# Resonating emotions: an embodied perspective on alterations in facial emotion processing in autism and social anxiety

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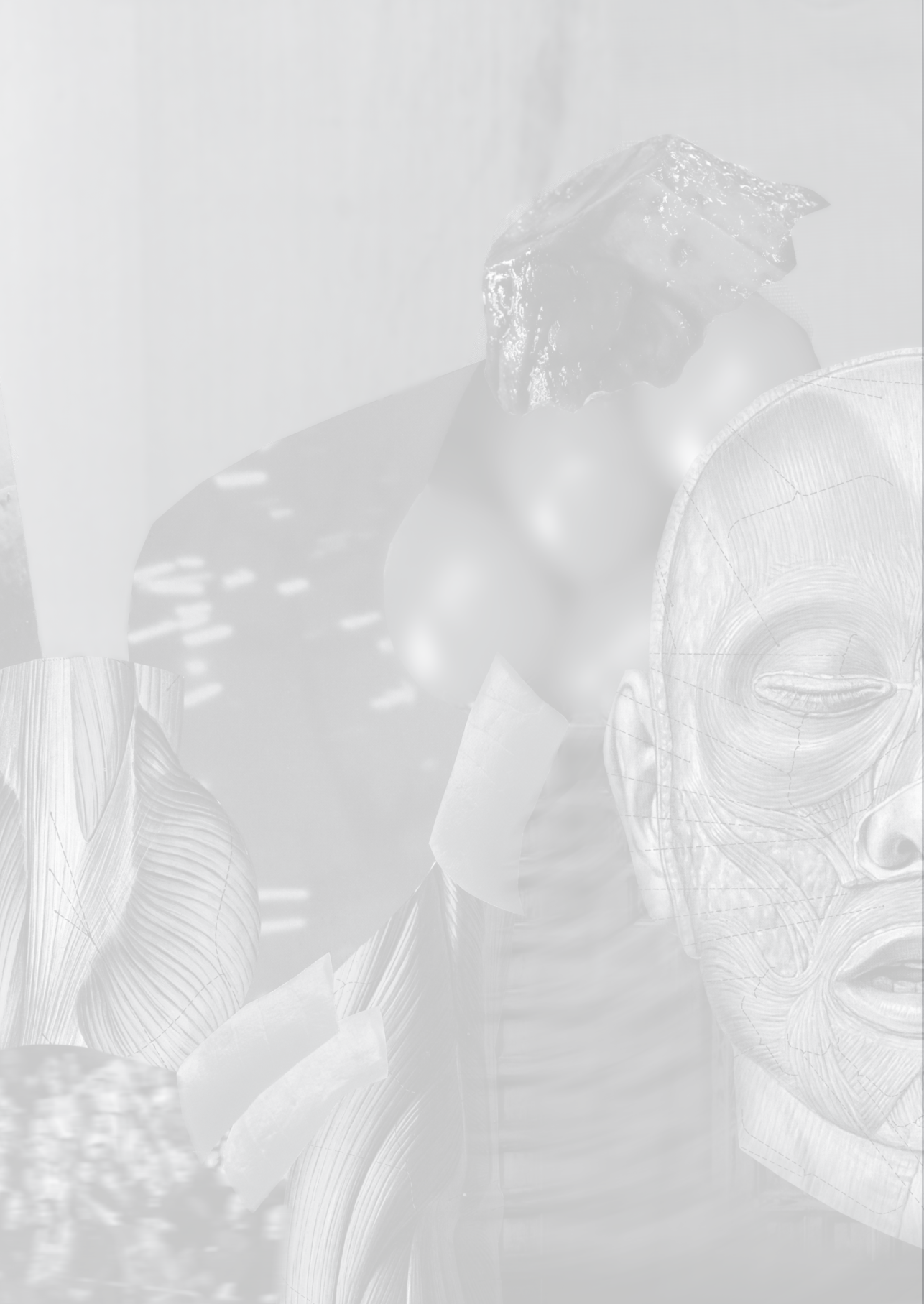

# Chapter 1

## General Introduction

The need to form meaningful relationships with others is an integral part of human nature (Baumeister & Leary, 1995). Social interactions - everyday instances reflecting this need – are known to play an important role in determining an individual's well-being and their life satisfaction (Diener et al., 2018; Sun et al., 2020). In interactions, people share their emotional and mental states, both verbally and non-verbally, with others. An alignment to each other facilitates mutual understanding, and allows for supporting each other in regulating imbalanced emotional states or in updating inaccurate beliefs. The ability to "tune in" to another person is an important resource in daily social functioning, which is described to be "impaired"[1] in the DSM-V diagnostic criteria of both Social Anxiety Disorder and Autism Spectrum Disorder (American Psychiatric Association, 2013). Alterations in experiences and behaviour, similar to those described in individuals with a diagnosis of autism or social anxiety, can also be observed in individuals without a diagnosis (see Box 1 for a description of the two conditions and the association with trait levels). The present dissertation therefore includes research in both non-diagnosed individuals with varying autistic trait levels and social anxiety trait levels, and individuals with a diagnosis of either Social Anxiety Disorder (referred to as "individuals with social anxiety") or Autism Spectrum Disorder (referred to as "individuals on the autism spectrum") to approach a better understanding of potential alterations in processes which may contribute to social interaction difficulties in the two conditions.

## Difficulties in Social Interactions in Autism and Social Anxiety

Research on social functioning in social anxiety and autism highlights alterations in social cognition and behaviour, which are linked to a lower quality of life in the two conditions (S. Y. Kim & Bottema-Beutel, 2019; Oakley et al., 2020; Olatunji et al., 2007). For example, altered trust in social interactions has been described in both autism and social anxiety. While individuals on the autism spectrum are less influenced by another persons' looks or their prosocial behaviour in trust decisions

1 Deficit-oriented language (e.g., "impairments", "Disorder") is used here in order to adhere to the clinical diagnostic criteria. Yet, I would like to highlight that I do not believe social interaction difficulties to be necessarily the result of one individual's "impairment". Following a neurodiversity perspective, individuals differ in their cognitive styles, which also reflects in interpersonal communication. This idea will be elaborated on in more detail in the discussion.

(Ewing et al., 2015; Hooper et al., 2019; Maurer et al., 2018), individuals with social anxiety are less inclined to trust in general (Rodebaugh et al., 2016, 2017) compared to controls. Moreover, both individuals on the autism spectrum and individuals with social anxiety perceive themselves as less socially competent and liked (Voncken et al., 2020; Williamson et al., 2008). There is some evidence that this self-perception matches others' impressions: they actually make less positive impressions in interactions compared to controls, which is also reflected in others' relatively lower wish for future interactions (Morrison et al., 2020; Voncken & Bögels, 2008). Yet, specifically in the case of social anxiety, negative self-perceptions are highly exaggerated compared to negative perceptions by others (Christensen et al., 2003). Generalizing negative beliefs about one's abilities, which are formed in interactions with others, might tremendously contribute to a reduced confidence in social skills and affect social functioning in social anxiety (Müller-Pinzler et al., 2019).

Some theoretical perspectives suggest that impairments in social functioning would arise from a decreased social motivation. In the case of autism, the social motivation theory suggests that, overall, less attention would be employed to social information, which has a lower reward value (Chevallier et al., 2012; however see Bottini, 2018). In the case of social anxiety, theoretical accounts propose that reduced social motivation would be rooted in behavioural inhibition, that is, the temperamental trait to avoid unknown people and novel situations which elicit distress (Fox et al., 2021; Kimbrel et al., 2012), or in overvaluing social rank over affiliation in social situations, hindering the approach of others (Gilboa-Schechtman, 2020). Importantly, both individuals with social anxiety and a substantial share of individuals on the autism spectrum do not report a reduced need to interact and build relations with others, and they also participate in social life (L. H. Brown et al., 2007; Chan et al., 2023). The quality of social interactions is, however, perceived to be lower by individuals with social anxiety compared to controls (Villanueva et al., 2021), and they report to prefer to be alone in the context of unfamiliar others (L. H. Brown et al., 2007). Social interaction difficulties in autism have been reflected in less involvement in peer relationships as well as in social and recreational activities (Orsmond et al., 2004). Hence, alterations in social functioning occur in both conditions and seem to hamper forming new, meaningful relationships with others. While the general profiles as well as theoretical perspectives on the aetiology of social anxiety and autism

**BOX 1** | Description of Autism Spectrum Disorder, Social Anxiety Disorder, and Associated Trait Levels

According to the DSM-V (American Psychiatric Association, 2013), Social Anxiety Disorder (SAD; or social phobia) belongs to the cluster of Anxiety Disorders, which are mental health conditions characterized by excessive and uncontrollable fear and anxiety in everyday life situations. Within this cluster, SAD manifests specifically in a disproportionate fear and avoidance of social situations, which is based on fears of evaluation by others, and causes substantial distress to the individual. Autism Spectrum Disorder (ASD) is a neurodevelopmental condition characterized by "impairments" in social communication, such as eye contact or social reciprocity, and restricted, repetitive behaviours, such as stereotypic movements or sensory interests, which already manifest in early development. As reduced intellectual development (e.g., being less verbal) complicates the study of social functioning in autism, most research (including this thesis) includes individuals on the autism spectrum with intellectual ability that is comparable to control participants to target alterations specifically linked to social cognition and behaviour.

Alterations in experiences and behaviour that show similarities to those described in individuals with a diagnosis of autism or social anxiety present themselves to varying degrees in the general population. These characteristics are commonly referred to as autistic traits or social anxiety traits (Rapee & Spence, 2004; E. B. Robinson et al., 2011). To give an example, people with high autistic trait levels can find it difficult to infer others' intentions or have a hard time deviating from established routines. In the case of social anxiety, people with high trait levels can, for example, experience anxiety when meeting strangers or avoid giving a speech in front of others. Individuals with high social anxiety trait levels but no diagnosis mainly differ from individuals with social anxiety in the degree to which symptoms impact their daily life (American Psychiatric Association, 2013). Experiences of individuals on the autism spectrum, in contrast, can be qualitatively different compared to experiences of neurotypical individuals with high autistic trait levels (Sasson & Bottema-Beutel, 2022). Yet, assessing trait levels in individuals without the respective condition can allow researchers to approach phenomena related to autism and social anxiety, and can inform studies in the two conditions, without immediately involving individuals with a diagnosis.

co-occurs in autism, with comorbidity rates ranging between 16.6% - 50% (Bejerot et al., 2014; Maddox & White, 2015; van Steensel et al., 2011). In order to get a better idea of potential shared and distinct mechanisms underlying alterations in social functioning in autism and social anxiety, a fine-grained investigation of alterations in processing social information is required. The present dissertation therefore zooms in on the perception and the resonance of others' nonverbal emotional expressions in both varying trait levels associated with autism and social anxiety in non-diagnosed individuals as well as in the two conditions.

## Perception of Nonverbal Signals of Emotions in Autism and Social Anxiety

Non-verbal expressions of emotions, such as facial displays, body postures, movements, vocalizations, or gestures (A. Cowen et al., 2019; Dael et al., 2013; de Gelder, 2006; Ekman, 1993; Sauter et al., 2010; Witkower & Tracy, 2019), are relevant signals in guiding social interactions, by providing information about the expressor's emotional state. This social-communicative function is, however, not considered the original function of emotional expressions. It is proposed to have emerged in socially complex animals to transfer information, going beyond a pure physiological function (Shariff & Tracy, 2011; Tracy et al., 2015). Namely, from an evolutionary perspective, emotions primarily served to promote survival, as specialized modes that allow the organism to adaptively respond to the environment (Nesse, 1990; Tooby & Cosmides, 1990). Here, basic emotion theory highlights a set of fundamental, evolutionary-adaptive emotions (commonly: anger, fear, happiness, surprise, sadness and disgust), which are distinct to each other and share differences to related phenomena, such as moods (Ekman, 1992). One of the shared characteristics of these emotions is their emotion-specific expression, which has primarily been described in the face in humans, including the definition of specific muscle activation patterns (Friesen & Ekman, 1983). Opposing the idea of emotions as universal, hardwired modes, constructionist perspectives point out the uniqueness of each emotional experience. They propose that emotions are constructed based on an individuals' past experiences, their current states and the environment that they are in, thus never resulting in the exactly same experience (see Barrett, 2006; Russell, 2003). While the debate on the nature of emotions is ever ongoing between proponents of the two different perspectives, many scholars acknowledge a functional basis, which allows for a categorization

of emotional states, without neglecting the uniqueness of experiences, based on individual characteristics or contextual factors (see also Scarantino & Griffiths, 2011; van Heijst et al., 2023). In the current dissertation, I examine emotional expressions in their social-communicative function more closely, zooming in on individual differences in their perception and interpretation that are associated with autism and social anxiety. In line with most research in this field, my main focus is on the processing of distinct facial displays of emotions, following basic emotion categories. For these "prototypical" expressions, alterations associated with autism and social anxiety have been described at various processing stages and various levels of description.

While emotional expressions are known to automatically capture and hold attention in general (Carretié, 2014), both individuals on the autism spectrum and individuals with social anxiety show altered patterns of attentional deployment. Following predictions of theoretical models, such as the Relevance Detection theory (Zalla & Sperduti, 2013) or the two-pathway model (Cuve et al., 2018), individuals on the autism spectrum tend to avoid faces, and specifically the eye region, to regulate arousal. According to the Relevance Detection theory, this avoidance stems from a hyper-activation of the amygdala in response to salient stimuli, such as others' eyes, which results in unpleasantly high arousal levels. Next to this explanation, the two-pathway model (Cuve et al., 2018) proposes a lower automatic engagement with the eye region in some individuals on the autism spectrum, accompanied by lower arousal levels and less attention to the eyes, as second path. Importantly, avoiding another individual's eyes seems to negatively impact the processing of their facially displayed emotions, as alterations in gaze, including an avoidance of the eye region, have been linked to a lower emotion recognition performance in individuals on the autism spectrum compared to control participants (Kliemann et al., 2010). In contrast, angry facial expressions have repeatedly been shown to affect both initial and sustained attention more strongly in individuals with social anxiety compared to controls (Clauss et al., 2022; Lazarov et al., 2021; Mogg, Bradley, et al., 2004). The proposed explanation for this phenomenon is that they represent social threat (i.e., negative evaluations), as described in the cognitive behavioral model of social anxiety by Rapee & Heimberg (most recent update: Heimberg et al., 2010), which highlights an increased vigilance to external social cues.

In addition to attentional alterations, individuals on the autism spectrum and individuals with social anxiety tend to interpret observed facial emotional expressions differently than controls. Namely, individuals on the autism spectrum may perceive emotional expressions as less intense (Tseng et al., 2014), have more difficulties in recognizing emotions (Yeung, 2022), and struggle in inferring mental states of others (Quinde-Zlibut et al., 2022) when compared to controls. These findings have been conceptualized as "impairments" in traditional models such as the Theory of Mind model (ToM model; Baron-Cohen et al., 1985) and the broken mirror hypothesis (Ramachandran & Oberman, 2006; Southgate & Hamilton, 2008; J. H. G. Williams et al., 2001): According to ToM model, children on the autism spectrum would be less able to represent others' mental states and predict their behaviour, as they show difficulties in inferring another individual's mental state about a third person (second-order ToM; however see Tager-Flusberg, 2007). In contrast to this rather conceptual model, the broken mirror hypothesis links alterations in behaviour to alterations in neural activity that have been observed in autism. Difficulties in imitation, and other processes requiring attunement to other individuals, are proposed to stem from a dysfunction of a brain system, the mirror neuron system, whose activity reflects simulations of observed actions. Novel perspectives, in contrast, focus on identifying different strategies that individuals on the autism spectrum employ in processing others' emotions (Arnaud, 2020; Keating et al., 2023; Rutherford & McIntosh, 2007). In individuals with social anxiety, negatively-biased processing of facial information(Machado-de-Sousa et al., 2010) is assumed to explain observations such as a higher sensitivity towards negative expressions (Gutiérrez-García & Calvo, 2017a; Joormann & Gotlib, 2006) and a higher misattribution of negative affect to neutral faces (Peschard & Philippot, 2017). Although individuals with social anxiety do not necessarily recognize expressions of others worse than controls, they have difficulties interpreting them (Buhlmann et al., 2015). In those lines, individuals with social anxiety are less accurate in inferring complex mental states of others (i.e., cognitive empathy) compared to controls, whereas the sharing of other's emotions (i.e., affective empathy) is comparable or under specific circumstances even enhanced (Alvi et al., 2020; Pittelkow et al., 2021). Taken together, individuals with social anxiety specifically seem to be receptive to negative facial expressions and biased in the interpretation of others' emotional displays. Individuals on the autism spectrum, in contrast, seem to attend to (emotional) facial displays less and process them differently, which can result in a misunderstanding of others' emotional states. Relevant alterations in processing facial information, thus, likely occur at various processing stages in autism and

social anxiety (e.g., attention, interpretation), affecting different levels of description (e.g., experience, physiology). Importantly, the covered processing stages and levels in this dissertation are neither conclusive nor do they occur in a consecutive or hierarchical order, as one might infer. Understanding others' emotions is a highly complex, dynamic and versatile phenomenon, in which various individual and environmental factors can play a role.

## Resonance of Observed Emotional Expressions in Autism and Social Anxiety

Humans "feel" emotions in their bodies: they consistently link distinct bodily states to specific emotional states (Nummenmaa et al., 2014). In those lines, various seminal emotion theories, such as the James-Lange-Theory (James, 1884; Lange & Kurella, 1887) or the Somatic Marker Hypothesis (Damasio, 1996) among others (e.g., Levenson, 2003), highlight the role of physiological feedback in the experience of emotions. Here, automatically evoked activity changes in targets of both the somatic nervous system (e.g., facial muscles) and the autonomic nervous system (e.g., the heart) can inform consciously experienced emotional states (Buck, 1980; Critchley, 2009). Next to emotion-specific facial muscle configurations (Friesen & Ekman, 1983), distinct emotional states also show consistent (de-)activations in different measures of autonomic nervous system activity (Friedman, 2010; Kreibig, 2010; Levenson, 2014), yet no clearly distinguishable patterns (Kragel & LaBar, 2013; McGinley & Friedman, 2017; Siegel et al., 2018). Crucially, physiological response patterns in observers of emotional expressions are, specifically when it comes to facial expressions (Wingenbach et al., 2020), highly similar to the direct experience of the observed emotional state. They "resonate" in the observer (Lomas et al., 2022). This correspondence is integral to the broader idea of emotional contagion, that is an automatic alignment to another person's emotional state in physiology, behaviour and experience (E. Hatfield et al., 1993; Prochazkova & Kret, 2017). From the functional perspective, the internal simulation of an observed state leads to a better understanding of the other, makes them more predictable and likely results in smoother interactions (Arnold & Winkielman, 2020; Niedenthal, 2007; Preston & de Waal, 2002; Wood et al., 2016). In turn, a reduced simulation of others' emotions or altered physiological feedback interferes with this function, and might contribute to difficulties in social interactions, and social functioning more broadly, in autism and social anxiety (Alkire et al., 2021).

Research on spontaneous facial mimicry, that is the mirroring of observed facial expressions, has indeed shown that individuals on the autism spectrum mimic expressions of others less (Davies et al., 2016), or differently (Oberman et al., 2009; Weiss et al., 2019), than controls. Some studies also report reduced physiological arousal in response to others' emotions (Hubert et al., 2009; Keil et al., 2018; however see Dijkhuis et al., 2019; Mathersul et al., 2013). For individuals with social anxiety, results regarding spontaneous alterations in facial mimicry (e.g., Dijk et al., 2018; Vrana & Gross, 2004) as well as physiological arousal responses to emotional expressions (e.g., Dimberg & Thunberg, 2007; Tsunoda et al., 2008) are less conclusive. Here, the presence of a social context and its effects on information processing and behaviour might play a crucial role (Rapee & Heimberg, 1997). Namely, individuals with social anxiety care more about behaving socially desirable and overestimate the visibility of their actual physiological arousal in a social context (Edelmann & Baker, 2002; Nikolić et al., 2015), which may lead them to control their expressions more strongly than control participants (Dijk, Fischer, et al., 2018) and act rigidly, thereby limiting the resonance of others' expressions in their own body. In those lines, even if others emotions' would resonate similarly in the two conditions compared to controls, this "feedback", may not necessarily be integrated to a similar degree or in a similar way.

## Sensation of Embodied Emotions in Autism and Social Anxiety

Individuals indeed vary widely in how strongly signals from their bodies link to the perception of their own as well as observed emotional states (Coles et al., 2019; Holland et al., 2020). Recent approaches that aim for a mechanistic understanding of individual differences in emotion processing, therefore, investigate the role of interoception (Critchley & Garfinkel, 2017), that is the sensation, integration, interpretation and regulation of internal signals (W. G. Chen et al., 2021). Corresponding to this definition, interoceptive processes can be described at different levels of processing ("dimensions"), such as the strength of the afferent signal, as well as for different bodily systems ("axis"), such as the cardiovascular system (Suksasilp & Garfinkel, 2022). Existing theoretical frameworks focus on different aspects to describe individual differences in interoceptive processing. In the dimensional approach by Garfinkel and colleagues (2016), three dissociable

measures of interoception are distinguished (see also Forkmann et al., 2016), namely interoceptive accuracy (i.e., the objective accuracy in the detection of interoceptive signals), interoceptive sensibility (i.e., the self-reported, subjective tendency to focus and be aware of interoceptive signals) and interoceptive awareness (i.e., the ability to assess one's interoceptive accuracy correctly).

Importantly, the self-reported tendency to attend to bodily signals in daily life does not necessarily translate to a more accurate detection, as the above-mentioned overestimation of bodily responses in social anxiety illustrates. To capture this dissociation, Murphy and colleagues (2019) developed a 2x2 factor model of interoceptive ability, with the first factor ('What is measured?') distinguishing between accuracy and attention. The second factor ('How is it measured?') contrasts beliefs regarding one's performance (i.e., self-reports) with one's actual performance (i.e., objective measures). Although individuals with Anxiety Disorders overall (Domschke et al., 2010) or non-diagnosed individuals with high social anxiety trait levels (Stevens et al., 2011) tend to be more accurate in sensing their heartbeats in experimental tasks than control participants, individuals with social anxiety specifically seem to perform as well (Antony et al., 1995) or even worse (Gaebler et al., 2013) than control participants. Similarly, individuals on the autism spectrum perform worse in interoception tasks compared to controls (Failla et al., 2020; Garfinkel et al., 2016). At the same time, some individuals on the autism spectrum report to overperceive specific body signals (Garfinkel et al., 2016), while having difficulties in their integration to a coherent percept and in their interpretation (e.g., Fiene et al., 2018). This observation has been delineated in the framework of the weak (central) coherence account of autism (Happé & Frith, 2006), which describes a bias to processing local features (here: distinct body signals) and difficulties to integrating those to a global form (here: physiological state; see T. R. Hatfield et al., 2019). The overrepresentation of distinct body signals is also central to a predictive coding perspective on altered interoceptive processing in autism, namely the idea of highly inflexible precise prediction errors (Van de Cruys et al., 2017). Simplified, by constantly reinforcing irrelevant body signals (via high precision), body signals of actual interest do not "stand out". In contrast to this altered integration of low-level information (bottom-up), top-down processing rather seems to be affected in anxiety, operationalizing it as "altered interoceptive state[s] as a consequence of noisily amplified self-referential interoceptive predictive belief states" (Paulus & Stein, 2010, p. 451). The idea that self biases in social anxiety

would result from discrepancies in expected and actual physiological states was recently elaborated in detail in a predictive coding framework (Gerrans & Murray, 2020), and currently seems the most agreed-upon explanation of biased perception of physiological responses in social anxiety. Although alterations in sensing bodily signals, including their potential underlying mechanism(s), have been described in the literature on autism and social anxiety, studies investigating the role of these alterations in processing others' emotions are scarce. There is only some evidence that (changes in) arousal levels in individuals on the autism spectrum would indeed be less strongly linked to sharing other emotions compared to controls (Dijkhuis et al., 2019; Mathersul et al., 2013). Reduced empathy in autism has further been associated with lower objectively-measured interoceptive accuracy (Mul et al., 2018), yet not consistently (Butera et al., 2023).

## Employment of More Naturalistic Stimuli in Facial Emotion Perception Research

Even though humans are confronted with a broad variety of rich emotional facial expressions in daily life, research on facial emotion perception has mostly employed static images of exaggerated and posed stimuli (Kret, 2015). In order to gain more valid insights into processing others' emotions in a laboratory setting, novel stimulus sets with more naturalistic emotional expressions have recently become more popular (Dobs et al., 2018; Krumhuber et al., 2017). The advantage of their usage has already been demonstrated in several studies in the general population. For example, dynamic (versus static) facial displays emotion elicit stronger responses on multiple levels, including subjective reports (Krumhuber et al., 2013), physiological resonance (Rymarczyk et al., 2011), as well as neuronal responses (Schultz & Pilz, 2009). Dynamic information in facial emotion recognition seems to become particularly relevant when individuals are exposed to subtle and ambiguous displays (Ambadar et al., 2005; Krumhuber et al., 2013), whereas evidence for a potential advantage when exposed to prototypical facial expressions is inconsistent (see Sauter & Fischer, 2018).

Dynamic information might, however, not facilitate processing for all observers of emotional facial expressions. Individuals on the autism spectrum do not seem to benefit from the addition of dynamic information in recognizing emotions,

but have rather been found to recognize dynamic sad facial expressions less accurately than static ones (Enticott et al., 2014). This could be due to differences in internal representations of facial motion associated with specific emotional expressions in individuals on the autism spectrum compared to controls (e.g., for anger expression, see Keating et al., 2021). Furthermore, while individuals with high social anxiety trait levels within the general population showed an advantage in recognizing static facial expressions of anger, this was not the case for dynamic expressions of anger (Torro-Alves et al., 2016). Thus, using richer facial emotional expressions as stimuli in laboratory settings might allow to tap into more diverse and relevant alterations in facial emotion perception associated with autism and social anxiety. An additional path for facial emotion perception research to obtain higher ecological validity is to study the role of more subtle indicators of emotional experiences. Cues of emotional arousal, such as a blush, tears or the dilation of pupils, are less easily controlled than facial muscle (de-)activations, and can hence be seen as an even more pure visible sign of emotions in others (Kret, 2015). Studying changes in indicators of autonomic nervous system activity associated with the expressions of these visible cues (e.g., pupil size, facial reddening) can provide promising insights in the alignment in (emotional) arousal.

## Outline of the Dissertation

Understanding others' emotions in interactions is crucial in forming social bonds which eventually contribute to an individual's well-being. Both individuals on the autism spectrum and individuals with social anxiety have difficulties in interactions with others, and past research suggests that they also differ in how they perceive and respond to others' emotions. So far, however, most studies have examined alterations associated with either autism or social anxiety (trait levels), complicating to unveil shared and distinct alterations. Often, they have focussed on alterations on one level of description (e.g., physiological resonance versus subjective interpretation), without considering potential links between levels. Addressing these limitations, the present dissertation aims to provide a more integrative understanding of alterations in the perception, resonance and interpretation of other individual's (facial) emotional expressions in autism and social anxiety (trait levels). As this is a complex process, the different chapters of the dissertation focus on relevant factors in different processing stages and at different levels of description, as well as the links between them.

Chapter 2 explores differences in attentional tendencies towards facial emotional expression that are associated with higher autism and social anxiety trait levels in a large, heterogenous sample, using a so-called dot-probe paradigm. By tracing systematic differences in responding to briefly presented facial emotional expressions, the goal of this chapter is to capture automatic and fast alterations in reactions to others' emotions, that are not heavily influenced by elaborate processing. Furthermore, going beyond previous research, I include a variety of distinct facial emotional expressions, which allows to differentiate between emotion-general and emotion-specific attentional tendencies.

In Chapter 3, I examine bodily responses to others' emotional expressions in observers as well as their interpretations, covering different levels of description in facial emotion perception. Since a comprehensive overview of the bodily resonance of diverse emotional expressions in non-clinical samples has been lacking in the literature, my aim was to gain a better understanding of this phenomenon, without considering the two conditions, as a first step. My examination includes (1) distinct facial emotional cues (tears, blushing and dilated pupils) and emotional expressions (anger, happiness, sadness, fear), the latter expressed via different modalities (face versus body), (2) different physiological measures (facial muscle activity, skin conductance and cheek temperature), as well as (3) different interpretation indices (emotion recognition, perceived intensity of others' emotions and confidence in own judgement).

In line with the broader literature, the resonance of facial emotional expressions shows to be most robust and distinguishable between different emotions in facial muscle (de-) activations in Chapter 3. It, therefore, seems most promising to focus on alterations in facial mimicry, as well as in its link to subjective facial emotion perception, in autism and social anxiety. In Chapter 4, I take a first step toward this goal by examining individual differences related to autistic and social anxiety trait levels in a student population, as indication of potential alterations in the two conditions. Processing of social information can be influenced by beliefs about one's abilities, as specifically highlighted in theories on social anxiety. This has, however, only rarely been examined in an emotion recognition context, and even less so in relation to the two conditions. Hence, I additionally investigate systematic variations related to autistic and social anxiety trait levels in how confidence in emotion recognition is linked to actual recognition performance. In contrast to

the posed facial expressions used in most previous research, I use standardized videos of spontaneous facial emotional expressions as stimuli, increasing the ecological validity of computer-based facial emotion recognition paradigms.

Chapter 5 examines a potential mechanism in altered integration of physiological information in emotion processing, namely interoception. Difficulties in interoception are broadly described in the literature on autism, but their role in interpreting others' emotional expressions is not well understood yet. In this chapter, I aim to quantify the degree to which different measures of interoception can explain altered perception of specific facial emotional expressions with higher autistic trait levels in the general population. In order to increase the explanatory power of my results, I replicate the initial online study in the lab, using the same task, and I add objective measures of facial muscle responses to observed expressions (i.e., mimicry) and of interoceptive accuracy.

In the previous chapters of this dissertation (apart from Chapter 2), I thoroughly examine alterations in facial emotion processing at different processing stages and at different levels of description in relation to autistic and social anxiety trait levels in the general population. Chapter 6 allows to test the thereupon based predictions in a clinical sample, that is, in individuals with a diagnosis of either Autism Spectrum Disorder or Social Anxiety Disorder. I specifically focus on the link between the physiological resonance of facial expressions, indexed by facial muscle activations and skin conductance, and facial emotion perception (recognition, confidence in recognition and perceived intensity), as well as the role of interoception therewithin. In order to be able to infer both the presence as well as the absence of differences in the two groups compared to the control group, I conduct Bayesian analyses next to Frequentist analyses.

Together, the five chapters present novel insights in the putative relevance of the spontaneous embodiment of others' emotions, including the sensation and integration of this physiological resonance, in alterations in facial emotion processing in autism and social anxiety (trait levels).