de Jong, 2007) was used to measure patients fear of being evaluated negatively by others. A sum score (ranging from 15-60) was calculated, with a higher score reflecting a stronger fear of being evaluated negatively by others.

Social Avoidance and Distress Scale (SADS). The 29-item SADS (Watson & Friend, 1969) measures the anxiety people feel in social situations and the extent to which they tend to avoid social situations. A sum score (ranging from 0-28) was calculated, with higher scores indicating more social avoidance and distress (for detailed information regarding the reliability of all scales, see supplementary material).

Procedure

The order of administration of the questionnaires was as follows: PANQOL, SF-36, BFNE, SADS, SWLS, BDI-II. Permission for the study was granted by the Medical Ethics Committee of the Leiden University Medical Centre. The study was conducted and written informed consent of each participant was obtained in compliance with the principles contained in the Declaration of Helsinki.

Statistical Analyses

We will test the hypothesis that VS patients with facial paresis experience lower health related QoL as well as negatively impacted social function and emotion compared to VS patients without facial paresis. We used Bayesian analyses to quantify the evidence in favour of the hypothesis under consideration (Hoijtink, Mulder, van Lissa & Gu, 2019). Bayesian Factors (BF) are reported, with a larger BF representing more evidence in the data set for the hypothesis under consideration. Considering the specific expectations regarding the direction of associations in the current study, informative hypotheses are tested (Hoijtink et al., 2019). In addition, we also provide classical statistical tests of our hypothesis in the form of one-tailed t-tests and effect sizes Cohen's *d*. Lastly, correlations between the different measurements and patients' HBG are reported in order to provide a more thorough view of the relationship between facial dysfunction in VS patients and health related QoL and social function and emotion.

RESULTS

1. Facial paresis in VS patients and health-related quality of life

As shown by the BF for the SF-36 and the PANQOL total scores (Tables 3 and 4), our data were 14.55 (SF-36) and 10.32 (PANQOL) times more likely to reflect lower overall health related QoL for VS patients with facial paresis compared to patients without facial paresis than for our data not to reflect such effect. The Cohen's *d* of these effects reflects a small to medium effect size.

Considering the SF-36 subscales (Table 3), our data were specifically more likely to reflect lower levels of physical role functioning, as well as emotional role functioning and social functioning compared to VS patients without facial paresis than for our data not to reflect such effect. The effect sizes for these subscales show to be small to large. Regarding the subscales of the PANQOL (Table 4), our data were specifically more likely to reflect much lower levels of facial functioning, and lower levels of energy for VS patients with facial paresis compared to those without facial paresis than for our data not to reflect such effect. The effects sizes show to be medium to large.

Thus, lower overall scores on health-related QoL corroborate previous reported findings on the negative relationship between facial dysfunction and health-related QoL in VS patients, with differences in the current study showing on the specific domains of facial functioning, energy levels, physical and emotional role functioning, as well as social functioning.

Table 3.

Facial paresis (present vs. absent) and Quality of Life Domains of the SF-36.

SF-36 Domain	No facial paresis <i>M (SD)</i>	Facial paresis <i>M (SD)</i>	BF	<i>t</i>	<i>p</i>	<i>d</i>
SF-36 total score	75.21 (18.66)	66.92 (18.73)	14.55	1.52	.068	.44
Physical functioning	81.30 (27.60)	78.96 (27.94)	1.59	0.30	.387	.08
Social functioning	71.20 (30.02)	60.94 (26.40)	8.39	1.25	.110	.36
Physical role functioning	70.11 (36.29)	42.71 (42.97)	107.41	2.36	.012	.69
Emotional role functioning	85.79 (25.08)	72.53 (36.60)	13.15	1.47	.075	.42
Mental health	76.96 (17.88)	73.75 (17.95)	2.71	0.61	.272	.18
Vitality and energy	55.71 (18.81)	51.65 (15.95)	3.71	0.80	.215	.23
Bodily pain	85.76 (22.76)	78.96 (22.90)	5.51	1.02	.157	.30
General health perceptions	75.83 (21.74)	76.83 (16.36)	0.75	0.18	.571	.05

Note. BF = Bayesian Factor for the hypothesis that VS patients with facial paresis experience lower health-related quality of life than VS patients without facial paresis.
p represents significance based on a directional (one-tailed) t-test.

Table 4.

Facial paresis (present vs. absent) and Quality of Life Domains of the PANQOL.

PANQOL domain	No facial paresis <i>M (SD)</i>	Facial paresis <i>M (SD)</i>	BF	<i>t</i>	<i>p</i>	<i>d</i>
PANQOL total score	70.99 (16.95)	64.19 (17.50)	10.32	1.35	.092	.39
Anxiety	80.90 (15.83)	79.10 (14.50)	0.52	0.41	.343	.12
Facial functioning	88.04 (23.14)	59.84 (19.12)	399355.37	4.56	<.001	1.33
General health	29.89 (27.88)	31.25 (22.12)	0.74	-0.19	.573	.05
Balance	67.39 (31.40)	64.76 (24.01)	1.68	0.32	.374	.09
Hearing loss	56.52 (27.27)	56.51 (27.30)	1.00	0.00	.500	.00
Energy	74.52 (17.17)	63.73 (22.31)	30.38	1.85	.035	.54
Pain	85.87 (28.03)	76.04 (36.47)	5.63	1.03	.154	.30

Note. BF = Bayesian Factor for the hypothesis that VS patients with facial paresis experience lower health-related quality of life than VS patients without facial paresis.

p represents significance based on directional (one-tailed) t-test.

2. Facial paresis in VS patients and satisfaction with life, social function and emotion

For all four measures the data were more likely to show that VS patients with facial paresis were impacted negatively compared to patients without facial paresis (showing in a larger BF) than for our data not to reflect such effect (Table 5). This difference was especially supported for the SWLS, BDI-II, and the BFNE, while the support for this effect regarding the SADS was not strong (BF = 2.46).

Thus, our data support the expectation that VS patients with facial paresis are likely to experience less satisfaction with life, more fear of being evaluated negatively by others and more characteristics and symptoms of depression than VS patients without facial paresis. The effects sizes for these three scales showed to be medium to large. Unexpectedly, there was only minor evidence for VS patients with facial paresis to feel more anxiety regarding social situations.

Table 5.

Facial paresis (present vs. absent) and scales of social function and emotional life.

Scale	No facial paresis <i>M (SD)</i>	Facial paresis <i>M (SD)</i>	BF	<i>t</i>	<i>p</i>	<i>d</i>
SWLS	27.39 (6.37)	23.17 (7.61)	49.76	2.06	.045	.60
BFNE	23.09 (7.82)	27.00 (7.59)	23.52	1.74	.088	.51
SADS	11.41 (2.57)	11.94 (3.75)	2.46	0.56	.580	.16
BDI-II	6.65 (5.75)	10.04 (7.85)	20.64	1.68	.099	.49

Note. BF = Bayesian Factor for the hypothesis that VS patients with facial paresis were impacted negatively compared to VS patients without facial paresis. SWLS = Satisfaction With Life Scale, BFNE = Brief version of the Fear of Negative Evaluation Scale, SADS = Social Avoidance and Distress Scale, BDI-II = Beck Depression Inventory.

p represents significance based on directional (one-tailed) t-test.

3. Correlations with HBG

As can be seen in the correlation matrix (Table 6), HBG correlates with all measures except for with the SADS. A higher degree of facial dysfunction thus showed to be related to lower health-related QoL, lower satisfaction with life, more depressive symptoms and more fear of being evaluated negatively by others. This supports the findings we reported comparing VS patients with and without facial paresis, with additionally showing increased negative impact for patients with higher HBG scores. A second point to be noted is that the different scales -except for the SADS- correlate moderate ($r = .45$) to strong ($r = .77$) with each other. This suggests that the scales are related and partly tap into similar processes. Lastly, the SADS does not show to correlate with any of the measures. This is unexpected but in line with the findings we reported comparing VS patients with and without facial paresis. It thus suggests that the amount of anxiety patients feel towards social situations is not related to their facial functioning.³

Table 6.

Correlation matrix for the different scales used in the current study.

Scale	HBG	SF-36	PANQOL	SWLS	BDI-II	BFNE	SADS
HBG							
SF-36	-.39**						
PANQOL	-.31*	.75**					
SWLS	-.38**	.60**	.60**				
BDI-II	.39**	-.74**	-.77**	-.68**			
BFNE	.39**	-.45**	-.50**	-.61**	.70**		
SADS	.00	-.21	-.20	-.03	.17	.13	

Note. HBG = House Brackman Grade, SF-36 = Short Form Questionnaire, PANQOL = Penn Acoustic Neuroma Questionnaire of Life, SWLS = Satisfaction With Life Scale, BFNE = Brief

³ When looking at the part correlations in a multiple regression analysis with all the scores as predictors and HBG as dependent variable, it showed that the total SF-36 score and the BFNE score were the strongest predictors of HBG when controlling for the other scales, with betas of .31 (SF-36) and .25 (BFNE) respectively, and part correlations of .18 (SF-36) and .17 (BFNE).

version of the Fear of Negative Evaluation Scale, SADS = Social Avoidance and Distress Scale, BDI-II = Beck Depression Inventory.

Reported correlations are Pearson's r .

** Correlation is significant at the .01 level (two-tailed).

* Correlation is significant at the .05 level (two-tailed).

4. Potential bias of the recruited sample of patients

The two different recruitment procedures of the present study might have encouraged mostly patients to participate who have had a particularly good or bad experience with their treatment. These patients can have strong opinions that may not be representative of broader patient groups. To examine a potential for bias in our sample, we conducted additional analyses in two steps.

First, we conducted a multiple regression analysis to explore whether the differences in entering the study (via physician or via website forum) was related to the QoL (measured by the SF-36 total score) after controlling for the HBG measure. This analysis showed that while the association between HBG and SF-36 total score remained significant ($p = .041$), there was no association between recruitment manner and SF-36 total score ($p = .326$). A Bayesian linear regression revealed that the model including only HBG as predictor of SF-36 total score indeed explained the data better ($BF_{10} = 7.00$) than did the model including both HBG and recruitment manner as predictors ($BF_{10} = 3.44$). This suggests that recruitment manner did not affect the subjective experiences of quality of life.

As a second step, we compared the correlation coefficient representing the association between HBG and SF-36 ($r = -.39$) as well as between HBG and PANQOL ($r = -.31$) of our study to the correlation between facial functioning and PANQOL reported in the study of for example Soulier et al⁵ in which all patients were recruited through a tertiary referral center in the Netherlands ($r = -.30$). As can be seen, the correlation strength between our study and the larger sample in Soulier et al. does not show substantial differences, suggesting that the present sample is representative of the general population of VS patients.

DISCUSSION & CONCLUSION

The current study aimed to replicate previous findings regarding the association between impacted facial functioning and health related QoL in a sample of Dutch VS patients, as well as to extend those findings by exploring whether VS patients with a facial paresis would experience less overall satisfaction with life, as well as impaired social function and emotional life than VS patients without facial paresis.

Our results revealed that VS patients with facial paresis indeed experienced lower levels of health related QoL, hereby replicating previous studies. Furthermore, we extended these findings and it showed that VS patients with a facial paresis experienced lower overall satisfaction with life, more characteristic attitudes and symptoms of depression, and more fear of being evaluated negatively by others than VS patients without facial paresis. This is important considering for example how depressive symptoms are related to increased patient suffering and morbidity, with depressed patients being found to have higher medical service costs than nondepressed patients (Valente, 2004). Thus, VS patients with facial paresis experienced less health related QoL as well as a negatively impacted social function and emotion.

Surprisingly, the measure of anxiety in relation to social situations did not show a large difference between the two groups. While we consider this a positive finding regarding the social life of VS patients with a facial paresis, future studies could aim at replicating and confirming this finding. Our results show medium effect sizes regarding total scores on health-related QoL measures (Cohen's d of .44 & .39, respectively), which is in line with the study conducted in the Netherlands reporting a medium effect size of ($r = .30$) the association between facial weakness and health related QoL (Soulier et al., 2017). Medium to large effect sizes (Cohen's d 's between .49 and .60) regarding the measures of overall satisfaction with life, fear of being evaluated negatively by others, and depression symptoms and characteristics showed. The difference between the two groups thus showed to be more pronounced for social function and emotion than for health-related QoL. This is in line with our reasoning that facial functioning is especially related to people's social and emotional life. It is therefore important to not only consider the impact of facial paresis on VS patients' health related QoL, but also how their social function and emotion might be affected.

Though the current study counted with a relatively small sample, the fact that the effects were mainly in line with our expectations based on previous studies, and that regarding the health related QoL scales the effect sizes were in line with a previously reported effect size (Soulie et al., 2017), suggest that the sample was representative. The current study was aimed at comparing VS patients with and without facial paresis, however the correlations between HBG and our measures revealed that not only the presence of a paresis, but also the degree of facial dysfunction is related to lower health related QoL and social function and emotion in VS patients.

To conclude, the findings of the current study suggest that it is especially relevant for physicians working with VS patients with facial paresis to consider, besides health related QoL, patients' satisfaction with life, depressive symptoms, and fear of being evaluated negatively by others. This first of all provides the possibility of making sure these patients get the proper guidance and help. Moreover, it is relevant to take the possible impact of a facial paresis on VS patients' life into account when deciding between treatment options and in case of surgery the type of resection.

Chapter 7

Lateralization of facial emotion processing and facial paresis in Vestibular Schwannoma patients

Based on: Blom, S.S.A.H., Aarts, H., Kunst, H.P.M., Wever, C.C., & Semin, G.R. (2020). Lateralization of facial emotion processing and facial paresis in Vestibular Schwannoma patients. *Brain and Behavior*, e01644.

Abstract:

This study investigates whether there exist differences in lateralization of facial emotion processing in patients suffering from Vestibular Schwannoma (VS) based on the presence of a facial paresis and their degree of facial functioning as measured by the House Brackmann Grading scale (HBG). Forty-four VS patients, half of them with a facial paresis and half of them without a facial paresis, rated how emotive they considered images of faces showing emotion in the left vs. right visual field. Stimuli consisted of faces with a neutral half and an emotional (happy or angry) half. The study had a mixed design with emotional expression (happy vs. angry) and emotional half (left vs. right visual field) of the faces as repeated measures, and facial paresis (present vs. absent) and HBG as between subjects' factors. The visual field bias was the main dependent variable. In line with typical findings in the normal population, a left visual field bias showed in the current sample: patients judged emotional expressions shown in the left visual field as more emotive than those shown in the right visual field. No differences in visual field bias showed based on the presence of a facial paresis nor based on patients' HBG. VS patients show a left visual field bias when processing facial emotion. No differences in lateralization showed based on the presence of a facial paresis or on patients' HBG. Based on this study, facial paresis thus does not affect the lateralization of facial emotion processing in patients with VS.

INTRODUCTION

Recognizing emotions and being able to simulate them -a process generally referred to as facial mimicry- are important facets of human social functioning. These elements are vital in human life. Newborn infants already show a preference for faces and face-like stimuli (Johnson, 2005), and facial mimicry is considered to be an automatic process (Dimberg, Thunberg & Grunedal, 2002) that supports a quick understanding of the emotionality of 'the other' in social interaction (Niedenthal, 2007). Thus, simulation and mimicry of facial emotion expressions is a human fundamental ability that plays a key role in attending to and interpreting other's facial expressions in human interaction and communication.

However, not all people are blessed with such ability. There are patients who can be assumed to encounter limitations in simulating facial expressions, due to impaired facial functioning such as facial paresis. In line with this idea, there is compelling evidence that impaired facial functioning undermines social functioning, emotional life, and mental health (Cross, Sheard, Garrud, Nikolopoulos & O'Donoghue, 2000; Fu, Bundy & Sadiq, 2011; Guntinas-Lichius, Straesser & Streppel, 2007; Ishii et al., 2011; Nellis et al., 2017; Ryzenman, Pensak & Tew, 2005). Because of the association between facial dysfunction and social and emotional factors of quality of life, it is especially relevant to understand whether facial dysfunction in patients impacts specific aspects of facial emotion processing. This study was designed to address this issue and to provide a first test to explore whether facial emotion processing might be impaired in specific patient group that suffers from facial dysfunction -- patients with a Vestibular Schwannoma.

Vestibular Schwannoma (VS) refers to a unilateral brain tumor also referred to as an acoustic neuroma (Weinberger & Terris, 2015). Typical clinical symptoms are hearing loss on the affected side, tinnitus, as well as disequilibrium (Weinberger & Terris, 2015). Because a VS is located near the facial nerve, surgical removal of it can cause a degree of unilateral paresis in the patient. To examine the potential disturbing impact of VS on facial emotion processing we used a well-documented method that tests a specific facet of facial emotion perception, namely hemispheric lateralization of facial emotion processing. Theories regarding hemispheric lateralization of facial emotion processing generally consider two main viewpoints. Whereas the right hemisphere hypothesis states that all emotions are, generally,

processed in the right hemisphere, the valence hypothesis states that the left hemisphere is dominant in processing positive emotions, and that the right hemisphere is dominant in processing negative emotions (e.g. Bourne, 2010).

Support for both viewpoints exist. For instance, right -compared to left- hemispheric processing of facial emotional expressions has often been reported to relate to better discrimination, recognition, and stronger perceived emotionality (e.g., Bourne, 2010). Furthermore, right hemisphere deficiencies have been shown to relate to difficulties in emotional facial expression recognition, as well as with difficulties in general social and emotional functioning (e.g., Meletti et al., 2003, Murray et al., 2015). However, other studies show a more varied picture, providing evidence for both the right hemisphere as well as the valence hypothesis (e.g., Wyczesany, Capotosto, Zappasodi & Prete, 2018). For example, a recent study in which behavioral -i.e.- as well as electrophysiological data was collected of participants while they viewed faces presented in either the left or right visual field, or in both, the behavioral data was more in support of the valence hypothesis, while the electrophysiological data was more in line with the right hemisphere hypothesis (Prete, Capotosto, Zappasodi & Tommasi, 2018). All in all, while the main evidence appears to suggest that the right hemisphere generally plays a more important role in emotion processing than the left hemisphere (Murray et al., 2015), evidence is definitely not conclusive and it is suggested that the two main hypotheses regarding the hemispheric lateralization of emotion processing are not mutually exclusive (Prete et al., 2018). Therefore, though this study is mainly focused on examining possible differences in lateralization of emotion processing between VS patients with and without facial paresis, we will examine the overall lateralization -in line with the right hemisphere hypothesis- as well as possible differences in lateralization based on valence -in line with the valence hypothesis.

The current's study addresses the lateralization of hemispheric processing by a method that has been extensively used in previous research: the chimeric faces test, a behavioral test of facial emotion processing which presents a face with an emotional expression in one half of the face and a neutral expression in the other half of the face. The image of the face is presented centrally, with the emotional facial expression thus being presented either in the left or the right visual field. This test examines whether there exists a bias in the observer considering the perception of emotional expressions presented in the left compared to the right visual field (e.g.

Bourne, 2010; Bourne & Gray, 2011; Levy, Heller, Banich & Burton, 1983). Hemispheric lateralization of emotion processing concerns the bias people tend to show in perceiving emotional expressions shown in the left or the right visual field as more emotional, or to recognize them more accurately depending on the visual field in which they are portrayed (Bourne, 2010; Murray et al., 2015). Considering that the information that is shown in the left visual field initially is received and processed by the right brain hemisphere, a left visual field bias is interpreted as support for the notion that the right hemisphere is more strongly involved in emotion processing than the left hemisphere (Bourne, 2006).

The role of the facial muscles of the observer in relation to hemispheric lateralization has been partly examined in healthy individuals as well as patients with mild unilateral facial paralysis (Blom, Aarts, & Semin, 2019; Korb et al., 2016). First, a recent study (Blom et al., 2019) using the chimeric faces test reported typical left visual field bias on perceived emotionality, but this visual field bias did not directly emerge in facial muscle activation. Furthermore, a study testing patients with acute, subacute or chronic unilateral facial paresis found that patients with a left vs. right facial paresis processed emotional expression of happiness and anger equally. Interestingly, patients with a left facial paresis processed happy expressions more accurately when presented in the right vs. left visual field, indicating a somewhat complicated relationship between facial paresis and emotional processing of others' expressions (Korb et al., 2016). In short, although suggestive, the research conducted so far does not give a clear picture about the role of facial muscles in perceiving emotionality in facial expressions of others.

The current study aims to enhance the understanding of the possible role of facial mimicry in perceived emotionality by examining the impact of being limited in one's facial functioning on emotion processing of hemispheric lateralization. First of all, while the left visual field bias -in line with the right hemisphere hypothesis- has often been observed in healthy individuals, we aim to replicate this typical bias effect in a sample of patients with VS. Additionally, we test for possible differences in bias based on the valence of the emotional expression. If the patients show a left vs. right visual field bias for positive vs. negative facial expressions, this would relate to the valence hypothesis. Most importantly however, we examined the role of facial functioning in hemispheric lateralization of emotion processing by comparing VS patients with and without facial paresis, as well as by examining the association

between hemispheric lateralization of emotion processing and the degree of facial dysfunction as measured by the House Brackmann Grading scale (HBG) (House, 1985). If facial functioning plays an important role in this, patients' facial functioning should be related to the visual field bias.

MATERIALS & METHODS

Study overview

We investigated the role of facial functioning in how emotional patients with VS perceive faces showing emotional expressions in the left or right visual field, with the other visual field being neutral in expression. Treatment of VS can include surgical removal of the tumor that causes a degree of (chronic) unilateral paresis in the patient. To take this important facial functioning difference into account, the study had a mixed design with emotional expression (angry vs. happy) and emotional half (left vs. right visual field) of the stimulus as repeated measures, with facial functioning (patients with or without facial paresis) as the main independent variable. The study was conducted and written informed consent of each participant was obtained in compliance with the principles contained in the Declaration of Helsinki. Permission for the study was granted by the Medical Ethics Committee of the Leiden University Medical Center.

Participants

Incidence rate of VS is low, with an estimated incidence rate of 15 persons per million in the Netherlands -where the current study took place-, with the highest latest incidence rate in one specific region of the Netherlands being 33.2 (Kleijwegt, Ho, Visser, Godefroy & van der Mey, 2016). Clearly, the number of VS patients experiencing a chronic condition of facial paresis due to surgical removal of the VS is even much lower. Considering this low incidence rate, we aimed at including a reasonable number of VS patients with or without facial paresis ($N = 44$) to examine interaction effects within our mixed design with two within subject repeated measures. Running a sensitivity analysis in G*Power 3.1 ($\alpha = .05$, power = 80%, $N = 44$) for an ANOVA: Repeated measures within-between interaction (including the moderator test of the patient group as well) indicated that we were able to detect a small to moderate effect size, $f = .18$.

All patients participating in the current experiment had previously been diagnosed with VS in the Leiden University Medical Center and the Radboud University Medical Center Nijmegen. In order to obtain a clear view of the specific impact of a unilateral facial paresis on lateralization of emotion processing, we aimed for a patient sample of which half had a chronic condition of unilateral facial paresis, while the other half of the sample had not developed a facial paresis at all.

Patients with and without facial paresis were matched as closely as possible (see Table 1 for details of the two subsamples) on the factors biological sex, age, side of the VS and the time that had elapsed since their diagnosis. In total, 28 females and 16 males participated ($M_{age} = 54.39$ years, $SD = 7.41$ years). Twenty-two patients experienced a degree of facial paresis after removal of their VS, while twenty-two patients had a VS but had not developed a facial paresis. Seventeen patients had a VS in the right cerebello pontine angle, while twenty-seven patients had it in the left cerebello pontine angle. The average time that had passed since being diagnosed with VS was 6.55 years ($SD = 4.74$). Facial dysfunction was graded by means of the House Brackman Grading scale (HBG); currently the most commonly used and accepted scale to document patients' degree of facial dysfunction (Zandian et al., 2014). This scale contains six levels of facial nerve function, with a higher grade representing stronger facial dysfunction. The HBG was scored both by the experimenter and by the patients themselves. Inter-rater reliability was high: Pearson's $r = .87$, therefore the average HBG was used for analyses.

Table 1.

Descriptives of VS patients with and without facial paresis.

	Patients without facial paresis	Patients with facial paresis
Age in years	$M = 55.32, SD = 6.99$	$M = 53.45, SD = 7.85$
Sex	Female (14), Male (8)	Female (14), Male (8)
Handedness	Left (1), Right (18), Mixed (0)	Left (2), Right (19), Mixed (1)
Average HBG	$M = 1.28, SD = 0.56$	$M = 3.85, SD = 1.15$
Localization VS	Left CPA (14), Right CPA (8)	Left CPA (13), Right CPA (9)
Time since diagnosis in years	$M = 5.92, SD = 3.84$	$M = 7.19, SD = 5.51$

Note. CPA = Cerebellopontine angle. HBG = House Brackman Grade

The number of patients in each category is reported between brackets when applicable.

Of the patients without facial paresis, we lack the information on handedness of 3 individuals.

Participant recruitment and response rate

Patients applied for participation either via responding to a letter of invitation received from their treating physician, or via responding to a call for participants on an online forum for people with VS¹. Out of the 62 patients who applied either via the online forum or who were invited by their treating physician, 42 (70.79%) decided to participate in the current experiment.

Stimuli

Chimeric faces that were created for and used in an earlier study (Blom et al., 2019) were used in this study as well. The chimeric faces were generated using images of four female and four male faces from the Dutch Radboud Faces Database (Langner et al., 2010). Each chimeric face was composed of an emotional (angry or happy) half face and a neutral half face (see Figure 1 for an example) of the same model, by blending the faces at the midline. We used both the original pictures and the mirrored pictures. The effects that we would find would then thus be due to a true visual field bias, not to a possible difference in expressiveness of the left or right side of the face of the poser. The final stimulus set consisted of 64 unique chimeric faces, differing in biological sex (4 male, 4 female), emotional expression (happy vs. angry), emotional visual field (left vs. right), and version (original vs. mirrored). The images of faces had a resolution of 462 x 562 pixels and an absolute size of 11.3 x 15.0 cm, and were presented in grayscale on a grey background. The visual angle was not measured *because participants'* head position was not fixed for the current experiment. Participants adjusted the distance to the laptop screen to their convenience.



Figure 1. Examples of a chimeric face showing a happy facial expression in the left visual field (left image) and in the right visual field (right image).

Procedure

Patients were informed that they had to rate on a 9-point scale -using the numeric keys 1 to 9- how emotional they found each face presented to them on the screen. They used their preferred hand to give their response, and were asked to not think too long about their rating and to trust their first impression. After 4 practice trials in which patients could get accustomed to the task and to the type of images, the experiment started. The task was presented in two blocks, each block consisting of the same 64 trials, presented randomly without replacement. Each trial started with a blank screen (1000ms), after which a fixation point appeared (random time between 600ms and 1000ms). Then, the chimeric face appeared with the rating scale below the face, which remained on screen until the face was rated. Patients went through the experiment self-paced, and could take a break in between blocks if they felt the need to. Average ratings of emotionality were calculated per stimulus type and served as dependent variable.

Statistical Analyses

We will first test the hypothesis that VS patients with and without facial paresis show differences in lateralization of facial emotion processing as measured by the visual field bias with classical statistical tests in the form of a mixed ANOVA (see Results, section 1). Normality of the data was confirmed by use of Q-Q plots as well the Kolmogorov-Smirnov test, and homogeneity of variances was confirmed by means of Levene's test for equality of variances. The sphericity assumption was met considering that each factor only consisted of two levels. Considering earlier research suggesting that the side of facial paresis matters for emotional processing of facial expressions (Korb et al., 2016), we include side of VS as an exploratory factor.

Next, we will perform a regression analysis with patients' HBG as predictor in order to provide a more thorough view of the relationship between the degree of facial dysfunction in VS patients and their visual field bias (see Results, section 2). Before running this analysis, linearity was inspected by means of scatterplots, and homoscedasticity and normality was checked by use of Q-Q plots of the regression standardized residuals, the Kolmogorov-Smirnov test, and by means of normal P-P plots of the regression standardized residuals.

Lastly, we will compare the visual field bias of VS patients to the visual field bias of a healthy control sample (reported in Blom et al., 2019) by running an ANOVA (see Results,

section 3). Homogeneity of variances was checked by means of Levene's test for equality of variances, and normality of the data was inspected by use of Q-Q plots as well the Kolmogorov-Smirnov test.

In addition to the classical statistical tests, Bayesian analyses are performed to quantify the evidence of the hypotheses under investigation. Bayesian Factors (BF) are reported, with a larger BF representing more evidence in the data set for the hypothesis under consideration.

RESULTS

1. Visual field bias and facial paresis in VS patients

In order to examine how patients respond to the chimeric faces, we performed an analysis of variance of the emotionality ratings as a function of emotional half (left vs. right visual field) and emotional expression (happy vs. angry) as within subject factors and facial paresis (present vs. absent) and side of VS (left vs. right *Cerebellopontine angle*, CPA) as between subject factors. The side of facial paresis was included as an exploratory factor, and it should be taken into account that the division of patients based on side of VS was not equal, given that 27 patients had their VS in the left, and only 17 had it in their right CPA. For the sake of clarity of reading, below we first report the main effects, followed by all higher order interaction effects.

Main effects

First of all, a large main effect of emotional half showed, $F(1,40) = 28.06, p < .001, \eta_p^2 = .41$. As expected, patients rated faces showing an emotional expression in the left visual field as more emotional ($M = 6.47, SD = .96$) than those showing an emotional expression in the right visual field ($M = 6.07, SD = 1.03$), mean difference 0.40, 95% CI [0.25, 0.54]. A Bayesian one sample *t*-test revealed that the data were 15532 times more likely to reflect a left visual field bias ($BF_{10} = 15532$), than for it to reflect a null effect. The basic left visual field bias of the chimeric faces test was thus replicated with the current patient sample, by revealing a large effect of emotional half of the face.

Second, a main effect of emotional expression, $F(1,40) = 5.54, p = .024, \eta_p^2 = .12$, showed that chimeric faces showing a happy emotional expression were rated as more

emotional ($M = 6.50$, $SD = 1.10$) than those showing an angry emotional expression ($M = 6.04$, $SD = 1.19$), mean difference 0.46, 95% CI [0.09, 0.83]. A Bayesian one sample t -test revealed that the data were 2.58 times more likely to reflect this difference in emotionality ratings based on the emotional expression ($BF_{10} = 2.58$), than for it to reflect a null effect.

No main effect of facial paresis emerged. VS patients with a facial paresis did not show overall differences in their emotionality ratings ($M = 6.18$, $SD = 1.16$) compared to VS patients without a facial paresis ($M = 6.36$, $SD = 0.76$), $F(1,40) = 0.15$, $p = .701$, $\eta_p^2 = .00$. A Bayesian independent samples t -test revealed that the data were 2.88 times more likely to reflect a null effect ($BF_{01} = 2.88$), than for it to reflect a difference in emotionality ratings based on facial paresis being present or absent. Also, the analysis did not yield a main effect of side of side of paresis. Patients who had the VS on the left side ($M = 6.31$, $SD = 0.87$) vs. the right side ($M = 6.21$, $SD = 1.14$), did not show an overall difference in emotionality ratings, $F(1,40) = .09$, $p = .771$, $\eta_p^2 = .00$. A Bayesian independent samples t -test revealed that the data were 3.17 times more likely to reflect a null effect ($BF_{01} = 3.17$), than for it to reflect a difference in emotionality ratings based on the side of the facial paresis.

Two-way interaction effects

The interaction between emotional half and valence of the emotional expression being positive or negative (happy vs. angry chimeric faces) showed to be significant, $F(1,40) = 4.43$, $p = .041$, $\eta_p^2 = .10$. A larger difference based on visual field in which the emotion was portrayed showed for happy ($M_{\text{difference}} = 0.50$, $SD = 0.72$) compared to angry ($M_{\text{difference}} = 0.29$, $SD = 0.34$) chimeric faces. A Bayesian paired samples t -test however, revealed that the data were only 1.23 times more likely to reflect this difference in visual field bias based on emotional expression ($BF_{10} = 1.23$), than for it to reflect a null effect.

Furthermore, and important to the present hypothesis, the effect of emotional half was not qualified by an interaction with facial paresis, $F(1,40) = 0.15$, $p = .705$, $\eta_p^2 = .00$, see Figure 2. Higher emotionality rating for emotional expressions shown in the left compared to the right visual field showed for VS patients without a facial paresis ($M_{\text{difference}} = 0.37$, $SD = 0.41$) as well as for VS patients with a facial paresis ($M_{\text{difference}} = 0.42$, $SD = 0.52$). A Bayesian independent samples t -test revealed that the data were 3.16 times more likely to reflect a null effect ($BF_{01} = 3.16$), than for it to reflect a difference in overall visual field bias based on facial

paresis being present or absent. The presence of a facial paresis thus most likely did not affect the visual field bias.

The analysis did not yield an interaction between emotional expression and facial paresis, $F(1,40) = .56, p = .457, \eta_p^2 = .01$. Lastly, the exploratory factor side of VS did not show to interact with any of the other factors. No interaction showed between side of VS and facial paresis (present vs. absent), $F(1,40) = .74, p = .395, \eta_p^2 = .02$, nor between side of VS and emotional expression (happy vs. angry), $F(1,40) = .18, p = .671, \eta_p^2 = .01$, or between side of VS and emotional half (left vs. right visual field), $F(1,40) = .08, p = .773, \eta_p^2 = .00$.

In line with this, a Bayesian analysis of variance indicated that neither the model including the interaction between emotional expression and facial paresis ($BF_{incl} = 0.32$), nor the model including the interaction between side of VS and paresis ($BF_{incl} = 0.57$), nor the model including the interaction between side of VS and emotional expression ($BF_{incl} = 0.27$), or the model including the interaction between side of VS and emotional half ($BF_{incl} = 0.23$) explained the data well compared to matched models not including these effects.

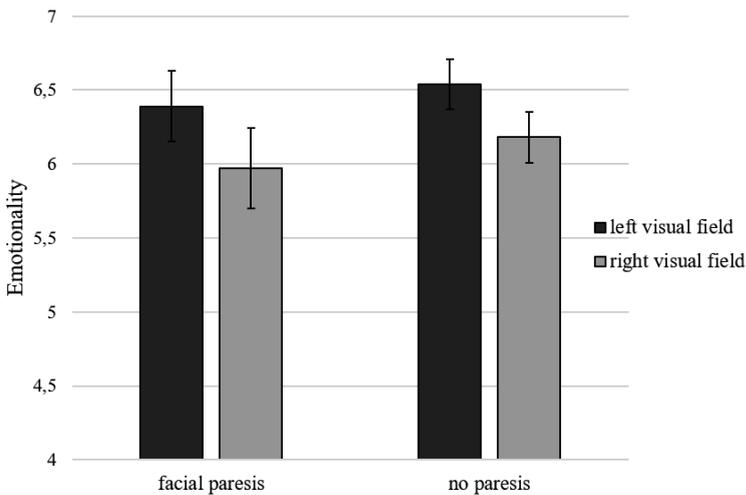


Figure 2. Left visual field bias in Vestibular Schwannoma patients. Error bars represent standard error.

Three-way interaction effects

The interaction between emotional half and valence did not show to be qualified by a further interaction with facial paresis, $F(1,40) = 0.15$, $p = .704$, $\eta_p^2 = .00$. A Bayesian independent samples t -test revealed that the data were 3.03 times more likely to reflect this null effect ($BF_{01} = 3.03$), than for it to reflect a difference in visual field bias based on valence between the two patient groups.

Furthermore, no three-way interaction showed between emotional expression, facial paresis, and side of VS, $F(1,40) = .50$, $p = .398$, $\eta_p^2 = .02$, nor between emotional half, facial paresis, and side of VS, $F(1,40) = .34$, $p = .562$, $\eta_p^2 = .01$. The Bayesian analysis of variance indicated that neither the model including the interaction between emotional expression, facial paresis, and side of VS ($BF_{incl} = 0.50$), nor the model including the interaction between emotional half, facial paresis, and side of VS ($BF_{incl} = 0.32$) explained the data well compared to matched models not including these effects.

Four-way interaction effect

Lastly, the interaction between emotional half, valence, facial paresis and side of VS was not significant, $F(1,40) = .06$, $p = .806$, $\eta_p^2 = .00$. The Bayesian analysis of variance indicated that the model including this interaction did not explain the data well compared to matched models not including this effect ($BF_{incl} = 0.39$).

To conclude, while the classic left visual field bias showed for the current patient sample, VS patients with and without facial paresis did not show a difference in this visual field bias (Figure 2). Furthermore, this left visual field bias showed to be slightly larger for happy than for angry chimeric faces.

2. Visual field bias and degree of facial dysfunction in VS patients

Second, it was examined whether the degree of facial dysfunction as measured by the average HBG score showed to be related to the above reported visual field bias. A score representing the visual field bias was computed by subtracting the average emotionality rating for faces with the emotional expression depicted in the right visual field, from those depicting the emotional expression in the left visual field. A positive visual field bias score thus represented a left visual field bias. A simple linear regression analysis with HBG score as independent variable and

visual field bias score as dependent variable showed to be not significant, $F(1, 42) = .08, p = .776, R^2 = .00$. HBG thus did not predict the overall visual field bias $b^* = .04, t(42) = .29, p = .776, B = .01, 95\% \text{ CI } B [-.08, .10]$. A Bayesian correlation revealed that the data were indeed 5.11 times more likely to reflect a null effect ($\text{BF}_{01} = 5.11$), than for it to reflect an association between degree of facial dysfunction and the visual field bias.

We furthermore examined the relationship between the degree of facial dysfunction as measured by the average HBG score and the visual field bias for positive and negative (happy and angry chimeric faces). Separate scores representing the visual field bias for happy and angry chimeric faces were computed as described previously, with a positive visual field bias score again representing a left visual field bias¹⁸.

The association between HBG score and visual field bias score for happy chimeric faces was not significant, $F(1, 42) = .00, p = .964, R^2 = .00$. HBG thus did not predict the visual field bias for positive expressions $b^* = .04, t(42) = .05, p = .964, B = .00, 95\% \text{ CI } B [-.14, .15]$. A Bayesian correlation revealed that the data were indeed 5.32 times more likely to reflect a null effect ($\text{BF}_{01} = 5.32$), than for it to reflect an association between degree of facial dysfunction and the visual field bias for positive expressions.

The association between HBG score and visual field bias score for angry chimeric faces was also not significant, $F(1, 42) = .46, p = .504, R^2 = .01$. HBG thus did not predict the visual field bias for negative expressions $b^* = .10, t(42) = .67, p = .504, B = .02, 95\% \text{ CI } B [-.05, .09]$. A Bayesian linear regression revealed that the data were indeed 4.29 times more likely to reflect a null effect ($\text{BF}_{01} = 4.29$), than for it to reflect an association between degree of facial dysfunction and the visual field bias for negative expressions.

3. VS patient sample versus a healthy control sample

¹⁸ Homoscedasticity was somewhat violated -as indicated by the Kolmogorov-Smirnov test- considering the dependent variable visual field bias of happy faces ($D(44) = .154, p = .011$) as well as the dependent variable visual field bias of negative faces ($D(44) = .162, p = .005$). For this reason, we applied a more conservative p -value (.01 instead of .05) for the significance tests. It should be noted that this adjustment did not change our outcomes.

While we report a strong replication of the left visual field bias in the current patient sample, no relationship revealed between hemispheric lateralization of emotion processing and facial functioning of the current sample of patients with VS, neither with the mere presence or absence of a facial paresis nor with the degree of facial dysfunction (as measured by the HBG). The null effects regarding possible differences in lateralization of facial emotion processing based on VS patients' facial paresis could first of all be due to the absence of such hypothesized effect of facial functioning. This would be in line with the results of a previous study showing no meaningful association between facial muscle activity in the form of facial mimicry and the visual field bias (Blom et al., 2019). On the other hand, the null effects could also be due to an affected visual field bias in the VS patient sample as a whole (i.e., irrespective of their facial functioning).

In order to test this, we compared the data of the current patient sample, to the data of a previous sample ($N = 23$) of healthy college students (Blom et al., 2019). Both studies made use of the exact same stimulus material as well as the same task and setup of the chimeric faces test. An analysis of variance with overall visual field bias as dependent variable, and group (VS patients without facial paresis, VS patients with facial paresis, and healthy controls) as between subject factor¹⁹ showed no significant effect of group, $F(2, 64) = 0.04$, $p = .965$, $\eta_p^2 = .00$. Bonferroni post-hoc tests confirmed that there was no difference between the overall visual field bias of the healthy control sample ($M = 0.38$, $SD = 0.46$) and VS patients with facial paresis ($M = 0.41$, $SD = 0.53$), $p = .997$, nor between the healthy control sample and VS patients without facial paresis ($M = 0.37$, $SD = 0.41$), $p = .980$. A Bayesian ANOVA confirmed that the data were 7.82 times more likely to reflect a null effect ($BF_{01} = 7.82$), than for it to reflect a difference in visual field bias comparing healthy controls, VS patients with facial paresis, and VS patients without facial paresis. Accordingly, we consider it most likely that the null effects

¹⁹ Non-normality revealed for the data for one of the three groups (VS patients with facial paresis, $D(21) = .23$, $p = .007$). We report one-way ANOVA results, considering that is a robust test against the normality assumption. Inspecting the alternative non-parametric one-way ANOVA (the Kruskal-Wallis test), suggests that the pattern of results does not change. No significant differences ($\chi^2 = .01$, $p = .995$) were found among the three participant groups (VS patients without facial paresis, VS patients with facial paresis, healthy student sample)

were due to the absence of a relationship between facial functioning and lateralization of facial emotion processing, and not because of an affected visual field bias in the VS patient sample as a whole.

DISCUSSION & CONCLUSION

The current study was aimed at examining hemispheric lateralisation of facial emotion processing by means of the chimeric faces test in Vestibular Schwannoma patients with and without facial paresis. First of all, we replicated the left visual field bias in this patient sample, meaning that when an emotional expression was depicted in the left visual field, rather than in the right visual field, the face was perceived as being more emotional. This left visual field bias showed to be somewhat stronger for positive (happy) than for negative (angry) facial expressions. Our findings are therefore in line with the right hemisphere hypothesis, and not with the valence hypothesis. No difference in this bias showed based on the mere presence or absence of a facial paresis, nor did it show to be associated with the specific degree of facial functioning of the patients. Furthermore, exploratory analyses revealed no relationship between the side of the facial paresis and the visual field bias. Lastly, no difference showed between the visual field bias of VS patients and a healthy control sample. All in all, VS patients with and without a facial paresis show the same type of hemispheric lateralization of facial emotion processing as has been reported in non-patient samples and thus do not appear to differ in this facet of emotion processing.

The current findings suggest that facial functioning and facial mimicry are not vital for hemispheric lateralization of facial emotion processing. These findings are in line with previous research, showing no direct association between emotion processing of other's expressions and facial muscle activity in healthy participants (Blom et al., 2019). Another recent related study however, reported that individuals with left facial paresis showed an opposite error pattern compared to individuals with a right facial paresis when detecting whether a happy facial expression first appeared in the left vs. right visual field (Korb et al., 2016). There are some differences between the Korb et al and our study that could explain this apparent disparity in findings. First, the present study examined and compared VS patients with and without a facial paresis (matched on various factors), while Korb et al tested a varied group of patients with a

facial paresis (including patients with acute -- less than 6 weeks -- to chronic -- more than 4 months paresis). Second, we examined differences between patients with or without facial paresis in lateralization of perceived emotionality of facial expressions, while Korb et al (2016) tested whether patients with a left or right facial paresis were able to detect in which visual field a happy facial expression first appeared. Though speculative, then, differences in patient groups and task measurements might have produced different findings between the studies as a result of tapping into different aspects of emotion processing (e.g., detection of emotion in faces vs. perceiving emotionality in faces).

Considering that the current study does provide a strong replication of the left visual field bias, a finding in line with numerous previous studies showing the occurrence of this hemispheric bias in facial emotion perception, and the absence of facial paresis effects suggests that processes other than facial mimicry play a more important role here.

First of all, the perceived emotional intensity of emotional facial expressions could involve a neural network that is distinctive from mimicking the emotional expression itself. Perceived intensity of emotion has been associated with a network implicating more rudimentary subcortical processing and related to activity of the amygdala and nucleus accumbens (e.g., Gainotti, 2012; Phan et al., 2004), whereas the act of mimicking facial expressions involves more cortical processing related to motor simulation of facial expressions, the posterior cingulate cortex, and medial temporal lobe structures (Schilbach, Eickhoff, Mojzisch & Vogeley, 2008). Accordingly, a possible explanation for the current findings might be that encoding the emotionality of another person's facial expression might occur (partly) independent from the mere mimicry of the facial expression itself. Furthermore, a recent study showed that the recognition of facial expressions can be achieved via two routes, namely by relying mainly on visual information and by sensorimotor information such as facial mimicry (de la Rosa, Fademrecht, Bülthoff, Giese & Curio, 2018). Extrapolating those findings to the current study would suggest that hemispheric lateralization of facial emotion processing might be a process that relies more on visual and subcortical information processing, rather than on sensorimotor information processing involved in simulating the facial expressions of others.

Though our findings could be interpreted as evidence against the role of facial mimicry in emotion processing, we would like to stress here that the findings reported in this study do not necessarily go against the important function of facial mimicry. Other information -such as

the visual (de la Rosa et al., 2018)- can sometimes provide sufficient input in order to complete emotion processing tasks, hence reducing the ‘need’ for facial mimicry for certain tasks (e.g., Arnold & Winkielman, 2019). For example, while facial mimicry did show to relate to the valence of the chimeric faces in a previous study (Blom et al, 2019), it did not show to relate to the visual field in which the expression was shown. Hence, though the facial muscles might react to the facial expressions shown in the paradigm used in the present study, participants apparently can judge the emotionality of presented faces without relying on the sensorimotor route. Relatedly, the task utilized by Korb et al (2016) might have relied more on the sensorimotor route than the current studies’ task, hence providing a different account for their reported findings somewhat diverging from our present findings.

In closing, although the present study mainly aimed to address the role of facial functioning in emotional processing of facial expressions, we would like to stress that is of equal importance to study different facets of emotion processing in patients with a facial paresis, as well as in patients with cerebellar damage. Other studies have for example reported differences in emotion perception and regulation in individuals with cerebellar damage (e.g., Houston et al., 2018). We therefore believe that future studies could examine this further by use of additional tasks that have previously been proven insightful for individuals with facial paresis and/or cerebellar damage. We wish to note here that the current study is part of a larger project that examined possible differences in *emotion processing* of facial expressions as well as perceived quality of life, social function and emotion between VS patients with and without facial paresis. This project aims to provide a first step in obtaining a more complete picture of emotion processing and emotion regulation in patients by using several experimental tasks as well as questionnaires (see Blom, Aarts, Wever, Kunst & Semin, in press^b; Blom, Aarts, Kunst, Wever & Semin, 2020a).

The current study is one of the few experimental studies on facial emotion processing in patients with a facial paresis, and patients with a VS in particular. Knowledge on emotion processes that are and that are not affected in VS patients’ with and without facial paresis informs health practitioners regarding the care they could provide patients with respect to their wellbeing. Although the present study suggests that facial paresis is not associated with impaired lateralization of emotion processing, future studies could focus on other types of

facial emotion processing to further the understanding of the possible impact of a facial paresis on emotion processing.

ⁱ The Dutch website for vestibular schwannomas: www.brughoektumor.nl.

Chapter 8

Facial emotion detection in Vestibular Schwannoma patients with and without facial paresis.

Based on: Blom, S.S.A.H., Aarts, H., Kunst, H.P.M., Wever, C.C., & Semin, G.R. (under review). Facial emotion detection in Vestibular Schwannoma patients with and without facial paresis.

Abstract:

This study investigates whether there exist differences in facial emotion detection accuracy in patients suffering from Vestibular Schwannoma (VS) due to their facial paresis. Forty-four VS patients, half of them with and half of them without a facial paresis, viewed pictures of facial expressions and had to classify each image as being emotional or non-emotional. The visual information of images was systematically manipulated by adding different levels of visual noise. The study had a mixed design with emotional expression (happy vs. angry) and visual noise level (10 to 80%) as repeated measures, and facial paresis (present vs. absent) and degree of facial dysfunction as between subjects' factors. Emotion detection accuracy levels declined when visual information declined, an effect that showed to be stronger for angry than for happy facial expressions. Overall, emotion detection accuracy did not turn out to differ between VS patients with or without a facial paresis, although exploratory analyses clearly revealed differences between the two groups on the detection accuracy of angry faces. The findings are discussed in the context of the effects of facial paresis on emotion detection, and the role of facial mimicry in particular as an important mechanism of facial emotion processing and understanding.

INTRODUCTION

The human face carries information that provides insight into people's mental states. One profound piece of information concerns emotional states. Recognizing emotions and simulating them are vital in human social life. Newborn babies like faces and face like stimuli (Johnson, 2005), and they already employ facial mimicry at young age (e.g., Beall et al., 2008; Kaiser et al., 2017). Furthermore, the ability to simulate other's facial expressions and mimicking them is argued to play a fundamental role in detecting and comprehending the emotional state of others (e.g., Bornemann, Winkielman & Van der Meer, 2012; Neal & Chartrand, 2011; Niedenthal, 2007), and supporting social interactions and social bonding (e.g., Fischer & Hess, 2016; Hess et al., 2016).

For most people, facial mimicry and recognizing and other's facial emotional expressions seem to come rather natural and automatically (e.g., Dimberg, Thunberg & Grunedal, 2002). However, in rare cases emotion processing of facial expressions might be severely impaired as a result of neural disorders (e.g., Cristinzio, Sander & Vuilleumier, 2007; Kumfor et al., 2014). Moreover, mimicking other's facial expressions might be corrupted due to facial dysfunction such as facial paresis. When patients with facial paresis are unable to mimic the expression of others, then not only the expression of their own emotional state but also their understanding of the emotional state of others could possibly be affected. Consistent with this idea, several studies show that patients with impaired facial functioning in general report lowered social and emotional functioning, as well as impacted mental health (e.g., Fu, Bundi & Sadiq, 2011; Guntinas-Lichius, Straesser & Streppel, 2007; Nellis et al., 2017; Van Swearingen et al., 1998). The association between facial functioning and socioemotional facets of quality of life thus gives reason to suggest that facial functioning and particularly impaired facial functioning in patients impacts specific aspects of their emotion processing.

In the present study we explored this association between facial paresis and emotion recognition in more detail. Specifically, we examined a specific group of patients that suffer from Vestibular Schwannoma (VS), also referred to as acoustic neuroma (Weinberger & Terris, 2015). VS's are benign unilateral tumors with typical clinical symptoms being hearing loss on the affected side, tinnitus, and disequilibrium (e.g., Johnson & Lalwani, 2012; Weinberger & Terris, 2015). Due to its location near the facial nerve, surgical removal of the tumor can cause

injury to the facial nerve, and hence facial paresis. Experimental studies on emotion processing in patients with facial paresis are rare, and the studies that have been conducted report differing results. While some studies suggest that impaired facial muscle movements due to Parkinson's (Argaud et al., 2016) or due to the locked-in syndrome (Pistoia et al., 2010) negatively affects emotion recognition or decoding accuracy, another study examining patients with Moebius syndrome—a condition resulting in facial paresis and an impaired abduction of the eyes—report no differences in accuracy of facial emotion recognition between patients with a facial paresis and healthy controls (Rives Bogart & Matsumoto, 2010). This state of affairs raises doubt about the importance of facial functioning and facial mimicry in emotion processing. The present study therefore aims to add to this area of research by examining the ability to accurately detect emotional facial expressions in VS patients who suffer from facial paresis (vs. not) due to surgical removal of the tumor.

Facial mimicry plays a more important role when emotional expressions are more difficult to detect. Impoverished visibility of emotional information diminished classification accuracy of emotional stimuli, especially angry facial expressions (e.g., Du & Martinez, 2011). When visual information is scarce, one would thus expect facial mimicry to start playing a more crucial role. Consequently, people who are limited in facial mimicry due to facial paresis might show reduced emotion detection when visual information is degraded. This concurs with the notion that emotional simulation only occurs when it adds new information about the other person's emotional state (e.g., Winkielman, Niedenthal & Obermann, 2008; Winkielman et al., 2015). Consistent with this notion, recent research suggests that facial mimicry plays a more important role in emotion processing when the emotions are more subtle, but is less vital when emotional expressions are easier to perceive. For example, participants who received Botox injections in their facial muscles showed reduced emotional experience only to less intense emotional video clips, and not to more intense emotional video clips (Davis et al., 2010). Relatedly, a different study (Baumeister, Papa & Foroni, 2016) examining Botox users yielded impaired emotion categorization only for less intense emotional stimuli. Botox users rated slightly emotional sentences and facial expressions as less emotional, an effect that did not show for more intense emotional stimuli or for neutral stimuli. Building on these findings, VS patients with facial paresis might show reduced emotion detection accuracy, especially when emotional visual information is blurred.

The Present Study

The current study involved a unique group of patients with a Vestibular Schwannoma (VS). VS is a relatively rare disease, and facial paresis after surgical removal in VS patients is even more rare. In the Netherlands –where the current study took place – the prevalence was estimated to be 15.5 persons per million in 2012 (Kleijwegt et al., 2016). Considering the low prevalence of VS, we were able to recruit forty-four VS patients: one group that had a unilateral facial paresis after surgical removal of the VS, while another group did not have a facial paresis, thus constituting a matched VS control group. The study aims to further our knowledge by focusing on whether the presence of a facial paresis impairs emotion detection accuracy of emotional facial expressions of anger and happiness with different levels of visibility. Manipulating the precise level of visibility of the image as well as utilizing two types of emotional facial expressions thus provided us with a test to examine differences in impairment of emotion detection. Based on earlier research it might be expected that patients with a facial paresis are less accurate in detecting highly impoverished face images compared to patients without a facial paresis.

MATERIALS AND METHODS

Study overview: Detecting emotion in faces with different levels of image visibility

Images of happy and angry facial expressions served as target stimuli, and images of neutral faces served as fillers. As a measure of emotion detection accuracy, participants were asked to indicate whether the image displayed an emotional expression or not (e.g. as in emotion detection tasks such as employed in: Goren & Wilson, 2006; Smith & Rossit, 2018). The study had a mixed design with emotional expression (2 levels: happy vs. angry) and visual noise level (8 levels: 10, 20, 30, 40, 50, 60, 70, and 80%) as repeated measures, and facial paresis (present vs. absent) as between subjects' factor.

Participants

Forty-four patients who had been diagnosed with VS participated in this study. Half of them had developed a unilateral facial paresis after removal of the VS, and half of them did not have

their VS removed and had not developed a facial paresis. Running a sensitivity analysis in G*Power 3.1 ($\alpha = .05$, power = 80%, $N = 44$) for an ANOVA: Repeated measures within-between interaction (including the moderator test of the patient group as well) indicated that we were able to detect a small difference between the two groups in our experimental design, effect size $f = .12$. Due to a technical issue the data of one participant was not recorded correctly, leaving us with a final sample of 43 patients. Permission for the study was granted by the Medical Ethics Committee of the Leiden University Medical Center. Participants provided written informed consent in accordance with the principles contained in the Declaration of Helsinki.

Distinctive properties of the participants

Twenty-one patients with a one-sided facial paresis participated (13 female, $M_{\text{age}} = 54.00$, $SD_{\text{age}} = 7.61$, time passed since diagnosis $M = 6.99$ years, $SD = 5.60$). Of these, 13 were left-sided, and 8 were right-sided. Twenty-two participants (14 female, $M_{\text{age}} = 55.82$, $SD_{\text{age}} = 7.13$, time passed since diagnosis $M = 5.76$ years, $SD = 3.82$) with a VS but without facial paresis served as a control group. Of this group, 14 had a VS on the left side, and 8 had it on the right side. The participants in the VS control group were matched as closely as possible to the facial paresis VS group on gender, age, side of the VS and time that had elapsed since the diagnosis. Facial functioning was graded using the House Brackman Grading scale (HBG) (House, 1985), currently the most widely used and accepted scale to document the degree of facial paresis (Zandian et al., 2014). This scale includes six levels of facial nerve function, with a HBG of 1 representing normal facial function, a HBG 6 representing complete paralysis. HBG was scored both by the participants themselves as well as by the experimenter. Inter-rater reliability showed to be high ($r = .86$, $p < .001$), hence the average of these two scores was used for analyses. As expected, patients with a facial paresis had a substantial average HBG score ($M = 3.90$, $SD = 1.15$) compared to patients without a facial paresis ($M = 1.27$, $SD = .55$), $t(42) = 9.82$, $p < .001$, $d = 2.99$, 95% CI [2.11; 3.86].

Participant recruitment and response rate

Part of the participants applied for participation via responding to a call for participants on an online forum for people with VS (i.e., the Dutch website for vestibular schwannomas:

www.brughoektumor.nl). The remaining participants were invited to participate by a letter they received from their treating physician explaining the study. In total, 44 out of 62 (71%) - including the participant who participated but of whom the data was not saved correctly - participants who either applied via the online forum or were invited by their physician participated.

Stimuli

Facial expression stimuli were created using images of four males and four females (from the Radboud Faces Database: Langner et al., 2010) portraying a happy, angry or neutral expression. For each unique face, 8 versions were created introducing different levels of noise in Photoshop (10, 20, 30, 40, 50, 60, 70, and 80% noise), see Figure 1 for an example. Faces were presented in grayscale against a grey background. The stimuli thus consisted of 64 happy facial expressions (8 per noise level), 64 angry facial expressions (8 per noise level), and 64 neutral facial expressions (8 per noise level). Only the emotional facial expressions were target stimuli, the neutral stimuli served as fillers.

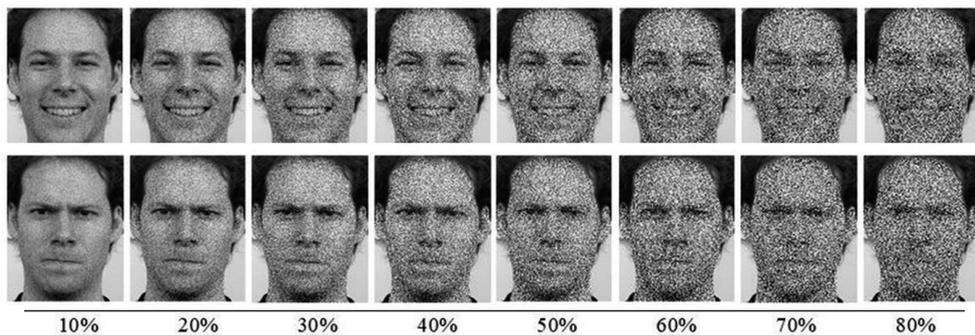


Figure 1. Examples of a male happy face and a male angry face, image noise levels of 10 until 80%.

Procedure

On the day of the appointment, the experimenter visited the participants at their home, where the experiment was conducted on a laptop. Participants were told that they would see pictures of emotional and neutral facial expressions. They were instructed to indicate whether the face was an emotional one or a non-emotional one (neutral) by pressing the corresponding key on

the keyboard. Thus, a correct response would be that a happy or angry face is emotional, and an incorrect one when indicating that a happy or angry face is non-emotional. It was further emphasized that they should be accurate and fast.

The experiment started with 16 practice trials in which patients received feedback on screen after each trial regarding their performance. Then the experiment started. In the actual experiment, no more feedback was provided. Half of the trials were neutral faces; the other half were expressions of emotions (happy or angry). In order to keep the number of emotional and non-emotional faces equal, but without adding pictures of new actors, each neutral face was used twice. In total, the experiment consisted of 256 trials, presented in four blocks of 64 trials each. Emotional and non-emotional faces were presented randomly without replacement. After each block, participants could take a short break if needed. Each trial started with a blank screen (1000ms), after which a fixation point appeared (randomized times of 600-700-800-900 and 1000ms), followed by the image of the face (presented until classification as emotional or neutral), after which the next trial would start again with a blank screen. The experiment was self-paced. Accuracy (in percentage) of emotion detection in the faces was used as the dependent variable.

Statistical Analyses

We will first test the hypothesis that VS patients with and without facial paresis show differences in emotion detection accuracy based on the visibility of images of happy and angry facial expressions with frequentist statistical testing in the form of Anova and *t*-tests. Next, we will perform an Anova with patients' HBG as covariate in order to provide a more thorough view of the relationship between the degree of facial dysfunction in VS patients and their emotion detection accuracy. In addition to the frequentist statistical tests, Bayesian analyses are performed to quantify the evidence of the hypotheses under investigation given the data. Bayesian Factors (BF) are reported, with a larger BF representing more evidence in the data set for the hypothesis under consideration. In case sphericity was violated for any of the reported results, Greenhouse-Geisser corrections were applied and adjusted degrees of freedom were reported.

Finally, to gain more specific insight into potential differences between the two VS patient groups we conduct two exploratory analyses. First, we examine the pattern of emotion

detection accuracy across the noise levels by inspecting the linear or quadratic trends for happy vs. angry faces between the two groups by means of a repeated measure Anova. Second, we examine whether emotion detection accuracy differ from chance (50%) for the two patient groups at each level of noise, separately for happy vs. angry faces by use of t-tests.

RESULTS

1. Emotion detection accuracy and presence vs. absence of facial paresis

To test whether facial paresis would play a role in emotion detection accuracy, a repeated measures analysis was done with noise level of the image (10-80%, in steps of 10%) and type of emotional expression (happy vs. angry) as within subject factors, and facial paresis (group where facial paresis is present vs. absent) as between subject factor.

First of all, this analysis yielded a significant and large main effect of noise level, showing that emotion detection accuracy decreased when the visual noise level of the image increased, $F(3.21, 134.91) = 99.30, p < .001, \eta_p^2 = .70$. Moreover, a main effect of type of emotional expression was found, $F(1,42) = 107.86, p < .001, \eta_p^2 = .72$. Emotion detection accuracy was higher for expressions of happiness ($M = 98.51, SD = 3.41$) than for expressions of anger ($M = 74.22, SD = 14.27$). These two main effects were classified by a strong interaction effect between noise level of the image and type of emotional expression, $F(2.81, 115.28) = 65.36, p < .001, \eta_p^2 = .61$. As can be seen in Figure 2, while for both happy and angry expressions accuracy levels decreased for increasing noise levels in the image, for happy expressions detection accuracy levels went down only slightly, while for angry expressions detection accuracy went down much sharper when noise levels in the image increased. In line with this, Bayesian analysis of variance indicated that the model including the interaction between visual noise and type of emotional expression explained the data very well compared to matched models not including this effect ($BF_{incl} = 1.263e+ 53$).

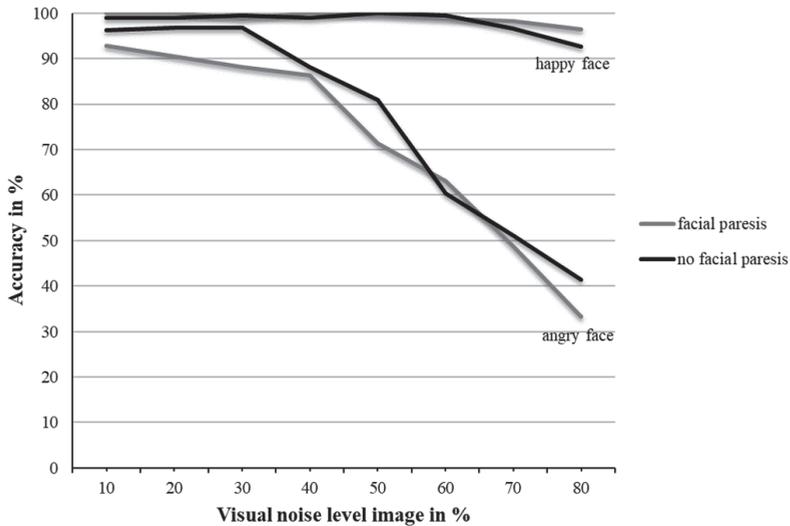


Figure 2. The effect of visual noise per type of emotional expression for patients with Vestibular Schwannoma with and without facial paresis.

Importantly, patients with and without facial paresis did not differ in their overall emotion detection accuracy, $F(1,41) = 0.94, p = .337, \eta_p^2 = .02$. Furthermore, there was no interaction between noise level and facial paresis, $F(7,287) = 0.77, p = .611, \eta_p^2 = .02$, nor between emotional expression and facial paresis $F(1,41) = 1.70, p = .200, \eta_p^2 = .04$. Lastly, the above described interaction between noise level and the emotion depicted in the image was not classified by a further interaction with facial paresis, $F(7,287) = 0.80, p = .591, \eta_p^2 = .02$. In line with this, Bayesian analysis of variance indicated that neither the model including a main effect of facial paresis ($BF_{incl} = 0.27$), nor the model including the interaction between visual noise and facial paresis ($BF_{incl} = 0.01$), or the model including the interaction between visual noise, type of emotional expression and facial paresis ($BF_{incl} = 0.03$) explained the data well compared to matched models not including these effects.

To conclude, these findings reveal strong classic effects regarding emotion detection accuracy for the current task, including the differential effects of happiness and anger. However, VS patients with and without facial paresis did not show to differ in their emotion detection accuracy levels.

2. Emotion detection accuracy and degree of facial dysfunction (HBG)

To examine whether the degree of facial dysfunction (HBG) was associated with emotion detection accuracy, a repeated measures analysis was done with noise level of the image (10-80%, in steps of 10%) and type of emotional expression (happy vs. angry) as the within subject factors, and degree of facial dysfunction as measured by the HBG as covariate.

HBG was not related to the overall emotion detection accuracy, $F(1,41) = 0.18, p = .672, \eta_p^2 = .00$. Secondly, no interaction showed between noise level and HBG, $F(3.15, 129.23) = 0.58, p = .773, \eta_p^2 = .01$, nor between emotional expression and HBG $F(1,41) = 0.77, p = .387, \eta_p^2 = .02$. Lastly, the interaction between noise level and the emotion was not classified by a further interaction with HBG, $F(7,287) = 0.90, p = .511, \eta_p^2 = .02$.

In line with this, Bayesian analysis of variance indicated that the model including the interaction between visual noise and type of emotional expression again best explained the data compared to matched models not including this effect ($BF_{incl} = 7.311e+52$). Neither the model including a main effect of HBG ($BF_{incl} = 0.19$), nor the model including the interaction between visual noise and HBG ($BF_{incl} = 6.97e-5$), or the model including the interaction between visual noise, type of emotional expression and HBG ($BF_{incl} = 0.00$) explained the data well compared to matched models not including these effects.

The degree of facial dysfunction thus did not show to be associated with patients' emotion detection accuracy levels.

3.1. Exploratory analysis 1: Emotion detection accuracy patterns

For exploratory purposes, we conducted two additional analyses. First, inspection of the pattern of emotion detection accuracy suggests different specific trends for the different levels of noise. We therefore examined whether the (linear and quadratic) trends for happy vs. angry faces differed between the two groups. Accordingly, a repeated measures Anova analysis was conducted with noise level of the image (10-80%, in steps of 10%) and type of emotional expression (happy vs. angry) as within subject factors, and facial paresis (group where facial paresis is present vs. absent) as between subject factor. These analyses showed a large linear main effect for visual noise level, $F(1,41) = 187.81, p < .001, \eta_p^2 = .82$, while the quadratic effect also showed to be significant but smaller in size than the linear effect, $F(1,41) = 77.75, p < .001, \eta_p^2 = .66$.

This linear main effect of visual noise level showed a strong interaction with type of emotional expression, $F(1,41) = 122.37, p < .001, \eta_p^2 = .75$, while the quadratic effect of visual noise level showed to interact with type of emotional expression to a lesser degree, $F(1,41) = 30.15, p < .001, \eta_p^2 = .42$. Thus, while for both happy and angry expressions accuracy levels decreased for increasing noise levels in the image, for happy expressions detection accuracy levels went down only slightly, while for angry expressions detection accuracy showed a sharp decrease for increased visual noise levels in the image. Lastly, this interaction between the linear effect of visual noise level and the emotion depicted in the image was not classified by a further three-way interaction with facial paresis, $F(1,41) = 0.03, p = .869, \eta_p^2 = .00$. An interaction that as could be expected also did not show with the quadratic effect of visual noise level, $F(1,41) = 0.58, p = .449, \eta_p^2 = .01$.

In short, the linear effect of visual noise thus showed to be a good explanation of the observed emotion detection accuracy pattern. With increasing levels of visual noise, overall emotion detection accuracy showed to decline in a linear fashion, with the decline in detection accuracy declining strongly for expressions of anger, and only slightly for expressions of happiness. These effects were not different for VS patients with and without facial paresis.

3.2. Exploratory analysis 2: Emotion detection accuracy at chance level

Second, we analyzed whether the two groups of patients would differ from chance (defined as a score of 50%) at each level of noise, separately for happy vs. angry faces. T-tests of the eight comparisons per emotion, comparing per group if the score per noise level was different from chance were conducted. As can be seen in Table 1, for both VS patients with and without facial paresis, recognition of emotion in facial expressions of happiness was generally very high and above chance level, at all visual noise levels. VS patients with facial paresis even showed 100% classification accuracy scores for three noise levels, while VS patients without facial paresis showed such scores for one noise level.

Table 1.

Facial paresis (present vs. absent) and classification accuracy of happy facial expressions, testing difference from chance (50%).

	No Facial paresis				Facial paresis			
Visual noise	<i>M (SD)</i>	<i>t</i>	<i>p</i>	<i>d</i>	<i>M (SD)</i>	<i>t</i>	<i>p</i>	<i>d</i>
10%	98.86% (5.33)	43.00	< .001	9.17	100% (0.00)	NA	NA	NA
20%	98.86% (3.68)	62.31	< .001	13.29	100% (0.00)	NA	NA	NA
30%	99.43% (2.67)	87.00	< .001	18.55	98.81% (3.76)	59.49	< .001	12.98
40%	98.86% (5.33)	43.00	< .001	9.17	100% (0.00)	NA	NA	NA
50%	100% (0.00)	NA	NA	NA	99.40% (2.73)	83.00	< .001	18.11
60%	99.43% (2.67)	87.00	< .001	18.55	98.81% (3.76)	59.49	< .001	12.98
70%	96.59% (7.89)	27.70	< .001	5.91	98.21% (4.48)	49.30	< .001	10.76
80%	92.61% (19.16)	10.43	< .001	2.23	96.43% (5.79)	36.77	< .001	8.02

NA = Not applicable: there are no statistics available due to absence of variance

A different pattern emerged for angry facial expressions. As can be seen in Table 2, while emotion detection accuracy was significantly higher than chance at visual noise levels 10% to 50% for both groups, VS patients with a facial paresis were less accurate in their perception of emotion in images of angry expressions with 10-30% visual noise than VS patients without a facial paresis. VS patients with or without facial paresis performed at or near chance level (i.e. they remained uncertain whether a face showed emotion or not) for visual noise levels of 60% and 70%. Interestingly, VS patients with a facial paresis performed significantly lower than chance level (i.e., they became certain that the face did not show an emotion) at a visual noise level of 80%.

Table 2.

Facial paresis (present vs. absent) and classification accuracy of angry facial expressions, testing difference from chance (50%).

Visual noise	No Facial paresis				Facial paresis			
	<i>M (SD)</i>	<i>t</i>	<i>p</i>	<i>d</i>	<i>M (SD)</i>	<i>t</i>	<i>p</i>	<i>d</i>
10%	96.20% (6.99)	31.72	< .001	6.61	92.86% (14.02)	14.01	< .001	3.06
20%	96.74% (5.61)	39.94	< .001	8.33	90.48% (19.73)	9.40	< .001	2.05
30%	96.74% (5.61)	39.94	< .001	8.33	88.10% (16.04)	10.88	< .001	2.37
40%	88.04% (13.31)	13.70	< .001	2.86	86.31% (16.25)	10.24	< .001	2.23
50%	80.98% (15.93)	9.33	< .001	1.94	71.43% (20.97)	4.68	< .001	1.02
60%	60.33% (27.61)	1.79	.087	0.37	63.10% (22.87)	2.62	.016	0.57
70%	51.09% (26.89)	0.19	.848	0.04	48.81% (26.78)	-0.20	.841	-0.04
80%	41.30% (31.63)	-1.32	.201	-0.28	33.33% (24.47)	-3.12	.005	-0.68

DISCUSSION

The goal of the present study was to examine the accuracy of detecting emotion in facial expressions with different levels of visibility, and potential disturbances in such emotional detection in patients with a Vestibular Schwannoma (VS) with a facial paresis compared to VS patients without a facial paresis. Half of the VS patient sample had a unilateral facial paresis and the other half did not have a facial paresis and thus served as a matched VS control group.

First, emotion detection accuracy diminished in a linear fashion with increasing visual noise levels for facial emotional expressions. This effect showed to be different for expressions of happiness and anger; the accuracy of detecting angry facial expressions was affected more strongly by the visual noise level of the images than the accuracy of detecting happy facial expressions was. Emotion detection accuracy showed a much sharper decline with increasing visual noise levels for angry facial expressions. These findings are in line with previous research on facial emotion processing, and indicate that the amount of visual information available influences emotion detection, and more so for angry than for happy facial expressions (e.g., Du & Martinez, 2011).

Furthermore, none of the effects described above showed to be associated with the mere presence or absence of a facial paresis, nor did they show to be related to the specific degree of facial functioning of the VS patients. All in all, VS patients with and without a facial paresis show a similar pattern of emotion detection accuracy in facial expressions of happiness and anger, even when the images were highly impoverished. VS patients with and without facial paresis thus do not appear to differ in this facet of emotion processing.

Exploratory analyses did yield a few interesting differences between the two groups, particularly regarding angry facial expressions. First, patients without (vs. with) a facial paresis appeared to be more certain that angry facial expressions were emotional when the level of added noise was low (10-30%), but at the highest (80%) visual noise level it became clear that only VS patients with a facial paresis scored below chance. The latter group actually indicated that such angry expressions did not show any emotion. These findings suggest that facial paresis affects the processing of angry expressions, even at higher levels of visual input, and that angry faces might even appear to be non-emotional to people with a facial paresis when visual input becomes rather low.

Whereas the exploratory analysis showed a few subtle differences between the two patient groups, we wish to stress here that our main findings do not provide clear evidence that facial dysfunction hampers facial emotion processing. These general findings thus suggest that facial mimicry does not play a critical role in detecting emotion in facial expressions of anger and happiness, even when these images become highly impoverished. These results are in line with previous studies, showing no direct association between emotion processing of facial expressions and impaired facial functioning in facial paresis patients (Rives Bogart & Matsumoto, 2010) and with facial muscle activity in healthy participants (Blom, Aarts & Semin, 2019).

Considering that the current study does provide a strong replication of the impact of reduced visual information on emotion perception in happy and angry facial expressions (e.g., Du & Martinez, 2011), the absence of strong facial paresis effects suggests that other processes play a more important role here. For example, a recent study showed that recognition of emotional facial expressions can be achieved via two routes, namely by relying on visual information or on (sensori)motor information such as facial mimicry (de la Rosa et al., 2018). Considering our findings in light of that study would suggest that participants relied on visual

information even when this information was highly reduced, rather than relying on sensorimotor information processing involved in simulating the facial expressions of others. In closing, the present experiment is one of the few experimental studies focusing on emotion processing in people with a facial paresis, and one of the first studies focusing on emotion processing in patients with a VS in particular. Manipulating the precise level of visibility of the image as well as utilizing two types of emotional facial expressions provided us with specific information about possible differences in impairment of emotion detection. Future research could explore emotion perception in facial paresis patients further by for example by use of dynamic emotional stimuli (as for example addressed in Carr et al., 2014). This would provide more understanding on the relationship between facial dysfunction and emotion processing. Increased knowledge on emotion processing in VS patients' with and without facial paresis is not only relevant for theory building of emotion processing. It is also important for informing health practitioners concerning the care they could provide facial paresis patients regarding their wellbeing.

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Appendix I: words (translated from Dutch) selected for the study reported on in Chapter 5

	Positive words	Negative words	Neutral words	
Bradley & Lang (1999)	Friendly	Disgusted		Icebox
	Nice	Upset		Ankle
	Thoughtful	Morbid	Contents	Time
	Adorable	Cruel	Avenue	Hat
	Cute	Selfish	Clock	Hammer
	Hopeful	Insane	Doctor	Trunk
	Pleasure	Terrible	Context	Stool
	Reward	Rotten	News	Material
	Cuddle	Aggressive	Stove	Elevator
			Month	Scissors
			Obey	Knot
			Gloom	Office
			Radiator	Rattle
			Passage	Truck
		Tool	Odd	
		Glass		
		Appliance		
<hr/>				
Foroni & Semin (2009)	To smile	To frown		
	To laugh	To cry		
	To grin	To squeal		
	Comical	Irritating		
	Funny	Frustrating		
	Entertaining	Annoying		
<hr/>				
Hermans & De Houwer (1994)	Healthy	Hateful	Table	Wallpaper
	Happy	False	Page	Sidewalk
	Fortunate	War	Branches	Stripe
	Optimistic	Cancer	Circle	Square
	Cheerful	Torture	Clay	Sewing
	Pleasant	Accident	Paper	machine
	Love	Pain	Box	Bow
	Peace	Sadness	Plate	Microscope
	Hug	Death	Bag	Yeast
			Line	

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Contributions

Chapter 1

Author Blom wrote the first draft of the manuscript, authors Aarts and Semin edited the manuscript.

Chapter 2

Author Blom wrote the first draft of the manuscript, authors Aarts and Semin aided with conceptualization and theory and edited the manuscript.

Chapter 3

Author Blom aided in study design, data collection, conducted statistical analyses, interpreted results, and wrote the first draft of the manuscript. Author Semin aided in designing the study and interpreting the results, and edited the manuscript.

Chapter 4

Author Blom aided in study design, data collection, conducted statistical analyses, interpreted results, and wrote the first draft of the manuscript. Author Aarts aided in interpreting the results and edited the manuscript. Author Semin aided in designing the study and interpreting the results, obtained grant funding, and edited the manuscript.

Chapter 5

Author Blom aided in study design, data collection, conducted statistical analyses, interpreted results, and wrote the first draft of the manuscript. Author Aarts aided in interpreting the results and provided conceptualization used to integrate the findings and edited the manuscript. Author Semin aided in designing the study, conceptualization, interpreting the results, obtained grant funding, and edited the manuscript.

Chapter 6

Author Blom aided in study design, data collection, conducted statistical analyses, interpreted results, and wrote the first draft of the manuscript. Author Aarts aided in interpreting the results and edited the manuscript. Author Semin aided in designing the study and interpreting the results, obtained grant funding, and edited the manuscript. Authors Wever and Kunst aided in participant recruitment as well as in background theory regarding the patient sample.

Chapter 7

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Chapter 8

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Nederlandse samenvatting

Het begrijpen van de emoties van anderen is van essentieel belang voor het onderhouden van sociale interacties en relaties. Elkaars emoties begrijpen geeft waardevolle informatie over elkaars mentale toestand en intenties. Dat is handig wanneer je dezelfde of verschillende belangen hebt. Emotionele informatie moet hiervoor vaak snel en goed verwerkt en geïnterpreteerd worden, een proces waarvan de totstandkoming niet geheel bekend is. Een belangrijke vorm waarin emotie wordt uitgedrukt in sociale interactie is door middel van onze gezichtsexpressies. Door middel van subtiele verschillen in gezichtsspieractivatie, kan iemand laten zien hoe hij of zij zich voelt. Onderzoek laat zien dat we onze gezichtsspieren niet enkel gebruiken om emotie uit te drukken, maar ook om emotie die we waarnemen in anderen te simuleren.

Simulatie van waargenomen emotie vindt plaats wanneer in de waarnemer in zekere mate dezelfde emotioneel-congruente spieren (en onderliggende neurale netwerken) worden geactiveerd waardoor de waarnemer dezelfde emotie kan ervaren. Bijvoorbeeld, wanneer iemand een vrolijk gezicht ziet, worden de spieren die gebruikt worden om een lach te produceren (de *zygomaticus major*) actiever in de waarnemer, een proces dat in de internationale emotieliteratuur ook wel *facial mimicry* genoemd wordt. Vanuit het *embodied cognition* perspectief wordt verondersteld dat niet enkel ons brein en cognitieve functies, maar ook het lichaam en lichamelijke activiteit onderdeel zijn van cognitie. In lijn met het *embodied cognition* perspectief wordt dan ook gedacht dat een van de functies van emotie simulatie is om emotiebegrip te faciliteren.

Deze thesis richt zich op de rol van facial mimicry in het begrijpen van andermans emoties zoals uitgedrukt in gezichtsexpressies. We hebben hiervoor ten eerste recente literatuur geanalyseerd waarbij de rol van facial mimicry in emotiebegrip wordt onderzocht door middel van metingen van de gezichtsspieren (EMG), en metingen van emotiebegrip wanneer facial mimicry (tijdelijk of chronisch) niet mogelijk is. Daarnaast hebben we in het empirische gedeelte van deze thesis emotiebegrip in combinatie met metingen van gezichtsspieractivatie (EMG) onderzocht, alsook emotiebegrip in patiënten die gelimiteerd zijn in het gebruik van hun gezichtsspieren, namelijk patiënten met een aangezichtsverlamming.

Het onderzoek beschreven in deze thesis suggereert dat de gezichtsspieren voornamelijk reageren op de valentie van de waargenomen emotionele informatie, en dat facial mimicry mogelijk minder belangrijk is voor emotiebegrip dan eerder gedacht werd. Onze resultaten zijn in lijn met de notie dat facial mimicry vooral belangrijk is in emotiebegrip wanneer geen helder beeld gevormd kan worden en emotiebegrip niet gemakkelijk tot stand kan komen op basis van andere aanwezige informatiebronnen, zoals zicht, gehoor of kennis opgedaan door ervaring. Deze bevindingen zijn in lijn met het *embodied cognition* perspectief, en ondersteunen het idee dat simulatie van waargenomen emotie nuttige informatie kan verstrekken aan de simulator, specifiek wanneer de representatie van emotionele expressies niet gemakkelijk tot stand kunnen komen.

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About the Author

Stephanie Blom was born on 7 July 1986, in Breda, the Netherlands. She started her undergraduate education in 2005, at Utrecht University, majoring in Social Psychology. After graduating in 2008 she started with the research master Social and Health Psychology in 2009, focusing on the social and health-related aspects of behavior regulation. She graduated in 2011 (cum laude). Afterwards, she started her PhD project at Utrecht University under the supervision of Gün Semin in 2011. From 2015-2018, she studied in Barcelona and obtained her degree in art therapy. In 2017, she started working as a lecturer at the Communication Science department at the University of Amsterdam. Simultaneously, from 2017 onwards, she continued her PhD project under the supervision of Gün Semin and Henk Aarts, which led to this dissertation. In 2020, Stephanie started as a postdoctoral researcher at the Self-Regulation Lab of Utrecht University, on the Supreme Nudge project.

