Bodies, features and visual awareness

Appendix A

Impact paragraph

Emotions play an essential role in our daily lives. They help us understand other people's feelings and respond to them accordingly (Darwin, 1872). The importance of emotional recognition becomes evident in social interactions, and even more so in certain neurodevelopmental and psychiatric conditions characterized by deficits in the accurate perception and response to others' emotional displays (e.g., autism spectrum disorder and schizophrenia) (Archer, Hay, & Young, 1994; Hobson, Ouston, & Lee, 1988).

Although emotions can be conveyed and perceived through several verbal and nonverbal channels (e.g., facial expressions, eye gaze, bodily postures and movements, voice), most research has focused on facial expressions (de Gelder, 2009). This has led to a bias in current theories about human emotion perception as they are based almost exclusively on how faces are perceived and processed in the brain (Adolphs, 2002; Fusar-Poli, Placentino, Carletti, Landi, & Abbamonte, 2009; Haxby, Hoffman, & Gobbini, 2000; Posamentier & Abdi, 2003). I believe that the studies presented in this thesis contribute to the expansion of this narrow view on human emotion perception by considering another source of social and emotional information exceptionally relevant in our daily lives: body expressions. In the five empirical chapters, the mechanisms underlying body expression perception were investigated with various different methodologies and perspectives. Altogether, the findings presented here have several noteworthy implications, spanning theoretical, experimental as well as clinical repercussions.

Given the above, it is not surprising that one the first things emotional researchers do when investigating emotional processing is comparing it to previous face studies. Following the tradition, frequent comparisons between emotional face and body processing have been made throughout this work, either directly with our experimental conditions (e.g., **Chapter 2**) or by comparing the current findings with previous literature. Despite many similarities, the work of this thesis provides evidence for several important differences between the two. One of the most important ones is probably the fact that body expressions constitute a closer link to the argued role of emotion: survival. Indeed, body expressions contain action-related information, making it an essential tool for adaptive behavior. This underscores the need for revising and expanding current theories of

human emotion not only considering facial expressions but also other sources of emotional information.

Another issue emphasized in **Chapter 2** is the importance of studying the joint perception of different emotional signals. Far from what occurs in real life, most studies have focused on the behavioral or neural fingerprints of isolated emotional cues. Yet, increasing evidence has shown that emotional information from different sources is quickly integrated and can drastically change behavioral outcomes and brain processes (e.g., Meeren, van Heijnsbergen, & de Gelder, 2005; Van den Stock, Righart, & De Gelder, 2007). **Chapter 2** showed the case of combining congruent and incongruent emotional face and body expressions. This approach is not only crucial for elucidating the underlying mechanisms behind our daily social interactions but has also proven useful in clinical populations. This is the case of people with amygdala calcification due to Urbach-Wiethe disease (de Gelder et al., 2014; Hortensius et al., 2016). People suffering from this genetical disorder show a strong interference of unattended body expressions during facial expression recognition tasks (de Gelder et al., 2014). Taken together, these findings highlight the need for new models of human emotion that incorporate different emotional sources and how they are combined.

In a more direct manner, the work presented in **Chapter 3** and **4** has led to the proposal of a new framework for the study of body expression perception and emotion in general (see de Gelder & Poyo Solanas, 2021). Prior work often focused on investigating (body) expression perception at the category representation level, typically comparing bodies with other high-level visual objects (e.g., faces, houses, words) or contrasting different emotional body expressions. We moved beyond these traditional methods by investigating how certain postural and kinematical body features relate to emotion recognition and brain processes. As an example, we found that limb contraction constitutes a biologically relevant feature for threat signaling (see **Chapter 3** & **4**), being represented in several cortical and subcortical areas previously reported for fear processing (see **Chapter 4**). The results of these studies led us to reject the *classical hierarchical model* postulating that emotion representation results from the communication between object-selective areas with emotion-related regions only after successful object categorization in the former. Instead, we proposed a *radically distributed model*, in which the category of the stimulus and its particular attributes (e.g., emotion) can rely on parallel and distributed processes (de Gelder & Poyo Solanas,

2021). Thus, emotion representation does not need prior categorical representation but can already be represented at the mid-feature level.

The empirical, theoretical and clinical implications of this new framework are far-reaching. For example, this approach promises a more detailed understanding of body expression perception, social interactions and their brain basis, closing the substantial gap between low-level vision and conceptual category processing (de Gelder & Poyo Solanas, 2021; Long, Yu, & Konkle, 2018). It also provides a new means to clarify the functions of the areas involved in body expression perception and the information exchange between them. A feature-based approach may also shed light into the temporal dynamics of body expression perception. In this regard, previous EEG and MEG studies have reported emotional modulations around 80-100ms post-post stimulus onset, before any categorical representation has taken place (Meeren, Hadjikhani, Ahlfors, Hämäläinen, & de Gelder, 2016; Pizzagalli et al., 2002; van Heijnsbergen, Meeren, Grezes, & de Gelder, 2007). It could be that this early activity is related to the processing of midlevel features and that this information may be enough to trigger adaptive behavior (de Gelder & Poyo Solanas, 2021). In a similar manner, midlevel features may provide an effective framework for investigating the relation between emotion and perceptual awareness. Why do some body expressions escape suppression faster than others (see **Chapter 5**)? In conditions of unawareness, is emotional information represented at a high-order semantic level or is it only processed at midlevel stage? According to our radically distributed model, the feature "limb contraction" (see **Chapter 3** & **4**) may be already enough to signal threat and initiate adaptive behaviors, independently of complete perceptual awareness and of a complete representation of the affective body expression. Finally, this approach may have a crucial impact in clinical settings. For instance, this knowledge may benefit the development of neuropsychological rehabilitation programs (e.g., chronic pain, hemiplegia) or clinical interventions focused on affect recognition and normal social functioning (e.g., autism spectrum disorder, aggression, domestic violence) (de Gelder & Poyo Solanas, 2021). Other areas of society may also benefit from a feature-based approach, such as education, games and entertainment as well as law enforcement and security (Kleinsmith & Bianchi-Berthouze, 2012).

The previous paragraphs summarized the theoretical, empirical and clinical gains and repercussions of the research presented in this thesis. However, every research comes with limitations and intrinsic considerations. One of the clearest shortcomings of the work presented in **Chapter 3** & **4** is the lack of a biologically plausible model that could have guided us in the identification and definition of critical emotion-related features. Such model would have to overcome several methodological challenges (e.g., high dimensionality of body expressions) as well as incorporate the biological constraints of the visual system and the ecological and survival functionalities of the organism (Mobbs, Headley, Ding, & Dayan, 2020). I hope the work of this thesis and its limitations contributes to the development of such model.

On another note, this thesis highlights several theoretical and methodological concerns regarding the study of emotional perception without awareness (see **Chapter 5, 6** & **7**). On one side, it stresses the lack of emphasis on the use of emotional stimuli (especially beyond facial expressions) in the study of non-conscious processing, as most theories of consciousness mainly concern cognitive processes (Seth & Bayne, 2022). On the other side, it reviews several methodological considerations in the design of experiments that are relevant for the interpretation of perceptual awareness findings. Aspects such as the paradigm used to render stimuli invisible, the type of task or the method to assess awareness have a huge impact on what aspect of perceptual awareness is being measured and how results can be interpreted. I hope that the considerations argued in those chapters inspire others to think further about their experimental designs, research questions and findings.

To summarize, this doctoral thesis aimed to broaden the current view on human emotion perception by investigating the underlying mechanisms behind the perception of body expressions. The findings reported in this thesis have been communicated to the scientific community through scientific articles as well as through various international scientific conferences and workshops (see "About the Author" for a comprehensive overview). At the host university, several aspects of this thesis have been shared with different research groups as well as with master students on the occasion of an invited lecture. In addition, the studies forming this thesis have been internally communicated with other members of several grants supporting this work as well as to the general public though workshops organized by the EnTimeMent consortium.

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