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EMOTION PROCESSING IN POSTTRAUMATIC STRESS DISORDER: EMOTION RECOGNITION, INTERPRETATION OF NEUTRAL FACIAL EXPRESSIONS, AND FACIAL MIMICRY

Thesis (cumulative thesis)
Presented to the Faculty of Arts and Social Sciences of the University of Zurich
for the degree of Doctor of Philosophy

by Sandra Passardi

Accepted in the fall semester 2018
on the recommendation of the doctoral committee:

Prof. Dr. phil. Markus Landolt (main supervisor)
Prof. Dr. phil. Monique C. Pfaltz

Zurich, 2018

To my patients, survivors of torture and war - may they be able to find peace and heal their emotional wounds

“It is both a blessing
And a curse
To feel everything
So very deeply.”
- David Jones

ABSTRACT

Correct interpretation of facial expressions is important for the success of social relationships. Furthermore, automatic facial responses to facial emotion (facial mimicry), among others, facilitate empathy. There are hints for emotion recognition deficits in individuals with posttraumatic stress disorder (PTSD), yet research is sparse. Neutral facial expressions are sometimes interpreted as more negative by individuals with child maltreatment. However, research on misinterpretations of facial expressions and on facial mimicry is missing in PTSD. The three studies of this dissertation project analyzed emotion recognition accuracy and misinterpretations of neutral facial expressions in individuals with PTSD. In addition, facial electromyography responses were recorded to explore facial mimicry. Trauma history, dissociation, alexithymia, and expressive suppression were assessed by questionnaires in order to explore factors possibly related to emotion recognition deficits. PTSD individuals showed deficits in recognition of positive and neutral facial expressions, and interpreted neutral expressions more often as anger and contempt. Comparisons of statistical model fits suggest that child maltreatment might play a more important role than PTSD diagnosis in explaining these abnormities. Furthermore, cumulative traumatic events, dissociation, and alexithymia were associated with emotion recognition deficits. Finally, facial mimicry was intact in individuals with PTSD. If these results are replicated in more real-life situations, future studies should test whether emotion recognition training can improve emotion recognition in PTSD and whether interaction partners can improve relationship quality with individuals with PTSD by increased awareness of their own facial expressions.

ZUSAMMENFASSUNG

Die korrekte Interpretation von Gesichtsausdrücken ist wichtig für den Erfolg sozialer Beziehungen. Zudem fördern automatische Mimikreaktionen auf emotionale Gesichtsausdrücke (Mimikry) unter anderem die Empathie. Es gibt Hinweise für Emotionserkennungsdefizite bei Personen mit Posttraumatischer Belastungsstörung (PTBS), jedoch gibt es wenig Forschung dazu. Neutrale Gesichtsausdrücke werden manchmal als negativer interpretiert von Personen mit Erfahrungen von Kindheitsmissbrauch. Forschung zu Fehlinterpretationen von Gesichtsausdrücken und zu Mimikry fehlt jedoch bei Personen mit PTBS. Die drei Studien dieses Dissertationsprojektes untersuchten die Emotionserkennungsgenauigkeit sowie Fehlinterpretationen neutraler Gesichtsausdrücke bei Personen mit PTBS. Auch wurde Elektromyographie aufgenommen, um Mimikry-Reaktionen zu untersuchen. Die Traumaanamnese, Dissoziation, Alexithymie und die Unterdrückung des Gesichtsausdrucks wurden mittels Fragebogen erhoben, um Faktoren zu analysieren, die mit Emotionserkennungsdefiziten in Zusammenhang stehen könnten. Personen mit PTBS zeigten Defizite in der Erkennung positiver und neutraler Gesichtsausdrücke und interpretierten neutrale Gesichtsausdrücke öfters als Ausdrücke von Wut oder Verachtung. Vergleiche der statistischen Modellanpassung (model fit) legen nahe, dass Kindheitsmissbrauch möglicherweise eine grössere Rolle spielt bei diesen Auffälligkeiten als die Diagnose einer PTBS. Auch gab es einen Zusammenhang zwischen wiederholter Traumatisierung, Dissoziation, Alexithymie und Emotionserkennungsdefiziten. Schliesslich erwies sich die Mimikry als intakt bei Personen mit PTBS. Falls diese Resultate in realen Situationen im Alltag repliziert werden können, sollte zukünftige Forschung untersuchen, ob ein Emotionserkennungstraining die Emotionserkennung bei Personen mit PTBS verbessern kann. Auch sollte es Gegenstand zukünftiger Forschung sein, ob Interaktionspartner ihre Beziehungsqualität mit Personen mit PTBS verbessern können, indem sie sich ihrer eigenen Mimikreaktionen bewusster sind.

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ABBREVIATIONS

ACE	Adverse Childhood Experience
ADFES	Amsterdam Dynamic Facial Expression Set
ADFES-BIV	Amsterdam Dynamic Facial Expression Set–Bath Intensity Variations
ANOVA	Analysis of Variance
BDI	Beck Depression Inventory
BPD	Borderline personality disorder
CAPS	Clinician-Administered PTSD Scale for DSM-5
CTQ	Child Trauma Questionnaire
df	Degrees of Freedom
DSM	Diagnostic and Statistical Manual of Mental Disorders
EMG	Electromyography
ER	Emotion recognition
ERQ	Emotion Regulation Questionnaire
exp(*b*)	Odds Ratio (multinomial logistic regression)
fMRI	Functional Magnetic Resonance Imaging
HC	Non-traumatized Healthy Controls
ICD	International Classification of Diseases
IQ	Intelligence Quotient
M	Mean
mass	Sum of significant *F*-values in a cluster (nonparametric cluster level statistics)
Mdn	Median
M.I.N.I.	Mini International Neuropsychiatric Interview
N	Sample size (total)
n	Sample size (subsample)
NOET	Number of Lifetime Experienced Traumatic Events
OR	Odds Ratio
p	Level of Significance
PTBS	Posttraumatische Belastungsstörung
PTSD	Posttraumatic Stress Disorder
PDS	Posttraumatic Diagnostic Scale
QICC	Corrected Quasi-Likelihood Information Criterion
QQ	Quantile-Quantile

r	Correlation Coefficient
RMET	Reading the Mind in the Eyes Task
RSDI	Responses to Script Driven Imagery Scale
RT	Reaction Time
SD	Standard Deviation
t	Test Statistic of t-Tests
TAS-20	Toronto Alexithymia Scale
TC	Traumatized Healthy Controls
U	Test Statistic of Mann-Whitney U-Tests
USZ	University Hospital of Zurich
Wald X^2	Test Statistic of the Wald test
WST	Wortschatztest (english: vocabulary test)
α	Cronbach's α; Index of Internal Consistency
β	Regression Coefficient
η_p^2	Partial Eta-squared; Measure of Effect Size
$\chi 2$	Test statistic of Chi-Squard Tests

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A. GENERAL INTRODUCTION

"The human face - in response and in movement, at the moment of death as in life, in silence and in speech, in actuality or as represented in art or recorded by a camera - is a commanding, complicated, and at times confusing source of information"

- P. Ekman and W. Friesen, 1972

Sometimes we might wish that other people were not able to read our emotional state from our face, maybe especially so when feeling embarrassed. However, life would be very complicated and even dangerous if we had to communicate all our feelings explicitly. Correct interpretation of emotional expressions is a basic human skill that is necessary for social relationships. This dissertation project adds to the current scientific knowledge in posttraumatic stress disorder (PTSD) and fills research gaps by analyzing emotion recognition, misattributions of neutral facial expressions, and facial mimicry in individuals with PTSD.

The first part of the introductory chapter A provides a definition for the term “emotion” and gives an overview about historical and current emotion theories. Thereafter, the field of emotion recognition is illustrated by emphasizing its relevance, outlining its development through infancy, and summarizing theories that explain the process of emotion recognition. Further, different methods on how to assess emotion recognition are described and its advantages and disadvantages are discussed. Then, current research on recognition of emotional and neutral facial expressions in healthy and clinical populations is summarized. In addition, the concept of alexithymia and its association with emotion recognition is outlined. The second part of Chapter A introduces PTSD, outlining its symptoms, etiological theories and epidemiological findings. Further, different types of traumatization and its consequences are summarized, in particular the consequences of child maltreatment and cumulative traumatic events. Thereafter, “dissociation” - often associated with PTSD - is defined and its consequences are outlined. Finally, the current scientific knowledge on PTSD and emotion recognition, facial mimicry, and emotion regulation (in particular expressive suppression) is summarized. Part three of Chapter A discusses limitations of previous studies on emotion recognition in PTSD.

The empirical study part B entails three empirical studies and begins with an overview of the research questions and the general methods. The first study analyzed the recognition of positive and negative facial expressions in individuals with PTSD and its relation to child maltreatment, cumulative traumatic events, and dissociation. In the second study, we looked at

the recognition of neutral facial expressions and misattribution patterns in individuals with PTSD and/or child maltreatment. The third study explored automatic facial responses to observed facial emotion (facial mimicry). In addition, study three analyzed alexithymia and expressive suppression as possible contributing factors to emotion recognition deficits in PTSD.

Part C (general discussion) summarizes and reflects on the main findings, embedding them into the current body of literature. It is discussed how individuals with PTSD and interaction partners might benefit from our findings and suggestions for future research are provided. In addition, strengths and limitations of our studies are outlined. Finally, part C ends with a general conclusion.

1. Psychology of Emotions

1.1. Definitions

It is surprising that despite thousands of psychological studies in the field of emotion no exact definition exists. Scientists agree that emotions are comprised of multiple aspects and different components (e.g. neurobiological and behavioural activation, subjective experience/feeling, cognitive processes) (Izard, 2010). However, there is not much agreement about the different aspects that should be included in the definition (Izard, 2010). Depending on the theoretical background, authors tend to emphasize the aspects which they are most interested in (e.g. physiological, cognitive, neurobiological, evolutionary) (Carlson & Hatfield, 1992).

Because of the ambiguity of the term "emotion", it is necessary to provide a working definition that is broad enough to include the most important aspects without making theoretical assumptions. Meyer, Schützwohl, and Reisenzein (1993) give a working definition of emotion as different states (in contrast to traits or dispositions) that are characterized by their specific quality (type of emotion) and intensity, which normally come together with a characteristic subjective experience and often with physiological changes (e.g. in heart rate, respiration, and/or body temperature, regulated by the autonomic and central nervous system) and with behavioural changes (facial expression, body posture, and gestures). These emotional states have a beginning and an end and are generally of short duration. Normally, emotions are related to an object. An object can be an external situation, a thought, or an appraisal. In addition, emotions can also arise following a change in hormones or neurotransmitters (Carlson & Hatfield, 1992).

1.2. Emotion theories[1]

1.2.1. Evolutionary approaches

Evolutionary theorists explain emotions in terms of their function for survival and reproduction: Emotions prepare readiness for action (e.g. fight or flight) or are a means of transmitting important information to others (Darwin, 1972/1998; Ekman, 1993). Charles Darwin (1809-1882) was the first who provided an evolutionary theory of emotion (Darwin, 1972/1998). He analyzed facial emotional expressions in animals and humans and found that they are very similar. He concluded that facial emotional expressions do not need to be learned; they have a biological basis and come together with autonomous nervous system activation.

[1] Although emotions cannot be seen separate from their corresponding brain processes, neuropsychological emotion theories are beyond the scope of this thesis. For an introduction and overview of neuronal structures that are involved in emotional processes see Schmidt-Atzert, Stemmler, and Peper, 2014, p. 185.

They are universal and prepare the individual for an action helpful for survival. For example, a dog that bares his teeth is prepared for an attack. One argument encouraging this view is that blind people who have never seen emotional expressions show very similar emotional facial expressions as sighted people (Galati, Scherer, & Ricci-Bitti, 1997; Matsumoto & Willingham, 2009). Furthermore, Peleg et al. (2006) found that congenitally blind people showed more similar facial emotional expressions compared to their sighted relatives than to non-relatives, supporting the genetic basis of emotional expressions.

Another evolutionary theorist of emotions is Paul Ekman. He focuses more on the communicative function of emotion and found evidence for the biological basis of certain emotions in cross-cultural studies, which he and his mentor Silvan Tomkins called basic emotions: Basic emotions are discrete (in contrast to complex and mixed) emotions that are expressed and recognized in all cultures around the globe. They developed because they helped with adapting to the environment, especially because of their communicative function (Ekman & Cordaro, 2011). For example, a fearful face indicates a potential threat. Basic emotions have distinctive facial expressions, which are proven for happiness, anger, sadness, disgust, fear, and surprise (however, there is no final agreement on the number of basic emotions; see Ekman, 1992; Ekman & Cordaro, 2011). People from very isolated cultures like Papua-New Guinea, who never had contact with Western cultures, were able to identify facial emotional expressions depicted by Western people (Ekman & Friesen, 1971). Furthermore, individuals from Papua-New Guinea showed the same facial emotional expressions as Westerners, and Americans were able to identify the emotions that they expressed (Ekman, 2007). However, how emotions are shown publicly is also shaped by cultural rules ("display rules"): Individuals learn from their culture in which situation and in which way it is appropriate to show a specific emotion (Ekman, 2007).

Scherer, Clark-Polner, and Mortillaro (2011) conducted a literature review and concluded that there is not enough evidence to draw firm conclusions about universality vs. culture-specificity of emotions. Methodologies of cross-cultural studies are often weak, mixing encoding (production of an emotional expression) and decoding (recognition) studies. There is less evidence for the cultural universality of emotional expression (although more similarities than dissimilarities) and more evidence for the universality of emotion recognition. However, there is an in-group advantage for emotion recognition, probably due to "cultural dialects" in emotion expression. Elfenbein and Ambady (2002) confirmed the universality of emotion recognition across cultures in their meta-analysis, acknowledging its biological basis. They also found an in-group advantage for emotion recognition, which they attributed to cultural learning,

cultural shaped expressive styles and different decoding strategies. Masuda et al. (2008) found different decoding strategies for Japanese and Western individuals in an eye-tracking experiment: Whereas Japanese individuals looked at and integrated the facial expressions of the surrounding people, Westerners only focused on the facial expression of the target person for making their judgment.

1.2.2. Behavioural approaches

Behaviourists like John Watson (1978-1958) and B.F. Skinner (1904-1990) both acknowledged the genetic basis of emotions but stated that most emotional behaviour was learnt (conditioned) (Skinner, 1953; Watson, 1919). According to Watson, there are three innate emotions: fear, love, and rage, characterized by a specific behaviour and elicited by a few stimuli. Based on these innate emotions, emotional reactions are learnt. For example, fear can be learnt by simultaneously presenting an aversive stimulus with a neutral stimulus (Watson & Rayner, 1920). The most famous example for this process is the infant Little Albert, who developed a fear of rats after they had been continuously presented with a very loud aversive sound. Albert even generalized his fear to other animals (and objects) with white hair. This emotional behaviour can also be unlearnt again (extinguished) if the neutral stimulus is presented alone for a longer period. Skinner stated that emotional behaviour will be repeated if it is (positively or negatively) reinforced by the environment.

Watson and Skinner contributed a great deal about how emotional behaviours are learnt, on which principles behavioural therapy is based. However, they focused on stimulus-response processes, neglecting the experiential, subjective aspect of emotions, and the cognitive processes that take place in-between stimulus and response (Schmidt-Atzert, Stemmler, & Peper, 2014).

1.2.3. Physiological approaches

Physiological theories of emotions emphasize the physiological arousal that is associated with emotions. Counterintuitive for the historical time and in contrast to what some cognitive theorists say, William James (1842-1910) argued that the physiological (visceral and behavioural) reaction comes first in the emotional process, and the perception of this arousal informs the person about the emotion (James, 1884). Carl Lange (1834-1900) developed a similar theory - emphasizing more the vascular reactions - and together the theory is called James-Lange theory. According to this theory, the first reaction to a situation is bodily arousal and/or a behavioural action, which then informs the individual about the emotion (see Figure 1). For example, we see a dangerous animal, run away and only later we realize that we feel fear. Although this might be true for instinctive reactions, this view was criticized by Walter

Cannon and Philip Brad who argued that the physiological reaction and the emotion are both independent reactions to a stimulus (Cannon-Brad theory). Cannon argued that visceral sensations are not sufficient to differentiate between different emotions. According to him, the origin of emotions lies within the brain, in the Thalamus, from where the subjective experience and bodily arousal are elicited (see Figure 2). Today researchers agree that both Lange and Cannon both added important information for understanding emotions (Carlson & Hatfield, 1992).

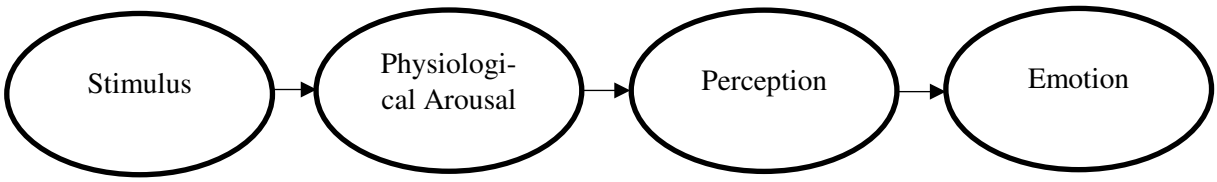

Figure 1. Illustration of the James-Lange theory.

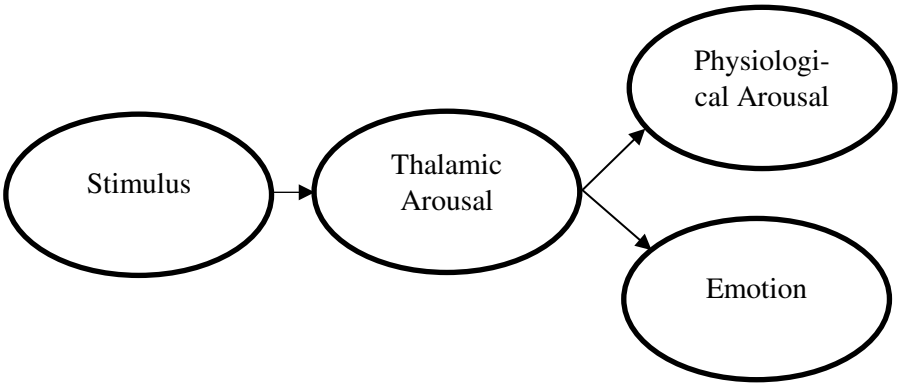

Figure 2. Illustration of the Cannon-Brad theory.

The facial feedback hypothesis – a special type of physiological emotion theory - states that the facial expressive behaviour influences the quality of the emotional experience. The explanation is similar to the one of James and Lange: Internal perception of the expressive behaviour informs the individual about the emotion (Laird, 1974). When individuals were instructed to tense and relax specific facial muscles, they reported being more happy when their expression was similar to a smile and more angry when their expression resembled a frown (Laird, 1974). According to Izard (1990), the feedback happens through a neurophysiological feedback-loop. Strack, Martin, and Stepper (1988) tested the facial feedback hypothesis by letting their participants hold a pen in their mouths that either facilitated or hindered a smile. Cartoons elicited more positive emotional responses when a smile was facilitated than when it was hindered. Soussignan (2002) improved the methodology of Strack et al. (1988) and found

an intensified emotional reaction when the facial emotional expression was congruent with the emotion-eliciting situation, for example watching pleasant scenes with a smiling expression. These intensified emotional reactions were associated with heightened autonomic arousal (increased heart rate and skin conductance). Today, there is evidence that the facial expressive behaviour alone is sufficient to produce an emotion (Flack, 2006; Kleinke, Peterson, & Rutledge, 1998).

1.2.4. Cognitive approaches

One of the most famous theories of emotion is the two-factor theory of emotion by Stanley Schachter (1922-1997) and Jerome E. Singer (1934-2010). Schachter agreed with Cannon that emotion-elucidated visceral activity is unspecific and therefore not sufficient to differentiate between different emotions. Even if there was emotion-specific visceral activation, the viscera does not have enough peripheral receptors (Schachter, 1964). In line with James, Schachter agreed that the perception of an emotion-eliciting stimulus follows physiological arousal, which is necessary to feel an emotion. However, on the basis of that arousal, the evaluation of the situation determines the emotion, depending on what emotion seems appropriate in this situation. The physiological arousal determines the intensity of the emotion whereas the cognition determines the quality (see Figure 3) (Schachter, 1964). In their famous experiments, Schachter and Singer found that manipulating the interpretation of physical arousal will result in different emotions (Schachter & Singer, 1962). However, attempts to replicate this finding failed (Marshall & Zimbardo, 1979). Furthermore, several authors found that there are not only quantitative differences in emotion elicited autonomic nervous system activation but also qualitative ones (for review see Kreibig, 2010).

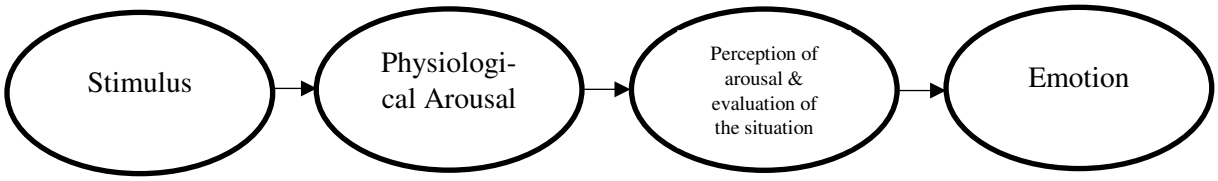

Figure 3. Theory of Schachter and Singer.

Arnold (1960) and Lazarus (1966) introduced appraisal theories of emotion, agreeing with Schachter and Singer that a stimulus does not automatically elicit an emotional reaction. Rather, it is the evaluation of the stimulus that determines the emotion. However, they stated that the evaluation of a situation comes first in the emotion-process and is a necessary condition

for an emotion. The evaluation of the subjective significance of a situation related to the own well-being (primary appraisal) and the possibilities of coping (secondary appraisal) lead to a specific emotion (including physiological arousal) (Lazarus, 1991). Appraisal theories explain individual differences in emotional reactions to the same situation and they acknowledge the complexity of emotions, which also depend on cognitive abilities. For example, surprise depends on the ability to perceive novelty, which is not yet possible for a newborn (Moors, Ellsworth, Scherer, & Frijda, 2013). Although it is widely accepted that appraisals play an important role in emotions, Lazarus theory has been criticized because it lacks empirical testing (Schmidt-Atzert et al., 2014, p. 146). Furthermore, there are cases when people experience emotions without a cognitive appraisal involved, for example, when in pain, in aversive physical or social conditions (Berkowitz & Harmon-Jones, 2004). In addition, correlations between appraisals and emotions sometimes are weak (Mauro, Sato, & Tucker, 1992).

Modern appraisal theories of emotions define emotions as a process with several components (e.g. appraisal of the situation, physiological activation, action tendencies, subjective experience, expressive behaviour) with the appraisal component as the key component for determining the quality and intensity of emotion (Moors et al., 2013). Among others, appraisal is related to personal goal relevance, coping potential, certainty and source of agency. For example, a person concludes that her neighbor is responsible for her sleep disturbances (goal incongruence) but unsure (certainty) if she/he is able to change the situation (coping potential) (Moors, 2013). An event is evaluated sequentially on these different levels, which leads to motivational changes, physiological activation and action tendencies (Scherer, 2009). All these components are represented in the central nervous system, and only parts of it become conscious. Through feedback processes, different components influence each other in a continuous and recursive process. Most modern appraisal theorists accept that there are situations in which appraisal is not necessary for eliciting an emotion (Moors et al., 2013).

However, emotion is not only a matter of appraisal. Emotions can be influenced and counteracted actively (Gross, 1998, 2015; Moors et al., 2013; Schmidt-Atzert et al., 2014). Individuals try to choose what emotion they want to experience, and they control their emotional, physiological, and behavioural reactions by using different emotion regulation strategies (Gross, 1998, 2015). Emotion regulation refers to the strategies - consciously or unconsciously – that individuals use to influence their emotions, for example selection and/or modification of the situation, modification of cognitions, modification of attentional processes, and response modulation (Gross, 1998). The future development of modern (appraisal) theories of emotions is to include emotion regulation as well (Moors et al., 2013).

1.3. Emotion recognition

The ability to infer emotional states of others from their emotional expressions is called emotion recognition. Emotional expressions include voice, gestures, body posture and facial expression. Most researchers focus on facial expression. Voice, gestures, and body posture are very seldomly investigated (Banse & Scherer, 1996; Scherer, 1986; Wallbott, 1998). In this thesis, I focus on facial expression as a means of emotional expression.

1.3.1. Facial expressions

Unlike in the experiments of Ekman (e.g. Ekman et al., 1987), in everyday life people have to infer emotions from subtle and dynamic facial expressions that normally last only for a short moment. An internal emotional state is externalized physically by different patterns of facial behaviour and these external cues have to be decoded by the perceiver (Scherer et al., 2011). That means different muscles around the eyes, mouth, and nose are activated, changing the visual appearance of the face. These cues are perceived and interpreted by the decoder, either automatically or as a conscious interpretation. Most facial activity occurs within a very short time (under 1sec) (Ellgring, 2000). Several coding systems have been developed to code these subtle changes in facial expression, the most famous one being the *Facial Action Coding System* (FACS, Ekman & Friesen, 1978). With FACS, 44 of these subtle changes in facial expression are coded in order to describe facial expressions as exhaustively as possible.

By inferring the emotion from the expression, it is assumed that the emotional expression reflects the inner state of the person. However, only few studies analyzed the correlation between facial expression and emotional state in real-life situations (Otto, Euler, & Mandl, 2000). Some studies report strong associations between facial emotional expression and subjective experience of emotion (Brown & Schwartz, 1980; Dimberg, 1988), whereas others only show weak correlations (Ekman, Freisen, & Ancoli, 1980; Reisenzein & Hofmann, 1990). A difficulty in analyzing facial emotional expressions in real-life situations is that much facial activity does not only reflect expressing an internal state, but also non-verbal communication, e.g. transmitting a social cue like a social smile or signalizing the intention to start a conversation by raising the eyebrow (Ellgring, 2000; Frith, 2009). What makes emotion recognition even more difficult is that individuals sometime actively change their (natural) emotional expression, mask it or hide it, and cultural rules determine when and how it is adequate to express emotions (Ekman, 2007).

1.3.2. Relevance of emotion recognition

According to the evolutionary view, the ability to read emotions from emotional expressions has served survival by being informed about others' intentions, possible threats and others' action readiness (see 1.2.1. Evolutionary approaches). However, the environment has changed considerably since the beginning of humankind. Nowadays, the direct function for survival might have stepped back in favour of its social and communicative function. The ability to recognize emotions is a condition for the success of social relationships and is a component of social competence (Halberstadt, Denham, & Dunsmore, 2001). Halberstadt et al. (2001) define affective social competence as the ability to identify, communicate, and regulate one's own emotions and to correctly interpret and respond to emotions of others. Without emotion recognition, it would not be possible to empathically respond to others. Individuals who have problems identifying emotions, for example individuals with autism spectrum disorders or alexithymia (see Chapter 1.3.7.), also lack social abilities (American Psychiatric Association, 2013; Kauhanen, Kaplan, Julkunen, Wilson, & Salonen, 1993). In undergraduate students, deficits in (non-verbal) emotion recognition were associated with poorer relationship wellbeing even after controlling for depression (Carton, Kessler, & Pape, 1999).

1.3.3. Development of facial emotion recognition abilities

The ability to detect emotions in facial expressions develops early in infancy (Walker-Andrews, 1997), significantly improves during preschool time, and is not fully developed until the age of ten (adult level) (Durand, Gallay, Seigneuric, Robichon, & Baudouin, 2007) and there is evidence for an improvement in emotion recognition abilities in youth until the age of 14 (Kolb, Wilson, & Taylor, 1992). In addition, emotion recognition abilities for different emotions have different trajectories, with happiness and sadness the earliest ones, reaching adult level at five to six years and, for example, disgust at the age of eleven (Boyatzis, Chazan, & Ting, 1993; Durand et al., 2007). Children under the age of nine years have problems recognizing neutral facial expressions. They have a tendency to perceive an emotion in neutral facial expressions (Durand et al., 2007). Some studies find gender differences already in preschool children (girls being superior to boys) (Boyatzis et al., 1993) whereas other studies find them later, at eight years (Juen, Huber, & Peham, 2012).

It is difficult to test to which part emotion recognition abilities depend on biological programming and to which part on learning by experience (Pollak & Sinha, 2002). Children have an innate ability to express and recognize basic emotions (Ekman, 1993) and they also learn about emotions and how to recognize them in their interactions with caregivers and significant others. Steele, Steele, and Croft (2008) found that children's attachment style at the

age of one year predicts emotion recognition abilities five and ten years later. They explain that facial affective exchange between mother and child is vital for both forming secure attachment and learning about emotions. Less facial affective exchange might be a reason why abused and neglected children have a restricted internal lexicon of emotions (Steele et al., 2008). Calvo, Gutiérrez-García, Fernández-Martín, and Nummenmaa (2014) argue that the more often specific facial emotional expressions are encountered, the more easily accessible cognitive representations of these expressions become (Calvo et al., 2014). Boyatzis et al. (1993) suggest that children normally are better at detecting positive than negative emotions because they are exposed more to positive (compared to negative) emotions in interactions with their environment. Research on children who grew up in abusive and maltreating environments suggests that learning experiences shape their emotion recognition abilities: There is some evidence that maltreated children are better at recognizing anger and show an attention response bias for anger, probably an adaptive development in an abusive environment, but with long-term negative consequences (Pollak & Sinha, 2002).

1.3.4. Process of emotion recognition

Different brain structures are involved in emotion recognition (e.g. occipitotemporal neocortex, amygdala, orbitofrontal cortex and right frontoparietal cortices) (Adolphs, 2002; Fusar-Poli et al., 2009; Jehna et al., 2011) which will not be expanded on in this thesis (see Fusar-Poli et al., 2009 for meta-analysis and detailed neurofunctional maps).

There are different theories that explain the process of emotion recognition:

1.3.4.1. Processing of perceptual information

In order to correctly recognize an emotion from a facial expression, it is necessary to detect and discriminate the distinctive features in the dynamically moving facial expression, combine them into a gestalt, and infer a particular emotion (Maurer, Le Grand, & Mondloch, 2002; Walker-Andrews, 1997). This recognition process depends on internal knowledge ("recognition memory") about emotional expressions: Concepts that entail knowledge about distinct emotions and their expressions (Adolphs, 2002). Pollak and Sinha (2002) suggest that visual features of the face are compared with internal representation of emotional expressions, which have a biological basis and are shaped by experience. Hypotheses about the underlying emotion are made very early in this process, before the peak of the emotional expression. Calvo and Nummenmaa (2016) differentiate between a perceptual and an affective processing of the visual input of the facial expression. The perceptual processing refers to detecting and analyzing morphological changes of the facial expression, which leads to categorical recognition of emotions (see also categorical view of emotions, Ekman, 1992;

Ekman & Cordaro, 2011; Izard, 1994; Levenson, 2011; Panksepp & Watt, 2011). Affective processing refers to extracting the core affect of the facial expression, which is constructed upon valence and arousal evaluations (see also dimensional view of emotions, J. A. Russell, 1994). There is evidence from priming studies that affective processing happens automatically, involuntarily, and earlier than categorical processing (for review see Calvo & Nummenmaa, 2016). However, affective processing has no substantial impact on emotion recognition accuracy, which seems to rely more on perceptual analysis of the visual input. In line with that, Adolphs (2002) concludes in his review that processing of visual features is sufficient to detect emotion categories. According to Calvo and Nummenmaa (2016), this process is genetically prepared and also influenced by learning. The more often we see an emotional expression, the more detailed and easily accessible are inner representations of this emotional expression. This could also explain the in-group advantages in cross-cultural emotion recognition studies. In line with this, Calvo et al. (2014) found a strong correlation between emotion recognition accuracy and the frequency with which these emotions were encountered in daily life.

1.3.4.2. Simulation theory and facial mimicry

Sometimes categorization of visual features of facial processing and matching it with internal knowledge might not be possible, perhaps because the internal knowledge ("recognition memory") is incomplete. There is empirical support for another mechanism helpful for emotion recognition: Simulating the state of the other person and then inferring the emotion of the other person (Goldman & Sripada, 2005). Automatic facial mimicry seems to play a role in this simulation process: Facial mimicry is the tendency to spontaneously and unconsciously imitate the other person's facial expression (for review see Hess & Fischer, 2014). Sometimes facial mimicry is very subtle and not visible by eye but measurable by electromyography (EMG): Activity in the muscle *zygomaticus major* increases in response to positive facial expressions (smiling), and in response to negative emotional expressions *currogator supercilii* activity increases (frowning). This reaction is visible 200ms after stimulus onset for *currogator* and after 500ms for *zygomaticus* (Achaibou, Pourtois, Schwartz, & Vuilleumier, 2008) and is difficult to voluntarily counteract (Dimberg, Thunberg, & Grunedal, 2002). Originally, mimicry was interpreted as a matched motor response: Seeing a non-verbal (facial) behaviour automatically elicits the same expression in the perceiver (matched motor hypothesis) (Hess & Fischer, 2014). However, Hess and Fischer (2014) argue that facial mimicry should not be seen as a mechanistic response to perceiving a facial expression, but rather as a more complex reaction with a social function: Mimicry is dependent on affiliation

goals and the social context. A person is more likely to mimic someone that they like. Mimicry itself increases liking, prosociality, and empathy (Duffy & Chartrand, 2015).

The occurrence of facial mimicry is explained by overlapping brain areas for production and perception of an action: The mere watching of an action (in this case the facial expression of another person) increases the likelihood of performing that action (Hess & Fischer, 2014). This is in line with research about mirror neurons, located in the premotor cortex and bordering areas, which not only fire while performing an action but also while watching it (Fadiga, Fogassi, Pavesi, & Rizzolatti, 1995; Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Iacoboni et al., 2001). The facial expression itself then generates an emotional state with physiological changes within the subject (see 1.2.3. Physiological approaches, facial feedback hypothesis), which provides information about the emotional state of the other person (Laird, 1974).

There is evidence that mimicry facilitates emotion recognition: Hindering someone from facial mimicking, e.g. biting on a pen or wearing a mouthguard, disturbs emotion recognition (Oberman, Winkielman, & Ramachandran, 2007; Ponari, Conson, D'amico, Grossi, & Trojano, 2012; Rychlowska et al., 2014; Wingenbach, Brosnan, Pfaltz, Plichta, & Ashwin, 2018). However, some studies failed to find an association between facial mimicry and emotion recognition (Hess & Blairy, 2001; Kosonogov, Titova, & Vorobyeva, 2015; Rives Bogart & Matsumoto, 2010; Zwick & Wolkenstein, 2017). For example, individuals with Moebius syndrome – an inherent syndrome characterized by paralysis of facial muscles, which makes mimicry impossible – did not perform worse in emotion recognition tasks than matched controls (Rives Bogart & Matsumoto, 2010). Furthermore, Gallese and Caruana (2016) criticize the postulated serial processing in the emotion recognition process (first imitation of the facial expression, subsequent internal feedback from motorneurons, then activation of neurons in the brain that are associated with emotional experience) and suggest a more direct link of perceiving an emotional expression and generating an internal simulation. Similarly, Adolphs, Damasio, Tranel, Cooper, and Damasio (2000) propose a direct link from perceiving an emotional expression to generating a somatosensory image, without the need for facial mimicry. However, facial mimicry might be important for the recognition of complex and subtle emotions (Niedenthal, Mermillod, Maringer, & Hess, 2010).

1.3.4.3. Contextual factors

In addition to the information extracted from the face, individuals also use contextual information to interpret the emotional facial expression of a person. Indeed, contextual information can overwrite information from the facial expression. For example, students interpreted an emotion as fear when the circumstances were described as frightening

even though the person was displaying an angry facial expression (Carroll & Russell, 1996). It seems that the context automatically influences the interpretation of the facial expression: Aviezer, Bentin, Dudarev, and Hassin (2011) instructed participants to use only information from the facial expression in pictures and ignore the context. Participants performed much worse when the context did not match the facial expression of the person. However, in research, emotional expressions are often separate from their context (Otto et al., 2000, p. 112).

1.3.5. Assessment of emotion recognition

The most common way to assess emotion recognition is by showing participants standardized pictures of facial emotional expressions, for example the widely used set of pictures ("Pictures of Facial Affect") developed by Ekman and Friesen (1976). In Ekman's emotion recognition studies, participants saw pictures of high intensity emotional expressions for several seconds and had to indicate if it was anger, fear, disgust, sadness, enjoyment, contempt, or surprise (e.g. Ekman et al., 1987). Hit-rates were very high and similar across cultures (between 74% and 90%). However, their studies have been criticized because they showed prototypical expressions of emotions lasting for several seconds, which is not typical for emotional expressions in everyday life (J. A. Russell & Bullock, 1986). Until today, many standardized sets of pictures have been developed, showing emotional facial expressions of different intensities (Beaupré & Hess, 2005; Biehl et al., 1997; Goeleven, De Raedt, Leyman, & Verschuere, 2008; Tracy, Robins, & Schriber, 2009).

Because emotional expressions are moving and dynamic in their nature, static pictures lack ecological validity and results are not generalizable to natural situations (Tcherkassof, Bollon, Dubois, Pansu, & Adam, 2007; Wehrle, Kaiser, Schmidt, & Scherer, 2000). More recently, standardized filmed sequences of dynamically moving facial expressions have been developed, showing emotional facial expressions of different intensities (Krumhuber, Skora, Küster, & Fou, 2017; Scherer et al., 2011; Wingenbach, Ashwin, & Brosnan, 2016). However, displays of dynamically moving stimuli still lack ecological validity because the facial expression is separated from its context. Only few studies used spontaneous emotional expressions and hit-rates were much smaller than with posed expressions (Elfenbein & Ambady, 2002; Naab & Russell, 2007). The problems with spontaneous expression are big interindividual differences in facial expressivity, lack of standardization, and lack of differentiation between production and interpretation of emotional facial expressions (Scherer et al., 2011).

Most emotion recognition studies used accuracy and sometimes reaction times as outcome measures (Scherer et al., 2011). To better understand mechanisms underlying emotion

recognition, confusion patterns should also be analyzed (Scherer et al., 2011; Wingenbach et al., 2016) . Confusing an emotional expression with a neutral expression provides insight into recognition *sensitivity*, whereas confusing two different emotional expressions provides insight into recognition *specificity* (Wingenbach, Ashwin, & Brosnan, 2017).

A problem in many emotion recognition studies concerns the forced-choice paradigm: In case participants are unsure about an emotion, they are tempted to guess (J. A. Russell, 1994). Some studies used an open format (for example Wagner & Linehan, 1999), which however impacts standardization and makes statistical analysis more complex.

A big limitation of all the above mentioned methodologies is that they depend highly on verbal abilities. In everyday life, we normally do not label emotions verbally and it is not clear today if a lack in verbally assessed emotion recognition ability impacts social relationships. Therefore, verbal methods should be combined with non-verbal emotion recognition methods like, for example, matching an emotional prosody with a facial expression (Pell, 2005; Wilhelm, Hildebrandt, Manske, Schacht, & Sommer, 2014).

Because there is no state-of the art assessment of emotion recognition, different methods should be combined (Scherer et al., 2011).

1.3.5.1. Reading the Mind in the Eyes Task

The Reading the Mind in the Eyes Task (RMET; Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997; Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001) assesses the theory of mind. The theory of mind refers to the ability to impute mental states to others, for example beliefs, intentions, hopes, expectations, and thoughts (Leslie, 2001; Premack & Woodruff, 1978). In the RMET, participants have to infer complex mental states (e.g. guilt, thoughtful, admiring) from black and white pictures depicting the eye area (Baron-Cohen et al., 2001). The theory of mind seems to involve more higher-order cognitive processes and, although related, should not be confused with emotion recognition (Lee et al., 2014).

1.3.6. Recognition of facial expressions in healthy individuals

Depending on the methodology and on the emotions that are shown to participants, recognition rates vary greatly. For example, Ekman et al. (1987) found general recognition rates of 88% for photographs of high intensity facial expressions (only basic emotions) whereas Wingenbach et al. (2016) found a general hit rate of 69% for videotaped dynamic facial expressions (basic plus three complex emotions) averaged on three intensities of expression. In general, women perform better in emotion recognition tasks than men (Kret & De Gelder, 2012). Happiness is most easily detected, followed by surprise, sadness, anger, disgust, and fear (Calvo et al., 2014). Basic emotions are more easily identified than complex or social emotions

(combination of basic emotions and cognitions or moral standards like jealousy, embarassement or guilt; Keltner & Haidt, 1999; Van Der Schalk, Hawk, Fischer, & Doosje, 2011). Dynamic facial expressions lead to better recognition rates than static pictures because they provide more information about the time course of the facial movements (Krumhuber et al., 2017; Wehrle et al., 2000). Emotional expressions depicted at low intensity lead to lower recognition rates than high intensity expressions (Wingenbach et al., 2016). Response time for emotion recognition is proportional to accuracy: Happiness has the shortest and fear the longest response time within the basic emotions (Calvo et al., 2014). Confusion patterns between different emotions are similar across cultures, with more confusions between negative emotions or between mixed emotions (Bänziger, Mortillaro, & Scherer, 2012; Elfenbein, Beaupré, Lévesque, & Hess, 2007; Scherer et al., 2011).

1.3.7. Recognition of facial expressions and alexithymia

The psychological construct of alexithymia was introduced by Nemiah (1976), which comprises the difficulty in describing, identifying, and differentiating feelings, a poor imaginary life, and an externally orientated cognitive style (Sifneos, 1973). It reflects a deficit in processing and regulating emotions (Taylor, 2000). Because the formulation is very close to emotion recognition, not surprisingly alexithymia has been found to be associated with emotion recognition deficits in healthy (Grynberg et al., 2012; Ihme et al., 2014) and in clinical populations, for example Asperger syndrome, somatoform disorders, and eating disorders (Grynberg et al., 2012). The prevalence of alexithymia is higher in somatoform disorders (Waller & Scheidt, 2004), autism spectrum disorders (Poquérusse, Pastore, Dellantonio, & Esposito, 2018), alcohol use disorders (Thorberg, Young, Sullivan, & Lyvers, 2009), eating disorders (O'Driscoll, Laing, & Mason, 2014), depression, anxiety disorders (Marchesi, Brusamonti, & Maggini, 2000), and PTSD (meta-analysis: Frewen, Dozois, Neufeld, & Lanius, 2008) compared to the normal population. Alexithymic individuals suffer from interpersonal problems, avoidant social behaviour, and poor social functioning (Spitzer, Siebel-Jürges, Barnow, Grabe, & Freyberger, 2005; Vanheule, Desmet, Meganck, & Bogaerts, 2007). There is evidence that psychotherapy might reduce alexithymic features (Beresnevaite, 2000; Taylor, 2000).

1.3.8. Recognition of facial expressions in clinical populations

Emotion recognition impairments are found in various clinical populations: Individuals with severe mental disorders like schizophrenia and autism spectrum disorders show a general impairment in emotion recognition (Kohler, Walker, Martin, Healey, & Moberg, 2009; Lozier, Vanmeter, & Marsh, 2014). Furthermore, individuals with major depression, bipolar disorders,

and substance use-disorders perform worse than healthy controls in emotion recognition (Castellano et al., 2015; Kohler, Hoffman, Eastman, Healey, & Moberg, 2011). In addition, individuals with personality disorders like schizotypal and psychopathic show a general emotion recognition deficit whereas individuals with borderline personality disorder have difficulties identifying angry, disgusted, and neutral facial expressions (Daros, Zakzanis, & Ruocco, 2013; Dawel, O'kearney, McKone, & Palermo, 2012; Dickey et al., 2011). There is only one study that analyzed emotion recognition in individuals with PTSD and found deficits in the recognition of negative emotions (fear and sadness) (Poljac, Montagne, & de Haan, 2011) (see Chapter 2.6.1.).

1.3.9. Recognition of neutral facial expressions

Neutral facial expressions are highly ambivalent and difficult to interpret because they lack information about the other person's internal state, motives and intentions. As evidenced from the still face paradigm, when a mother suddenly stops her facial expressions and shows a still face, this is highly threatening for infants younger than one year and leads to physiological stress reactions (Mesman, van IJzendoorn, & Bakermans-Kranenburg, 2009; Tronick, Als, Adamson, Wise, & Brazelton, 1978). Young children tend to interpret neutral facial expressions as sad or happy facial expressions; the ability to correctly identify neutral facial expressions seems to be developed quite late at the age of nine (Durand et al., 2007). Not only for infants, but also for adults, neutral facial expressions sometimes are difficult to recognize and can even be frightening. Some clinical populations have problems identifying neutral facial expressions, for example individuals with autism spectrum disorders (Eack, Mazefsky, & Minshew, 2015), depression (Bourke, Douglas, & Porter, 2010), schizophrenia (Kohler et al., 2003), and borderline personality disorder (BPD) (Daros et al., 2013; Mitchell, Dickens, & Picchioni, 2014). Individuals with major depression interpret neutral facial expressions as expressions of sadness (Bourke et al., 2010) whereas schizophrenic patients over attribute disgust to neutral facial expressions (Kohler et al., 2003). Individuals with BPD and dissociative identity disorder perceive neutral facial expressions as threatening (Donegan et al., 2003; Schlumpf et al., 2013). In individuals with borderline personality disorder, research consistently shows a negative interpretation bias, wrongly attributing anger (Daros et al., 2013; Mitchell et al., 2014) to neutral expressions. Processing of neutral facial expressions seems to have a different neural correlate than processing of emotional facial expressions (see Fusar-Poli et al., 2009; Jehna et al., 2011).

2. Posttraumatic Stress Disorder

2.1. Symptoms

PTSD is characterized by intrusion, avoidance, negative alterations in cognition and mood, and alterations in arousal and reactivity after the exposure of traumatic events (American Psychiatric Association, 2013). More specifically, individuals with PTSD suffer from involuntarily re-experiencing the traumatic event in intrusive memories, dreams and/or flashbacks (vivid re-experiencing as if the event was occurring again) and experience psychological distress or physiological reactions when confronted with reminders of the trauma. They try to avoid thoughts or memories of the trauma and/or external reminders and show alterations in cognition and mood, for example negative beliefs about oneself or the world ("I am a bad person", "The world is a dangerous place"). Furthermore, they often blame themselves for the trauma and/or its consequences, show a persistent negative emotional state (e.g. guilt, shame or fear), and/or emotional numbing (feelings of detachment from others, loss of interest, inability to experience positive emotions). In addition, individuals with PTSD suffer from heightened arousal and reactivity, for example impulse control deficits (angry outbursts, irritability), concentration and sleeping problems. The symptoms last longer than one month and lead to significant distress or impairment in important areas of functioning (American Psychiatric Association, 2013).

2.2. Etiology

The development of PTSD is explained by an interplay of individual pretraumatic risk and protective factors, determinants of the traumatic event (severity, controllability), and maintaining factors like avoidance and alterations in cognitions (see Figure 4) (Maercker, 2013). Risk factors for the development of PTSD are childhood adversity and abuse, trauma occurring at a younger age, previous traumatisation and psychiatric history, lower intelligence, education or socioeconomic status, and female gender (although this last factor was not consistent in all studies) (for meta-analyses see Brewin, Andrews, & Valentine, 2000; Ozer, Best, Lipsey, & Weiss, 2003). In addition, there is evidence from twin studies for a genetic vulnerability to PTSD (M. B. Stein, Jang, Taylor, Vernon, & Livesley, 2002). However, associations between risk factors and PTSD are much smaller than with trauma severity (duration, and degree of damage and loss), peritraumatic responses, and maintaining factors (Maercker, 2013; Ozer et al., 2003). Strong emotional and cognitive reactions like shame, guilt, fear, helplessness, mental defeat, and perceived uncontrollability are related to higher posttraumatic symptoms (Ehlers, Maercker, & Boos, 2000; Ozer et al., 2003). Further, difficulties in emotion regulation seem to play a major role in developing posttraumatic

symptoms (Bardeen, 2013). The strongest predictor of later PTSD turned out to be peritraumatic dissociation (see Chapter 2.5.) (Ozer et al., 2003), the strongest protective factor is social support, and one of the strongest maintaining factors for PTSD is ongoing life stress (interpersonal/relationship problems, incapacity for work, financial and medical damage) (Brewin et al., 2000; King, King, Foy, Keane, & Fairbank, 1999).

In cognitive models of PTSD, cognitive distortions and negative alterations in cognitions are believed to be a central etiological and maintaining factor. Individuals with PTSD process the trauma in a distorted way that results in a constant feeling of current threat due to insufficient elaboration of the traumatic events (Ehlers & Clark, 2000). In addition, avoidance is a key maintaining factor, preventing an elaboration of the trauma in the autobiographical memory, which is addressed in evidence-based treatments (Pineles et al., 2011; Schnyder et al., 2015).

The fear network model explains intrusions, flashbacks and the ongoing feeling of threat as a function of memory processes (Elbert & Schauer, 2002; Foa & Kozak, 1986): The strong emotions during the traumatic event enhance establishing a memory network of sensory and perceptual information of the traumatic event including emotional, physiological and cognitive responses. These elements are highly interconnected and insufficiently related to contextual information. The network can easily be activated by any reminder, which leads to strong reactions and memories with a ”here and now“ quality (Kolassa, Illek, Wilker, Karabatsiakis, & Elbert, 2015). Aligning with the fear network model, PTSD is characterized by alterations in the biological stress response and in neuroanatomical functioning, in particular chronic activation, sensitisation and hyperreactivity of the hypothalamic–pituitary–adrenal axis, reduced diurnal cortisol levels (De Kloet et al., 2006; Yehuda, 2001) and hyperresponsitivity of the amygdala (for review and meta-analysis see Liberzon & Sripada, 2007; Patel, Spreng, Shin, & Girard, 2012). In line with this, there is strong evidence for structural brain changes associated with traumatic stress in brain areas that are involved in emotion processing (including emotion recognition) and regulation, namely in the frontal cortex, occipital cortex and limbic system (e.g. hippocampus, amygdala, anterior cingulate cortex) (for meta-analyses and reviews see Karl et al., 2006; Li et al., 2014; O'Doherty, Chitty, Saddiqui, Bennett, & Lagopoulos, 2015).

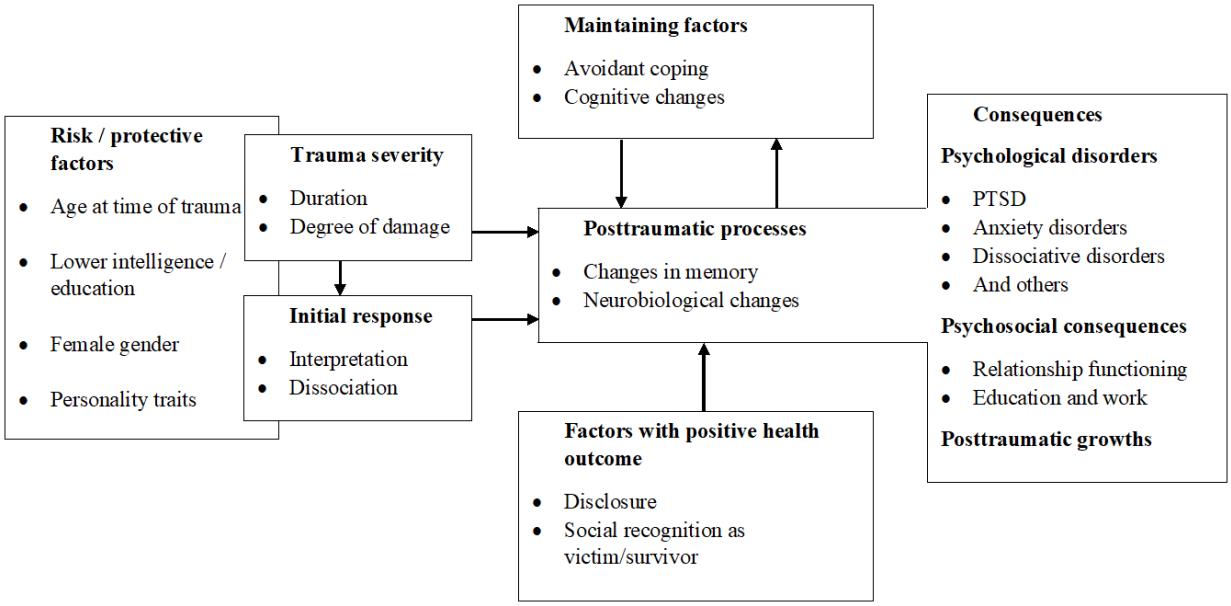

Figure 4. Etiological model of the consequences of trauma. Adapted from Maercker (2013, p. 37).

2.3. Epidemiology and comorbidity

Because the prevalence of PTSD depends on the frequency rates of traumatic events like natural disasters, political violence, war or torture, prevalence differs in different world regions depending on environmental and political conditions (Maercker, 2013). A recent nationwide epidemiological study in Germany found a one-month's prevalence of PTSD of 1.5% in individuals aged 14-99 (Maercker, Hecker, Augsburger, & Kliem, 2018). There were no gender differences in prevalence. They used the ICD-11 criteria for PTSD (World Health Organization, 2017), which differs slightly from the DSM-V version, having fewer criteria. In Switzerland, month prevalence for sub-threshold PTSD was estimated 1.9% from a representative cohort survey (none of the participants met full PTSD criteria) (Hepp et al., 2006). An international representative community survey in six European countries also found relatively low prevalence rates: Lifetime prevalence of 1.9% and one-month prevalence of 0.9% for PTSD (Alonso et al., 2004). US nationwide epidemiological studies found one-year prevalence for PTSD of 3.5%, life-time prevalence of 7.8%, with higher prevalence for women than men (Kessler, Chiu, Demler, & Walters, 2005; Kessler, Sonnega, Bromet, Hughes, & Nelson, 1995). An Australian representative study found one-month prevalence of 1.3% and no gender differences (Creamer, Burgess, & McFarlane, 2001). In conflict-affected populations and refugees, rates for current PTSD are as high as 30.6% (for meta-analysis see Steel et al., 2009).

PTSD seldomly comes alone: Comorbidity is high for anxiety disorders, mood disorders, obsessive-compulsive disorder, alcohol abuse and dependency, and attention-deficit/hyperactivity disorder (Kessler et al., 2005). A representative study of US adults with

PTSD found life-time comorbidities of 35.2% for major depressive disorder, 59.0% for any anxiety disorder, 41.8% for alcohol abuse/dependency, and 13.9% for suicide attempts (Pietrzak, Goldstein, Southwick, & Grant, 2011). PTSD is also associated with physical health problems like cardiovascular, respiratory, and gastrointestinal diseases, diabetes, chronic fatigue, chronic pain, and cancer (Sareen et al., 2007) and with increased mortality (Schlenger et al., 2015). Furthermore, PTSD is associated with lower cortisol levels, altered inflammatory processes, and autoimmune diseases like, for example, rheumatoid arthritis (e.g. Boscarino, 2004).

2.4. Different kinds of traumatisation and its consequences

Trauma is defined as "exposure to actual or threatened death, serious injury, or sexual violence" either directly experiencing, witnessing or learning that the event happened to a family member or close friend; or repeated exposure to details of the event (for example work-related in police officers) (American Psychiatric Association, 2013). Trauma is often divided into three categories: 1) Man-made or accidental 2) sudden or long-lasting / repeated (type I vs. type II trauma; (Terr, 1991); and 3) medically induced trauma (e.g. critical illness) (Maercker, 2013; Parker et al., 2015).

An international survey conducted in 24 countries (low-, middle-, and high-income countries) on six continents found that 70.4% of all respondents experienced at least one traumatic event (Benjet et al., 2016). The five most common traumatic events were the unexpected death of a loved one, witnessing death or serious injury, being in a life-threatening car accident, experiencing a life-threatening illness or injury, and being mugged; the least common traumatic event was collective violence. Most individuals experienced more than one traumatic event (mean number was 3.2) and the exposure to a traumatic event increased the risk for subsequent traumatic events, with the highest risk after interpersonal violence. Women were more at risk for intimate partner violence, sexual violence, or unexpected death of a loved one, whereas men were more at risk for other forms of interpersonal violence, collective violence, bodily harm, injuries, and accidents.

Generally, trauma that are caused deliberately by humans or that are long-lasting have more severe and more chronic outcomes for mental health (Benjet et al., 2016). Rape, kidnapping, sexual violence, childhood abuse, and combat exposure are strongly associated with PTSD (Brewin et al., 2000; Kessler et al., 1995; Maercker et al., 2018). Although most individuals do not develop PTSD after trauma exposure, there is evidence for long-term neuronal changes after trauma exposure even in healthy individuals (meta-analysis see Stark et al., 2015).

2.4.1. Childhood maltreatment

Childhood maltreatment is defined by the World Health Organisation as sexual, physical, mental abuse and/or neglect (failure to meet a child's emotional, physical, medical, or educational needs) before the age of 18 years (Leeb, Paulozzi, Melanson, Simon, & Arias, 2008; Sethi et al., 2013). The prevalence of childhood maltreatment is high in all countries and cultures, with higher prevalence of fatal childhood maltreatment in low- and middle-income countries. In Europe, the prevalence for sexual abuse is 13.4% for girls and 5.7% for boys, 22.9% for physical abuse (both sexes), 29.1% for emotional abuse, and between 16.3% and 18.4% for neglect (fewer studies investigated neglect). Often, childhood maltreatment is a repeated and chronic condition (Sethi et al., 2013).

For healthy mental, social, physical, and emotional development, a child needs safety and loving care by its caregivers (Hein & Monk, 2017). If the children's needs are neglected or the child is physically, sexually, or emotionally harmed, the consequences are severe. Childhood maltreatment belongs to the most detrimental aversive experiences: It has long-lasting and fatal effects for brain, cognitive, mental, behavioural, social, and neurobiological development that continue into adulthood. More specifically, child maltreatment is associated with increased risk for behaviour problems, depression, PTSD, anxiety disorders, eating disorders, attempted suicides, alcohol or drug abuse, criminal behaviour, risky sexual behaviour, relationship difficulties, obesity, and premature death (Brietzke et al., 2012; Carr, Martins, Stingel, Lemgruber, & Juruena, 2013; Colman & Widom, 2004; DiLillo, Lewis, & Loreto-Colgan, 2007; Gilbert et al., 2009; Reyome, 2010; Sethi et al., 2013). There is recent evidence that child maltreatment leads to neurocognitive alterations even in healthy children that are associated with increased threat processing (correlated with heightened amygdala reactivity), altered reward processing, functional changes in brain regions associated with emotion regulation (e.g. ventral anterior cingulate cortex, amygdala, and lateral frontal regions), and some evidence for alterations in functional brain processes associated with executive control (McCrory, Gerin, & Viding, 2017; Teicher, Samson, Anderson, & Ohashi, 2016). On the one hand, these alterations probably reflect partly functional adaptations to an abusive environment, on the other hand have long-term negative consequences and reflect latent vulnerability for mental disorders (McCrory et al., 2017).

2.4.2. Cumulative traumatic events

PTSD is more commonly associated with multiple than with just one traumatic event and the risk for PTSD is higher after multiple traumatic events (Bromet, Sonnega, & Kessler, 1998; Darves-Bornoz et al., 2008; Kolassa et al., 2010; Nelson et al., 2011; Neuner et al., 2004).

Conjoint analyses over 20 surveys in low-, middle- and high-income countries showed that the majority of individuals with PTSD reported having experienced four or more traumatic events (Karam et al., 2014). Furthermore, PTSD prevalence is much higher in regions with greater traumatic exposure (Kessler et al., 1995; Neuner et al., 2004) and there is evidence for a dose-response relationship between the number of traumatic events and PTSD (Kolassa et al., 2010; Kolassa et al., 2015; Neuner et al., 2004). A study conducted in the West Nile region found that after having experienced 28 or more different traumatic events, everyone suffered from PTSD, which indicates a trauma threshold for developing PTSD (Neuner et al., 2004).

Furthermore, individuals with PTSD who experienced a higher number of traumatic events are more severely impaired than PTSD individuals with fewer traumatic events (Karam et al., 2014; Kolassa et al., 2010). For some functional impairments in individuals with PTSD (e.g. work and close relationship functions), the number of traumatic events explains more than the trauma type or comorbid disorders. In addition, individuals with cumulative traumatic events have an earlier onset of PTSD, longer duration, more severe symptoms, higher comorbidity with other mental disorders, and less spontaneous remission (Karam et al., 2014; Kolassa et al., 2010). Additionally, there is evidence that cumulative traumatic events are associated with medical problems that are independent of PTSD (Cloitre, Cohen, Edelman, & Han, 2001; Sledjeski, Speisman, & Dierker, 2008). For instance, a representative study in the US found that the correlation of PTSD with chronic medical conditions (e.g. cardiovascular disease, chronic pain, allergies) was not longer significant after controlling for number of lifetime traumatic events (Sledjeski et al., 2008). However, some studies failed to find an association between traumatic exposure and health issues independent of PTSD (Vedantham et al., 2001). More evidence for the cumulative impact of traumatic stress on mental and physical conditions derives from the famous Adverse Childhood Experience (ACE) Study and its replications (Dong, Dube, Felitti, Giles, & Anda, 2003; Dong et al., 2004; Felitti et al., 1998). The number of ACE's (e.g. child maltreatment, witnessing violence against the mother, living with a mentally ill household member) correlated with psychological disorders in adulthood and a broad range of physical diseases (e.g. auto-immune, ischemic heart, liver, and lung diseases). Explanations for the cumulative impact of traumatic exposure on physical and mental health are the repetitive activation and dysregulation of the hypothalamic-pituitary-adrenocortical axis and the sympathoadrenal system and functional changes in brain regions (e.g. limbic system, hippocampus, prefrontal cortex) (Sledjeski et al., 2008; VanItallie, 2002; Weiss, 2007) but also change in behaviour that increases the risk for specific diseases, and epigenetic alterations (Cecil et al., 2016; Dong et al., 2003).

2.5. Dissociation

Dissociation during or after a trauma refers to alterations in awareness and distorted perception of oneself or the environment (Bryant, 2007). In DSM V, dissociation is defined as a mental state in which perception, memory, identity, consciousness, emotion, and sometimes also sensory or motor systems lose their integrational functions (American Psychiatric Association, 2013). Dissociative symptoms include derealisation (reduced and altered awareness of the environment, time, and place like in a dream-like state, a sense of numbing and unreality), depersonalization (perceiving oneself as fragmented, detachment from oneself, out-of-body experiences), bodily symptoms (e.g. numbness, analgesia), and/or dissociative amnesia (memory distortions, reduced encoding of events) (Bryant, 2007; Hunter, Sierra, & David, 2004; Marmar, Weiss, & Metzler, 1998). DSM V (American Psychiatric Association, 2013) distinguishes a non-dissociative from a dissociative subtype of PTSD, which includes depersonalization and/or derealisation.

Dissociative symptoms are frequent in individuals who experienced childhood maltreatment (Draijer & Langeland, 1999; D. J. Stein et al., 2013; Terock et al., 2016) and in individuals with PTSD (Bremner & Southwick, 1992; Nejad & Farahati, 2007). A community sample in 16 Countries found dissociative symptoms in 14.4.% of individuals with current PTSD (D. J. Stein et al., 2013).

Peritraumatic dissociation is a strong predictor for later PTSD (Lensvelt-Mulders et al., 2008; Ozdemir, Boysan, Ozdemir, & Yilmaz, 2015; Ozer et al., 2003; Peltonen, Kangaslampi, Saranpää, Qouta, & Punamäki, 2017) and there is preliminary evidence that distorted memory processes might be a mediator (Peltonen et al., 2017). During dissociation, perceptual, emotional, and cognitive processing is disturbed and therefore, memories lack consistency and coherence (Peltonen et al., 2017; Schauer & Elbert, 2010). In line with this, undergraduate students with high trait dissociation showed reduced memory regarding trauma stimuli (Olsen & Beck, 2012). In addition, dissociatiotion during trauma is sometimes theorized as a state of high arousal and anxiety, often in combination with panic attacks (Bryant, 2007; Nixon & Bryant, 2003; Schauer & Elbert, 2010). During states of high arousal, emotional processing is reduced. It is hypothesized that during dissociative states, the prefrontal cortex inhibits emotional processing in the limbic system, (i.e. amygdala) which leads to less sympathetic output (R. Lanius, Bluhm, Lanius, & Pain, 2006). In accordance with this, there is evidence for less autonomous activity during dissociative states in individuals with PTSD - although only few studies exist (Griffin, Resick, & Mechanic, 1997; R. A. Lanius et al., 2002). However, Oathes and Ray (2008) argued that dissociative tendencies do not impair but rather facilitate

emotional processing due to high sensitivity to emotional stimuli, and that dissociation follows at later stages when individuals avoid remembering traumatic events.

2.6. Emotion processing in PTSD

2.6.1. Emotion recognition

Despite its relevance for social functioning and social relationships, only one study analyzed emotion recognition in individuals with PTSD (Poljac et al., 2011). War veterans from Bosnia and Herzegovina with and without PTSD saw computer-generated videoclips starting with a neutral expression and then transforming into one of six emotions (happiness, surprise, anger, sadness disgust, and fear) and had to indicate which of the six emotions it was. Individuals with PTSD performed worse in recognizing fear and sadness. Other studies in individuals with PTSD used the RMET (see Chapter 1.3.5.1.) to explore theory of mind: Mazza et al. (2012) found that among military police officers who survived a terrorist attack in Iraq, those with PTSD performed worse than those without PTSD and than police officers with no war trauma. J. Z. Schmidt and Zachariae (2009) found that 16 Bosnian refugees with PTSD performed worse in the RMET than a non-PTSD refugee control group and than a non-refugee control group. In contrast, women with PTSD related to childhood abuse did not differ in RMET performance from a healthy control group, but accuracy was negatively related to dissociative symptoms (Nazarov et al., 2014). Similarly, Nietlisbach, Maercker, Rösler, and Haker (2010) found no difference in accuracy in the RMET between individuals with PTSD/subsyndromal PTSD and a healthy control group.

Detection of neutral facial expressions was only explored in the study of Nazarov et al. (2014) (with the RMET) and they found no difference between PTSD individuals and controls. There is preliminary evidence from an event-related potentials study that individuals with PTSD have a limited capacity to discriminate between angry and neutral facial expressions: Healthy controls only showed early cortical activation in response to threat-related stimuli (angry faces) whereas neutral faces were processed more slowly. Individuals with PTSD, in contrast, showed early cortical processing in response to both angry and neutral faces (Felmingham, Bryant, & Gordon, 2003).

2.6.1.1. Emotion recognition in PTSD-related populations

Individuals with PTSD have a high prevalence of childhood maltreatment (Gabbay, Oatis, Silva, & Hirsch, 2004; Widom, 1999) and there is evidence from two meta-analyses for general emotion recognition deficits in maltreated children (da Silva Ferreira, Crippa, & de Lima Osório, 2014; Luke & Banerjee, 2013). However, not all studies found differences between maltreated and non-maltreated children, and some studies even found that

maltreated children were better (or faster) in recognition of negative emotions (anger, fear, and sadness) (Leist & Dadds, 2009; Masten et al., 2008; Pollak, Klorman, Thatcher, & Cicchetti, 2001; Shackman & Pollak, 2005). Further, maltreated children tend to wrongly attribute anger (and sadness) to expressions of other basic or ambiguous emotions and show an attention bias towards angry facial expressions (Ardizzi et al., 2015; Ardizzi et al., 2013; da Silva Ferreira et al., 2014; Gibb, Schofield, & Coles, 2009; Pollak & Tolley-Schell, 2003). Yet, results are somewhat conflicting and firm conclusion cannot be drawn. Pine et al. (2005) found that maltreated children show attentional avoidance towards angry facial expressions. Also, methods to assess emotion recognition in children varied greatly, making it difficult to compare results and often used static stimuli of high intensity (black and white pictures of facial emotional expressions), compromising generalizability of results (da Silva Ferreira et al., 2014; Luke & Banerjee, 2013).

Pollak (2003) interprets children's abnormities in emotion processing mechanisms in the context of their learning experiences with the environment: Children filter the environment for salient and important cues. For maltreated children, anger is a highly salient cue because it is associated with harm. Furthermore, fast recognition of anger is an advantage for survival because children can leave the situation before a new abuse is about to happen (Ardizzi et al., 2013; Gibb et al., 2009; Pollak, 2003, 2008). When analyzing emotion recognition deficits in maltreated children, it is important to distinguish between different forms of abuse: Whereas physically abused children showed a response bias to angry facial expressions, neglected children had difficulties differentiating different emotions perhaps because they did not receive enough learning opportunities on emotional expressions from their caregivers (Pollak, 2003; Pollak, Cicchetti, Hornung, & Reed, 2000).

Individuals with BPD who also show high rates of childhood maltreatment (Battle et al., 2004) seem to have difficulties in recognition of negative emotions (for review and meta-analyses see Daros et al., 2013; Domes, Schulze, & Herpertz, 2009; Mitchell et al., 2014). The most consistent finding in individuals with BPD was a negative response bias: Aligning the research on maltreated children, individuals with BPD tend to wrongly attribute angry facial emotional expressions to neutral or ambiguous facial expressions (Daros et al., 2013; Mitchell et al., 2014).

Nicol, Pope, and Hall (2014) found an association between the severity of childhood trauma (physical and emotional abuse) and reduced recognition of disgust in individuals with BPD, suggesting that emotion processing difficulties in BPD might be linked to negative childhood experiences.

2.6.2. Facial mimicry

Investigation of facial mimicry can shed light on whether there are abnormalities in automatic emotion processing. While reduced or atypical facial mimicry has been found in some clinical populations, e.g. individuals with autism spectrum disorders (McIntosh, Reichmann-Decker, Winkielman, & Wilbarger, 2006), BPD (Matzke, Herpertz, Berger, Fleischer, & Domes, 2014), depression (Zwick & Wolkenstein, 2017), and schizophrenia (Varcin, Bailey, & Henry, 2010), mimicry has not yet been assessed in PTSD. Perhaps related to mimicry, children and adults with PTSD showed reduced facial expressivity, and facial expressivity increased during a successful traumatherapy (Fujiwara, Mizuki, Miki, & Chemtob, 2015; Kirsch, Krause, Spang, & Sachsse, 2008). However, until today, no study tested the correlation between facial expressivity and facial mimicry.

There is preliminary evidence that childhood maltreatment is associated with reduced mimicry: Maltreated Sierra Leonean street children showed less automatic mimicry while watching video-clips of facial expressions of joy, fear, anger, and sadness and Currogator responses were the same while watching negative or positive facial expressions (Ardizzi et al., 2013; Ardizzi et al., 2016). Yet, while individuals with BPD showed increased EMG reactions to negative emotional expressions and weaker reactions to positive facial expressions (Matzke et al., 2014), female students with childhood abuse showed the reverse pattern (Reichmann-Decker, DePrince, & McIntosh, 2009). It is thus difficult to draw hypotheses about facial mimicry in individuals with PTSD from research on individuals with childhood maltreatment.

2.6.3. Emotion regulation: Expressive suppression

The processing of a traumatic event highly challenges emotion regulation strategies. PTSD is associated with difficulties in emotion regulation and dysfunctional emotion regulation strategies. More specifically, a meta-analysis found posttraumatic stress symptoms are associated with rumination, thought suppression, experiential avoidance, expressive suppression, and worry (Seligowski, Lee, Bardeen, & Orcutt, 2015).

Expressive suppression is an effortful emotion regulation strategy entailing the inhibition of emotion-expressive behaviour, e.g. suppressing tears when sad (Gross, 1998). It comes along with increased psychological distress, negative affect, heightened amygdala activity, and increased sympathetic arousal – even for the interaction partner, and it disturbs memory processes and exhausts executive cognitive resources (Ben-Naim, Hirschberger, Ein-Dor, & Mikulincer, 2013; Brans, Koval, Verduyn, Lim, & Kuppens, 2013; Goldin, McRae, Ramel, & Gross, 2008; Gross, 2015; Johns, Inzlicht, & Schmader, 2008; Richards & Gross, 2006).

Individuals with PTSD reported that they apply expressive suppression for both positive and negative emotions (Roemer, Litz, Orsillo, & Wagner, 2001). Furthermore, there is a strong correlation between posttraumatic symptoms and expressive suppression (Amstadter & Vernon, 2008; Boden et al., 2013; Chukwuorji, Ifeagwazi, & Eze, 2017; Ehring & Quack, 2010; Jerg-Bretzke, Walter, Limbrecht-Ecklundt, & Traue, 2013; Moore, Zoellner, & Mollenholt, 2008; Seligowski et al., 2015; Shepherd & Wild, 2014).

Possibly, expressive suppression could be related to emotion recognition deficits: Individuals with autism spectrum disorders have problems with emotion recognition and also show less facial expressivity (American Psychiatric Association, 2013; Davies et al., 2016; Harms, Martin, & Wallace, 2010). Furthermore, women are superior to men in emotion recognition and they show more facial emotional expressivity (Hall, 1978; Kret & De Gelder, 2012; Kring & Gordon, 1998). Aligning with these results, Halberstadt, Dennis, and Hess (2011) found a positive relationship of emotion recognition abilities and emotional expressiveness. However, to date, research investigating these associations is missing.

3. Limitations of Previous Research on Emotion Recognition in PTSD

In the only study that explored emotion recognition in PTSD, the sample consisted of male veterans from Bosnia and Herzegovina who had been exposed to prolonged and repeated traumatic events during the war in Bosnia (Poljac et al., 2011). Thus, we do not know if findings are generalizable to not war-related PTSD. In addition, dissociative symptoms were not assessed. Dissociative symptoms are frequent in war-related PTSD and it is unknown to what extent dissociation might have accounted for recognition deficits in this study. Furthermore, despite the fact that women are at higher risk to develop PTSD (Frans, Rimmö, Åberg, & Fredrikson, 2005; Kessler et al., 1995; Perkonigg, Kessler, Storz, & Wittchen, 2000), all of the participants were male. Further, trauma history and childhood maltreatment were not assessed and no information about medication was provided. Moreover, Poljac et al. (2011) used computer-generated facial morphing techniques to generate video-clips of facial expressions, thereby compromising ecological validity.

Sample sizes in studies that explored theory of mind in PTSD were all small (Mazza et al., 2012; Nazarov et al., 2014; Nietlisbach et al., 2010; J. Z. Schmidt & Zachariae, 2009), and two of them only included war-related trauma and did not provide information about trauma history (Mazza et al., 2012; J. Z. Schmidt & Zachariae, 2009). All used high-intensity static pictures for the mental state recognition task, not corresponding with everyday situations.

B. EMPIRICAL STUDIES

1. Research Questions

Given the paucity and limitations of emotion recognition studies in individuals with PTSD outlined in part A, the three empirical studies aimed at replicating previous findings with an ecologically more valid emotion recognition task and looking at related processes more in depth than previous studies. More specifically, emotion recognition, interpretation of neutral facial expressions, and facial mimicry were analyzed in individuals with PTSD and the role of possibly influencing factors was explored. The following research questions were addressed:
In individuals with PTSD:

a) Are there deficits and/or systematic misinterpretations in the recognition of emotional and neutral facial expressions?
b) Are childhood maltreatment, cumulative traumatic events, alexithymia, expressive suppression, and dissociation related to emotion recognition deficits?
c) Are there abnormities in automatic responses to facial emotion expressions (facial mimicry)?

2. General Methods

To answer the research questions, a cross-sectional study was conducted. Participants with PTSD, traumatized healthy controls (TC) and non-traumatized healthy controls (HC) performed an emotion recognition task during which facial electromyography was recorded and expressive suppression, alexithymia, childhood maltreatment, and dissociation were assessed by questionnaires. Data collection took place between October 2014 and September 2016.

The study was approved by the Cantonal Ethics Committee of Zurich. Participants were informed about the study procedure prior to participation and gave written informed consent. Participants were reimbursed for participation (CHF 130 for HC, 140 for TC, and 150 for PTSD participants).

2.1. Participants

Participants were aged 18-65 years. Inclusion criteria comprised of normal or corrected-to-normal vision, and mother tongue German proficiency. Exclusion criteria included acute suicidality, psychotic symptoms (current or lifetime), substance use disorders (past 12 months), a verbal IQ lower than 70 according to the WST (a German multiple-choice vocabulary test; K. Schmidt & Metzler, 1992), medicines like benzodiazepines, tricyclic antidepressants, beta-

blockers, antiepileptics, antipsychotic medication, and medical conditions like epilepsy and cardio-vascular diseases (due to their possible influence on psychophysiological measurements). Exclusion criteria for the control groups were current mental disorders assessed by the Mini International Neuropsychiatric Interview (M.I.N.I.) (Ackenheil, Stotz-Ingenlath, Dietz-Bauer, & Vossen, 1999). For HC the exclusion criteria were the following: Lifetime traumatic event according to DSM V (American Psychiatric Association, 2013). Participants in the PTSD group suffered from current PTSD according to DSM V, assessed by the German version of the Clinician-Administered PTSD Scale for DSM-5 (CAPS) (Müller-Engelmann et al., 2018), gold standard in PTSD assessment.

Recruitment took place via newspaper advertisements, online platforms, announcements, and postings at the University Hospital of Zurich (USZ) and surrounding area, and from a participant study pool. PTSD participants were also recruited by psychotherapists or psychiatrists of the USZ Department of Consultation-Liaison Psychiatry and Psychosomatic Medicine, by external psychotherapists, and via the USZ clinical information system.

Of the original 145 participants, 27 were excluded: Four out of 39 HC were excluded due to substance use disorders (n = 1), other mental disorders (n = 2), or past trauma experience (n = 1). Eight out of 52 TC were excluded due to current or lifetime psychotic symptoms (n = 2), current substance use disorders (n = 1) or other psychiatric disorders (n = 3), and lifetime PTSD diagnosis (n = 2). Fifteen out of 54 PTSD participants were excluded due to psychotic symptoms (n = 3), substance use disorders (n = 4), not meeting full PTSD criteria (n = 7), and insufficient German proficiency (n = 1), resulting in group sizes of 39 PTSD participants, 44 TC and 35 HC. Mean age (M = 37.3, SD = 11.7), attended school years (M = 11.9, SD = 3.1), and percentage of female participants (71%) did not differ between groups. On average, individuals in the PTSD group experienced 3.5 different trauma types (TC: 2.0); see Table 1 for trauma characteristics. In the PTSD group, 95% of index trauma were man-made (n = 37), 64% type II, (longstanding or repeated; Terr, 1991) (n = 25), and 74% deliberately caused trauma (n = 29). Index trauma within TC group were 82% man-made (n = 36), 11% type II (n = 5), and 34% deliberately caused trauma (n = 15). Comorbid disorders in the PTSD group included panic disorder (n = 11), agoraphobia (n = 16), social phobia (n = 7), generalized anxiety disorder (n = 7), major depression (n = 23), dysthymia (n = 10), obsessive-impulsive disorder (n = 2), and bulimia nervosa (n = 1).

Study 1 and 2 used the above-mentioned sample. In Study 3, a subsample of this sample was used due to missing EMG data. Subsample description is provided in Study 3.

Table 1
Trauma Types by Group

Trauma types	**PTSD**	**TC**
	n (%)	**n (%)**
Natural disasters	0 (0)	3 (6.8)
Life-threatening illness	1 (2.6)	2 (4.5)
Accidents	7 (17.9)	18 (40.9)
Sexual assault by a family member or acquaintance	15 (38.5)	2 (4.5)
Sexual assault by a stranger	2 (5.1)	2 (4.5)
Non-sexual assault by a family member or acquaintance	7 (17.9)	5 (11.4)
Non-sexual assault by a stranger	2 (5.1)	3 (6.8)
Work-related trauma	0 (0)	2 (4.5)
Witnessing suicide	1 (2.6)	1 (2.3)
Mix of different trauma types	1 (2.6)	2 (4.5)
Other traumatic experiences	3 (7.7)	3 (6.8)

2.2. Measures

An overview of all interviews and self-rating instruments used in the empirical studies is provided in Table 2. Regarding psychophysiological measurements, facial electromyography was recorded from the left *corrugator* and *zygomaticus* muscle using (Biopac Systems, Inc., Goleta, CA) and AcqKnowledge (AcqKnowledge Software Palo Alto, CA), according to the guidelines by Fridlund and Cacioppo (1986). The measurements are described in more detail in the empirical studies' methods sections.

Table 2

Overview of Measurements

Instrument	Outcome measure	Form of administration	Reference
Clinician-Administered PTSD Scale for DSM V	PTSD diagnosis	Clinical interview	Müller-Engelmann et al. (2018)
Posttraumatic Diagnostic Scale, part III	PTSD symptoms and severity	Phone interview	(Ehlers, Steil, Winter, & Foa, 1996)
Posttraumatic Diagnostic Scale, part II	Trauma history	Interview	(Ehlers et al., 1996)
Mini International Neuropsychiatric Interview	Comorbid diagnoses	Clinical interview	Ackenheil et al. (1999)
Responses to Script Driven Imagery Scale	Dissociative symptoms during emotion recognition task	Self rating questionnaire	Hopper, Frewen, Sack, Lanius, and Van der Kolk (2007)
Childhood Trauma Questionnaire	Childhood maltreatment	Self rating questionnaire	Wingenfeld et al. (2010)
Beck Depression Inventory	Depressive symptoms	Self rating questionnaire	Hautzinger, Bailer, Worall, and Keller (1994)
Toronto Alexithymia Scale	Alexithymia	Self rating questionnaire	Bagby, Parker, and Taylor (1994)
Emotion Regulation Questionnaire	Expressive suppression	Self rating questionnaire	Abler and Kessler (2009)

2.3. Emotion recognition task

The Amsterdam Dynamic Facial Expression Set–Bath Intensity Variations, ADFES-BIV (Wingenbach et al., 2016); the adaptation of the ADFES (Van Der Schalk et al., 2011) was used as emotion recognition task, which entails one-second videos of actors portraying facial emotional expressions in three intensities (low, intermediate, and high) - in line with everyday situations. The videos were standardized based on FACS (Ekman & Friesen, 1978). Every video starts with a neutral expression and then transforms into one of six basic emotions (happiness, anger, sadness, disgust, fear, surprise) or one of three complex emotions (embarrassment, contempt, pride), or remains neutral (see Figure 5). In this dissertation project, facial expressions were displayed by ten actors (five male and five female), each displaying every emotion at every intensity one time. Videos were presented by E-Prime (Psychological Software Tools Inc.). Participants saw 310 videos (including ten practice trials), after which a blank screen appeared for 500ms. Thereafter, participants had to indicate which emotion they saw on an answer screen with ten response fields (corresponding with the emotions in the

videos). After the answer screen, a blank screen appeared for 500ms. Before the emotion recognition task began, participants were handed out a list with definitions of the emotions to ensure understanding. The videos started with a fixation cross, remaining for either 1000ms, 1500ms, 2000ms, 2500ms, or 3000ms (at random).

Figure 5. ADFES-BIV: Neutral expression, last frame of disgust at low, intermediate, and high expression intensity (from left to right). © 2016 Wingenbach et al., with permission from the first author and PLOS One.

2.4. Procedure

All potential participants were screened through phone interviews for inclusion and exclusion criteria by the principal investigator, the author of this thesis, or trained and supervised graduate psychology students. For participants who experienced lifetime trauma, a modified version of the Posttraumatic Diagnostic Scale[2] (PDS) (Ehlers et al., 1996; Foa, 1995), part III, was administered during the phone-interviews to assess PTSD symptoms and severity. Participants who met inclusion criteria scheduled an appointment for the diagnostic interview, which took place at the laboratory and was conducted by trained and supervised graduate psychology students. The diagnostic interview included the CAPS (Müller-Engelmann et al., 2018), and the M.I.N.I. (Ackenheil et al., 1999); the Childhood Trauma Questionnaire (Wingenfeld et al., 2010) and the PDS (Ehlers et al., 1996; Foa, 1995) were also administered.

Participants took part in the second part of the study the same day or within one week. Beforehand, they filled out online versions of the Toronto Alexithymia Scale (Bagby, Ayearst, Morariu, Watters, & Taylor, 2014) and the Beck Depression Inventory (Hautzinger et al., 1994) (at home or in the laboratory). The study part started with the WST (K. Schmidt & Metzler, 1992). Thereafter, electrodes were attached for the psychophysiological measurements, which remained until the end of the study. After a five-minute baseline, the participants started the emotion recognition task. Thereafter, dissociative symptoms and expressive suppression during

[2] Because PDS for DSM-5 was not yet available during data collection, a modified version was created by adding five items and deleting three items to meet DSM-5 criteria.

the task were self-reported using the Responses to Script Driven Imagery Scale and the Emotion Regulation Questionnaire (Hopper et al., 2007).

2.5. Statistical analyses

All analyses were conducted with SPSS (IBM SPSS statistics, version 23). For each subject, the percentage of correct responses and the median of the corresponding reaction times were calculated for each emotion at each intensity and then averaged across emotion valence category: positive (joy, pride) and negative (anger, embarrassment, sadness, disgust, fear, and contempt). Percentage of correct responses and median of the reaction time was calculated separately for neutral facial expressions.

In Study 1 and 2, Generalized Estimating Equations Analyses were used to determine the effect of group (PTSD group vs. the two control groups, or groups based on childhood maltreatment and other variables, respectively) on emotion recognition accuracy and response time as the dependent variables (Study 1) and on recognition of neutral facial expressions (Study 2). In Study 2, confusion patterns were analyzed (confusing a neutral expression with an emotional expression) using multinomial logistic regression. In Study 3, EMG responses were analyzed using nonparametric cluster level statistics to determine if responses corresponded to facial mimicry reactions and if there were differences between groups. Furthermore, to determine if alexithymia or expressive suppressions predicted deficits in emotion recognition in the PTSD group, stepwise linear regressions were calculated in Study 3. Further analyses and more detailed descriptions of statistical analyses are provided in the methods sections of the empirical studies.

3. Published and Submitted Studies

The research questions mentioned in B.1. resulted in three empirical studies. To date (November 2018), the first study has already been published, as a letter to the editor. In this dissertation, the full-length manuscript is provided. After the first review, Study 2 has been sent back for revision and re-submission, and study 3 is currently under review.

The first study analyzed possible impairments in the recognition of positive and negative facial expressions in individuals with PTSD by conducting Generalized Estimating Equations Analyses. The second aim of this study was to analyze the association of child maltreatment, dissociation, and number of traumatic events with emotion recognition accuracy. Because these factors were substantially correlated with the group label (PTSD group vs. control groups), additional Generalized Estimating Equations Analyses were conducted by using grouping variables based on child maltreatment, dissociation, and number of different trauma types. To estimate a possible impact of these factors on emotion recognition, the model fits of the original model, and the additional models were compared.

The second study explored a possible negativity bias in interpreting neutral facial expressions in individuals with PTSD and its association to childhood maltreatment and negative thinking styles. Generalized Estimating Equations Analyses were conducted in order to analyze recognition accuracy of neutral facial expressions. Five additional statistical models were calculated with groups based on the subscales of the Childhood Trauma Questionnaire (Wingenfeld et al., 2010) and statistical model fits were compared. Confusion patterns were analyzed using multinomial logistic regressions. To explore if negative thinking styles were associated with a negativity bias, confusions of neutral expressions with negative emotions were correlated with the DSM V symptom cluster D (negative alterations in cognitions and mood) (American Psychiatric Association, 2013).

The third study explored the occurrence of facial mimicry in PTSD by analyzing zygomaticus and corrugator muscle responses while participants watched videos of positive and negative facial emotional expressions during the emotion recognition task. For this purpose, nonparametric cluster level statistics were calculated. In addition, in order to explore if alexithymia or expressive suppression could predict emotion recognition deficits, stepwise linear regressions were conducted.

All studies are explained in detail below. The following statements concerning funding and conflict of interest are valid for all three studies: “This research was supported by the Olga Mayenfisch Foundation (grant to M.C. Pfaltz). All authors declare no conflicts of interest.”

3.1. Study 1: Impaired recognition of positive emotions in individuals with posttraumatic stress disorder, cumulative traumatic exposure and dissociation

Reference: Passardi, S., Peyk, P., Rufer, M., Plichta, M. M., Mueller-Pfeiffer, C., Wingenbach, T. S., ... & Pfaltz, M. C. (2018). Impaired recognition of positive emotions in individuals with posttraumatic stress disorder, cumulative traumatic exposure, and dissociation. *Psychotherapy and Psychosomatics*, *87*(2), 118-120.

Abstract

Background: Reading other people's emotions is an essential human skill. Previous research suggests that individuals with posttraumatic stress disorder (PTSD) have difficulties recognizing facial emotional expressions, yet the underlying factors are unknown. We aimed at extending previous findings to a sample with various types of traumatic events. Additionally, we assessed if state dissociation, childhood trauma and number of lifetime experienced traumatic events (NOET) affect the hypothesized deficits. Methods: PTSD participants (n = 39), traumatized healthy controls (TC, n = 44), and non-traumatized healthy controls (HC, n = 35) completed a forced choice facial emotion recognition task consisting of standardized filmed emotional facial expressions, and indicated which of 10 emotions were presented in each movie. Results: PTSD individuals performed more poorly than TC and HC in recognizing positive (*p*'s < .034) but not negative expressions. Recognition of positive expressions was unrelated to comorbid depression and depression severity. State dissociation and higher NOET were associated with impaired recognition of positive expressions ($p = .006$ and *p*'s < .028). Childhood traumatic events were associated with impaired recognition of positive ($p = .019$) and better recognition of negative emotions ($p = .007$), which may serve an adaptive, protective function. Comparisons of statistical model fits suggest that dissociation, childhood and multiple types of traumatization play a more important role for emotion recognition than a diagnosis of PTSD. Conclusion: Difficulties in recognition of positive expressions might lead to social problems, disturb the therapeutic relationship, and contribute to the maintenance of PTSD by reinforcing negative beliefs. Future studies should test whether emotion recognition training programs improve emotion recognition deficits in individuals with PTSD.

Introduction

Reading other people's emotions is an essential human skill. Facial expressions can provide important information about another person's emotional state and the corresponding motives and intentions. According to the most prominent emotion theory, humans have an innate, culturally independent ability to recognize basic emotions in others (Ekman, Sorenson, & Friesen, 1969). However, people differ widely in their emotion recognition (ER) abilities and many clinical populations, including schizophrenia, major depression (Wolf, Maß, Lambert, Wiedemann, & Naber, 2014), bipolar disorders (Goghari & Sponheim, 2013) and borderline personality disorder (Domes et al., 2009) are impacted.

Only one study has examined emotion recognition (ER) in adult individuals with posttraumatic stress disorder (PTSD): Poljac et al. (2011) used colour pictures of actors' faces showing one of the six basic emotions, from which they generated morphed video clips of the faces changing from neutral to emotional expressions. They found specific impairments in the recognition of fear and sadness in war veterans with PTSD compared to mentally healthy war veterans. Other studies have examined theory of mind, a construct related to ER, by the Reading the Mind in the Eyes Task (RMET; Baron-Cohen et al., 2001). The RMET asks participants to decipher the mental state from static black and white pictures, showing the eye region of various faces. Mazza et al. (2012) assessed a sample of military police officers who survived a terrorist attack. They found that participants with PTSD performed more poorly in the RMET than participants without PTSD and police officers without military related trauma. J. Z. Schmidt and Zachariae (2009) found that 16 refugees with PTSD performed more poorly on the RMET than non-PTSD refugees and non-PTSD controls. In contrast, Nazarov et al. (2014) found no difference in RMET accuracy between a female PTSD sample with childhood abuse and healthy controls. Similarly, PTSD individuals after man-made and non-man-made trauma did not underperform in the RMET (Nietlisbach et al., 2010).

These studies used either high intensity static images (Mazza et al., 2012; Nazarov et al., 2014; Nietlisbach et al., 2010; J. Z. Schmidt & Zachariae, 2009) or computer-generated video clips (Poljac et al., 2011), thereby compromising ecological validity. In addition, the only study which explored ER in the narrow sense assessed male participants with PTSD and war-related trauma (Poljac et al., 2011). It is thus unknown whether PTSD patients who had been exposed to non-war-related trauma show ER deficits and which factors contribute to the observed deficits. One such factor might be dissociation, an heterogeneous concept including derealisation (reduced perception of the environment, e.g. perceiving it like in a dream) and depersonalization (fragmented perception of the self, e.g. from the outside perspective) (Bryant,

2007). During dissociative states, seeing, hearing, reasoning and constructing the reality becomes difficult (Schauer & Elbert, 2010), which might interfere with and make it difficult to focus on the perception and interpretation of facial expressions.

Trauma history, e.g., the presence of childhood traumas and the number of lifetime experienced traumatic events (NOET), is another factor that might be linked to ER deficits. Childhood traumas and NOET are associated with PTSD severity and complexity (Cloitre et al., 2009; Owens et al., 2009; Stevanović, Frančišković, & Vermetten, 2016) and – on the one hand - might interfere with ER by hindering learning processes during childhood (e.g., due to a lack of expressed emotions by primary caregivers in the case of neglect or a lack of positive expressed emotions in the case of abusive or violent caregivers). On the other hand, individuals exposed to recurrent traumatic events may learn to detect facial expressions pointing to potentially harmful situations more quickly and/or accurately. In fact, independent of PTSD diagnosis, maltreated children are faster at identifying fearful (but not neutral or happy) facial expressions compared to non-maltreated controls (Masten et al., 2008), which may serve an adaptive, protective function.

The aim of the present study was to extend previous findings on ER to individuals suffering from PTSD following various types of traumatic experiences, using more ecologically valid stimuli that include natural characteristics of facial expressions, i.e. videos of posed expressions displayed at various expression intensity levels. Additionally, we explored the relationship between ER and childhood trauma, NOET, and dissociative symptoms. We assumed that the ER task would be moderately stressful and lead to a significant increase of state dissociative symptoms in PTSD participants. We hypothesized (1) that in comparison to healthy traumatized (TC) and healthy non-traumatized controls (HC), individuals with PTSD would show ER deficits, and (2) that ER would be affected by childhood trauma, NOET, and state dissociative symptoms. As one ER study found effects on reaction times (RT's), we used RT's as additional, exploratory outcome measure for all analyses.

Materials and Methods

Participants

All participants were selected within the following criteria: Normal or corrected to normal vision, principal language spoken is German or equivalent proficiency and aged 18-65. Participants were recruited through the University Hospital of Zurich (USZ) via their mailing lists, online platforms, newspaper advertisements, and from a pool of former participants. Psychiatrists and psychotherapists from the USZ were used for the recruitment of PTSD participants, as well as external mental health professionals and the USZ clinical information

system. Exclusion criteria comprised current or lifetime psychotic symptoms, a verbal IQ < 70 according to a German multiple-choice vocabulary test (WST; K. Schmidt & Metzler, 1992), acute suicidality, substance use disorders during the past 12 months, medication with strong effects on the autonomous nervous system (i.e., benzodiazepines or antipsychotic medication) and major somatic illness.

After the diagnostic interview, 15 out of 54 PTSD participants were excluded due to current or lifetime psychotic symptoms (n = 3), current substance use disorders (n = 4), not meeting full PTSD criteria (n = 7), and insufficient German proficiency (n = 1). Eight out of 52 TC were excluded due to current or lifetime psychotic symptoms (n = 2), current substance use disorders (n = 1) or other psychiatric disorders (n = 3), and lifetime PTSD diagnosis (n = 2). Four out of 39 HC were excluded due to current substance use disorders (n = 1) or other psychiatric disorders (n = 2), or past trauma experience (n = 1). This resulted in group sizes of 39 PTSD participants, 44 TC and 35 HC.

See Table 3 for participants' characteristics and Table 4 for characteristics of index trauma. Comorbid disorders in PTSD participants comprised of generalized anxiety disorder (n = 7), agoraphobia (n = 16), panic disorder (n = 11), social phobia (n = 7), obsessive-impulsive disorder (n = 2), major depression (n = 23), dysthymia (n = 10), and bulimia nervosa (n = 1).

Table 3

Participants' Characteristics

	PTSD (*n*=39)	TC (*n*=44)	HC (*n*=35)	Group comparison
Gender (% female)	74 %	66 %	74 %	PTSD > TC[1], PTSD > HC[1], TC > HC[1]
Age (M, SD)	38.7 (12.8)	36.5 (12.0)	36.6 (10.2)	PTSD > TC[1], PTSD > HC[1], TC > HC[1]
School years (M, SD)	11.4 (2.6)	12.1 (3.3)	12.4 (3.3)	PTSD > TC[1], PTSD > HC[1], TC > HC[1]
BDI (M, SD)	24.5 (8.8)	3.3 (3.3)	2.6 (5.0)	PTSD > TC[2], PTSD > HC[2], TC > HC[1]
PDS (M, SD)	36.3 (8.7)	8.7 (7.1)	-	PTSD > TC[2]
RSDI* (M, SD)	3.5 (4.7)	0.3 (0.8)	0.3 (0.9)	PTSD > TC[2], PTSD > HC[2], TC > HC[1]
CTQ (M, SD)	65.3 (23.8)	37.4 (10.9)	33.2 (8.7)	PTSD > TC[2], PTSD > HC[2], TC > HC[1]
NOET (M, SD)	3.5 (1.6)	2.0 (1.0)	-	PTSD > TC[2]

* during emotion recognition
[1] not significant
[2] $p < .001$

Note. PTSD: Posttraumatic stress disorder; TC: Traumatized healthy controls; HC: Non-traumatized healthy controls; BDI: Beck Depression Inventory; PDS: Posttraumatic Diagnostic Scale (modified according to DSM V); RSDI: Responses to Script Driven Imagery Scale; CTQ: Childhood Trauma Questionnaire, NOET: Number of experienced traumatic events.

Table 4

Characteristics of Index Trauma by Group

Index trauma	**PTSD**	**TC**
	n (%)	**n (%)**
Man-made	37 (94.9)	36 (81.8)
Type II (longstanding or repeated)	25 (64.1)	5 (11.4)
Deliberately caused	29 (74.4)	15 (34.1)
Natural disasters	0 (0)	3 (6.8)
Accidents	7 (17.9)	18 (40.9)
Life-threatening illness	1 (2.6)	2 (4.5)
Sexual assault by a family member or acquaintance	15 (38.5)	2 (4.5)
Sexual assault by a stranger	2 (5.1)	2 (4.5)
Non-sexual assault by a stranger	2 (5.1)	3 (6.8)
Non-sexual assault by a family member or acquaintance	7 (17.9)	5 (11.4)
Work-related trauma	0 (0)	2 (4.5)
Mix of different trauma types	1 (2.6)	2 (4.5)
Other traumatic experiences	4 (10.3)	4 (9.1)

Diagnostic Instruments and Psychometric Measures

The German version of the Clinician-Administered PTSD Scale for DSM-5 (CAPS) (Müller-Engelmann et al., 2018) was used to determine the presence of current and past PTSD in the participants. In addition, the Mini International Neuropsychiatric Interview (M.I.N.I.) (Ackenheil et al., 1999) was used to determine the diagnoses of other current mental disorders.

Dissociative symptoms during the ER task were assessed by having participants complete the German version of the Responses to Script Driven Imagery Scale (RSDI) (Hopper et al., 2007) with respect to the time interval during which they completed the ER task. The RSDI is a brief self-report instrument originally developed to assess state PTSD and dissociative symptoms after symptom provocation (Pitman, Orr, Forgue, de Jong, & Claiborn, 1987). Here, we only used the dissociative symptoms subscale (4 items). Internal consistency was high (Cronbach's $\alpha = .91$).

The German version of the Childhood Trauma Questionnaire (CTQ) (Wingenfeld et al., 2010) was used to evaluate childhood trauma. The CTQ consists of 28 items asking about childhood and/or youth experiences relating to the five subscales emotional abuse, physical abuse, sexual abuse, emotional neglect, and physical neglect on a five-point Likert scale ("never true" to "very often true"). The German CTQ is a valid and reliable self-rating measurement to assess childhood maltreatment (Wingenfeld et al., 2010). In line with the literature, internal

consistency for the total score was high (α = .90). To determine the NOET, we counted the number of different trauma types according to the PDS, part II (Ehlers et al., 1996; Foa, 1995).

Emotion Recognition Task

Participants were shown 310 standardized filmed emotion expressions (incl. 10 practice trials) displayed by ten models (five male and five female) at three intensity levels of expression (low, intermediate, and high; Amsterdam Dynamic Facial Expression Set–Bath Intensity Variations, ADFES-BIV) (Wingenbach et al., 2016); the adaptation of the ADFES (Van Der Schalk et al., 2011), presented in E-Prime 2.0 (Psychological Software Tools Inc.). Each model displayed each expression at each intensity level one time. Each of these video sequences lasted 1s (reflecting situations of everyday life) and showed a facial expression, changing from neutral into one of nine emotions (joy, anger, fear, sadness, surprise, disgust, contempt, pride, embarrassment) or remaining neutral. Immediately after, a blank screen appeared for 500ms, followed by the response screen, which contained ten response fields corresponding to the emotion categories displayed in the stimuli including one emotion label each. Participants were asked to identify the emotion corresponding the displayed expression by clicking on the respective field. They were instructed to respond as quickly as possible. If they felt that no category seemed to match, participants were told to select the response that fitted best. Immediately after selection, a blank screen appeared for 500ms. Prior to completing the task, participants were given a list with definitions and explanations for each emotion to ensure they had a correct understanding of the emotions used in the task. Each trial started with a fixation cross in the middle of the screen, remaining for 1000s, 1500s, 2000s, 2500s or 3000ms (randomized duration). Correct responses and response times (in ms) were recorded by means of E-Prime.

Procedure

The study was approved by the Cantonal Ethics Committee of Zurich. All participants gave written consent prior to participation. Phone interviews were conducted by the first author (SP), the last author (MCP) or by graduate psychology students trained by MCP, to screen participants for inclusion and exclusion criteria. In addition, we used the Posttraumatic Diagnostic Scale (PDS), part III on potential TC and PTSD participants during the phone interview, in order to evaluate the presence and severity of PTSD symptoms. Due to the PDS for DSM-5 not being available during data collection, a modified PDS was created by adding five items and deleting three items (resulting in 20 items) to cover items introduced to the PTSD diagnosis in DSM-5. Participants who passed the phone interviews stage were scheduled for

their first session in the laboratory, for the administering of the CAPS and M.I.N.I. by graduate psychology students who had been thoroughly trained by MCP.

Participants were free to complete the second part of the study immediately after the interview or to return to the laboratory for a second visit within one week. Prior to the second session, the Beck Depression Inventory (BDI) (Hautzinger et al., 1994) was completed by participants. In the beginning of the second session, participants completed the WST. From this point onwards and for the rest of the study, psychophysiological measures (electrodermal activity, respiratory rate, facial electromyography and electrocardiogram), were recorded (will be reported elsewhere). After a 5-minute baseline measurement serving psychophysiological assessments, participants underwent the ER task. Next, participants completed the RSDI and were then reimbursed for their time and involvement in the study.

Statistical Analyses

SPSS (IBM SPSS statistics, version 23) was used to carry out all analyses. For each subject, the percentage of correct responses and the median of the corresponding RT were calculated for each intensity of two valence groups: positive[3] (joy, pride) and negative (anger, fear, sadness, disgust, contempt, and embarrassment). Generalized Estimating Equations Analyses were then carried out with the within-subject factors valence (positive, negative) and intensity (low, intermediate, and high) and the between-subject factor group (PTSD, TC, HC). We inspected the distributions of the dependant variables visually using quantile-quantile (QQ)-plots, and selected the regression models accordingly. RT's were analyzed using gamma distributions with a log link, whereas recognition accuracy was analyzed using binomial distributions and a logit link. From all available working correlation matrix types in SPSS, we selected the type providing the best model fit ("unstructured" in all cases). Being confident in the appropriate distribution and working correlation matrix type selection, we used model-based estimation rather than robust estimation of the covariance matrix.

Significant effects were explored using post-hoc marginal mean comparison, and multiple comparisons were accounted for using the Bonferroni-Holm correction. Significant group differences in ER were further explored using Kruskal-Wallis tests for systematic patterns of misidentification (confusing target emotions with a positive emotion, with a negative emotion, with surprise or with neutral expressions), separately for each intensity level, resulting in 12 analyses.

[3]To improve readability, we are using the terms "positive emotions and "negative emotions" instead of "positively valenced emotions" and "negatively valenced emotions". We do not mean to imply that emotions themselves are positive or negative but rather see them as functional, regardless of their valence.

State dissociation (RSDI), childhood trauma (CTQ) and NOET were substantially correlated with experimental group (cf. Table 3): Therefore, in spite of their high clinical relevance, these variables could not be entered into the same statistical model. However, to retrieve a possible estimate of their impact on the dependant variables, we conducted the described analyses also using groups based on quantiles of these measures and compared the model fit of the resulting models (alternate models) to the original group design (standard model). For CTQ and RSDI, groups were based on median splits (high and low CTQ / high and low RSDI groups), and for NOET, the group factor had three levels (no trauma, 1-2 trauma types, 3 or more trauma types).

Results

Accuracy

In line with the validation study (Wingenbach et al., 2016) , overall accuracy across groups was 66 % (*SD* = 8%) and positive emotions were recognized more accurately than negative ones (Wald $X(1) = 210.31$, $p < .001$). Emotion intensity had a strong impact on recognition accuracy (Wald $X(2) = 1911.92$, $p < .001$): high intensity emotions were better recognized than intermediate intensity emotions ($p < .001$) and intermediate intensity emotions were better recognized than low intensity emotions ($p < .001$). Intensity influenced recognition more for positive expressions (intensity x valence interaction; Wald $X(2) = 22.31$, $p<.001$).

A valence x group interaction (Wald $X(2) = 18.7$, $p < .001$) and post-hoc tests (after Bonferroni-Holm corrections) revealed that PTSD individuals performed more poorly than TC ($p = .006$) and HC ($p = .034$) at detecting positive but not negative emotions (see Figure 6, Panel 1). ER of positive emotions did not correlate with the BDI sum scores within each group (r's < .124, p's > .481). Also, PTSD participants with comorbid major depression ($n = 23$) did not underperform compared to PTSD participants without major depression ($n = 16$; $p = .338$) in recognizing positive emotions. Groups did not differ regarding misidentifications (p's > .068).

Reaction times

The mean median RT across groups was 1297.18ms (*SD* = 391.79). Positive emotions were recognized faster than negative ones (Wald $X(2) = 157.38$, $p < .001$). In line with the validation study (Wingenbach et al., 2016), intensity had a strong impact on RT (Wald $X(2) = 129.07$, $p < .001$): higher intensity expressions were recognized faster than intermediate intensity expressions ($p < .001$) and intermediate intensity expressions were recognized faster than low intensity expressions ($p < .001$). Intensity had a greater impact on RT's for positive expressions (intensity x valence interaction; Wald $X(2) = 14.95$, $p < .01$). RT analyses revealed no group main effects or interactions involving the group factor.

Dissociation, childhood trauma and NOET

Table 5 shows the model fits for the alternate statistical models using subject groups based on state dissociation (RSDI), childhood trauma experience and NOET. For recognition accuracy and RT's for positive and negative expressions, all alternate models revealed an improved model fit over the standard model.

Overall, group dependent effects on recognition accuracy in the alternate models were consistent with the results for the standard group model (see Figure 6, Panel 2-4). More specifically, the high RSDI, CTQ, and NOET groups underperformed in the recognition of positive emotions compared to the low RSDI, CTQ, and NOET groups (see Table 5). For the NOET model, this effect was found for the group with three or more trauma types (compared to the two other groups) and restricted to low and intermediate intensity expressions (group x valence x intensity interaction). In addition, the high CTQ group performed better than the low CTQ group in recognition of negative emotions and the high-RSDI group even showed a general ER deficit although interpretation of this main effect is restricted due to interaction effects. Additionally, we found an intensity x group interaction in all alternate models. Post-hoc tests revealed that the high RSDI group performed more poorly than the low RSDI group in ER for low and intermediate intensity. We found no significant group dependent effects for any of the RT analyses.

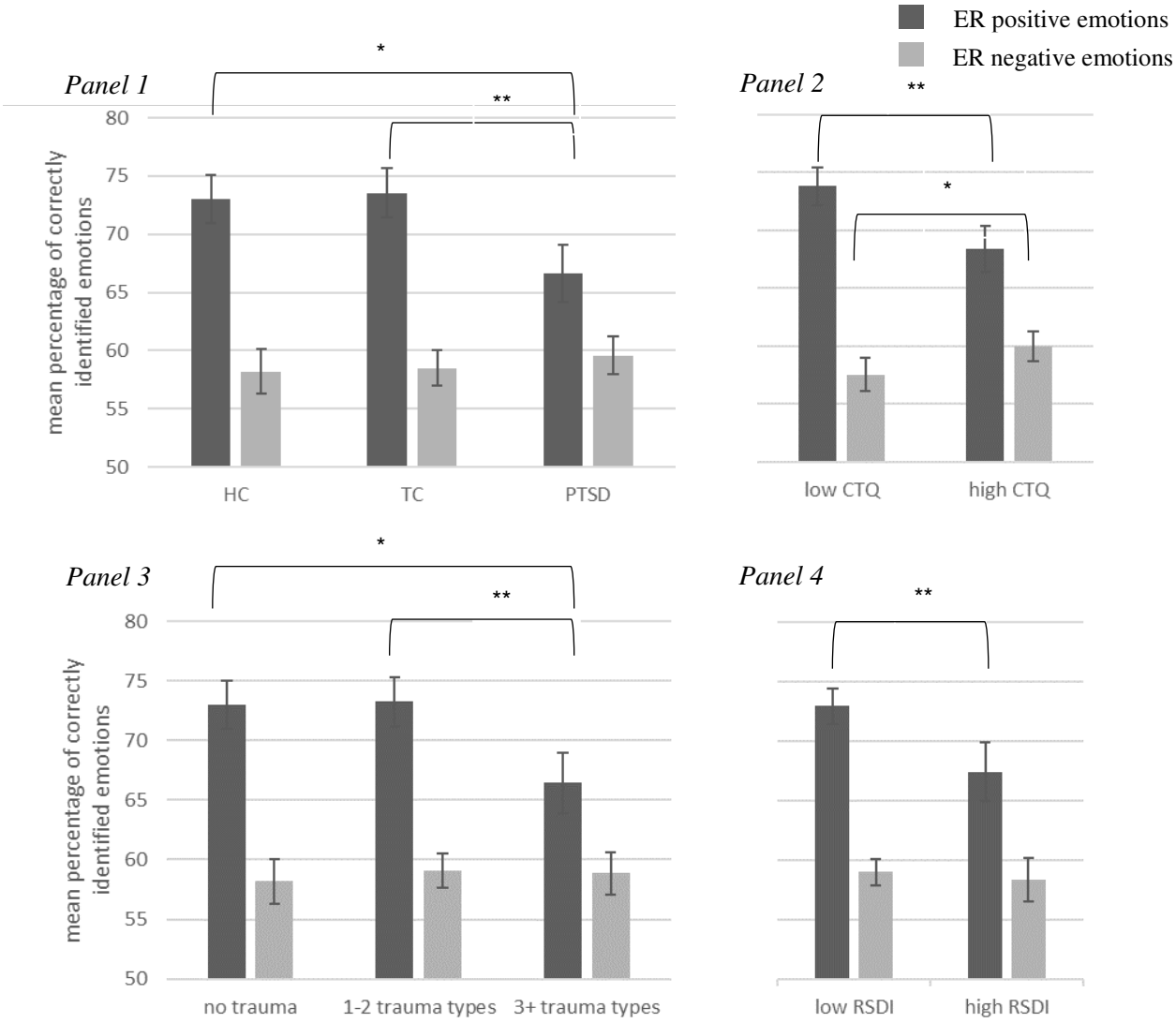

Figure 6. Emotion recognition (ER; percentage of correctly identified emotions) based on different group categories. Error bars represent standard errors; ** significant (α = .01); * significant (α = .05).
Panel 1: HC: non-traumatized healthy controls; TC: traumatized healthy controls; PTSD: posttraumatic stress disorder group.
Panel 2: low CTQ: group with lower Childhood Trauma Questionnaire scores; high CTQ: group with higher Childhood Trauma Questionnaire scores.
Panel 3: no trauma: participants who have never experienced a trauma; 1-2 trauma types: participants who experienced one or two different trauma types; 3+ trauma types: participants who experienced three or more different trauma types.
Panel 4: low RSDI: group with lower Responses to Script Driven Imagery Scale scores; high RSDI: group with higher Responses to Script Driven Imagery Scale scores.

Table 5.

Model Fit (QICC) and Effect Statistics (Wald X^2) for Models with Alternate Grouping Variables (GVs)

	GV	QICC	GV	GV x Inten	GV x Val	GV x Inten x Val
Accuracy	Group	92684.04	4.72	8.20	18.70 * p	3.18
	CTQ[1]	92238.71	1.41	11.53 *	19.31 * pn	4.66
	RSDI[1]	92296.65	16.52 *	12.59 * lm	14.39 * p	.67
	NOET[1]	92381.11	7.39	16.42 *	13.75 * p	27.27 * lm/p
RT	Group	139.90	.05	1.58	.63	.65
	RSDI[1]	127.72	.16	4.66	.24	.05
	CTQ[1]	128.08	.06	1.78	.42	.29
	NOET[1]	139.65	.16	1.76	.35	.29

* = significant effect, $p < .05$

[1] better model fit

Note. GV: Grouping variable. Inten: Intensity, Val: Valence, CTQ: Childhood Trauma Questionnaire, RSDI: Responses to Script Driven Imagery Scale, NOET: Number of experienced trauma types, l: significant group comparisons for low intensity, m: significant group comparisons for intermediate intensity, p: significant group comparisons for positive valence, n: significant group comparisons for negative valence

Discussion

The present study assessed ER in individuals with PTSD, as compared to healthy traumatized (TC) and healthy non-traumatized controls (HC). PTSD participants performed more poorly than controls in recognizing positive but not negative emotions. In addition, comparisons of statistical model fits suggest that childhood traumatisation, state dissociation and number of experienced traumatic events may have a greater impact on ER than PTSD diagnosis.

Individuals with PTSD: poor recognition of positive emotions

Individuals with major depression show deficits in recognizing positive emotions (Wolf et al., 2014; Yoon, Joormann, & Gotlib, 2009). However, in our study, these deficits do not seem to be a function of depressive symptoms, because PTSD participants with and without comorbid depression did not differ in the ability to recognize positive expressions and BDI scores were unrelated to ER. Also, our results are not explained by specific confusion patterns.

In general, positive emotions are recognized more easily than negative ones. Calvo et al. (2014) argued that in daily life, positive emotions are encountered more frequently than negative ones and therefore, representations of positive expressions are more detailed and more easily accessible. PTSD individuals likely have fewer positive encounters, e.g. due to symptoms of avoidance and social withdrawal, which may result in less detailed and accessible representations, interfering with ER capabilities. Diminished recognition of positive emotions

in PTSD might also be linked to numbing symptoms, which in DSM-5 are subsumed under criterion D (negative alterations in cognitions and mood such as feelings of detachment from others, loss of interest, inability to experience positive emotions). Numbing seems to be a distinct feature of PTSD that differs from depression (Asmundson, Stapleton, & Taylor, 2004; Feeny, Zoellner, Fitzgibbons, & Foa, 2000). In fact, Mazza et al. (2012) found a relationship between ER and numbing symptoms and suggested a common neuropsychological mechanism underlying numbing and social cognition, including ER.

Reaction times

While Masten et al. (2008) found that maltreated children identify negative (fearful) facial expressions at an increased speed, none of our ER variables was associated with reaction times. One explanation for the difference between Masten et al.'s (2008) and our findings might be that most of the maltreated children in Masten et al.'s (2008) sample had only recently been traumatized. In comparison to our sample, these participants may have experienced more pronounced, i.e. more acute symptoms of hyperarousal, which may have resulted in altered response times. Further research should clarify if and under what conditions ER speed is linked to PTSD (or to trauma history and dissociation).

Dissociation and Trauma History

Our study suggests that trauma history and state dissociation might be related to ER more strongly than PTSD diagnosis. Group classification based on these variables fitted our data better and the main result remained the same: Individuals with more childhood trauma, state dissociation, and experienced traumas performed worse at detecting positive emotions.

Studies assessing the impact of childhood trauma on ER in adulthood are rare. Nazarov et al. (2014) found no difference between PTSD individuals after childhood abuse and HC in the RMET. However, the RMET uses high intensity static images with complex mental states, only depicting the ocular region. Young and Widom (2014) found that childhood trauma but not PTSD diagnosis predicted deficits in recognition of positive (and neutral) images. Calvo et al. (2014) reported that the ability to recognize specific emotional expressions depends on how frequently these expressions are seen in everyday life. Individuals with a history of childhood maltreatment probably have experienced fewer positive interactions with primary caregivers and thus fewer opportunities to learn to identify positive emotional stimuli, including facial expressions. In addition, for individuals with sexual abuse histories, positive expressions may be ambiguous as they were sometimes followed by traumatic events. This lack of predictive value of positive expressions may have interfered with learning processes.

Similar to childhood trauma, the number of traumatic event types was linked to deficits in recognition of positive emotions. Similar factors (less positive encounters, ambiguous meaning of positive expressions in the past) may explain these deficits.

Our findings also show that traumatization can be linked to enhanced ER abilities. Individuals with a greater number of childhood traumatic experiences showed – next to deficits in recognizing positive emotions – better recognition of negative emotions compared to controls. Masten et al. (2008) showed that maltreated children are faster at identifying negative emotions. Increased accuracy and detection speed might be an advantage in a malicious and unpredictable environment where negative emotions may indicate possible threats (Masten et al., 2008). Assuming that childhood traumas are linked to frequent exposure to negative emotions, our own findings and those of Masten et al. (2008) are in line with Calvo et al. (2014) who found a positive link between speed and accuracy of facial expression recognition and frequency with which expressions occur in social encounters.

State dissociation was linked to a general ER deficit (that was more pronounced for positive and for low and intermediate intensity expressions, which are generally more difficult to recognize than high intensity expressions). This is in line with Nazarov et al. (2014) who found a correlation between (trait) dissociation and underperformance in the RMET. Our study shows that even moderate levels of dissociation are linked to ER deficits. This might explain the finding of a general ER deficit (deficit in theory of mind as assessed by the RMET, respectively) in previous studies in subjects exposed to war or military-related trauma (Mazza et al., 2012; J. Z. Schmidt & Zachariae, 2009), showing a high prevalence of dissociative symptoms (Nejad & Farahati, 2007). It could be worthwhile to explore the processes affected by dissociative symptoms that contribute to the observed deficits. Dissociation has been linked to impaired information integration (Schauer & Elbert, 2010). More specifically, Oathes and Ray (2008) argued that dissociative tendencies are not linked to impaired processing (e.g. attention lapses) of emotional stimuli but to high sensitivity to emotional stimuli, leading to subsequent dissociation and avoidance of further elaboration of upsetting stimuli. In line with this argumentation, in our study, state dissociation was linked to accuracy but not speed of ER.

Strengths, Limitations and Conclusions

In comparison to previous ER and theory of mind studies in PTSD individuals using static images (Mazza et al., 2012; Nazarov et al., 2014; Nietlisbach et al., 2010; J. Z. Schmidt & Zachariae, 2009) or computer generated videos (Masten et al., 2008; Poljac et al., 2011), our participants viewed short video sequences showing actors' emotional expressions. This task resembles everyday situations where facial expressions are dynamic and change quickly. In everyday life, facial expressions are often subtle. It is therefore important to identify people who have difficulties in identifying not only high but also low intensity expressions because they will likely underperform in social interactions. In our ER task, emotions were displayed at varying intensity levels. With this rather naturalistic task, ER deficits in PTSD were restricted to positive emotions. While the only previous ER study in adult PTSD individuals exclusively assessed male participants suffering from war related trauma (Poljac et al., 2011), we collected a representative PTSD sample with more women than men and a wide range of traumatic experiences (Kessler et al., 1995; Perkonigg et al., 2000).

Although we used an ER task with relatively high ecological validity, future studies should assess ER in even more naturalistic settings, outside the laboratory and/or during social interactions. Another limitation of our study is the difference in trauma characteristics between PTSD and TC, for example, more type II trauma in the PTSD group. However, risk for PTSD is higher after type II trauma (Brewin et al., 2000), making it difficult to find comparable control groups when assessing samples with mixed trauma types. Finally, while trauma history and PTSD diagnosis are confounded, future studies should assess the specific impact of dissociation by manipulating dissociative states experimentally.

Nevertheless, our findings show that individuals suffering from PTSD show deficits in recognizing positive expressions and that state dissociative symptoms and trauma history seem to account more strongly for these deficits than the diagnosis itself. Deficits in recognizing positive emotions likely affect social interactions and the quality of therapeutic and other relationships. In fact, the ability to recognize positive (and negative) emotions has been linked to couple's well-being (Petrican, Moscovitch, & Grady, 2014) and, in schizophrenic patients, to social functioning (Hooker & Park, 2002). Deficits in processing positive facial expressions may contribute to social problems through a perceived lack of reinforcement and a reduction of approach behaviour (Yoon et al., 2009). Future studies should explore if deficits in identifying positive emotions in persons with PTSD are evident in additional, non-verbal signals like the tone of the voice, and whether these deficits contribute to the maintenance of symptoms, e.g. by reinforcing negative beliefs.

Health professionals and other interaction partners might improve their relationship with the patient by communicating positive emotions through explicit (verbal) channels. Some evidence further suggests that methylenedioxymethamphetamine (MDNA) may increase sociability and facilitate therapeutic relationships by specifically improving recognition of positive emotions (Hysek, Domes, & Liechti, 2012). In autism spectrum disorders and schizophrenia, computer-assisted ER trainings show promising effects on ER (Bölte et al., 2006; T. A. Russell, Chu, & Phillips, 2006). If our findings are replicated in naturalistic settings, affected individuals might benefit from similar trainings, aiming at improving their social performance.

3.2. Study 2: Perception of neutral facial expressions in traumatized individuals

Reference: Passardi, S., Peyk, P., Fares-Otero, N. E., Schnyder, U., & Pfaltz, M. C. (revise and resubmit). Perception of neutral facial expressions in traumatized individuals. *European Journal of Psychotraumatology*.

3.3. Study 3: Facial mimicry, facial emotion recognition and alexithymia in post-traumatic stress disorder

Reference: Passardi, S., Wingenbach, T. S., Peyk, P., Rufer, M., & Pfaltz, M. C. (under review). Facial mimicry, facial emotion recognition and alexithymia in post-traumatic stress disorder. *Behaviour Research and Therapy*.

C. GENERAL DISCUSSION

The objective of the present dissertation project was to analyze the processing of facial emotional and neutral expressions (including facial mimicry) in individuals with PTSD and its relation to childhood maltreatment, cumulative traumatic events, dissociation, alexithymia, and expressive suppression. Table 10 summarizes the main results of the three empirical studies. The following sections reflect on the main results integrating it into current scientific knowledge and discuss the role of factors that might contribute to emotion recognition deficits in individuals with PTSD. After highlighting the strengths and limitations of the empirical studies, the implication of the results are outlined, in particular how individuals with PTSD and interaction partners could benefit from the findings and the direction of future research. Finally, the thesis ends with a general conclusion.

Table 10.

Summary of the Main Results of the Three Empirical Studies

Study 1	**Impaired recognition of positive emotions in individuals with posttraumatic stress disorder, cumulative traumatic exposure and dissociation.**
Main results	• Individuals with PTSD showed deficits in the recognition of positive facial expressions • Groups based on childhood maltreatment, dissociation, and number of traumatic events fitted the data better than groups based on PTSD diagnosis • Groups with high childhood maltreatment (high number of traumatic events, high dissociative symptoms) performed worse at detecting positive facial expressions compared to groups with low manifestations of these variables • The group with high childhood maltreatment was more accurate at detecting negative facial emotions than the group with low childhood maltreatment
Study 2	**Perception of neutral facial expressions in traumatized individuals**
Main results	• Individuals with PTSD showed deficits in the recognition of neutral facial expressions and misinterpreted them more often as anger and contempt than healthy controls • Individuals with high versus low levels of childhood sexual abuse, emotional abuse, and physical neglect misinterpreted neutral expressions more frequently as anger, sadness and contempt • Statistical model fits suggest that childhood sexual abuse, emotional abuse, and physical neglect play a more important role than PTSD diagnosis in explaining the observed negativity bias
Study 3	**Facial mimicry, facial emotion recognition and alexithymia in post-traumatic stress disorder**
Main results	• Automatic facial mimicry is intact in individuals with PTSD • Individuals with PTSD report greater expressive suppression than healthy controls • Individuals with PTSD are more alexithymic than healthy controls • Alexithymia predicts emotion recognition deficits in individuals with PTSD

1. Summary and reflections on the main results

1.1. Emotion recognition, interpretation of neutral facial expressions and automatic responses to facial emotional expressions in individuals with PTSD

PTSD individuals in this dissertation project showed deficits in facial emotion recognition, in line with research on emotion recognition in PTSD (Poljac et al., 2011) and in other psychological disorders (Castellano et al., 2015; Daros et al., 2013; Dawel et al., 2012; Dickey et al., 2011; Kohler et al., 2011; Kohler et al., 2009; Lozier et al., 2014). This is not surprising given that difficulties related to experiencing and regulation of emotions is part of PTSD diagnosis (American Psychiatric Association, 2013). Furthermore, research shows structural brain changes in individuals with PTSD in regions that are associated with emotion recognition (Karl et al., 2006; Li et al., 2014; O'Doherty et al., 2015). However, studies which explored the theory of mind in PTSD yielded mixed results (Mazza et al., 2012; Nazarov et al., 2014; Nietlisbach et al., 2010; J. Z. Schmidt & Zachariae, 2009): Two out of four studies found no differences between individuals with PTSD and healthy controls in the recognition of complex mental states (Nazarov et al., 2014; Nietlisbach et al., 2010). Nevertheless, these studies used black-and-white stimuli of high intensity and analyzed a concept that is related to but not identical with emotion recognition (Leslie, 2001; Premack & Woodruff, 1978). Therefore, given our study and the study of Poljac et al, it seems likely that individuals with PTSD indeed have problems identifying emotions in facial expressions.

Whereas Poljac et al. (2011) found deficits in the recognition of *negative* facial expressions, in our study PTSD individuals performed worse in the detection of *positive* facial expressions (Passardi et al., 2018). In general, individuals with PTSD are more hypervigilant towards negative facial expressions (Armony, Corbo, Clément, & Brunet, 2005; Fonzo et al., 2010; Rauch et al., 2000), which might facilitate recognition of negative facial expressions or could lead to avoidance. Individuals in our study with higher levels of child maltreatment performed better at detecting negative emotions than individuals with low level child maltreatment, which supports the view that recurrent traumatic interpersonal experiences rather lead to a hypervigilance towards negative facial expressions than avoidance (Ardizzi et al., 2015; Ardizzi et al., 2013; da Silva Ferreira et al., 2014; Pollak, 2003). In addition, positive facial expressions are probably encountered less frequently by individuals with PTSD due to social withdrawal, growing up with abusive and/or neglectful caregivers, and/or cumulative traumatic events. This could lead to less detailed representations of positive facial expressions, possibly interfering with recognition of positive emotions, in line with the results of our study (Calvo et al., 2014; Pollak & Sinha, 2002). Poljac et al. (2011) used a sample of male

participants with war-related PTSD. Results might not be generalizable to PTSD individuals with other types of trauma and to female individuals. However, further investigation and replication is required to draw firm conclusions about which valence of emotion recognition is impaired in individuals with PTSD.

A novel research finding of this dissertation project is the systematic misinterpretation of neutral facial expressions in individuals with PTSD (Passardi et al., revise and resubmit), similar to individuals with BPD (Daros et al., 2013; Mitchell et al., 2014). Individuals with PTSD wrongly attributed anger or contempt to neutral facial expressions (Passardi et al., revise and resubmit). When facial expressions are ambivalent, other information is used to facilitate interpretation, for example contextual information or internal knowledge (Adolphs, 2002; Carroll & Russell, 1996). One could assume that this interpretation bias is associated with negative expectations about other persons or with disruptive learning experiences. Although negative thinking styles in individuals with PTSD, assessed with the CAPS (Müller-Engelmann et al., 2018), did not correlate with misinterpretations of neutral expressions, childhood maltreatment came out to be associated with the negativity bias in interpreting neutral facial expressions, which will be expanded on further down (section 1.2.).

Despite the emotion recognition deficits in individuals with PTSD, we found that automatic facial responses to emotional facial expressions seem to be intact (Passardi, Wingenbach, Peyk, Rufer, & Pfaltz, under review). There was no difference in automatic facial mimicry between PTSD participants and healthy controls. This is an important finding because mimicry facilitates prosociality, empathy, and emotional closeness (Duffy; Hess & Fischer 2014). To our knowledge this was the first study that explored facial mimicry in individuals with PTSD. Replication is needed to confirm these results.

1.2. The role of child maltreatment and trauma history

This dissertation adds to the current body of research in showing that deficits in recognition of positive and neutral facial expressions and misinterpretations of neutral facial expressions seem to be related more strongly to childhood maltreatment (or number of traumatic events for positive emotional expressions) than to PTSD diagnosis. Furthermore, a novel research finding is that adults with high levels of childhood maltreatment are better at detecting negative facial expressions than adults with low levels of childhood maltreatment.

Next to an innate ability for emotion recognition (Ekman, 1993), emotion recognition skills are acquired through interactions with caregivers and significant others during infancy and over the lifespan (Pollak & Sinha, 2002). The facial affective exchange between mother and child seems to be vital for both forming emotion recognition skills and for attachment security (Steele et al., 2008). In a neglectful environment, children have less learning opportunities for facial emotional expressions (Luke & Banerjee, 2013). Furthermore, children who grow up in an abusive environment probably encounter less positive facial expressions and more negative facial expressions, which probably lead to less detailed representations of positive facial expressions and more detailed representations of negative facial expressions (Calvo et al., 2014; Pollak & Sinha, 2002). Better or faster recognition of negative facial expressions might be an advantage because it can help to prevent abusing situations (Masten et al., 2008; Pollak, 2003, 2008). Indeed, some studies found that maltreated children are better at detecting negative emotions (Leist & Dadds, 2009; Masten et al., 2008; Pollak et al., 2001; Shackman & Pollak, 2005). Negative facial expressions are more important for predicting the parents' behaviour and therefore have an advantage for learning (Pollak, 2003). An overrepresentation and hypersensitivity for negative facial expressions could also lead to a negative interpretation bias for neutral facial expressions. In addition, neutral facial expressions might become aversive stimuli because they may trigger memories of neglect or other forms of child maltreatment (Guitart-Masip et al., 2009; Schlumpf et al., 2013). There is some evidence in adults with dissociative identity disorder (a mental disorder associated with severe childhood maltreatment) that perceiving neutral facial expressions activate brain areas that are associated with re-experiencing traumatic events (Schlumpf et al., 2013).

Similar to individuals who experienced childhood maltreatment, individuals who experienced cumulative traumatic events probably have fewer representations of positive facial expressions. Cumulative traumatic events are associated with more severe PTSD and greater functional impairment, for example in relationship functioning (Karam et al., 2014; Kolassa et al., 2010). A higher psychopathological severity and problems with social relationships

decreases the chance of positive social encounters, probably reducing mental representations of positive facial expressions and impairing the ability to recognize positive emotions (Calvo et al., 2014).

1.3. Other influencing factors: dissociation and alexithymia

In order to better understand mechanisms underlying emotion recognition deficits in PTSD, it is important to explore factors that are associated with these deficits. Although expressive suppression is a common emotion regulation strategy in individuals with PTSD (Roemer et al., 2001) that has various negative effects, e.g. on affective wellbeing, arousal, relationships, and memory (Ben-Naim et al., 2013; Brans et al., 2013; Goldin et al., 2008; Gross, 2015; Johns et al., 2008; Richards et al., 2003; Richards & Gross, 2006), our study showed that it is not associated with emotion recognition accuracy (Passardi et al., under review). However, we identified two other factors that were associated with decreased emotion recognition accuracy: Alexithymia and dissociation. State dissociation was associated with a general emotion recognition deficit (more pronounced for positive and low and intermediate intensity emotional expressions). This is in line with the study of Nazarov et al. (2014), who found that dissociation in individuals with PTSD was associated with deficits in the recognition of complex mental states. It might be a reason why studies that explored emotion recognition or recognition of complex mental states found a general recognition deficit in individuals with war-related traumatisation (Mazza et al., 2012; J. Z. Schmidt & Zachariae, 2009), which have a high prevalence of dissociation (Nejad & Farahati, 2007). In our study, even moderate levels of dissociation were associated with emotion recognition deficits (Passardi et al., 2018). It remains unclear whether state dissociation disturbs processing of emotional expressions (Peltonen et al., 2017; Schauer & Elbert, 2010) or whether dissociation impairs later stages of elaboration due to avoidance (Oathes & Ray, 2008). This has to be tested in future studies, e.g. with eye-tracking technology.

To our knowledge, our study was the first that explored the relationship between alexithymia and emotion recognition in PTSD. We found that alexithymia – i.e. the subscale "externally-oriented-thinking" (Bagby et al., 1994) – was a predictor of reduced recognition of negative valenced emotional expressions (Passardi et al., under review). Negative emotions are more difficult to recognize than positive ones (Calvo et al., 2014; Wingenbach et al., 2016) and alexithymia seems to impact more the recognition of negative emotions (Grynberg et al., 2012). However, because in our study individuals with PTSD showed deficits in the recognition of *positive* emotions (Passardi et al., 2018), alexithymia does not seem to account for this deficit. Poljac et al. (2011) found that war veterans with PTSD have problems identifying negative

facial expressions. Alexithymia might be a possible explanation for this finding because war veterans show high prevalence of alexithymia (Becirovic, Avdibegovic, Softic, Mirkovic-Hajdukov, & Becirovic, 2017).

2. Strengths

This dissertation project adds to the current emotion recognition literature in PTSD by using a more naturalistic emotion recognition task than previous studies. Whereas previous studies used high intensity static stimuli (Mazza et al., 2012; Nazarov et al., 2014; Nietlisbach et al., 2010; J. Z. Schmidt & Zachariae, 2009) or computer-generated videos (Poljac et al., 2011), the emotion recognition task in our study contained filmed dynamic facial expressions at varying intensities, closer to real-life situations and also ensuring standardisation. In contrast to static stimuli, dynamic facial expressions contain additional information about the time course of the facial movements, important for emotion recognition (Bould & Morris, 2008; Wingenbach et al., 2016). Although morphed video clips are dynamic, they do not necessarily reflect natural facial movements (Wingenbach et al., 2016). For example, the speed and dynamics of facial movements is different for different emotional expressions, which is often not taken into account when using morphing techniques (Sato & Yoshikawa, 2004; Wingenbach et al., 2016). Furthermore, facial emotional expressions in everyday situations are mostly subtle (Motley & Camden, 1988; Wingenbach et al., 2016). Aligning with that and increasing ecological validity, videos of expressed emotions in our emotion recognition paradigm entailed three different intensities (low, intermediate, and high).

Furthermore, among all studies that analyzed emotion recognition and recognition of complex mental states in PTSD, the sample size in this dissertation project was the largest, consisting of both men and women whereas two studies only analyzed men (Mazza et al., 2012; Poljac et al., 2011) and two studies only analyzed women (Nazarov et al., 2014; Nietlisbach et al., 2010) except for a gender-mixed but very small sample in J. Z. Schmidt and Zachariae (2009). Whereas PTSD in previous studies was either related to war trauma (Mazza et al., 2012; Poljac et al., 2011; J. Z. Schmidt & Zachariae, 2009) or childhood abuse (Nazarov et al., 2014) except for one study with various traumatisation (but also including subsyndromal PTSD in the PTSD group, (Nietlisbach et al., 2010), PTSD in our sample was related to different kinds of traumatisation (see Chapter B, Table 1, p. 32).

A further strength of this project is that it fills a research gap by analyzing facial mimicry, misattributions of neutral facial expressions, and the association of alexithymia and emotion recognition deficits in individuals with PTSD. In addition, this dissertation project

explores the role of trauma history (especially child maltreatment) and its relation to emotion recognition deficits in order to gain a deeper understanding about deficits and generating hypotheses about possible origins of deficits.

3. Limitations

Despite the relative high ecological validity of our emotion recognition task, facial expressions in our task were separate from its context, which is important for emotion recognition (Aviezer et al., 2011; Carroll & Russell, 1996). In addition, posed facial expressions have been criticized because they lack realism and differ from spontaneous emotional expressions (Cowie, Douglas-Cowie, & Cox, 2005; Ekman & Rosenberg, 2005; Krumhuber et al., 2017; Zeng, Pantic, Roisman, & Huang, 2009). However, datasets with spontaneous facial expressions lack standardisation and experimental controllability (for review see Krumhuber et al., 2017).

A further limitation of our paradigm is its dependence on verbal abilities. In everyday situations, judgements about emotions are normally made implicitly. Therefore, it is not clear whether emotion recognition deficits found in this dissertation project correspond to deficits in real situations where emotions are recognized implicitly. In future studies, emotion recognition tasks should use a combination of language based and non-language based recognition tasks (e.g. Pell, 2005; Wilhelm et al., 2014). In addition, although most information about an emotion lies in the face, information is also extracted from other modalities of non-verbal communication like the tone of the voice or body gestures and emotion recognition deficits might not be equally present in all modalities. For example, Niedtfeld et al. (2017) found that individuals with BPD were impaired in emotion recognition when visual stimuli were presented (alone or in combination with other modalities), but not when only audio stimuli were presented. Therefore, future studies should explore if emotion recognition deficits in PTSD extend to other channels of non-verbal communication.

Finally, although it is a strength of this project to have a healthy traumatized control group, trauma characteristics differed from the PTSD group (more type II and deliberately caused trauma). However, long-lasting and deliberately caused traumatic events are strongly associated with PTSD (Brewin et al., 2000; Kessler et al., 1995; Maercker et al., 2018), making it difficult to find comparable control groups.

4. Implications and consequences

4.1. For individuals with PTSD

Emotion recognition is a basic social skill important for the success of social relationships and deficits in emotion recognition seem to be related to poor relationship wellbeing (Carton et al., 1999; Fischer & Manstead, 2008). Social relationships, in turn, are an important resilience factor after traumatic experiences and can protect against negative effects of stress (Afifi & MacMillan, 2011; Agaibi & Wilson, 2005; Kienle, Knoll, & Renneberg, 2006) whereas a lack of social support / secure social relationships is associated with PTSD, psychopathology, bad physical health, and with low social functioning in individuals with PTSD (Brewin et al., 2000; Kienle et al., 2006; Tsai, Harpaz-Rotem, Pietrzak, & Southwick, 2012; Whisman & Baucom, 2012).

In this dissertation project, we found that individuals with PTSD are impaired in the recognition of positive emotions and have a tendency to see negative emotions in neutral facial expressions, which might contribute to social or relationship problems in PTSD (MacDonald et al., 1999). A deficit in recognition of positive emotions may lead to interpersonal problems due to a perceived lack of reward for approach behaviour (Yoon et al., 2009) whereas an increased ability to detect positive emotions may help to improve sociability (Hysek et al., 2012). In fact, the ability to detect positive emotions in others correlates with the wellbeing in long-term married couples (Petrican et al., 2014). A negative interpretation bias for (neutral) facial expressions might provoke negative reactions from others and thereby confirm negative interpretations, leading to a vicious circle (Luke & Banerjee, 2013). If our findings are replicated in real-life situations outside the laboratory, it would be important to support individuals with PTSD improving their emotion recognition skills in order to help them enhance their relationship functioning. Developing emotion recognition trainings for individuals with PTSD might be a promising approach to improve recognition of positive facial expression and reduce the negativity bias. There is evidence from healthy adults, adolescents at high risk for crime, and adults with high depressive or social anxiety symptoms that emotion recognition training can reduce a negativity bias, which had a positive effect on mood, behaviour, and even changed neural activity during emotion recognition (Penton-Voak et al., 2018; Penton-Voak et al., 2013; Rawdon et al., 2018). Furthermore, emotion recognition training in individuals with traumatic brain injury (Neumann, Babbage, Zupan, & Willer, 2015; Williamson & Isaki, 2015), autism spectrum disorders (Berggren et al., 2018), and schizophrenia (T. A. Russell et al., 2006) seems promising although research about transfer to everyday situations is lacking.

In addition, the finding that alexithymia is associated with emotion recognition deficits in PTSD might be another approach for interventions. There is preliminary evidence that psychotherapy can reduce alexithymia (Beresnevaite, 2000; Tulipani et al., 2010), which in turn might improve emotion recognition skills.

4.2. For interaction partners

Relatives, close others, and health care professionals such as psychotherapists should be made aware of emotion recognition deficits and alterations in individuals with PTSD. It might be beneficial to communicate positive emotions explicitly and to avoid longer phases of neutral facial expressions. There is some evidence that certain positive facial expressions of counsellors (interest, excitement and enjoyment) are associated with a better therapeutic relationship and it is suggested that facial expression trainings for health care professionals might be beneficial (Sharpley et al., 2006). Future research should explore if awareness of facial expressive behaviour in professionals or close others can improve the relationship quality with individuals with PTSD.

4.3. For future research

Future research should test whether emotion recognition deficits in individuals with PTSD are also present in non-language based emotion recognition tasks (Pell, 2005; Wilhelm et al., 2014), in other channels of non-verbal communication, and in real interactions outside the laboratory. Further, although our findings suggest that emotion recognition deficits might be caused by distorted learning experiences while growing up in an abusive or neglecting environment, mechanisms underlying these deficits are still unknown, which should be addressed in future studies. Eye-tracking methods could be useful to explore if and how attention and avoidance are related to emotion recognition deficits. For example, we found that the “externally-oriented-thinking”-subscale of the Toronto Alexithymia Scale (Bagby et al., 2014) was associated with deficits in the recognition of negative facial emotions. An external focus of attention might consume too many cognitive resources that are needed for emotion recognition of negative emotions, which are more difficult to detect than positive ones (Calvo et al., 2014; Wingenbach et al., 2016). In addition, eye-tracking could also help to explore how dissociation disturbs emotion recognition (e.g. hindering the processing of emotional cues or further elaboration) (Oathes & Ray, 2008)).

As mentioned above, in case emotion recognition deficits in PTSD are replicated in real-life situations, future studies should explore if emotion recognition training can help to improve these skills and if interaction partners can enhance relationship quality with individuals with

PTSD by awareness of or training in facial expressions. Finally, future emotion recognition studies should control for state dissociation as it disturbs emotion recognition.

5. General conclusions

The present dissertation thesis has contributed to a deeper understanding of emotion processing in PTSD. With an emotion recognition task consisting of filmed and standardized emotion expression of short duration - reflecting situations of everyday life - individuals with PTSD underperformed in the recognition of positive and neutral facial expressions compared to healthy non-traumatized and healthy traumatized controls. Furthermore, a novel finding in the current research of PTSD is that individuals with PTSD tend to interpret neutral expressions as anger and contempt. Deficits and alterations in emotion recognition seem to be explained better by child maltreatment (and dissociation and number of traumatic events for positive facial expressions) than by PTSD diagnosis. In addition, this dissertation project filled a research gap by showing that facial mimicry in PTSD is intact. Also, the three studies add to the current body of literature in showing that alexithymia can predict deficits in the recognition of negative facial expressions in PTSD. Furthermore, consistent with PTSD literature, individuals with PTSD applied more expressive suppression during the emotion recognition task.

Given that emotion recognition is a basic socio-emotional skill important for social relationships, the found deficits might contribute to relationship problems in PTSD (MacDonald et al., 1999). If our findings are replicated in real-life situations, emotion recognition trainings might be useful to address emotion recognition problems in PTSD. Finally, future studies should test whether awareness of facial expressions in interaction partners can improve relationship quality with individuals with PTSD.

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