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„The Connection between Alexithymia and spontaneous Facial Mimicry in Emotion Recognition"

verfasst von / submitted by
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Introduction (written by Lydia Schlager)

Emotions are the foundation of a successful socialisation as they are omnipresent in each social interaction from the earliest childhood on. In our everyday life it is of great importance to detect and interpret emotional facial expressions correctly - but recognizing emotional expressions can be a perceptual challenge sometimes. Emotions as such are complex short termed, involuntary psychological and neurophysiological reactions to meaningful internal or external events and are needed in order to adapt to a changing environment. Emotion involves perceptual, visceral, and somato-motor components of experience (Panksepp, 2005). Emotion-evoking sensations can be universal, culturally, or individually specific. The so called "*basic*" emotions can be differentiated from each other and are considered as evolved reactions to fundamental topics of human life, such as losses, rejection, resentment or achievement and joy (Ekman & Davidson, 1994; Ekman & Cordaro, 2011).

At the end of the 19th century William James and Carl G. Lange proposed nearly simultaneously, but not together, an emotion theory - better known as *The James-Lange Theory*. Their assumption was, that physiological changes cause distinct emotions (Lang, 1994). This led to controversial theories and research, but not at least to the deliberation of the embodiment of emotion. Recent theories of emotion processing suggest that re-experiencing relevant components of the emotion in oneself is an important part of perceiving and recognizing emotions in the self and others (Gallese & Sinigaglia, 2011; Niedenthal, 2007; Oberman, Winkielman & Ramachandran, 2007). Consequently, the ability to adequately understand one's own emotional state is crucial in comprehending others' emotions (Scarpazza & di Pellegrino, 2018).

Complex emotional states are connected to certain overt motor behaviours (i.e. smiling) or overt physiological reactions (i.e. faster heartbeat). This relationship between emotional states and motor behaviours or physiological reactions is bi-directional. Smiling as a motor behaviour can be the cause and vice versa the product of happiness. Similarly, a faster heartbeat, for instance, can cause anxiety or be the consequence of anxiety (Frijda, 2009). It is assumed that experiencing those overt motor behaviours or physiological reactions automatically generates an understanding for the emotional state they are linked to, serving as a direct way of emotion understanding. (Gallese & Sinigaglia, 2011; Niedenthal, 2007; Scarpazza & di Pellegrino, 2018). This concept is called embodiment of emotion (Niedenthal, 2007). Consequently, this indicates that several aspects of cognition are in parts shaped by the body (Neal & Chartrand, 2011; Price & Harmon-Jones, 2015). Whereby congruence between the bodily experience and relevant external cues facilitates comprehension and fewer cognitive resources are needed. Vice versa incongruence between bodily experience and the relevant content impairs comprehension and requires more cognitive effort (Davis, Winkielman & Coulson, 2017; Gallese & Sinigaglia, 2011). A well-known example of this interaction is a study where participants had to either nod or shake their heads while learning a list of words with positive and negative valence. Participants who were nodding remembered the positive words better, whereas the ones shaking their heads remembered the negative words better. The authors called this the "*conceptual-motor compatibility mechanism*" (Forster & Strack, 1996). This and several similar studies, that followed, stress the role of the body in cognition and emotion.

Facial Mimicry (written by Lisa Meier)

For us embodiment through imitation of facial movements is the most interesting when it comes to understanding how emotional expression in others is recognized and comprehended. Besides visual and contextual cues, people also use sensorimotor simulation in order to recognise emotions, whereby activity in somatosensory and motor systems can cause activity in facial muscles (Wood, Rychlowska, Korb & Niedenthal, 2016). This imitation of the observed emotional facial expression is called facial mimicry. It occurs spontaneously, rapidly after 300 - 400 milliseconds (Dimberg & Thunberg, 1998) and mostly unconsciously (Korb, With, Niedenthal, Kaiser & Grandjean, 2014), through afferent feedback to the brain (Niedenthal, 2007). Facial mimicry can be considered a "short route" of processing emotional expressions and therefore it is an accelerator of emotion recognition (Stel & van Knippenberg, 2008). Facial mimicry seems to occur even in minimal social contexts (Likowski, Mühlberger, Seibt, Pauli & Weyers, 2008) and when the emotional facial expression of the other is not consciously perceived. Even when a very brief presentation of 30 milliseconds of an emotional expression is backward masked with a neutral expression, thus only the neutral expression is presented long enough to be consciously perceived, facial mimicry appears (Dimberg, Thunberg & Elmehed, 2000). An antecedent of facial mimicry might be neonate imitation. Newborns can imitate facial gestures, for instance mouth opening and tongue protrusion, immediately or with a delay (Meltzoff & Moore, 1994). So, this shared physical experience appears to be a very early capacity (Decety & Meyer, 2008).

A broad network of brain regions is active when it comes to perception and processing of emotional facial expressions. According to current literature the mirror neuron system (MNS), which is considered of great importance for human imitation, seems to be involved in facial mimicry (Iacoboni & Dapretto, 2006; Niedenthal, 2007). But it appears that only few parts of the MNS are related to the observed strength of facial mimicry (Likowski et al., 2012). It is assumed that the inferior frontal gyrus, the ventral premotor cortex, the inferior parietal lobule and the superior temporal sulcus are the main regions in the brain forming the human MNS (Cattaneo & Rizzolatti, 2009; Iacoboni & Dapretto, 2006).

It has been shown that facial mimicry is substantial for perceiving emotion. In line with current theories of embodied emotion, there is empirical evidence that sensorimotor activity involved in imitating facial expression modulates emotion processing (Price & Harmon-Jones, 2015; Stel & van Knippenberg, 2008; Wood et al., 2016). Increasing facial movements can intensify emotional experience and improve emotion recognition. If facial mimicry is intensified, by a skin tightening gel, emotion recognition is accelerated (Neal & Chartrand, 2011). When facial mimicry is manipulated by holding a pen with the teeth to reinforce positive emotional experience and simulating a motor reaction similar to smiling, automatic processing of happy faces is increased, whereas processing of sad faces is decreased (Kuehne, Siwy, Zaehle, Heinze & Lobmaier, 2019).

Vice versa studies found evidence suggesting that impaired facial movement results in reduced emotional experience and recognition (Davis, Senghas, Brandt & Ochsner, 2010; Obermann et al., 2007; Stel & van Knippenberg, 2008; Wood et al., 2016). Paralysis because of Botox injections in the corrugator supercilii muscle, which is responsible for frowning, reduces emotional responding to negative stimuli. It is hypothesised that Botox injections could reduce depressive symptoms in patients with major depression, as the experience of negative affect is reduced due the paralysis (Davis et al., 2010). Participants with acute facial paralysis due to Bell’s Palsy showed a significantly delayed emotion recognition, when compared to healthy controls. By the time their paralysis went into remission the delay in emotion recognition decreased as well (Storbeck, Schlegelmilch, Streitberger, Sommer & Ploner, 2019). Children with congenital bilateral facial paralysis due to Moebius Syndrome showed less psychophysiological emotional responses when they are observing social stimuli, such as emotional facial expressions. It seems that the inability to produce motor simulation influences emotion processing and thus autonomic adaption to social cues (DeStefani et al., 2019). Furthermore, the promptness and accuracy of recognizing emotional facial expressions, is reduced when facial mimicry is pointedly inhibited (Obermann et al., 2007).

All together it seems that emotion recognition relies in parts on facial mimicry. Since difficulties in understanding and perceiving emotions are part of the Autism Spectrum Disorder (ASD) the connection between autistic traits and facial mimicry is of interest. Facial mimicry appears to be atypical in people with ASD (Edwards, 2014). It was shown that lower autistic traits are connected to facial mimicry, which suggests that people with less autistic traits use more spontaneous facial mimicry while perceiving emotional expressions (Neufeld, Ionnou, Korb, Schilbach & Chakrabarti, 2016). However, recent research suggests that it is rather the co-occurring construct alexithymia, but not the primary disorder, that seems to account for the difficulties in producing and recognizing facial expression (Brewer, Cook & Bird, 2016; Cook, Brewer, Shah & Bird, 2013; Trevisan, Bowering & Birmingham, 2016) and empathy deficits in ASD (Bird et al., 2010). People on the Autism Spectrum with co-occurring high alexithymia showed significantly lower cognitive and affective empathy, as well as reduced interoceptive sensitivity compared to people on the Spectrum with low alexithymia (Mul, Stagg, Herbelin & Aspell, 2018). For this reason, we want to take a closer look at alexithymia and its connection to facial mimicry when it comes to emotion recognition.

Alexithymia (written by Lydia Schlager)

Alexithymia is derived from Greek word stems and stands for “no words for feelings”. It describes difficulties in identifying, describing and appropriately verbalizing emotions in the self and others. It was first identified as a common factor in patients with somatoform disorders (Sifneos, 1973). It subsequently became known that alexithymia is a dimensional construct which is normally distributed in the general population and should be understood as a continuous personality variable (Salimen, Saarijarvi, Aärela, Toikka & Kauhanen, 1999). To distinguish alexithymic individuals from non-alexithymic individuals, scales to assess alexithymia, such as the TAS-20, were developed and cut-off scores have been established empirically (Bagby, Taylor & Parker, 1994).

Although alexithymia is a personality trait independent from clinical diagnoses, it is related to a variety of psychiatric disorders (Donges & Suslow, 2017; Panayiotou et al., 2015). It is especially associated with psychosomatic disorders (De Gucht & Heiser, 2003), anxiety disorders (Bankier, Aigner & Bach, 2001), addiction (Morie et al., 2017) and depression (Li, Zhang, Guo & Zhang, 2015). It is assumed that alexithymia can be considered as a risk factor for developing mental disorders, since alexithymia in general is related to deficits in emotion processing on a behavioural and neurobiological level (Donges & Suslow, 2017). Individuals with high levels of alexithymia tend to feel socially inhibited, show lower relationship satisfaction, and receive lower social support (Humphreys, Wood & Parker, 2009). This enhanced interpersonal stress could be one reason for the reported association between mental health problems and alexithymia. Moreover, alexithymia is also linked to maladaptive emotion regulation that may contribute to being more vulnerable to mental illness. Yet, little is known about possible underlying mechanisms that account for the connection between psychiatric disorders and alexithymia (Leweke, Leichsenring, Kruse & Hermes, 2011). Detecting emotional expressions in others correctly is a precondition to adapt one`s own behaviour in a socially acceptable way and hence for intact interpersonal relationships. Consequently, new findings regarding emotion recognition in alexithymia could provide a basis for understanding the interpersonal problems alexithymic individuals experience (Prkachin, Casey & Prkachin, 2009).

Studies have shown that alexithymia is related to deficits in processing, recognizing, and producing facial expressions (Donges & Suslow, 2017; Kafetsios & Hess, 2019; Parker, Taylor & Bagby, 1993; Trevisan et al., 2016; Wagner & Lee, 2008). Children on the Autism Spectrum with higher levels of alexithymia tend to show less facial expressiveness while watching emotionally charged videos compared to those with low levels of alexithymia. That suggests alexithymia influences the ability to produce facial expressions (Trevisan et al., 2016). Similarly, there is evidence that healthy adults scoring high in alexithymia tend to imitate facial expressions less (Sonnby-Borgström, 2009) and are less expressive nonverbally (Wagner & Lee, 2008).

People with higher levels of alexithymia tend to make more mistakes when they are instructed to label emotions and show divergence in rating the perceived intensity of emotions. Alexithymia is especially associated with a diminished ability to detect the negative emotions anger, sadness and fear (Prkachin et al., 2009). Individuals with higher levels of alexithymia - different to those with low levels of alexithymia - show similar accuracy in detecting emotional facial expressions whether facial mimicry is blocked or not. That suggests that they underutilize sensorimotor simulation to recognize emotion (Lomoriello, Brigadoi & Sessa, 2019). Alexithymia is also associated with impaired semantic representations (Grynberg et al., 2012) and less granularity and dialecticism of negative but not positive emotions and moreover the tendency to report no emotional experience at all, after watching emotion-inducing video clips (Aaron, Snodgress, Blain & Park, 2018). These difficulties in identifying expressed emotions and the tendency to mislabel emotions or to perceive additional emotions, which were not expressed reduce the quality of social interaction (Kafetsios & Hess, 2019).

A systematic review of 22 recent studies showed that deficits in automatic emotion processing of external emotional stimuli on a neurological and behavioural level are associated with alexithymia. There also seem to be impairments in the implicit processing of emotional stimuli (Donges & Suslow, 2017). The extent to which someone focuses on the valence of emotion (negative versus positive) influences the efficiency of perceptual processing and is linked to the perceptual sensitivity to negative information in facial expressions (Barrett & Niedenthal, 2004). The amygdala seems to be a kind of precondition for experiencing negative affect. Higher levels of alexithymia are associated with a diminished amygdala activation when processing negative stimuli (van der Velde et al., 2013) and a reduced volume of the amygdala (Goerlich-Dobre, Lamm, Pripfl, Habel & Votinov, 2015; Xu, Opmeer, van Tol, Goerlich & Aleman, 2018). The amygdala is among others associated to arouse emotional reactions and the initiation of facial expressions (Barrett, Bliss-Moreau, Duncan, Rauch & Wright, 2007). Moreover, diminished amygdala activation can be associated with difficulties in identifying feelings during the presentation of negative emotional stimuli, as well as a decreased electrodermal reaction (Moriguchi & Komaki, 2013; van der Velde et al., 2013). During an emotion recognition task alexithymic individuals also showed less activity in the anterior cingulate cortex, the insula, the inferior frontal gyrus and the thalamus caudate, which are regions that are associated with face recognition, facial emotion recognition and emotional awareness (Jongen et al., 2014).

Due to the described diminished bodily and facial responses there might be deficits in somatosensory remapping and consequently fewer physiological information (Donges & Suslow, 2017). The deficits in recognizing emotions in the self and others in alexithymia could therefore be attributed to a deficient emotional embodiment and thus a lack of recreating emotions in one's own personal somatic motor system (Scarpazza & di Pellegrino, 2018).

Interoception (written by Lisa Meier)

Interoception describes the ability to sensitively percept and interpret physical signals emerging from one’s own body, such as heart rate, respiratory effort and temperature (Craig, 2002). Interoception seems to be strongly inter-dependent with emotional experience. High interoceptive ability is linked to a better performance in processing and recognizing emotional stimuli (Pollatos, Kirsch & Schandry, 2005). Individuals with higher interoceptive ability tend to have a better understanding of their own emotions, experience emotion more intensively (Herbert, Herbert & Pollatos, 2011) and show greater psychophysiological reactivity to emotional stimuli (Pollatos & Schandry, 2008). In line with that, it was found that lower levels of interoception are linked to a diminished performance in emotion recognition (Brewer et al., 2016).

Moreover, a connection between interoception and alexithymia has been shown (Mul et al., 2018). Alexithymia is associated with interoceptive deficits in healthy and clinical participants (Brewer et al., 2016). Individuals with higher alexithymic traits tend to underutilize interoceptive cues and perceive interoceptive information less accurate (Murphy, Catmur & Bird, 2018). Additionally, it has been shown that higher levels of alexithymia are often found in individuals with disorders correlated to low interoceptive ability, such as depression (Scarpazza, Huang, Zangrossi & Massaro, 2018) and eating disorders (Jenkinson, Taylor & Laws, 2018). It is assumed that highly developed interoceptive abilities are a negative predictor for alexithymia (Herbert et al., 2011). All this suggests that interoception is positively related to emotion processing and conversely negatively related to alexithymia.

Aim of the Study and Hypotheses (written by Lisa Meier)

On these grounds, it can be assumed that there is a strong link between facial mimicry, alexithymia and interoception when it comes to recognizing other’s emotions. Although there are several studies on the connection between facial mimicry and emotion recognition or alexithymia and emotion recognition, there seems to be hardly any research investigating the relation of alexithymia and facial mimicry in the general population. Research regarding somato-motor simulation of alexithymic individuals seems highly significant for theories of embodied emotion, assuming that motor reactions are an important part of emotion recognition. The main goal of this study is to integrate recent findings on facial mimicry and alexithymia in the context of emotion processing and to specifically examine the previously unsettled relationship between alexithymia and facial mimicry in a healthy population.

It must be emphasized that the aetiology of alexithymia is not quite understood yet. Since the ability to detect and interpret emotional facial expressions in other’s is of great importance in our everyday social interaction and alexithymia is linked to a reduced quality of interpersonal relationships (Kafetsios & Hess, 2019), we think it is essential to discover the underlying mechanisms of difficulties regarding these abilities. The present study was designed to shed some light on the question whether the problems recognizing emotions in alexithymia could be due to a diminished occurrence of facial mimicry. Furthermore, alexithymia co-occurs with several disorders, such as ASD, depression and psychosomatic disorders (van der Velde et al., 2013), which means knowing more about it and the surrounding processes has a relevant practical impact on clinical work. Especially when we consider that alexithymic individuals are prone to receiving lower social support (Humphreys et al., 2009), it seems important that techniques to improve alexithymia-related difficulties are developed. Subsequently, we want to explore if there are any differences in the extent facial mimicry is shown in each group, answering the question whether alexithymic individuals are imitating emotional expressions the same way non-alexithymics do. As the results could indicate that people with a high level of alexithymia have a deficit in emotion recognition because of the absence of or little facial mimicry and therefore lack in empathy.

This leads to the formulation of our first and main hypothesis (H1) as we assume that the HA group in general has less manifestation of simultaneous, automatic facial mimicry than the LA group.

As current theories of emotion processing stress the interaction of body and mind, this study further aims to confirm the reported previous results on diminished interoception in alexithymia. Interoceptive abilities are compared between the LA and HA group and set in context with problems in emotion recognition and facial mimicry. Due to the discussed connection of alexithymia and interoception we want to additionally use the interoception task as a supplementary behavioural measure of alexithymia, while previous studies predominately only used self-report data.

Consequently, this work will examine the second confirmatory hypothesis (H2) as we suppose that participants in the HA group show less accuracy in detecting their own heartbeat as a sign of lower ability of interoception.

Most previous studies investigating emotion recognition in alexithymia or facial mimicry used static stimuli. To create a more realistic representation of emotional expressions we are using high quality dynamic stimuli. Just like in previous studies, a group comparison of participants with lower (LA) and higher (HA) alexithymia scores was chosen. The current study's goal is to replicate past findings regarding differences in the accuracy of recognizing emotions between the LA and HA group using dynamic stimuli. Furthermore, we want to consider the reaction time alexithymic individuals need to detect the displayed emotions.

In line with past studies our third confirmatory hypothesis (H3) is that the HA group shows a lower accuracy in emotion recognition. Furthermore, for the fourth confirmatory hypothesis (H4) we expect that the HA group needs longer to detect an emotion.

To answer these four hypotheses, we are looking into main effects of group. Researching the questions regarding accuracy and reaction time in emotion recognition, as well as facial mimicry to emotional stimuli, we want to focus on primarily negative emotions. According to the presented literature it seems that there are stronger effects in alexithymic individuals for negative emotions (Prkachin et al., 2008; Scarpazza & di Pellegrino, 2018). Therefore, we chose the negative emotions sadness, anger, and disgust, as well as one positive emotion, happiness, for comparison.

Consequently, we formulated our fifth confirmatory hypothesis (H5) as we expect stronger deficits in recognizing negative emotions in the HA group.

Besides, after checking the main effects for group we want to explore possible differences due to the valence of the specific emotion. Does accuracy or reaction time vary among the different used emotions? Further, we will investigate if there is a differentiation between the emotions, sadness, anger, disgust, and happiness, in producing facial mimicry.

Methods

Sample (written by Lisa Meier)

A subclinical sample of only female participants in the age between 18 and 35 was envisaged for the study. To acquire participants the study was posted on several websites, such as the "*Schwarzes Brett der österreichischen Hochschülerinnenschaft*" and on social media. The post contained information about the study and a link to the online questionnaire, which had to be filled out preceding the study.

Potential participants were screened with an online questionnaire, we prepared on SoSci Survey, to be enrolled in the current study. We collected information about their gender and age. Furthermore, we assessed the prevalent alexithymia scores with the Toronto Alexithymia Scale, TAS-26 (Kupfer, Brosig & Brähler, 2001) and depressive symptomatic with the Becks Depression Inventory, BDI-II (Hautzinger, Keller & Kühner, 2009). Potential participants were then asked to report acute clinical neurological or psychiatric diagnosis or history, face paralysis or Botox injections. Participants were excluded when they showed subclinical or clinical depression with BDI-II scores above the cut-off (> 14), reported any kind of facial paralysis or past Botox injections. Moreover, individuals with an acute or past clinical neurological or psychiatric diagnosis were excluded from the study, as well as Psychology students and males. Participants were informed that based on their results in the screening they would be contacted if they matched the requirements of the study. For this matter a valid E-Mail address had to be given, under which we were able to reach the participants and potentially invite them to the testing in the laboratory.

In total 513 interested participants filled in the online screening questionnaire. The screening data were evaluated and participants meeting any of the above-mentioned exclusion criteria were excluded. We invited 124 participants to the laboratory based on their

TAS-26 scores. Literature proposes a cut-off score of > 54 to identify high alexithymia (Kupfer et al. 2001). Unfortunately, only very few of the screened participants had scores above the cut-off and we did not reach a sufficient number of individuals with clinical alexithymia scores. In order to still archive the greatest possible variance of alexithymic traits in our sample, we decided to invite all those participants with particularly low and high scores.

Eventually we tested 64 females at the age between 18 and 33 (*M* = 23.3, *SD* = 3.4). Two additional participants had to be excluded from the study since their BDI- II scores collected in the laboratory were above the cut-off (>14) and did not correspond to those of the preliminary screening. According to that, the final sample included 62 participants at the age between 18 and 33 (*M* = 23.45, *SD* = 3.42). The TAS-26 scores ranged between 21 and 66. After data collection participants were divided into two groups with a median split of the TAS-26 scores (*Mdn* = 35, *M* = 38.21, *SD* = 10.95). In the LA group below the median there were 30 participants (*M* = 28.83, *SD* = 3.91). In the HA group there were 32 participants (*M* = 46.72, *SD* = 7.78). The TAS-26 scores of three participants were at the median, therefore the distribution is uneven.

We conducted a rather homogenous sample regarding sociodemographic factors. The participants were all Austrian or German residents and most of them were students at the time of the experiment. Still, we checked for possible differences between LA and HA group regarding sociodemographic data, such as age and education.

Participants signed informed consent and were compensated with 25€ for their attendance. The financial compensation we offered was thankfully funded by a scholarship according to the *Studienförderungssgesetz (StudFG)* from the Austrian Federal Ministry of Science and Research. The study was approved by the Ethics Committee of the University of Vienna and conducted with the best interest of the participants in mind, according to the principles of the Declaration of Helsinki.

Procedure (written by Lydia Schlager)

The experiment took place in the EMG laboratory at the Faculty of Psychology in Vienna. Participants were tested individually with two female experimenters present. Each testing took between 90 to 120 minutes. Participants were seated in front of a 23-inch screen that was used to present the questionnaires and tasks. The entire procedure can be seen in Figure 1. The study was conducted as a group comparison between two groups, which we built post-hoc.

Progression of the Study

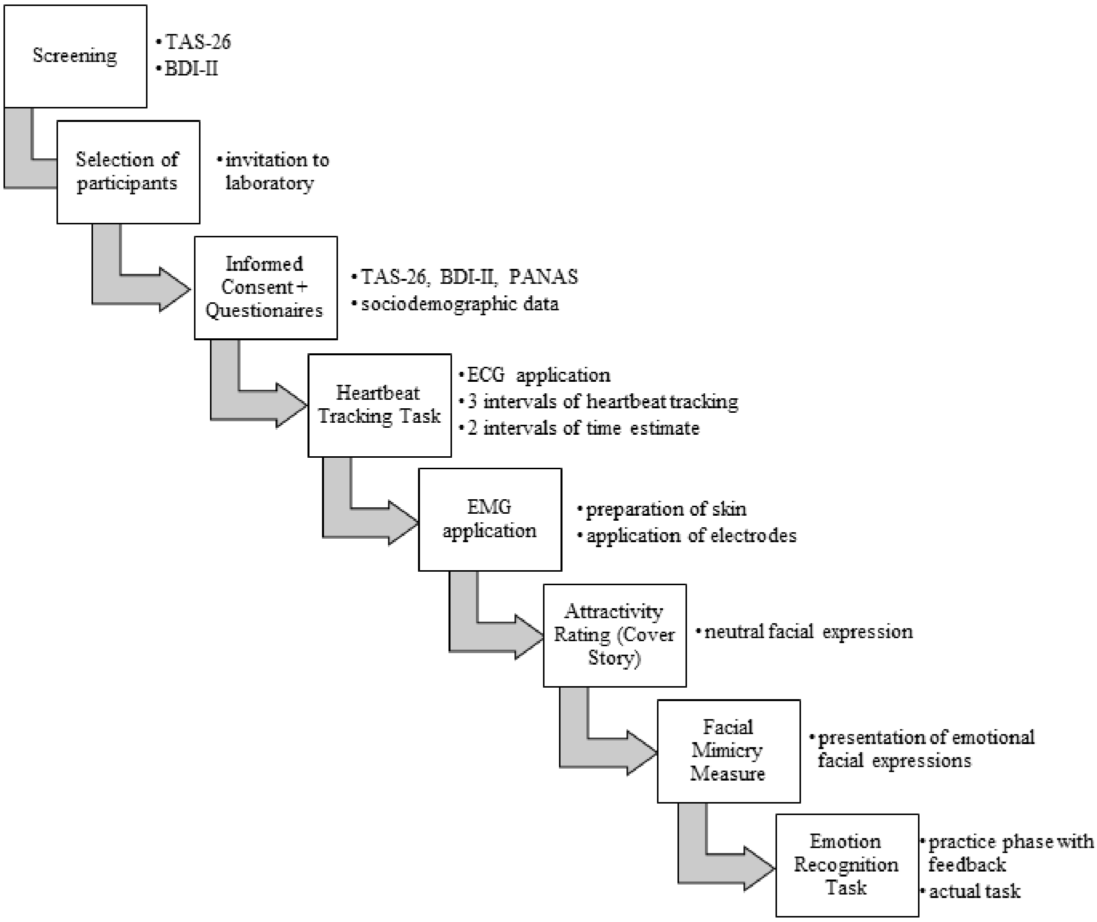

Figure 1. Procedure

First, participants were given the Informed Consent to read and sign. After that they were given time to fill in the questionnaires (TAS-26, BDI-II, PANAS, sociodemographic data). Thereupon, the ECG electrodes were attached, the Heartbeat Perception Task followed as described above and thereafter the ECG electrodes were removed. Subsequently, the skin of the participants' face was cleaned, and the electrodes were applicated for the electromyogram. The participants were not aware of the actual purpose of the experiment, to minimize the effect of influencing facial mimicry voluntarily. The participants were told that the aim of the experiment was to investigate how the expression of emotion affects the perception of attractiveness. The EMG was explained to them as a measure of blood flow in the face as an indicator for attraction. Hence participants had to rate attractiveness of the actors who`s faces were used for the facial mimicry and Emotion Recognition Task prior to the actual task. None of the participants reported that they were aware of the deception. The Emotion Recognition Task was then conducted as described above and thereafter the EMG electrodes were removed. Finally, the participants could ask questions and were informed about the purpose of the study. Afterwards they received the financial compensation.

Self-report Questionnaires (written by Lisa Meier)

Toronto Alexithymia Scale 26 (TAS-26). To measure alexithymia in the a priori screening and in the experiment, we used the TAS-26 (Kupfer et al., 2001), which is a German Version of the TAS-20 Toronto Alexithymia scale (Bagby et al., 1994). The self-report questionnaire contains 20 items with a 5-point Likert scale (*1 = "Trifft überhaupt nicht zu", 5 = "Trifft vollständig zu"*). The TAS-26 can be divided in three subscales: The first subscale "*Schwierigkeiten bei der Identifikation von Gefühlen*" surveys difficulties in identifying feelings (DIF), the second subscale "*Schwierigkeiten bei der Beschreibung von Gefühlen*" surveys difficulties in describing feelings (DDF) and the third subscale "*Extern orientierter Denkstil*" surveys external oriented thinking (EOT). All three scores can be added to an overall alexithymia-score, whereby higher scores are indicating a higher extent of alexithymic traits. Brähler, Brosig and Kupfer (2000) examined psychometric qualities of TAS-26 in a German population. Cronbach's Alpha was between r = .67 - .84 for each of the three scales, which is a satisfying to high range. Cronbach's alpha for the total score showed a high internal consistency, r = .81. The TAS-26 includes also a fourth subscale "*Reduzierte Tagträume*", which is not included in the total score due to a negative correlation with the other subscales. The TAS-20 is the most widely used device to measure alexithymia and it seems to be a reliable and valid tool in different languages (Bagby, Parker & Taylor, 2020).

Becks Depression Inventory Revision (BDI-II). In order to control for depression, because of a strong connection between depression and alexithymia, we used the BDI-II (Hautzinger et al., 2009), which is the German version of the revised Becks Depression Inventory (Beck, Steer & Brown, 1996). The self-report questionnaire contains 21 items with four statements of which the best fitting answer has to be picked (*0 = "Ich bin nicht traurig", 1 = "Ich bin traurig", 2 = "Ich bin die ganze Zeit traurig und komme nicht davon los", 3 = "Ich bin so traurig oder unglücklich, dass ich es kaum noch ertrage"*). To compute an overall score the values of each chosen statement are added and compared to certain cut-off levels. Higher scores are indicating a higher extent of depression. For our experiment we used a cut-off score of 14 to exclude participants from the study, as scores of 14 or higher suggest a mild, but clinically relevant depression. For the BDI-II Cronbach's alpha showed a satisfactorily high internal reliability, r = .84. Construct validity is considered given because of the positive correlation with construct related scales and respectively negative correlation with unrelated scales. The questionnaire differentiates well between different degrees of depression for clinical and non-clinical samples and is sensitive to change (Kühner, Bürger, Keller & Hautzinger, 2007).

Positive and Negative Affect Schedule (PANAS). To measure the participant's current positive and negative affect, we used the PANAS (Breyer & Bluemke, 2016) which is the German version of the Positive and Negative Affect Schedule (Watson, Clark & Tellegen, 1988). It has been shown that the participant's attitudes can moderate facial mimicry. When participants are in a sad mood facial mimicry is diminished and therewith the activity of their facial muscles (Likowski et al., 2011). The self-report questionnaire contains two scales with each ten adjectives describing either different positive or negative emotions, rated on a 5-point Likert scale (*1 = "gar nicht", 5 = "äußerst"*). For example, "proud" and "excited" as positive emotions and "distressed" and "guilty" as negative emotions. To compute an overall score for each of the two scales the rated values from each item in the subscale can be summarized. Higher scores indicating a more markedly positive or negative affect. For the PANAS the reliability was reviewed for both dimensions, positive and negative. Cronbach's Alpha showed the questionnaire to reach a satisfactorily high reliability, r = .89. Content validity and construct validity are considered given because of the construction based on factor analysis and the moderate positive correlation with construct related scales and respectively negative correlation with unrelated scales (Breyer & Bluemke, 2016).

The Heartbeat Perception Task (written by Lisa Meier)

Because of the earlier mentioned connection between interoception and alexithymia we used the Heartbeat Perception Task (HBT) as an objective behavioural measure of interoception (Schandry, 1981). The task was programmed using PsychoPy 3 (www.psychopy.org). All instructions were given on screen, including one trial round where the participants had the chance to ask questions and get further explanations from the experimenter when needed.

To measure the sensitivity to stimuli originating inside of the body, thus the ability of interoception, the participants were instructed to count their own heartbeat in a silent room, without using any kind of measuring-aid. For that reason, participants were asked to take of their watches and put them in their bags during the testing. In an upright seating position, participants were instructed to close their eyes and count their heartbeat without measuring their pulse for a varying interval of time (15, 25 and 35 sec.) with 30 second breaks between each trial. To rule out that the performance on the Heartbeat Perception Task is influenced by the participant's ability to estimate the time interval, according to Shah, Hall, Catmur & Bird (2016), a control condition is suggested. Participants were instructed to estimate the time of two randomized time intervals (17 and 22 sec.) alternating with the heartbeat counting intervals. The beginning and end of the intervals were indicated with a tone signal.

The actual heartbeat was measured simultaneously with an electrocardiogram (ECG) device, Mobi by TMS international (www.tmsi.com). The ECG was recorded at a 1024 Hz sampling rate with three electrodes, two attached left and right each two centimetres under the collarbone and the ground electrode attached over the left ankle. To flag the onset and end of each interval in the ECG file a manual trigger was used. To compute the accuracy we used a formula suggested by Werner et al. (2013). The counted heartbeats were compared to the actual heartbeats, whereby a smaller difference between counted heartbeat and actual heartbeat indicates a higher extent of interoceptive abilities.

Facial Mimicry and Emotion Recognition Task (written by Lydia Schlager)

Visual stimuli.

Male and female emotional Stimuli

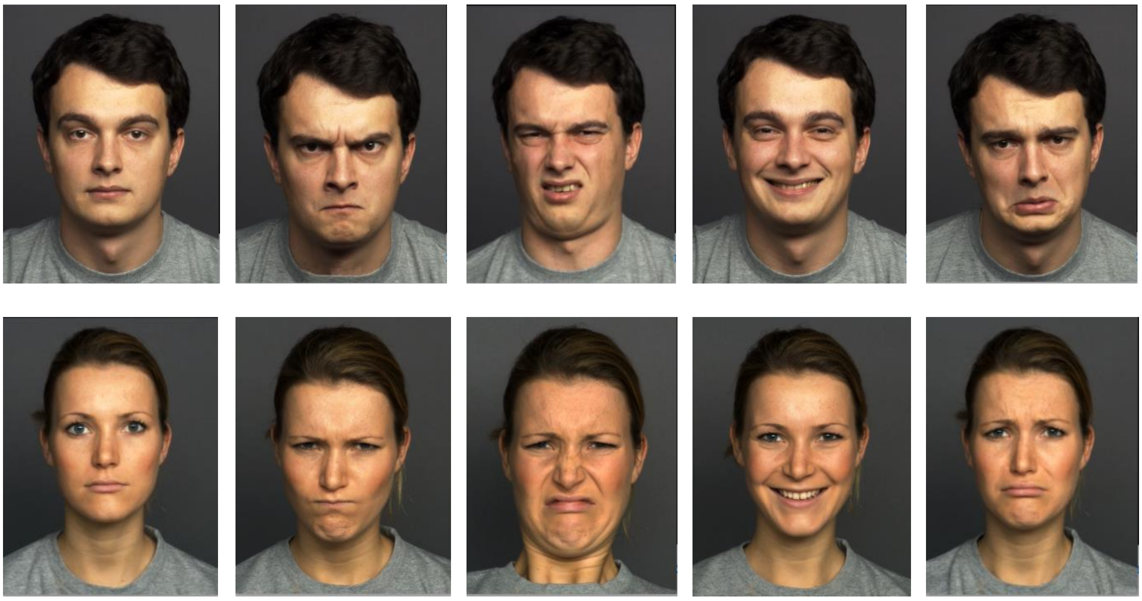

Figure 2. Examples of male and female stimuli. From left to right: Neutral (base image), Anger, Disgust, Happiness, Sadness.

For the Emotion Recognition Task dynamic stimuli were chosen over static pictures for a more natural presentation of emotional expression and as a result a more realistic representation of emotion recognition in interaction with people and more ecological validity (Trautmann, Fehr & Herrmann, 2009). We used high-quality coloured stimuli from the FACES-Database provided by the Max-Planck Institute Berlin (Ebner, Riediger & Lindenberger, 2010). In Figure 2 two examples of the stimuli as we used them in the task can be seen - each gender with the neutral baseline and the four emotional expressions. The morphed videos had a resolution of 384 × 480 pixels and were all displayed on a grey background. We selected stimuli of four male and four female actors, aged 19 to 31. Each actor demonstrated four emotional facial expressions: happiness, sadness, anger, disgust and neutrality as a baseline. In a validation study the facial expressions of our selected stimuli were rated correctly at a high percentage, especially by a sample of young women (Ebner et al, 2010). The naturalistic facial expressions change in the presentation time of two seconds from a neutral facial expression to an emotional expression. In the first second the morph appears until the full extent and is held static for the other second (Holland, Ebner, Lin & Samanez-Larkin, 2019). Before and after each stimuli a fixation cross was shown for 30 seconds. We illustrated the progression within one trial of the Emotion Recognition Task in Figure 3.

Emotion Recognition Task

30 sec Morph from neutral expression to an emotional expression 30 sec

2 sec

Figure 3. Example of a morphed video as displayed in the Emotion Recognition Task – here the emotion anger.

Task. To test if and to what extent participants imitate emotional facial expressions an Emotion Recognition Task (ERT) was programmed in PsychoPy 3(www.psychopy.org). In the first part of the task facial mimicry was measured with EMG. Participants were instructed to place both hands on the table in front of themselves and watch the presented faces on screen carefully. Continuous EMG was recorded during two blocks of 64 trials for each participant. One block contained 32 trials (8 faces x 4 emotions), therefore each stimulus was presented twice.

In the second part of the experiment data on reaction time and accuracy was collected during ERT. Participants were instructed to try to recognize the shown emotion and name it as fast as possible. For that participants needed to use the keypad, as they had to press the key that corresponded with the detected emotion. The keys A, S, H and J were used to each indicate one of the displayed emotions, for example A = happy, S = angry, H = sad and J = disgusted. For instance, participants were instructed to use the left middle and index finger to press A and S and the right index and middle finger to press H and J. Since a right hemispheric dominance in emotion recognition is assumed (Dimberg & Petterson, 2000), a possible influence of with which hand participants press the keys should be minded. For this reason, the correspondence of keys and emotions was counterbalanced over the participants. Consequently, six different versions of the task were programmed. A sheet with correct key-emotion combinations for each participant were illustrated on, was always placed in front of the keypad during the task. Prior to the actual trials the participants had to do 24 practice trials. For the practice trial visual stimuli of other actors than in the actual task, were used to prevent habituation. During practice trials participants got feedback for correctness and their reaction time. After that 128 trials in four blocks (8 faces x 4 emotions x 4 blocks) had to be completed, therefore each stimulus was represented four times.

Electromyography (EMG) (written by Lisa Meier)

Facial muscle activity from the corrugator supercilii (CS) and the zygomaticus major (ZM) was measured with Electromyography (EMG), using Ag/AgCL electrodes in a bipolar montage on each muscle. A ground electrode was placed on the midline of the upper forehead, as described in the guidelines by Fridlund and Cacioppo (1985). We placed the electrodes on the left side of the face in line with the hypothesis that stronger emotion related facial reactions are shown there (Dimberg & Petterson, 2000). To cover up that facial muscle activity was measured, participants were told that the electrodes were used to measure blood flow in the face as an indicator for perceived attraction. As each visual stimulus was coded with a number referring to the gender of the actor and the displayed emotion, we used these numbers to mark the onset and end of the corresponding stimulus in the EMG file. Therefore, the EMG file contained additional information of what gender and emotion was shown during the measured facial reaction.

EMG Data Processing (written by Lisa Meier)

Data was sampled with impedances below 20 kOHM at 1024 Hz. The TMS International Refa8 amplifier and the Portilab2 software (www.tmsi.com) were used. The EMG data was preprocessed with Matlab R2014b (www.themathworks.com) and partially we used EEGLAB toolbox (Delorme & Makeig, 2004). After a 20 to 400 Hz bandpass and a 50 Hz Notch filter were applied, data were adjusted and smoothed with a 40 Hz low-pass filter. From 500 ms before to 2000 ms after stimulus onset (SO) epochs were extracted. Data from SO onwards were expressed as percentage of the baseline (preceding 500 ms).

Separately for each participant outlier trials were identified and excluded. They were defined as outlier trials, if their average amplitude in the baseline or post-stimulus-onset period exceeded by more than two SDs the average amplitude of all baselines or trials (for a similar procedure see Korb et al., 2014, 2015, 2019; Trautmann et al., 2009). On average, 19.5 trials out of 64 trials per participant were excluded (*SD* = 4.8).

EMG data was averaged over four windows of 500 ms for statistics.

Statistical Analysis (written by Lisa Meier)

Data analysis was conducted with IBM SPSS Statistics Version 25 (www.ibm.com/analytics/spss-statistics-software). To create two groups (LA and HA) participants were divided by a median split based on their TAS-26 Scores, as we dichotomized the TAS-26 data into the categories low versus high. To investigate between-group differences regarding the scores on the self-report questionnaires we used independent sample *t*-tests. Since some of the variables in our sample did not follow a normal distribution, we partly used the Mann-Whitney-U-Test as a non-parametric method to investigate mean differences.

The actual heartbeats during the three heartbeat counting intervals recorded via ECG, were counted using the HRVtool (marcusvollmer.github.io/HRV/) in Matlab. The accuracy in detecting the heartbeat as an indicator of interoceptive ability was computed with the following formula by Schandry (1981): $\sum_{i=1}^{3}(1 - {}^{1}\frac{nai-nri}{nai})$. The Heartbeat Task score, which is based on the absolute value of the difference between counted heartbeats and actual heartbeats, can range between 0 and 1. Whereby a higher score indicates higher accuracy and thus higher interoceptive ability (Werner et al., 2013). To investigate between-group differences regarding the Heartbeat Task scores between LA and HA we again used an independent sample *t*-test. To examine the connection between interoception and alexithymia a correlation analysis was conducted between the TAS-26 scores and the degree of interceptional ability as calculated from the Heartbeat Perception Task. Since some of the variables in our sample did not follow a normal distribution, we used the Spearman correlation as a non-parametric measure of rank correlation.

To compute variables for accuracy and reaction time in the Emotion Recognition Task data of the trials was averaged separately for gender and emotion. The behavioural data was

[1] i = Number of time interval (15, 25, 35)
na = Number of actual heartbeats
nr = Number of reported heartbeats

analysed, using a mixed factor analysis (ANOVA) for repeated measures. A Repeated Measures ANOVA (rmANOVA) on accuracy was executed with group (two levels: LA and HA) as between-subject variable and emotion (four levels: angry, disgusted, happy and sad) and gender of stimuli (two levels: male and female) as within subject variables. The same way, a rmANOVA was conducted on reaction time with group (two levels: LA and HA) and between-subject variable and emotion (four levels: angry, disgusted, happy and sad) and gender of stimuli (two levels: male and female) as within-subject variables, the results were adjusted for a lack of sphericity with Greenhouse-Geisser.

EMG activity was analysed for each muscle, as they are separate within-subject variables, to investigate the extent of spontaneous facial mimicry. A rmANOVA with group (two levels: LA and HA) as a between-subject variable and with emotion (four levels: angry, disgusted, happy and sad) and time (four levels: 500 ms, 1000 ms, 1500 ms and 2000 ms from stimulus onset) as within-subject variables was computed separately for zygomaticus major and corrugator supercilii. This approach is in accordance with previous literature (Scarpazza et al., 2018).

Results (written by Lydia Schlager)

To check if there are any differences regarding sociodemographic factors between the groups, independent sample *t*-tests were conducted. The LA and HA group did not differ significantly regarding their age (t (60) = 1.77, p = .082) or education, t (60) = -.315, p = .754. Importantly, the means of the BDI-II were below the cut-off score in both groups, LA (M = 2.67, SD = 2.78) and HA (M = 6.56, SD = 4.11).

Self-report Questionnaires

Differences between the groups regarding the self-report questionnaires (TAS-26, BDI-II, PANAS) were analyzed with *t*-tests for independent samples. As reported in Table 1, the two groups differed significantly regarding all used self-report questionnaires and their subscales. The first TAS-26 subscale DIF, the BDI-II scores and the PANAS negative score were not normally distributed. Anyhow, for a better overview of the comparative questionnaire data the results of the parametric tests are displayed, since they are considered quite robust. The HA group showed significantly higher scores in all TAS-26 subscales, as well as in the BDI-II. The LA group had higher PANAS positive scores. Accordingly, the HA group scored higher on PANAS negative scale.

Since the TAS-26 total score and the PANAS negative score were not normally distributed Spearman correlations were calculated. There was a positive correlation between PANAS negative score and the TAS-26 total score (r_s=.47, p < 001), the first TAS-26 subscale DIF, r_s = .57, p < .001, and the second TAS-26 subscale DDF, r_s = .34, p = .007. No significant correlation with the third TAS-26 subscale EOT was found, r_s = .21, p = .108. Accordingly, there was a negative correlation between PANAS positive score and TAS-26 total score (r_s= -.38, p = .002), DIF (r_s = -.29, p < .001), DDF(r_s = -.30, p = .020) and EOT (r_s = -.39, p = .002).

A high positive correlation between the TAS-26 score and the BDI-II score (r_s = .53, p < .001) was found, as higher TAS-26 scores were linked to higher BDI-II scores. The TAS-26 subscales DIF and DDF correlated highly positive with BDI-II scores, DIF (r_s = .55, p < .001) and DDF (r_s = 55, p < .001). In contrast, the subscale EOT did not correlate with BDI-II scores, r_s =.12, p = .363. There was also a highly significant positive correlation of BDI-II scores and PANAS negative scores, r_s = .50, p < .001 and a significant negative correlation with PANAS positive scores, r_s = -.26, p = .038.

Table 1

Comparative Questionnaire Data of the LA and HA groups

	low alexithymia *M* (*SD*)	high alexithymia *M* (*SD*)		
n	30	32		
Age	24.23 (3.66**)**	22.72 (3.07)		
TAS-26			*t*	*p*
total score	28.83 (3.1)	46,72 (7.78)	11.54	>.001*
DIF	8.77 (1.79)	15.88 (3.93)	9.25	>.001*
DDF	8.10 (2.07)	15.81 (4.19)	9.28	>.001*
EOT	11.97 (3.10)	15.03 (2.85)	4.39	>.001*
BDI-II	2.67 (2.78)	6.56 (4.11)	4.39	>.001*
PANAS				
positive	36.40 (5.2)	32.25 (5.52)	3.05	.003*
negative	11.97(1.88)	15.38 (5.35)	3.39	.002*

Note. *t*-values for non-homogeneous variances. TAS-26 = Toronto Alexithymia Scale, DIF = difficulty in identifying feelings, DDF = difficulty in describing feelings, EOT = externally orientated thinking, BDI-II = Beck's Depression Inventory, PANAS = Positive and Negative Affect Schedule.

Interoception

Testing the second confirmatory hypothesis (H2), suggesting participants with higher TAS-26 scores show less accuracy in detecting the own heartbeat, we used a *t*-test for independent samples. There was no significant difference in the Heartbeat Task scores between the LA and HA group, $t(60) = 0.14$, $p = .889$.

We further analysed the correlation of the Heartbeat Task score and the TAS-26 score. According to the Kolmogorov-Smirnov Test, the Heartbeat Task scores were normally distributed ($p > .05$), but the TAS-26 scores were not ($p < .05$). Consequently, a Spearman correlation was calculated. There was no significant correlation between the Heartbeat Task score and the TAS-26 score, $r_s = .14$, $p = .275$. As displayed in Table 2, there were no significant correlations between the Heartbeat Task score and the TAS-26 subscales either. However, the Heartbeat Task score and the control variable, the participants ability to estimate the duration of time intervals, correlated significantly, $r_s = .40$, $p = .001$. There was no correlation between the Heartbeat Task score and BDI-II total score $r_s = -.08$, $p = .518$. The Heartbeat Task score and the sum of heartbeats had a significant negative correlation, $r = -.30$, $p = .017$.

Table 2

Correlations of TAS-26 subscales and Heartbeat Task Score

	DIF	DDF	EOT	TAS-26 total
	r_s, p	r_s, p	r_s, p	r_s, p
HBT	.12, .361	.17, .185	.08, .529	.14, .275

Note. DIF = difficulties identifying feelings, DDF= difficulties in describing feelings, EOT= externally orientated thinking.

Emotion Recognition

Testing the third confirmatory hypothesis (H3), if participants with higher TAS-26 scores are less accurate in emotion recognition, a Repeated Measures ANOVA was executed, with group (two levels: LA and HA) as between-subject variable and emotion (four levels: angry, disgusted, happy and sad) and gender of stimuli (two levels: male and female) as within-subject variables. For this analysis we had to exclude three additional outliers, because of three standard deviations outside from the mean. To analyse the accuracy in emotion recognition, means of correct answers for each emotion over all trials were computed.

The results of the rmANOVA were adjusted for a lack of sphericity with Greenhouse-Geisser and showed a main effect for emotion, $F(1.91, 108.71) = 78.39$, $p < .001$, partial $\eta^2 = .58$, and for the gender of stimuli, $F(1, 57) = 20.51$, $p < .001$, partial $\eta^2 = .27$. There was no effect for group, $F(1, 57) = 0.27$, $p = .600$. The interaction of emotion x gender was significant, $F(2.13, 121.21) = 89.79$, $p < .001$. There was no interaction for emotion x group, $F(1.91, 108.71) = 0.43$, $p = .733$, or group x gender, $F(1, 57) = 0.25$, $p = .620$. Post hoc tests as displayed in Figure 4, revealed that there were differences in accuracy between the emotions.

Accuracy of Emotion Recognition for each Emotion

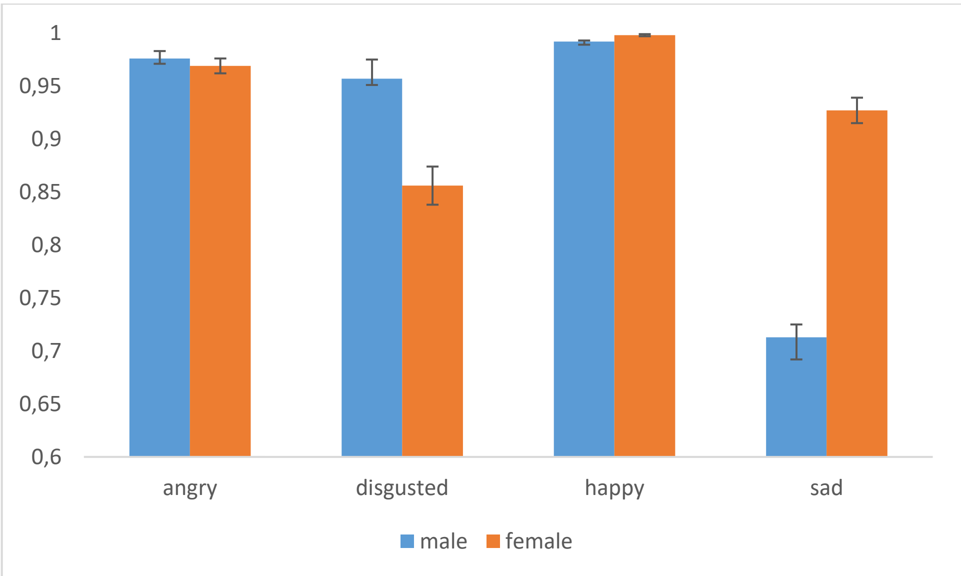

Figure 4. Accuracy of emotion recognition for each emotion separated for male and female stimuli. Errorbars = Standard Error.

Reaction Time

To test whether the HA group needs longer to detect the correct emotion (H4), a rmANOVA on reaction time was conducted, with group (two levels: LA and HA) as between-subject variable and emotion (four levels: angry, disgusted, happy and sad) and gender of stimuli (two levels: male and female) as within-subject variables. The results were corrected with Greenhouse-Geisser. The results reveal a main effect for emotion $F(2.61, 148.79) = 199.66$, $p < .001$, partial $\eta^2 = .78$, and an interaction of emotion x gender $F(2.26, 128.66) = 15.17$, $p < .001$, partial $\eta^2 = .21$. But there was no group effect $F(1, 57) = 0.10$, $p = .750$, nor any interaction for emotion x group $F(2.61, 148.79) = 0.34$, $p = .771$.

The results show that there was a difference in reaction time for the four different emotions, as illustrated in Figure 5. Post Hoc tests as displayed in Table 3, revealed that participants needed longer to recognize sad expression (*M* = 1.75), than disgusted (*M* = 1.52) and then angry expressions (*M* = 1.42). They were fastest in detecting happy expressions (*M* = 1.12).

Reaction Time of Emotion Recognition for each Emotion

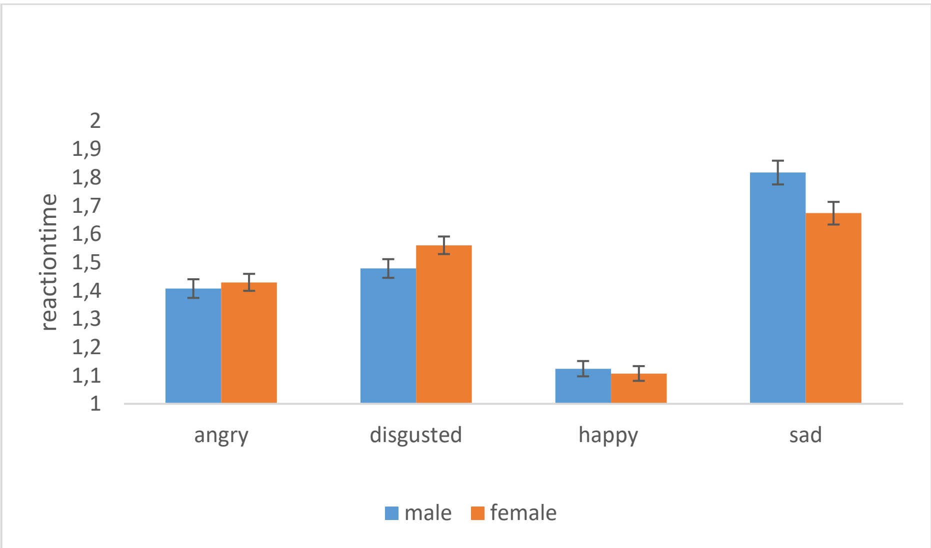

Figure 5. Reaction time for each emotion, separated for male and female stimuli during the Emotion Recognition Task.

Table 3

Post-Hoc Tests for Emotion

	mean difference (SE)	*confidence interval*	*p value*
accuracy			
happy vs angry	.02 (.00)	.01, .03	<.001*
happy vs disgusted	.09 (.01)	.06, .12	<.001*
happy vs sad	.18 (.02)	.14, .22	<.001*
angry vs disgusted	.07 (.01)	.03, .10	<.001
angry vs sad	.16 (.02)	.11, .20	<.001*
sad vs disgusted	-.09 (.02)	-.14, -.05	<.001*
reaction time			
happy vs angry	-.32 (0.2)	-.37, -.25	<.001*
happy vs disgusted	-.41 (0.3)	-.49, -.34	<.001*
happy vs sad	-.64 (0.3)	-.73, -.55	<.001*
angry vs disgusted	-.10 (.02)	-.16, -.03	.001
angry vs sad	-.33 (.03)	-.41, -.25	<.001*
sad vs disgusted	.23 (.03)	.16, .30	<.001*

Note. Post-Hoc Tests, adjusted for multiple comparisons (Bonferroni).

Facial Mimicry

Due to technical problems there was no EMG recording for four participants. Consequently, 58 participants were included in the EMG analysis, (LA = 26, HA = 31). EMG data was averaged for each participant per emotion before data analysis. A rmANOVA with groupfactor (two levels: LA and HA) as a between-subject variable and emotion (four levels: angry, disgusted, happy and sad) and time (four levels: 500 ms, 1000 ms, 1500 ms and 2000 ms from stimulus onset) as within-subject variables was computed separately for zygomaticus major and corrugator supercilii.

Zygomaticus Major. The ANOVA revealed main effects for time, $F(1.38, 76.02) = 12.22$, $p < .001$, partial $\eta^2 = .18$, emotion, $F(1.38, 72.64) = 15.14$, $p < .001$, partial $\eta^2 = .22$, and a significant interaction of emotion x time, $F(1.58, 86.69) = 12.30$, $p < .001$, partial $\eta^2 = .18$. This indicates that the participants showed measurable facial mimicry. There was no significant effect for group, $F(1, 56) = 0.10$, $p = .754$.

Post hoc tests as displayed in Table 4, revealed that there was a difference between happiness and the other three emotions. Anger, disgust, and sadness did not differ in the facial reactions. The ZM activation 500 ms and 1000 ms after stimulus onset differed significantly from every other level of time. ZM activation was highest at 2000 ms after stimulus onset. Post hoc tests are displayed in Table 5.

Corrugator Supercilii. There was also a main effect for emotion, $F(2.28, 125.51) = 39.71$, $p < .001$, partial $\eta^2 = .42$, but no effect for time, $F(1.35, 74.03) = 0.98$, $p = .687$. A significant interaction for emotion x time was found, $F(2.74, 150.88) = 24.99$, $p < .001$. partial $\eta^2 = .31$. There was no significant effect for group, $F(1, 55) = 0.54$, $p = .562$. The CS activation did not differ significantly between the four levels of time.

The post hoc tests as displayed in Table 4, revealed that the participants showed significantly less activity in the CS for happy stimuli than for angry, sad and disgusted stimuli. Vice versa participants showed significantly more activation in the ZM for happy stimuli than for angry, sad, and disgusted stimuli. These results are similarly displayed in Figure 6. It is shown that the activation of the CS even decreases below baseline after the onset of happy stimuli.

Table 4

Post-Hoc Tests for Facial Mimicry

	mean difference (SE)	*confidence interval*	*p value*
Corrugator			
happy vs angry	-8.51 (1.20)	-11.75, -5.27	<.001*
happy vs disgusted	-9.33 (1.20)	-12.74, -5.92	<.001*
happy vs sad	-9.02 (1.10)	12.06, -5.92	<.001*
angry vs disgusted	-0.82 (0.79)	-2.99, 1.36	1
angry vs sad	-0.51 (0.83)	-2.79, 1.76	1
sad vs disgusted	-0.31 (0.76)	-2.38, 1.76	1

Zygomaticus			
happy vs angry	9.03 (2.1)	3.30, 14.78	<.001*
happy vs disgusted	7.37 (1.8)	2.35, 12.19	.001*
happy vs sad	8.55 (2.2)	2.64, 14.46	.001*
angry vs disgusted	-1.76 (0.86)	-4.12, 0.60	.277
angry vs sad	-0.48 (0.57)	-2.00, 1.07	1
sad vs disgusted	-1.27 (0.82)	-3.50, 0.96	.747

Note. Adjusted for multiple comparisons (Bonferroni).

EMG Data separated for each Emotion

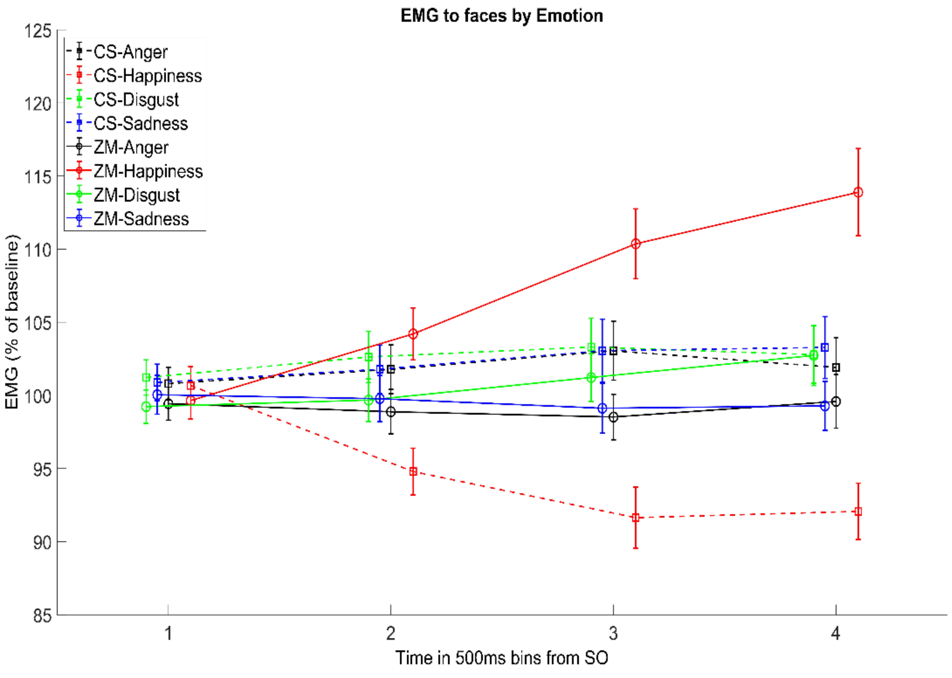

Figure 6. EMG data of CS activation and ZM activation for each emotion at the four levels of time from stimulus onset. The most distinct ZM activation and CS deactivation can be seen for the emotion happy, evolving from 500 ms until 2000 ms from SO. CS = Corrugator supercilii, ZM = Zygomaticus major, SO = Stimulus Onset.

Table 5

Post-Hoc Tests for Facial Mimicry at different points of time

	mean difference (SE)	*confidence interval*	*p value*
Zygomaticus			
500ms vs 1000ms	-1.13 (0.39)	-2.20, -0.05	.035
500ms vs 1500ms	-3.13 (0.77)	-5.24, -1.03	.001
500ms vs 2000ms	-5.12 (1.31)	-8.69, -1.55	.001
1000ms vs 1500ms	-2.01 (0.57)	-3.56, -0.46	.005
1000ms vs 2000ms	-3.99 (1.22)	-7.34, 0.64	.011
1500ms vs 2000ms	-1.99 (0.86)	-4.34, 0.37	.149

Note. Adjusted for multiple comparisons (Bonferroni).

Discussion

The aim of this study was to investigate the connection between alexithymia, interoception and facial mimicry during emotion recognition. Since we suspected differences regarding interoceptive abilities, accuracy and reaction time in emotion recognition and the extent of facial mimicry dependent on the level of alexithymia, the LA and HA groups were compared. We expected an advantage for LA in the Heartbeat Perception Task and the Emotion Recognition Task, as well as a more distinctive manifestation of corresponding facial mimicry. However, the results showed no significant differences between the groups regarding our hypotheses.

Self-report Data (written by Lisa Meier)

LA and HA group were significantly divergent in all used self-report data. The high positive correlation between TAS-26 scores and BDI-II scores we found in the present study is in line with previous findings suggesting a strong co-occurrence of alexithymia and depression (Hemming, Haddock, Shaw & Pratt, 2019; Panayiotou et al., 2015). Alexithymia, as assessed by the TAS-20, seems to be prevalent in nearly one-half of individuals diagnosed with major depression. Whereby alexithymia scores decreased as soon as the depression went into remission (Saarijarvi, Salminen & Toikka, 2001). This positive correlation of the DIF and DDF scales with depression seems to appear especially when depression is self-reported too (Li et al., 2015). Similarly, this could be displayed in our data as we found strong connections between DIF and DDF and BDI-II scores. Likewise, self-reported PANAS correlated highly significant with BDI-II scores. It could be considered as problematic that people with high alexithymia scores often do have depression scores above the BDI cut-off. We excluded participants with high depression scores to keep the influence of depression low. This can be seen as an artificial separation of two interrelated factors (Hemming et al., 2019). Nonetheless, there is evidence that participants with acute and remitted depression show impaired emotion recognition (Zwick & Wolkenstein, 2017) and reduced emotional reactivity, including facial mimicry (Bylsma, Morris & Rottenberg, 2008). That indicates that difficulties regarding emotion recognition and diminished facial mimicry in participants with high alexithymia and co-occurring depression cannot be explained clearly by one distinct variable. Future research must take both factors into account and control for possible interactions between them and confounding influence on the outcome variable. It is still in question whether alexithymia is a risk factor for developing depression or simply a co-occurring construct and how those two constructs are entangled with each other (Hemming et al., 2019). Longitudinal research should be conducted to investigate the stability of alexithymia and its relation to co-occurring psychopathology.

Generally, the evaluation by use of self-report questionnaires is clearly limited. Especially for alexithymia, as alexithymic individuals are characterized by their difficulties describing their own psychological states (Marchesi, Ossola, Tonna & De Panfilis, 2014). As reported above, we found that the HA group had significantly higher scores in the PANAS negative scale and significantly lower scores in the PANAS positive score. In addition, significant positive correlations were found between PANAS negative and the TAS-26 subscales DIF and DDF. Correspondingly, PANAS positive and DIF, DDF but also the subscale EOT correlated significantly negative. These reported coherences could have multiple explanations. It is possible that higher TAS-26 scores, increased negative affective state and decreased positive affective state are explained by a higher manifestation of depression. Another explanation might be a negative response bias in self-report.

According to a recent study the TAS-20 is rather measuring negative affect than alexithymia. The differences in TAS-20 scores among various clinical disorders, such as depression and panic disorder, disappear when controlled for effects of anxious and depressive symptoms (Marchesi et al., 2014). This is in line with the remarkable disparities in the PANAS negative scores between LA and HA in our study. That brings us back to the finding that negative affect itself reduces the extent one uses facial mimicry (Likowski et al., 2011). Possibly, it is rather the negative affect than alexithymia itself that is measured with the TAS-26 and has an impact on facial mimicry and thus emotion recognition. That reinforces the importance of attempting to find an additional way of assessing alexithymia independent from self-report in future research. However, the advantage of the TAS-26 is that it is an effective and simple tool to measure alexithymia especially for research purposes. It is suggested to include an observer rated tool to diminish the correlation with self-reported negative affect and make the assessment of alexithymia more valid (Montebarocci & Surcinelli, 2018).

Interoception (written by Lisa Meier)

First, we want to discuss our confirmatory hypotheses. LA and HA participants did not show differences in the Heartbeat Task score, which was used as an indicator for interoceptive ability. This leads to the conclusion that in our sample interoception was not remarkedly decreased in individuals with higher levels of alexithymia, as we hypothesized in H2. The results of the correlation analysis between the TAS-26 and the Heartbeat Task scores showed no significant correlation. It is important to note that the ability to count the own heartbeat correlated significantly with the ability to estimate time intervals correctly. This indicates that people with a higher accuracy in counting seconds and thus a better ability to estimate time intervals, have a higher accuracy in detecting their own heartbeat. Additionally, there seems to be an influence of the heart rate, as participants with a lower heart rate had a higher accuracy in detecting their heartbeat. Moreover, another influencing factor decreasing the validity of the Heartbeat Perception Task is, that the accuracy in heartbeat detection might also reflect an individual assumption of the heart rate at rest (Zamariola, Maurage, Luminet, & Corneille, 2018). This is in line with an observation we made in our sample – the heart rate had an influence on the accuracy with which participants estimated their own heartbeat. Participants who were noticeably better in the task than others had a lower heart rate and often reported that they are either meditating regularly or are sporty. It may be concluded that they have a better feeling for or a better knowledge about their pulse at rest.

Furthermore, the LA and HA group differed significantly in their depression scores. This is an important limitation for the interpretation of all comparative data, as we can assume an influence of depression on the correlation between the Heartbeat Task score and the TAS-26. Due to the non-normal distribution of some of the self-report data, we could not use partial correlation analysis. However, since the BDI-II scores have a minor tendency to a negative correlation with the Heartbeat Task score, while BDI-II scores and the TAS-26 scales correlate positively, it can be anticipated that the correlation between the Heartbeat Task score and the TAS-26 total score, as well as the subscales DIF and DDF would increase after controlling for an influence of the BDI-II scores.

The relationship between interoception and alexithymia is controversial, as literature suggests both, decreased and increased interoception in alexithymia. As mentioned before, a negative correlation between interoception, measured with the Heartbeat Perception Task, and the TAS-20 subscales ``difficulty in identifying feelings``(DIF) and ``difficulty in describing feelings``(DDF) was found (Herbert et al., 2011). In a recent study with participants on the Autism Spectrum too, higher levels of alexithymia measured by the TAS-20 were correlated with lower scores in the HBT, thus decreased interoceptive ability (Shah et al., 2016). To the contrary, a positive correlation between interoception assessed with a self-report questionnaire (SAQ) and the TAS-20 subscales DIF and DDF was found (Longarzo et al., 2015). High alexithymic individuals were also found to score higher in the HBT, indicating more interoceptive ability and seemed to be more driven by their own physiological arousal during intertemporal decision-making than low alexithymic individuals (Scarpazza, Sellitto & di Pellegrino, 2017).

This seems to be inconsistent with the recent literature we presented, suggesting a negative correlation between alexithymia and interoception. But on the other hand, it is currently assumed that individuals with alexithymia tend to focus strongly on physiological signals, as alexithymia is linked to psychosomatic disorder. It was shown that alexithymic individuals have a stronger awareness and neuronal activation for visceral sensations than the non-alexithymic group (Kano & Fukudo, 2013). It is believed that due to the impaired emotion processing and emotion regulation, alexithymic individuals are rather focussing on bodily reactions that are connected to emotional arousal and tend to misinterpret them, leading to somatisation and hypochondria (De Gucht & Heiser, 2003). This could explain the increased interoception found in alexithymic individuals and why they pay less attention to emotional processes on a cognitive-experiential level (Kano & Fukudo, 2013). However, in the present study no correlation was found between HBT score and TAS-26 subscales and it is not possible to draw conclusions from our data about a connection.

A three-dimensional model of interoception was proposed. It subdivides interoception into three possibly independent components: interoceptive sensibility, interoceptive sensitivity or accuracy and interoceptive awareness. Whereby interoceptive sensibility describes the tendency to be internally focused, interoceptive sensitivity describes the objective accuracy in detecting bodily signals and interoceptive awareness describes the metacognitive awareness of ones' objective accuracy (Garfinkel & Critchley, 2013). The Heartbeat Perception Task as we used it, is believed to rather measure interoceptive sensitivity, than an overall interoceptive ability. It is thinkable that alexithymia is associated with deficits in a certain component, but unrestricted abilities in the remaining components of interoception. Consequently, it seems possible that we could not find a connection between alexithymia and our measure of interoception, because it measured only one of the three components.

A clearer understanding of the association between impairments in interoception and alexithymia across the three dimensions is needed. Further research is needed to investigate other types of interoceptive ability in the non-cardiac domain, such as gastro-intestinal functioning and respiration. Since alexithymia is characterized by a deficit of emotional awareness the link to the interoceptive awareness component could be of special interest. Additionally, upcoming studies could use more differentiated tools, such as the observer-rating scales like the Toronto Structures Interview for Alexithymia (TSIA, Bagby, Taylor, Parker & Dickens, 2006) and a performance-based measure of alexithymia should be developed. This could help to shed some light onto the complex interaction of alexithymia and interoception. Especially, when we consider that for alexithymia too, a multi-dimensional model has been proposed (Goerlich-Dobre, Bruce, Martens, Aleman & Hooker, 2014).

Accuracy and Reaction Time (written by Lydia Schlager)

Even if at a theoretical level the association between alexithymia, emotion recognition and facial mimicry seems to be valid and plausible, our data could not support it. In the analysed sample there were no significant differences in accuracy of emotion recognition between HA and LA, as we hypothesized in H3. So, it seems that participants in our sample with higher scores of alexithymia had no remarkable difficulties in recognizing the displayed emotions when compared to the participants with lower alexithymia scores. There was also no interaction between group and emotion or group and gender of the stimuli. What could be displayed were differences in the accuracy of emotion recognition between happy, angry, sad, and disgusted countenances across the two groups. Nearly all happy stimuli were recognized correctly, which can be interpreted as a ceiling effect. Angry stimuli were detected correctly a little less frequently. Disgusted and sad stimuli seem to be more difficult to recognize. Whereby sad stimuli were detected with the lowest accuracy. There was also a difference regarding the gender of the stimuli: female disgusted stimuli were detected with less accuracy than male. Whereas sad expressions in male stimuli were recognized with less accuracy than female stimuli.

In addition, contradicting H4 the reaction time did not differ significantly between the two groups neither. Participants with higher alexithymia scores did not need longer to detect the displayed emotion. There was also no interaction between group and emotion or group and gender of the stimuli. However, the data again suggests differences in reaction time for different emotions across both groups. The shortest reaction time was measured for happy stimuli. Slightly more time was needed to recognize angry facial expressions. Participants again were slower in recognizing disgusted expressions while the longest reaction time was measured for sad expression. Here we found effects for the gender of the stimuli as well: female disgusted stimuli were detected slower than male stimuli, whereas sad expressions in male stimuli were detected slower than in female stimuli.

One explanation for the best accuracy and fastest reaction time for happy stimuli might be that it was the only positive emotion used in the task. Detecting happy stimuli could have been easier due to the simple fact, that when several stimuli are presented, all belonging to the same category (i.e. negative emotions), the one odd stimulus (i.e. positive emotion) stands out and is recognized faster (Treisman & Souther, 1985) Additionally, one study investigating emotion recognition, reported difficulties recognizing the emotions anger, fear and particularly sadness in participants with high alexithymia, whereas no effect for the emotion happiness was found. There was also a negative correlation between the TAS-20 scores and the ability to detect fear and sadness (Prkachin et al., 2009). We did not find difficulties specific to participants with high alexithymia in detecting anger and sadness. Still, our findings suggest likewise that sadness was the most difficult emotion to detect, since it has the lowest accuracy and reaction time in general.

Current literature proposes that negative and positive emotions are processed in different ways. There is evidence that there are distinct emotion recognition traits or mechanisms for negative emotions and the recognition of happiness, although the traits are not completely separate (Suzuki, Hoshino & Shigemasu, 2010). A recent fMRI study investigated emotion specific Mirror Neuron System activation, during the perception of dynamic stimuli of facial expressions and facial expression production. It was shown that happy stimuli evoke an activation of the MNS in the right temporal pole, whereas angry facial expressions correlated with neural activation in the left inferior frontal gyrus, pars orbitalis, and the cerebellum. The right limbic system was also more activated for happy expressions, which could be related to higher emotional contagion as reported by the participants of the study (Krautheim et al., 2020). The discrepancy in the performance during emotion recognition of positive and negative emotional expressions in our study could, therefore, be connected to distinct MNS activation as well.

The interaction of emotion and gender of the stimuli was significant for accuracy as well as for reaction time. Rahman, Wilson and Abrahams (2004) showed in their study that female participants where faster and more accurate in recognizing male facial affect than female. This is consistent with the difference in disgust recognition but contradicting with the lower accuracy in identifying sad male faces in our study. It seems relatively little research exists on the topic of differences in gender of stimuli. Studies regarding gender differences in emotion recognition focus primarily on the gender of participants. It is important to note that we used a relatively small quantity of different stimuli. The differences we found might therefore also be stimuli specific and not gender specific.

An explanation for the absence of a differentiation between the LA and HA group in our study could be that deficits in emotion processing in alexithymia could be due to impaired sematic representation of emotion concepts (Grynberg et al., 2012). It seems alexithymic individuals might not be missing a comprehension of terms for various feelings but rather lack the ability of recalling and applying emotion concepts and have subsequently literally "*no words for feelings*". Difficulties in emotion recognition in people with high alexithymia scores vanish when emotion labels are provided (Nook, Lindquist & Zaki, 2015). Since the emotional labels angry, sad, disgusted, and happy were provided, the participants in our study did not have to find their own words, neither use their own emotional concepts. The fact that no autonomous emotion labelling was required could account for not finding any differences between the LA and HA group regarding accuracy and reaction time in the Emotion Recognition Task. It could be useful to create a task were labelling the displayed emotions is required instead of providing a small preselection of labels for the emotions. This would also provide additional information about the participants active vocabulary for emotions.

We used dynamic stimuli instead of static pictures to create a more realistic representation of emotional expression in our experiment. A recent study investigated the influence of alexithymia on emotion recognition using static and dynamic stimuli (Starita, Borhani, Bertini and Scarpazza, 2018). When confronted with static stimuli the group with higher levels of alexithymia needed more intensity in the facial expressions to identify fearful expressions than the group with low alexithymia levels. Nevertheless, there was no significant difference for static images of disgust and happiness. Whereas, when dynamic morphed stimuli were used, there was no difference in the performance between the two groups for the expressions of fear, disgust, and happiness. It seems that the effect, alexithymia has on emotion recognition, depends on the used stimuli and experimental conditions (Starita et al., 2018). Dynamic stimuli contain more structural and configurational information than static stimuli due to the observable intensification of emotional expression over time (Kamachi et al., 2001). A possible explanation why there was no difference between the groups in our sample is that because of the intensity and additional information in dynamic stimuli, as we used them, emotion recognition was facilitated.

Further research could use shorter presentation time for a better discrimination between low and high alexithymia. We presented the stimuli for 2 seconds, which might have been too long. Previous findings suggest that when the temporal condition is not challenging enough individuals with high levels of alexithymia display no significant emotion recognition deficit. Alexithymic individuals showed no remarkable difficulties when a stimulus was presented for 3 seconds but showed clear deficits when the stimulus was presented for only 1 second (Parker, Prkachin & Prkachin, 2005). In addition, a way to make the task more challenging and increase discriminative power could be the use of stimuli which are presented subliminally. Whereby the accuracy of emotion recognition clearly decreases compared to a supraliminal task. That confirms that subliminal detection is more demanding (Prochnow et al., 2013).

Another interesting aspect to investigate would be using variations of intensity in the displayed emotions. All our stimuli morphed from neutral to the full extent of emotion and as a result might be too easy to recognize. In our everyday life it is relevant to recognize emotions from very small cues. Hence, a comparison of low and high alexithymic individuals regarding emotion recognition with more versus less obvious cues for emotion could be of interest (for a similar procedure see Montagne, Kessels, De Haan & Perrett, 2007).

Facial Mimicry (written by Lydia Schlager)

First, it is important to note that facial mimicry was displayed by our participants. Nevertheless, the in the main hypothesis assumed distinction in the extent of facial mimicry between the LA and HA group could not be verified. Hence, H1 is contradicted. Furthermore, we could not find any relation of alexithymia scores and EMG data and in addition there was no interaction between group and emotion. Post-hoc tests revealed less activation in the CS for positive stimuli than for negative stimuli. This seems plausible since the CS is responsible for frowning, which is not part of happy facial expressions, but is rather associated with negative emotions like anger, sadness, and disgust. The CS activation even decreases below the baseline after the onset of happy stimuli, which can be interpreted as deactivation. Conversely, more activation in the ZM was revealed for positive stimuli than for negative, because the ZM is responsible for smiling which is related to positive emotions like happiness. This indicates that the participants showed simultaneous, automatic facial mimicry, particularly during the presentation of happy stimuli. The ZM activation increased from every point of measure and was the highest 2000 ms after stimulus onset for disgusted and especially for happy stimuli. This supports the assumption that emotional stimuli evoke facial mimicry and suggests that our stimuli worked. It further is in line with previous literature reporting that there is more facial mimicry as a reaction to positive stimuli than to negative stimuli (Sonnby-Bergström, 2009).

There are only very few studies investigating the connection of alexithymia and facial mimicry and the results are mixed. Our study could not support the hypothesis of diminished facial mimicry in alexithymia. However, that could be because there was only a small extent of facial mimicry to negative stimuli in general. We found the biggest extent of facial mimicry for happiness, but past results suggest alexithymia is not linked to facial mimicry of happy expressions, as there was found no difference between alexithymic and non-alexithymic individuals (Sonnby-Bergström, 2009). Additionally, in line with past studies, the negative emotions were mimicked considerably less than happiness, but the effect of alexithymia on emotion recognition seems to be particularly evident in negative emotions (Prkachin et al., 2008; Scarpazza & di Pellegrino, 2018). Besides, it is possible that the alexithymia scores in our sample were not clinically distinct enough to determine measurable differences between the groups. One difference between previous studies and ours is, as discussed before, the use of dynamic stimuli. Since there is evidence that the difference in emotion recognition between LA and HA vanishes in a task with dynamic stimuli (Starita et al., 2018) this might also be the case for facial mimicry. Indicating that these differences between LA and HA are just present in certain conditions (Grynberg et al., 2012).

We calculated an additional correlation analysis and could not find any significant correlation between EMG data and the emotion recognition measures. A similar study with only female participants and also dynamic stimuli of the same emotions we used, showed no correspondence of facial mimicry and emotion recognition either (Hess & Blairy, 2001). In addition, Bogart & Matsumoto (2010) proposed that, contradicting the current theories of emotional embodiment, facial mimicry is not necessary to recognize emotional facial expressions correctly. Participants with Moebius Syndrome were compared to healthy controls and did not show any differences regarding emotion recognition accuracy and no correlation between accuracy and the extent of facial mimicry was found.

Even though we could not find any relation of alexithymia or emotion recognition and facial mimicry, we still expect facial mimicry to function as a facilitator of emotion recognition. When we look at our data and see that our participants showed facial mimicry, in particular for happy faces, whereby there was also the highest accuracy as well as lowest reaction time, it could be hypothesized, that there is a connection between these variables. Although, there might be different explanations for this relation. For instance, smiling is the most common social facial interaction and might therefore be also the easiest to recognize. Further, watching morphed pictures might not only evoke emotional categorization, but also have a rewarding aspect in happy pictures and an unpleasant aspect in negative emotions. Especially when we consider that the person showing the emotion looks straight in the camera, virtually in the viewers eyes.

Interestingly, in a study, spontaneous facial reaction to sadness correlated positively with social interaction quality. In contrast more facial reaction to disgust correlated negatively with social interaction quality, but there was no correlation between happiness and the quality of social interactions. Accordingly, facial mimicry of happiness might rather reflect learned behaviour or social norms (Mauersberger, Blaison, Kafetsios, Kessler & Hess, 2015). This is in line with findings of another study investigating the impact of social context on facial mimicry. Participants imitated happiness shown by in-group and out-group members, regardless of the social context, whereas they only mimicked negative emotions when they were shown by an in-group member. It is assumed that facial mimicry changes dependent on social context and the shown emotion (Bourgeois & Hess, 2008).

In everyday life when emotional expressions are displayed, we are in communicative situations, settled in different social contexts and body language as well as verbal language can help to inform us about the other’s intentions. Facial emotion recognition is also affected by postures and the context where it is embedded in. For instance, expressions of disgust in an anger context are probable to be incorrectly classified as anger (Reschke, Walle, Knothe & Lopez, 2018). Facial mimicry seems to be driven by affiliative goals and subtle cues during communication can evoke the implicit regulation of imitation (Rauchbauer, Majdand, Hummer, Windischberger & Lamm, 2015). Our findings are comparable to the results of a study with face to face emotion communication, where mainly happy expressions were imitated and sadness at a lower level (Künecke, Wilhelm & Sommer, 2017). The variable manifestation of facial mimicry for different emotions might be explained by their communicative consequences. Imitation of angry expressions might not be perceived as empathic, but rather aggressive and therefore as a possible threat. On the contrary mimicking sad or happy expressions might be perceived as compassion. This corresponds with the Emotion Mimicry in Context view of Hess & Fischer (2013). These consequences of mimicking others might be learned and therefore inhibit mimicry of anger and disgust. Conversely to the study of Künecke et al.(2017) facial mimicry of sad stimuli was hardly present in our study. Due to the use of videos instead of a dyadic emotion communication the need of showing empathy was possibly reduced. It can be assumed that there is more facial mimicry as well as other facial reactions in real communicative situations. When people communicate, they try to understand what the counterpart means and therefore they intend to find out which emotions are shown in order to be empathic. In our task participants did not need to be empathic, the emotion recognition was possibly also more analytic and cognitive than in real life situations. When we consider emotional mimicry as a social and empathic function with an affiliative intention it is arguable that watching videos with facial expression might not be an efficient cue. It could be assumed that the displayed facial expressions of the participants might therefore be just reactions to the stimuli, but not an actual imitation (Hess & Fischer, 2014). This might also explain why we could not find any differences regarding the extent of facial mimicry between LA and HA. It is possible that the stimuli we used and the lack of social context were not sufficiently triggering actual facial mimicry.

Many studies examined facial mimicry and there is a lot of evidence that facial expressions are imitated, but that evidence is largely restricted to accounts based only on the valence of emotions. There is a considerably large number of studies that found activation of the corrugator supercilii to negative emotions and activation of the zygomaticus major during the presentation of positive emotions. This does not necessarily indicate a specific mimicry of a concrete emotion. Also, it does not exclude other explanations for facial mimicry (Hess & Fischer, 2013). Various theories have been proposed, still little is known about the underlying processes and mechanisms of facial imitation. Moreover, the role of social context or situational meaning in which facial mimicry occurs seems to be of great interest when it comes to emotion recognition and empathic behaviour (Barrett, Mesquita & Gendron, 2011).

Conclusively, facial mimicry as a reaction to discrete emotions and the embedding of emotion recognition in social context should be considered more in future research. Investigating the function of facial mimicry could be of interest too. Since the reaction to happiness could rather be a learned behaviour of social norms and differs from the reaction to negative stimuli (Mauersberger et al., 2015), future research should aim at a clearer understanding of facial mimicry as an empathic versus responsive function.

Since we found no significant differences between LA and HA group regarding accuracy, reaction time and facial mimicry our data further cannot conclusively support our fifth hypothesis (H5) proposing a greater deficit for negative emotions in the HA group.

Additional Analyses (written by Lydia Schlager)

Prior to the implementation of the study we did not make any specific hypotheses regarding interoception and facial mimicry. We hypothesized, that there is a relation between alexithymia and interoception, which could not be validated with our data. Nevertheless, we also investigated if there was a connection between interoceptive abilities and facial mimicry during the process of data analysis. We analyzed EMG data separately for each emotion (angry, disgusted, happy, sad) and muscle (CS, ZM) with a rmANOVA with time (four levels: 500 ms, 1000 ms, 1500 ms and 2000 ms from stimulus onset) and interoceptive abilities as a covariate. There was a tendency for a difference for CS activation for angry stimuli, $F = 3.81$, $p = .056$, partial $\eta^2 = .07$. Correspondingly a trend in CS activation for sad stimuli could be displayed, $F = 2.91$, $p = .092$, *partial* $\eta^2 = .050$. For happy and disgusted stimuli there were no significant distinct muscle activations. ZM activation was not related with interoceptive ability. Overall, we did not find any significant effects, but graphical analysis and a consideration of the means showed differences. The group with better interoceptive abilities showed more corresponding facial mimicry. Anyhow, confidence intervals overlapped, and this observation is therefore not valid.

Higher interoceptive accuracy, also measured with the Heartbeat Perception Task, was found to be related to a higher ability in emotion recognition in a very recent study (Chick, Rounds, Hill & Anderson, 2020). Nonetheless, our study was not conducted to analyze coherences of facial mimicry and interoception. Consequently, we cannot make any conclusions about these additional results we found. Although, we would highly recommend further research on this connection, since relatively little research exists so far. Interoceptive accuracy as well as facial mimicry seem to contribute to a better emotion recognition and to interact with each other (Chick et al., 2020).

Limitations (written by Lisa Meier)

The main limitation of the present study is the conducted sample. We conducted a non-clinical sample of volunteer students. Most importantly the analysed sample was rather small and had a narrow variance in alexithymia scores – even the group mean of the HA group was below the clinical cut-off score. Despite higher compensation than usual and a high number of online screenings the response of people with higher TAS-26 scores was slight. In addition, some of the invited participants with high TAS-26 scores did not appear to the appointments. Including clinical groups to the sample would increase the proportion of participants with higher levels of alexithymia, scoring above the clinical cut-off. Since alexithymia is mostly co-occurring with clinical psychological disorders it also seems more naturalistic to take clinical groups into account as well.

Even though we screened the participants for depressive symptoms and excluded the ones who reported diagnosed disorders, we did not control for other psychological disorders and non-diagnosed psychological or psychiatric illnesses might be disregarded. We did not screen for autistic traits in our participants, despite the strong link between ASD and alexithymia and the finding that autistic individuals seem to have atypical imitation behaviours, such as facial mimicry (Edwards, 2014). Therefore, it could have been of interest to include an ASD measure. On the other hand, it seems that alexithymia is responsible for some of the symptoms prevalent in ASD. It is the co-occurring alexithymia, but not ASD itself, that accounts for diminished production of facial expressions (Trevisan et al., 2016), impaired empathic behaviour (Bird et al., 2010) and difficulties in recognizing emotional expressions (Cook et al., 2013), as well as impaired interoceptive abilities (Shah et al., 2016). Since we investigated the production of facial expressions in form of facial mimicry, emotion recognition and interoception, we assumed that ASD as such would not have an influence on possible differences. Still, future research is needed to reach more conclusive findings regarding alexithymia and co-occurring ASD when it comes to specific impairments in emotion processing, empathy, and their underlying mechanisms. In general, further studies are required to establish a direction of causality in which alexithymia is associated with mental disorders. Is alexithymia a risk factor for developing mental disorders, simply a co-occurring personality trait or is it rather a product of the maladaptive processes that are often part of mental disorders too?

We conducted our sample with women only since there is evidence that women display more facial mimicry in reaction to emotional stimuli than men. (Thunberg & Dimberg, 2000). Hence, we assumed that women display a bigger range of facial mimicry and thus a comparison would be more sensitive. Additionally, it is assumed that there are gender differences regarding the neural circuity underlying facial mimicry and the perception of emotional expressions (Korb et al., 2015). Furthermore, women seem to be faster than men and more accurate in recognising emotions in dynamic stimuli at varying intensities (Wingenbach, Ashwin & Brosnan, 2018). At the same time, it is assumed that men in general score higher in alexithymia (Levant, Hall, Williams & Hasan, 2009). A sample with men and women could therefore lead to the possibility of differences occurring only because of underlying gender effects. According to that it is important for upcoming research to include men and women in bigger samples to investigate differences regarding facial mimicry and alexithymia, taking possible disparities between genders into account.

It is possible that the measures we used lacked sensitivity for validating our hypotheses. We already pointed out the self-report character of the TAS-26 and the fact that the Heartbeat Perception Task supposedly only measures one aspect of interoception. As discussed before, the task is influenced by the ability of time estimating, the actual heart rate and knowledge about the heart rate at rest.

Furthermore, there are also possible weak spots regarding the Emotion Recognition Task. We had a total of 64 trials in two blocks (8 faces x 4 emotions x 2 blocks) in the first part of the Emotion Recognition Task during which facial mimicry was measured. This means each stimulus was shown only twice. It seems like it was not enough trials to reliably measure facial mimicry. Despite the high-quality stimuli, we used from the FACES database (Ebner et al., 2010), the morphed videos often have distortions and are sometimes a bit blurry. Consequently, a rather low number of repetitions was chosen because we got the feedback from our pilot participants that the morphed stimuli could cause vertigo and dizziness. Based on that we decided that more trials would have been too demanding for the participants to look at. Altogether, it seems that the Emotion Recognition Task was not challenging enough and therefore it lacks discriminative power. As we already reasoned, a shorter presentation time, stimuli with varying intensities or subliminally presented stimuli, as well as not providing any labels for the displayed emotions, could increase the difficulty and with that discriminative power of the task.

Another limitation of the task is that, although we used dynamic stimuli for a more realistic representation of emotional expression, facial reactions might still not be comparable to those in natural situations. It would be recommended that further studies use real interactions to measure facial mimicry, since the processing of emotion is durably influenced by the social context in which emotions are perceived (Barrett et al., 2011).

Conclusion and Future Prospects (written by Lydia Schlager)

In summary the current study could not support the predictions of our five hypotheses. Still, the inconclusive results point out that many controversies about the connection between alexithymia and interoception remain unsolved and more research in this area is needed. Regarding this, the need to critically investigate if the Heartbeat Perception Task is a valid measure of interoception and the need for a measurement independent from self-report for alexithymia should be stressed. A clearer understanding of the relation between alexithymia and facial mimicry and their influence on emotion recognition processes is needed, in order to investigate underlying mechanisms of the deficits prevalent in alexithymia. It is of importance to enhance the understanding of emotions in psychopathology (Rottenberg & Johnson, 2007). Therefore, research on emotional reactivity in other disorders besides depression and its connection to alexithymia and facial mimicry could be of interest. More knowledge in this field could also help to develop prevention and treatment strategies, as well as interventions to reduce the psychological vulnerability of individuals with alexithymia. Particularly, further research on the interaction of interoception, alexithymia and facial mimicry would be suggested as interoception seems to be inter-dependent with emotional experience. A holistic approach is needed to understand the interaction of the mind and body in experiencing and understanding emotion in changing environments.

We assume that the non-significant results in our study analysing the connection of alexithymia, facial mimicry and emotion recognition is mainly due to the limited manifestation of alexithymia in the tested population. Consequently, a similar study in a more diverse population would be advocated.

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Figures

Tables

Abbreviations

ASD...Autism Spectrum Disorder

CS...Corrugator Supercilii

DDF...Differences describing feelings

DIF..Differences identifying feelings

ECG...Electrocardiogram

EOT...Externally oriented thinking

EMG..Electromyogram

ER...Emotion Recognition

ERT...Emotion Recognition Task

FM...Facial Mimicry

HA...High alexithymia score group

HBT...Heartbeat Perception Task

LA..Low alexithymia score group

MNS...Mirror Neuron System

ZM...Zygomaticus Major

Appendix

Abstract - English

According to recent theories somatic experience is strongly inter-dependent with emotion recognition (ER). Other people's emotional facial expressions are often automatically imitated by the observer – a process called facial mimicry. Alexithymia is a dimensional personality construct characterized by difficulties identifying and describing feelings in the self and others and is linked to impaired facial ER. Interoception, the ability to percept and interpret signals emerging from the own body, seems to be connected to emotional experience and negatively linked to alexithymia. This study aimed to investigate the connection between facial mimicry, alexithymia and interoception in ER. A sample of 64 female participants, age 18-35, was conducted and individuals with low (LA) versus high alexithymia (HA) were compared. We assumed that the HA group shows less facial mimicry (H1), less interoceptive abilities (H2), recognizes emotions less accurate (H3) and slower (H4) and that these effects are stronger for negative emotions (H5). EMG was recorded during an Emotion Recognition Task (ERT) for the corrugator supercilii and the zygomaticus major. In our sample LA and HA showed no significant differences in the extent of facial mimicry (H1) and interoceptive abilities (H2). We further found no significant differences between LA and HA regarding accuracy (H3) and reaction time (H4) during the ERT and with that no stronger effect for negative emotions (H5). At a theoretical level, the association of our variables is valid and plausible, but our data failed to support it. The main limitation of the study is attributable to the sample and the small variance of alexithymia scores.

Keywords: alexithymia, facial mimicry, interoception, emotion recognition

Abstract - German

Aktuellen Theorien zufolge spielt körperliches Erleben eine zentrale Rolle bei der Emotionserkennung. Oftmals werden emotionale Gesichtsausdrücke des Gegenübers automatisch imitiert – man nennt dies Facial Mimicry. Alexithymie ist ein dimensionales Persönlichkeitskonstrukt, das sich durch Schwierigkeiten beim Erkennen und Beschreiben von Gefühlen bei sich und anderen auszeichnet. Es wird daher auch mit einer verminderten Fähigkeit, Emotionen aus Gesichtsausdrücken zu erkennen, in Verbindung gebracht. Interozeption beschreibt die Wahrnehmung und Interpretation von Signalen aus dem eigenen Körper, wobei ein starker Zusammenhang mit Emotionserkennung zu bestehen scheint, sowie eine negative Korrelation mit Alexithymie. Unser Ziel war es, die Verbindung zwischen Facial Mimicry, Alexithymie und Interozeption bei der Emotionserkennung zu untersuchen. Eine Stichprobe von 64 Probandinnen im Alter 18-35 wurde herangezogen und Personen mit geringen (LA) und hohen Alexithymiewerten (HA) wurden verglichen. Wir vermuteten, dass die HA-Gruppe weniger Facial Mimicry zeigt (H1), weniger interozeptive Fähigkeiten aufweist (H2), in der Emotionserkennungs-Aufgabe weniger oft richtig (H3), sowie langsamer (H4) antwortet und dieser Effekt für negative Emotionen stärker ist (H5). Eine EMG-Messung am Corrugator Supercilii und dem Zygomaticus Major wurde während der Emotionserkennungs-Aufgabe durchgeführt. In unserer Stichprobe zeigte sich kein signifikanter Unterschied zwischen den Gruppen in der Ausprägung von Facial Mimicry (H1) und Interozeption (H2). Außerdem zeigten sich keine signifikanten Unterschiede zwischen den Gruppen bezüglich der Richtigkeit (H3) und Reaktionsgeschwindigkeit (H4) bei der Emotionserkennung und somit auch kein stärkerer Effekt für negative Emotionen (H5). Die Verbindung der Variablen ist in der Theorie valide und plausibel, ließ sich jedoch anhand unserer Daten nicht bestätigen. Die größte Limitation unserer Studie liegt in der Stichprobe, die nur eine geringe Varianz in den Alexithymiewerten aufwies.

Schlagwörter: Alexithymie, Facial Mimicry, Interozeption, Emotionserkennung

Material

Visual Stimuli from the FACES Database.

Stimuli for each Emotion – Female Actors

Angry	Disgusted	Happy	Sad
010_y_f_n_a.mp4	010_y_f_n_d.mp4	010_y_f_n_h.mp4	010_y_f_n_s.mp4
040_y_f_n_a.mp4	040_y_f_n_d.mp4	040_y_f_n_h.mp4	040_y_f_n_s.mp4
115_y_f_n_a.mp4	115_y_f_n_d.mp4	115_y_f_n_h.mp4	115_y_f_n_s.mp4
140_y_f_n_a.mp4	140_y_f_n_d.mp4	140_y_f_n_h.mp4	140_y_f_n_s.mp4

Stimuli for each Emotion – Male Actors

Angry	Disgusted	Happy	Sad
008_y_m_n_a.mp4	008_y_m_n_d.mp4	008_y_m_n_h.mp4	008_y_m_n_s.mp4
031_y_m_n_a.mp4	031_y_m_n_d.mp4	031_y_m_n_h.mp4	031_y_m_n_s.mp4
049_y_m_n_a.mp4	049_y_m_n_d.mp4	049_y_m_n_h.mp4	049_y_m_n_s.mp4
127_y_m_n_a.mp4	127_y_m_n_d.mp4	127_y_m_n_h.mp4	127_y_m_n_.mp4

Note. Labels of all stimuli we used from the FACES Database for both, female and male actors, separated for each emotion. (y describes the age group: young)

Heartbeat Tracking Task & Time Estimate.

Practice trials:	
Heartbeat counting & Time estimating	15 s each
Break	60 s
Heartbeat (Trigger start + stop)	15 s
Break	30s
Time estimate	17 s
Break	30 s
Heartbeat (Trigger start + stop)	25 s
Break	30 s
Time estimate	22 s
Break	30 s
Heartbeat (Trigger start + stop)	35 s

Emotion Recognition Task.

Trigger:

66	**Fixation Cross**
100	gender male
200	gender female
10	angry
20	disgusted
30	happy
40	sad

Type of Collaboration

The current study respectively paper was developed, realised, and written in close collaboration between Lydia Schlager and Lisa Meier. Generally, a lot of the work has been done together, such as the early development of the study and all the presentations we did during the seminars, as well as the applications for approval through Ethics Committee and the funding from the Austrian Federal Ministry of Science and Research. When it came to develop the tasks for the study, we split the work. Lydia took care of the most complex task in the experiment, the Emotion Recognition Task, acquired the stimuli and programmed it in PsychoPy 3. Lisa took care of the Heartbeat Perception Task which was also programmed in PsychoPy3 and the questionnaires as well as sociodemographic data which were embedded into SoSci-Survey. Lisa evaluated the screening questionnaires and we both invited possible participants and fixed dates with them for the testing. The testing in the laboratory of the university were conducted together, whereby we switched the role of the “leading experimenter”.

After data collection we entered each half of the data in SPSS and Lydia prepared the data and calculated all variables that were used for the analysis. We computed all main analyses together. Lydia then computed the additional analyses as they are reported in the discussion. Lydia prepared all tables and figures that are included in the text, while Lisa was the in charge of formal aspects (APA) and the Appendix. The paper was written together, whereby we each focused on certain parts – but we eventually read and revised each other's parts and occasionally added sentences or further research. Therefore, the different paragraphs are not entirely separable. Still we tried to mark our work in a way that makes a separate assessment for each of us possible.

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