Embodying emotions: The role of body modifications in emotional processing in normal populations and psychopathology

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I. Introduction

From ancient times up to the present, numerous philosophers and scientists have focused on the complex relationship between mind and matter. For instance, the question of whether body and mind should either be considered as independent or interacting entities was famously addressed by René Descartes in the 17th century. According to his dualistic approach, minds and bodies are radically different kinds of substances that cannot causally interact (Vieillard-Baron, 1991). However, over time, various philosophical perspectives rejecting the body-mind dichotomy have been developed. These approaches, suggesting a close link between bodily and mental processes, significantly influence today's sciences, particularly in the area of psychology and neuroscience.

In line with this perspective, researchers currently agree on the idea that bodily responding and its perception play a key role in human's emotional experience and behavior. With regards to this, particular emphasis should be placed on William James' famous "theory of emotion" in which he defines an emotion as the consequence of the perception of bodily changes (James, 1884). Concretely, he states that an external, exciting stimulus leads to a physiological reaction, whose interpretation in turn leads to a given emotion. In other terms, we do not tremble because we are afraid, but we are afraid because we tremble (James, 1884). Following models, especially Antonio Damasio's "somatic marker hypothesis" extended existing knowledge by highlighting the close relationship between physiological, emotional and cognitive processes. Damasio states that physiological changes in response to different stimuli are relayed to the brain where they are transformed into a meta-representations of the bodily state constituting an emotional feeling (Damasio, 1994). Together with their associated past outcomes, these emotional feelings affect cognition and behavior, namely by guiding decision making (Damasio, 1994). While the above mentioned theories clarify the interactions between bodily states, emotional experiences as well as cognitive processing, it remained largely unclear whether the *acquisition of knowledge about emotion* and the processing of emotional information might also result from changes at a bodily level.

First answers to this question have been provided by a series of recent accounts, known as "theories of embodied (or grounded) cognition" (e.g., Barsalou, 1999, 2008; Niedenthal, Winkielman, Mondillon, & Vermeulen, 2009). Initially, theories of embodied cognition allowed for highlighting the involvement of modality specific systems (e.g., perception, action, interospection) in higher cognitive processes, such as memory, language or judgments (Vermeulen, Mermillod, Godefroid, & Corneille, 2009). Concretely, the latter approaches suggest that conceptual processing requires partial "as if" reactivation of the sensory-motor systems that are used during interactions with the real world (Barsalou, 1999, 2008; van Dantzig, Pecher, Zeelenberg, & Barsalou, 2008). That is, thinking about the concept of "chair" involves simulations of sitting on a chair in visual, motor, and even affective systems.

However, of particular interest here, the embodied cognition approach has also been applied to the area of emotions. In this view, knowledge about an emotion concept is not reducible to an abstract description, but involves the bodily simulation of experienced emotional states relevant to the concept (Niedenthal et al., 2009;). Even if these simulations can be unconscious and are not as marked as the original emotional state, they provide enough information to facilitate the access to the content of emotion knowledge. In line with Damasio's somatic marker hypothesis, it can thus be argued that the initial perception of an emotional stimuli leads to bodily responses, which are partially recorded and stored in the brain. Later, when cognitive processes require information about this emotional stimulus, the associated pattern of neural states is partially reactivated, stressing the link between modality-specific and conceptual systems (Niedenthal et al., 2009).

Over the past years, a significant number of empirical studies provided support for the embodied simulation account of emotion knowledge. In this chapter, we will review important research findings demonstrating the reciprocal link between bodily states of emotion (e.g., somatic responses) and the processing of emotional information. In fact, parts of the studies presented here examined the relation between motor- and conceptual systems, whereas others investigated the role of facial muscle feedback in this context. Moreover, we will have a closer look on recent findings demonstrating that the processing of emotion concepts is not only affected by peripheral bodily activations (e.g., posture, muscles) but also, more broadly, by physiological modifications, such as heart rate increase or decrease. Next, we will present findings from psychopathology linking reductions of body and brain responses to difficulties in emotional responding and social interactions. Finally, we will discuss possible intervention procedures that could allow improving embodied emotional responses.

II. Embodied emotion in normal populations

Amongst the numerous studies, which are consistent with the embodied emotion framework, several provide evidence for compatibilities between the motor and conceptual system. Indeed, early findings already suggest an influence of overt behavior on the processing of affective material. For instance, Förster and Strack (1996) had participants memorize positive and negative adjectives while performing either vertical or horizontal head movements, which are naturally associated with agreement and disagreement. Findings indicated that participants who nod during the encoding phase were more likely to recognize positive adjectives whereas those who shook their heads were more likely to recognize negative adjectives. Memory of valenced words seems thus to be facilitated by a congruent motor action at the time of learning. Similarly, it has been shown that executed and perceived movements of approach or avoidance influence the categorization of emotional stimuli. Concretely, positive words were categorized more quickly than negative words when flexing the arm and negative words were categorized more quickly than positive words when extending the arm (Neumann & Strack, 2000). Same results were observed when participants were provided with the impression that they were moving either towards (approach) or away (avoidance) from the computer screen (Chen & Bargh, 1999; Rotteveel & Phaf, 2004). Of interest too, Schubert (2004) observed that power related words (e.g.,) became more accessible for participants who made a fist (a behavior related to body force) than for those who made a neutral gesture (i.e., a “scissor” hand gesture). Therefore, evaluations or power related cognitions seem to be influenced by bodily feedback from making a gesture related either to bodily approach/avoidance or force (power).

Additionally, it has been shown that the activation of conceptual knowledge about emotion can initiate significant changes in overt behavior. In a study by Oosterwijk and colleagues (2009) participants were invited to generate as many words as possible that are associated with the concepts of pride/success and disappointment/failure. During the word generation task, participants were filmed in order to identify changes in posture height. Results revealed a decrease in posture height along the vertical axis during the generation of disappointment words and no changes during the generation of pride words. This finding indicates that activating the abstract concept of disappointment instantiates a re-enactement of the bodily state associated with actual feelings of disappointment (Oosterwijk, Rotteveel, Fischer, & Hess, 2009). In other terms, accessing conceptual knowledge about an emotion can lead to the spontaneous adoption of a posture typically related to the latter emotion, supporting the idea of an overlap between the mental representations activated while talking or thinking about an emotion and the experience of the emotion itself (Oosterwijk et al., 2009).

Other evidence supporting the embodied emotion framework comes from studies investigating the relationship between facial muscle activation and the cognitive processing of emotional information. For instance, research findings revealed that making judgments about emotionality of concrete and abstract words leads to emotion specific somatic responses (Niedenthal et al., 2009). Indeed, judgments about concepts typically evoking joy (e.g., sun, cuddle) were accompanied by facial electromyographic activity in the zygomaticus and orbicularis oculi muscles, both involved in smiling. Likewise, the processing of concepts eliciting anger (e.g., fight, murderer) caused activation in the corrugator “frowning” muscle, involved in several expressions of negative emotions (Niedenthal et al., 2009). Hence, it appears that spontaneous simulations of emotional reactions (i.e., discrete facial expressions) are used when it comes to processing emotion-related concepts. Interestingly, it has been shown that distinct positive and negative emotional facial emotional response pattern can even be observed when emotional stimuli are presented too quickly to allow conscious perception (i.e., emotional target faces masked by neutral faces) (Dimberg & Thunberg, 2000).

Besides, further noteworthy findings come from studies based on the so-called facial feedback hypothesis (FFH), which states that facial expressions can modulate subjective emotional experiences (Adelmann & Zajonc, 1989). For example, Strack and colleagues (1988) observed that manipulations of participants' facial expressions actively influenced their affective responses. Participants were instructed to hold a pencil either with the lips only (contracting the orbicularis oris muscle and inhibiting muscle activity associated with smiling), the teeth only (contracting the zygomaticus major and facilitating smiling) or the non-dominant hand (no effect on facial muscles). Subsequently, they were invited to rate the funniness of several cartoons while holding the pencil in the original position (lips, teeth or hand). Results revealed that the unconscious facilitation of smiling lead to more intense humor responses (i.e., significantly higher funniness ratings) in comparison with the inhibiting condition. Convergent findings have been reported by Soussigan (2002) and Duclos and Laird (2001). Furthermore, Ohira and Kurono (1993) observed an influence of facial feedback on social cognitive processes involved in impression formation. In fact, participants were instructed to display or conceal their facial expressions when interacting with a mildly hostile or friendly person. Displaying facial expressions lead to impressions congruent with the facial expression whereas concealing facial reactions had no effect on impression formation (Ohira & Kurono, 1993).

With regards to more cognitive performances, it has been demonstrated that manipulations of facial expressions affect participant's response patterns in an autobiographical memory task (Schnall & Laird, 2003). Participants who practiced facial expressions associated with happiness recalled more life events with content rated as happy, while participants who previously expressed anger recalled more angry information (Schnall & Laird, 2003). Of interest too, Niedenthal et al. (2009) observed an impairment in the processing of joy- and disgust-related concepts when participants were prevented from producing certain facial movements (by holding a pen laterally between lips and teeth). Consequently, it can be suggested that facial reactions are more than simple side-effect of thinking about or being exposed to an emotional stimulus. Support for this assumption comes from a series of recent studies testing the role of emotion simulation in language comprehension. For instance, manipulations of facial expressions influenced the amount of time participants needed to read and judge the valence of a sentence (Havas, Glenberg, & Rinck, 2007). Once again, a pen-holding procedure was used in order to produce or inhibit a smile. Results showed that participants' response speed for pleasant sentences was faster while they were smiling than while they were prevented from smiling. The reverse effect was found for unpleasant sentences, indicating that language comprehension involves mental simulations of sentence content relying on the same neural systems used in literal emotional experiences (Havas et al., 2007). However, it remains unclear whether participants' voluntary control of their facial expression could provide the basis for the observed interactions. To clarify this issue, the same research group conducted a follow-up study in which subcutaneous injections of botulinum toxin-A (Botox) were used to eliminate voluntary muscle control (Havas, Glenberg, Gutowski, Lucarelli, & Davidson, 2010). Participants were first time Botox patients receiving injections in the corrugators supercilii muscle used in expressing negative emotions (i.e., frowning). In two sessions (before and two weeks after Botox injection), participants were instructed to read angry, sad and happy sentences and to press a number on the keypad when they finished reading the sentence. Analysis revealed that reading times for angry and sad sentences were significantly longer in the second session (post-injection) than in the first session (pre-injection). There was no difference between the two sessions for happy sentences. These results emphasize that peripheral feedback from facial emotional expressions plays a central, functional role in understanding emotional language, thereby backing up facial feedback and embodied emotion theories. Similarly, it has been shown that selective denervation of face muscles (Botox-induced) reduces mimicry of others' facial expressions and modulates activation in neural areas (Hennenlotter et al., 2009). More precisely, during imitation of angry facial expressions, restricted muscle feedback due to Botox treatments attenuates activation of the left amygdale and its functional coupling with brain stem centers implicated in autonomic manifestations of emotional states (Hennenlotter et al., 2009). Consequently, it can be suggested that neural activity in central circuits of emotion provide a basis for the social transfer of emotion (i.e., mimicry of others facial expressions). Furthermore, it has been shown that the perception of emotional expressions can modulate sensory exposure at an attentional level. It is indeed known, that expressing fear enhances sensory input (e.g., larger visual field, faster eye movements, increase in nasal input) whereas the opposite pattern can be observed for disgust expressions (i.e., reduction in sensory exposure) (Susskind et al., 2008). Interestingly, by using an attentional blink paradigm, Vermeulen, Godefroid and Mermillod (2009) found evidence suggesting that these facial expressions produce similar effects at a cognitive (attentional) level. Fear and disgust emotion cause thus processes of closure and extension on perceivers attentional system that are similar to the sensory processes observed during emotional expression. This observation ties up with the embodied emotion literature suggesting that the processing of others' facial expressions of emotions relies on the same neural structures than the personal experience of emotions (e.g., Gallese, 2003). With regards to their findings, Vermeulen et al. (2009) conclude that perceivers are likely to act on the environment as expressers do to maximize beneficial adaptation. In other terms, when perceiving an expression of fear in another's face, we automatically behave as if we were actually experiencing fear which allows in turn to behave in the most adaptive way. Therefore, embodied emotions do not only facilitate the access to emotion knowledge but do also support survival by transmission of emotional states from expressers to perceivers.

While the above-mentioned studies provide evidence for the representation of emotion at a *peripheral* level (e.g., facial muscles, posture), the question of bodily representations of emotion at an *internal* level has also been examined through the investigation of interoceptive awareness. In fact, in their daily lives, humans do not only have access to external environmental cues but they also perceive signals from the inner body that provide a sense and feedback of their physical and physiological condition (Pollatos, Kirsch, & Schandry, 2005). This subjective awareness of inner feelings classically refers to the concept of "interoceptive awareness" (IA), which encompasses sensations pertaining to the physiological condition of the entire body, including muscles, joints, skin, teeth and viscera (Craig, 2004).

Studies have shown that higher level of interoceptive sensitivity is associated with greater emotional responses at subjective and physiological level (Pollatos et al., 2005) . Of particular interest, a recent study demonstrated that interoceptive awareness moderates embodied cognition (Häfner, 2013). Concretely, two experiments showed that the embodiment of weight and softness into judgments of value and persons is moderated by interindividual differences in interoceptive awareness.

However, the question of whether internal bodily changes might influence more specifically the processing of emotional information remains unanswered. For instance, first results showed that changes in participant's levels of physiological arousal (i.e., heart rate) significantly influenced the processing of arousal congruent and incongruent emotional words. Concretely, participants realized two blocks of an attentional blink (AB) paradigm, once after a short physical exercise session (increased arousal) and once after a relaxation session (reduced arousal). During the AB task, two target words (T1 and T2) were presented in close succession in a rapid serial visual presentation (RSVP) of distractor items (Raymond, Shapiro, & Arnell, 1992). The AB effect refers to the reduced ability to report the second of two targets (T2) if it appears 200 to 500 msec after the first to-be-detected target (T1). In the present study, T1 were always neutral words whereas T2 were either high arousal (e.g., vomit, wealth) or low arousal words (i.e., distress, flower). Results revealed that increased physiological arousal led to improved reports of high arousal T2 words, while reduced physiological arousal led to improved reports of low arousal T2 words. Neutral T2 remained unaffected by the arousing conditions. These findings are the first emphasizing that actual levels of physiological arousal modulate the cognitive access to arousal (in) congruent emotional concepts, and suggest a direct grounding of emotion knowledge in our bodily systems of arousal (Kever et al., 2014).

III. Embodied emotion in psychopathology

The experimental studies described in the first part of the chapter support the assumption that emotions are bodily represented at a *peripheral* (e.g., facial muscles), *central* (neural activity) and *internal* (physiological) level. These studies showed that preventing an embodied representation (e.g., by blocking facial expressions), impairs the processing of emotional information (e.g., recognition of emotional stimuli; (Niedenthal et al., 2009). Though, although they are innovating and experimentally valid, these studies are limited to healthy populations, and therefore limited to the normal functioning of embodied emotions. In order to provide additional support for theories of embodied emotion, it seems necessary to test the latter theories among psychopathological populations. It should be specified that although these impairments may be associated with problems in the processing of emotional stimuli, embodied emotional representations do not represent the unique available resource for emotional processing (Winkielman, McIntosh, & Oberman, 2009). Individuals may indeed also rely on non-embodied emotional representations such as knowledge about facial expression of happiness (e.g., smile) to access emotional content.

However, as suggested by Winkielman et al. (2009), the embodied emotional representations may be useful in specific situations, namely difficult and/or novel tasks.

In the following section, we will thus present a non exhaustive overview of studies that have investigated embodied representations of emotion in psychopathological populations.

Autism Spectrum Condition

Peripheral and central representations

According to the DSM-IV, Autism Spectrum Disorder (ASD involves impairments in social functioning, communication, and restricted repetitive and stereotyped patterns of behaviours, interests and activities. Regarding emotional processing, a large number of studies have highlighted impairment in the processing of emotional facial expressions (EFEs) among ASD individuals (see for review Uljarevic & Hamilton, 2013). However, evidence suggest that this deficit is limited to challenging tasks (i.e., short presentation; degraded image) (e.g., Winkielman et al., 2009), Therefore, one can hypothesize that ASD individuals do not use the same strategies to recognize EFEs and that relative to healthy individuals, ASD individuals may rely to a lesser extent on embodied emotional representation. This may then lead to impaired performances during challenging conditions only.

In support of this hypothesis, several studies suggest that ASD is characterized by impaired *peripheral* embodied representations of emotions. Specifically, these studies reveal impaired spontaneous emotional facial mimicry (Electromyography) when the task does not require recognizing EFEs (i.e., simply watch). For instance, ASD individuals have a significantly lower rate of congruent automatic facial mimicry responses to happy and angry facial expressions (zygomaticus activation to happy faces - corrugator supercilii activation to angry faces) than healthy individuals (McIntosh et al, 2006). This is in line with studies showing decreased spontaneous mimicry to happy and angry expressions in females with high level of autistic traits (Hermans, van Wingen, Bos, Putman, & van Honk, 2009) and in children with ASD (Beall, Moody, Mc Intosh, Hepburn, & Reed; 2008). Lower spontaneous mimicry in ASD has even been shown using emotional videos (Stel, van den Heuvel, & Smeets, 2008).

Importantly, the studies of McIntosh et al, (2006) and Hermans et al., (2009) revealed that ASD and control groups did *not* differ when instructed to voluntarily mimic emotional faces. Furthermore, when participants are instructed to recognize emotional facial expressions, ASD and healthy children do not differ in terms of EMG responses' amplitude but differ in terms of timing, with delayed mimicry (i.e., 160 ms) among ASD (Oberman, Winkielman, & Ramachandran 2009). On asis of these findings it can be assumed that lower spontaneous emotional mimicry in ASD does not result from general mimicry deficits. In terms of embodied emotional representations, ASD may rely on embodied representations of emotion, but with a delay, and only when the tasks require emotional processing (vs passive viewing), and thus motivational engagement (in ASD) (Mathersul, McDonald, & Rushby, 2013).

Therefore, in line with the facial feedback hypothesis (FFH) (Adelmann & Zajonc, 1989) according to which facial mimicking is useful for emotional processing (Harrison et al., 2010), one could argue that ASD's lower spontaneous emotional mimicry predicts their EFEs recognition deficits. However, no study has to date tested the correlations between mimicry and recognition performances. This question should thus be investigated in further studies. Furthermore, one recent study does not support the hypothesis of the influence of motivational and/or challenging conditions (Rozga et al., 2013), confirming the importance of future investigations of the moderating factors modulating the interaction between ASD, EFE recognition performances and EMG (mimicking) activation. In Rozga and colleagues (2013), there were no significant differences between zygomatic and corrugator activity 500 msec to 1000 msec after the presentation of happy, angry, and fearful faces in ASD during an EFE recognition task. However, ASD and healthy participants did not differ in the magnitude and timing of EMG activity in response to congruent emotions (i.e., zygomatic responses to happy faces and corrugator responses to fearful faces). Therefore, ASD might be characterized by undifferentiated EMG activation, and thus by impaired embodied representation of emotions.

In terms of neural mechanisms, further studies may investigate how ASD modulates the activation in regions involved in the association between facial mimicking and emotional processing, namely, rostral cingulate motor cortex, amygdala, somatosensory cortex and ventromedial prefrontal cortex. Previous research have indeed highlighted bidirectional connectivity between regions that code for the representation of upper face (rostral cingulate motor cortex; Ledoux, 2000) and a key structure in the processing of emotional stimuli, and more specifically, of EFEs (amygdala) (Sergerie, Chochol, & Armony, 2008). In addition, studies have highlighted the role of the right somatosensory cortex of in EFEs (Adolphs et al., 2000; Pitcher et al., 2008), supporting the role of the body in processing emotional material. Finally, the ventromedial prefrontal cortex, is involved in somatic markers (Damasio, 1996) which can transform facial changes into a meta-representations of the bodily state associated with a specific emotion. In ASD, previous findings showed that ASD present lower activation in the amygdala and somatosensory cortex during processing of emotional material (e.g., Baron-Cohen, Ring, Bullmore, Wheelwright, & Ashwin, 2000), as well as impaired connectivity between ventromedial prefrontal cortex and somatosensory cortex during self-judgments (Lombardo et al., 2009). Therefore, while future studies should investigate the neural underpinning of spontaneous mimicry, one might hypothesize that these neural impairment account for ASD lower used of embodied representation of emotion during processing of emotional stimuli.

In sum, previous research reveals that impaired processing of EFEs during challenging conditions and/or low motivational states, might be partly accounted for by lower relying of possibly preserved peripheral embodied emotional representations. Future studies are necessary in order to investigate the association between EFEs processing performances and spontaneous emotional facial mimicking as well as its neural underpinning.

Internal representations

As mentioned in the introduction, interoceptive awareness refers to the ability to represent the state of the body and to perceive changes arising from the body as feelings and sensations. Interoception refers to the perception of the physiological activity of the body (heart rate) and the representation of the internal state (stomach discomfort).

In relation to embodied representations of emotions, most models of emotions support that physiological responses are a component of emotional experience. Therefore, the ability to recognize sensory responses (i.e., interoceptive awareness) is important for the accurate identification of emotional experiences, and consequently for appropriate emotion regulation s can be regulated if necessary. Interoceptive awareness is suggested to contribute to emotional feelings in terms of arousal, such that interoceptive awareness leads to higher report of arousal (Critchley, Wiens, Rotshtein, Ohman, & Dolan, 2004). Recent studies support the hypothesis that greater interoceptive awareness is associated with reports of higher arousal in response to emotional pictures (e.g., Pollatos et al., 2005). Greater interoceptive awareness is also associated with greater heart rate deceleration in response to emotional stimuli, which was related to report of higher arousal (Pollatos, Herbert, Matthias, & Schandry, 2007), and with better memory of emotional words (Pollatos & Schandry, 2008). These findings thus indicate that these processes are associated one with the other another. In fact, interoceptive awareness, subjective experience of emotions, and cardiovascular arousal are underlined by similar brain region (e.g., insula, ACC; Critchley, et al., 2004). Moreover, the anterior insula is involved in the integration of visceroception with emotion processing (Craig, Hatton, Craig, & Bentall, 2004). Thus, altered activation in these regions could explain the associations between poor interoception and emotional experience.

Based on these findings, one may hypothesize that ASD individuals present impaired visceral embodied representation of emotions. Indeed, ASD is characterized by difficulties in identifying and describing emotional experience (i.e., alexithymia) (Hill, Berthoz, & Frith, 2004). Furthermore, alexithymia is associated with reduced ability to count one's heartbeats accurately (interoceptive sensitivity task; Pollatos et al., 2007). Thus, ASD impaired sensory experiences as being an emotion, and impaired understanding of one’s own emotional experiences (i.e., alexithymia) may be partly accounted for by lower interoceptive awareness. Although no study has examined interoceptive sensitivity in ASD, it has been argued that abnormalities of the anterior insula may be a main characteristic of ASD (Uddin & Menon, 2009). The interior insula is indeed a core region in the representation of emotions. Therefore, the hypo-activity of the anterior insula (Di Martino et al., 2009) and its reduced connectivity to emotional neural regions (e.g., ACC; amygdala) in ASD may support the hypothesis that ASD is characterized by reduced *internal* embodied representations of emotions through reduced activity and connectivity of the anterior insula.

In order to support this hypothesis, future studies should investigate if greater alexithymia levels in ASD are predicted by reduced anterior insula activation and/or reduced connectivity to the ACC or amygdala. During an empathy task, one study showed that when controlling for alexithymia there was no group effect (ASD versus healthy) on brain activation in the region typically activated in empathic responding to someone in a painful situation (i.e. the anterior insula, Bird, et al., 2010).

In sum, while future studies are necessary in order to support the present findings, these latter are in line with the hypotheses (1) that embodied representations of emotions may be impaired at peripheral, central and/or internal level in ASD and (2) that these impairments may be associated with reduced abilities in identifying emotional stimuli or emotional experience in ASD.

Schizophrenia

Peripheral and central representations

Emotional alterations are main characteristics of schizophrenia. Schizophrenia is a personality disorder characterized by behavioural and cognitive deficits, such as attentional and memory deficits. This disorder is also characterized by delusions, disorganized speech and thought, and by emotional impairments (e.g., loss of interest, affective blunting, anhedonia) (DSM -IV). Furthermore, social deficits have often been observed among schizophrenic people (e.g., Shamay-Tsoory, Shur, Barcai-Goodman, Medlovitch, & Hariri, 2007). For instance, studies have highlighted deficits in decoding EFEs. Furthermore, few studies have examined emotional facial mimicry in schizophrenia, and have revealed lower EFEs spontaneous mimicry (Kring et al., 1999). More specifically, schizophrenic patients showed unusual EMG activation in response to happy faces, leading to facial expression that cannot be assigned to any specific expression (Wolfs et al., 2006). More recently, Stetito and colleagues (2013) investigated the effect of visual and auditory emotional stimuli on EMG activation in schizophrenia and healthy patients. During this task, dynamic expressions of happiness, sadness or neural emotion were presented with congruent (i.e., laugh, cry or neutral) or incongruent auditory stimuli. Participants were instructed to recognize the EFE and to rate the perceived emotional intensity of the stimuli, from very negative to very positive. In addition, their EMG activity was recorded. Results showed that schizophrenic patients and control participants did not differ in terms of EMG activation in response to visual and/or auditory neutral stimuli. They also show a similar pattern for negative stimuli. However, for positive EFEs, schizophrenic patients and healthy participants differed regarding Zygomaticus activity (related to happy expressions). While the control group showed rapid EMG activation (between 0 and 500 ms), schizophrenic patients showed EMG activation that was independent of the happy facial expressions (delayed of more than 1000 ms after the onset of the EFEs or not specific to happy facial expressions), presented with or without auditory congruent stimulus (i.e. laugh). When happy faces were presented with incongruent auditory stimulus (e.g., cry), and when participants only heard the positive auditory stimulus (laugh) without visual EFEs, these patients did not show any EMG activation. Furthermore, schizophrenic patients with low average of EMG activity rated emotional visual images as less positive and less negative (i.e., neutral). Therefore, according to these findings, schizophrenia is characterized by impaired mimicry of positive emotions.

Similarly to ASD, schizophrenia may also be characterized by reduced central embodied representations of emotions. Indeed, schizophrenia patients present lower reduced or abnormal activation in regions associated with emotional processing and mimicking. They show abnormal activation in the amygdala and somatosensory cortex during processing of emotional material (e.g., Sugranyes et al, 2011), as well as reduced ventromedial prefrontal cortex gray matter volume that correlates with their social impairments (Hooker et al., 2011).

Taken together, these results suggest a possible role of facial mimicry in order to evaluate the valence of emotional stimuli. More globally, they suggest that schizophrenia may be associated with impaired peripheral representations of happiness, leading to impaired EFEs recognition abilities. Moreover, abnormal neural embodied representations may account for schizophrenia impairments in EFEs decoding and social deficits.

Internal representations

In addition to deficits in processing emotional stimuli, schizophrenia is associated to emotional self-awareness deficits. Previous research have indeed shown higher levels of alexithymia in schizophrenia (Todarello, Porcelli, Grilletti, & Bellomo, 2005), as well as abnormal activation of regions involved in interoception, such as anterior insula (Wilie & Tregellas, 2010). Although there are no empirical evidence in favor of interoceptive awareness deficits in schizophrenia in association with emotional experience, higher levels of alexithymia and abnormal activation of the anterior insula may suggest impaired internal embodied representations of emotions in schizophrenia.

IV. Toward Possible Embodied Rehabilitation

As previously mentioned, individual differences may influence the capacity to use the body as a support to represent emotions. At the extreme negative side of the continuum, we may find psychopathological states such as Autistic spectrum or Schizophrenia. But we may already find difficulties embodying emotions in normal people presenting difficulties identifying emotions (like alexithymia). One important question is related to possible training or rehabilitation of embodied skills. Is it possible to train participants to focus on their body responses in order to facilitate emotional adaptation?

Recent studies showed that training individuals to detect micro expression improves the detection of emotional expressions (micro or not) among healthy and clinical populations (e.g., schizophrenia), but also communication skills (e.g., Matsumoto and Hwang, 2011). The METT training program of Ekman (2002) is used in empirical studies. It consists of three training stages. In the first test phase of this paradigm, two neutral facial pictures are simultaneously presented. Then, both pictures gradually evolve to a specific emotional expression (e.g., anger and disgust). The paradigm consists of presenting pairs of facial expressions that are commonly confused with each other (anger/disgust, contempt/happy, fear/surprise, fear/sadness). This phase aims to train participants to notice the differences between the expressions that are often confused. In the second test phase, the display involves a single neutral face that rapidly (15msec) evolves to a specific emotional expression before returning to the original neutral expression. Participants have to label the EFE and they receive feedback on their performance. The METT was used by Russel et al. (2006) who tested twenty healthy individuals and twenty schizophrenic patients. The pre-test showed that schizophrenic patients had poorer performances at the METT than healthy subjects, but not at the post-test. They also showed that the effect was generalizable to a non-verbal emotion-matching task,. Indeed, the performance of schizophrenic patients, but not of healthy subjects, improved following training. Still, few studies have investigated this issue in clinical populations, and further studies should be conducted in order to support the relevance of such training on EFEs identification but also on communication, and social skills in general.

With respect to the embodied representation of emotions, one could suggest that this training, due to its challenging (i.e., temporal constraints) conditions of presentation, would lead patients to rely more on embodied representations of emotions. Through this practice, patients may strengthen their embodied representations of emotion, which may be beneficial for other types of emotional processing (e.g., non-verbal emotion-matching task). Future studies are still necessary in order to examine the effect of METT training on other emotional processing and how it is accounted by a greater use of peripheral embodied representation of emotion (e.g., emotional mimicry during EFEs decoding tasks).

Interestingly, there exist training solutions that aim at developing in people the awareness of what is happening at the present time either at the sensory level or at the internal (or interoceptive) level. Such training solutions include Mindfulness training. Mindfulness (MF) is a state of being characterized by an intentional orientation of attention toward all experiences in the present, as they arise moment by moment, in a non-judgemental and benevolent attitude (Kabat-Zinn, 2003), applying to all aspects of living (i.e., introspection, interpersonal relationships, sensory perception). In its occidental and scientific use, MF has been conceived as a measurable trait (FFMQ; Baer *et al.*, 2006) or a trainable competence through meditative practices (MBCT; Segal *et al.*, 2002) and showed multiple benefits on health (Carlson *et al.*, 2007), cognitive abilities (Chiesa *et al.*, 2011) as well as intrapersonal emotional competencies (e.g., emotion differentiation) (Hill & Updegraff, 2012). By bringing to consciousness upcoming information from all senses and observing the co-occurring mental activity, MF leads people to be highly aware of their embodied emotional experiences and develops the first person perspective of bodily states (see Hölzel *et al.*, 2011 for a review of neuroscientific studies). Standing at the crossroads of research on MF and embodiment, it can be hypothesized that consciously linking associated thoughts and sensations through MF creates or reinforce embodied knowledge. As an example, when a person puts herself in a MF set, thoughts of fear (e.g., anticipating sufferance) will be noticed as well as the related physiological reactivity patterns (e.g., heart beat acceleration, avoiding behaviour). These learned somatic markers of emotional experiences might then offer multiple available cues for emotion differentiation and for the activation of related concepts in memory. Future studies should investigate this potential effect of increased awareness on embodied (emotional) knowledge. Indeed, even though MF training programs show beneficial effects on emotional competences (e.g., emotion regulation; Ortner *et al.*, 2007), still little is known about the mechanisms of action from MF practice to enhanced emotional functioning and embodied responding (e.g., mimicry).

V. Conclusions

In the chapter, we present evidence that thinking about or evaluating emotions leads to reactivations of bodily responses. Whereas previous opponents naturally objected that these reactivations might only represent correlates (subsequent) of the emotional processing as a result of spreading of activations in the cognitive system, recent findings cannot be accounted for by such spreading. For instance, blocking facial response (i.e., with a pen or by using BOTOX) prevents or slows down natural processing of emotional information.

Importantly, in people presenting psychopathological traits, a correlation can be found between facial blunting and emotional responding difficulties. Alexithymia – the difficulty to identify and express one's own emotions– seems to be a transdiagnostic deficit in psychopathologies such as autism (Hill et al., 2004) or schizophrenia (Todarello, Porcelli, Grilletti, & Bellomo, 2005). Supporting the hypothesis of psyche-soma dissociation in individuals showing high levels of alexithymia (Lane *et al.*, 1997), neuroscientific evidence of a deficit in interoceptive awareness among the same psychopathological disorders has been observed (i.e., anterior insula; Bird, *et al.*, 2010). It might thus be suggested that the "disconnection or decoupling" between physiological (peripheral and central) and mental (i.e., subjective) states, found in alexithymic individuals, may explain their difficulty to distinguish between feelings and the bodily sensations of emotional arousal as these information insufficiently enter their conscience (interoceptive awareness). In the words of Damasio (1999), the feeling of experiencing an emotion – produced by the proto-self – emerges from the detection and mental representation of modifications in our body and cognitive states and their relation to our environment. Hence, we could argue that in some individuals the access to emotions is hampered by a lack of somatic markers and/or a poor awareness of physiological cues to process emotional information. Based on the embodiment theory, it might be hypothesized that individuals scoring high on alexithymia scales possess a poorly embodied emotional knowledge (semantic) (Vermeulen et al., 2006).

Finally, we believe that some training specifically oriented toward facial mimicry or more generally oriented toward the awareness of what is happening in the present time (Mindfulness) may help improving emotional embodiment. Such training may more globally increase the richness and the quality of the emotional repertoire.

References

Adelmann, P. K., & Zajonc, R. b. (1989). Facial Efference and the Experience of Emotion. *Annual Review of Psychology*, *40*(1), 249.

Baer, R. A., Smith, G. T., Hopkins, J., Krietemeyer, J., & Toney, L. (2006). Using self-report assessment methods to explore facets of mindfulness. *Assessment, 13*(1), 27-45.

Baron-Cohen S, Ring HA, Bullmore ET, Wheelwright S, Ashwin C, Williams SC (2000), "The amygdala theory of autism." Neurosci Biobehav Rev 24(3):355-64

Barsalou, L. W. (1999). Perceptual symbol systems. *Behavioral and Brain Sciences*, *22*(04), 577–660.

Barsalou, L. W. (2008). Cognitive and neural contributions to understanding the conceptual system. *Current Directions in Psychological Science*, *17*(2), 91–95.

Beall, P. M., Moody, E. J., McIntosh, D. N., Hepburn, S. L., & Reed, C. L. (2008). Rapid facial reactions to emotional facial expressions in typically developing children and children with autism spectrum disorder. Journal of Experimental Child Psychology, 101, 206 -223.

Bird, G., Silani, G., Brindley, R., White, S., Frith, U., & Singer, T. (2010). Empathic brain responses in insula are modulated by levels of alexithymia but not autism. Brain, 133, 1515-1525.

Carlson, L. E., Speca, M., Faris, P., & Patel, K. D. (2007). One year pre-post intervention follow-up of psychological, immune, endocrine and blood pressure outcomes of mindfulness-based stress reduction (MBSR) in breast and prostate cancer outpatients. *Brain, Behavior, and Immunity, 21*, 1038-1049.

Chen, M., & Bargh, J. A. (1999). Consequences of Automatic Evaluation: Immediate Behavioral Predispositions to Approach or Avoid the Stimulus. *Personality and Social Psychology Bulletin*, *25*(2), 215–224. doi:10.1177/0146167299025002007

Chiesa, A., Calati, R., & Serretti, A. (2011). Does mindfulness training improve cognitive abilities? A systematic review of neuropsychological findings. *Clinical Psychology Review, 31*, 449-464.

Craig, A. D. (2004). Human feelings: why are some more aware than others? *Trends in Cognitive Sciences*, *8*(6), 239–241.

Craig, J. S., Hatton, C., Craig, F. B., & Bentall, R. P. (2004). Persecutory beliefs, attributions and theory of mind: comparison of patients with paranoid delusions, Asperger's syndrome and healthy controls. Schizophrenia Research, 69(1), 29-33.

Critchley, H. D., Wiens, S., Rotshtein, P., Ohman, A., & Dolan, R. J. (2004). Neural systems supporting interoceptive awareness. [10.1038/nn1176]. Nat Neurosci, 7(2), 189-195.

Damasio, A. R. (1994). *Descartes' error: Emotion, reason and the human brain*. New York, USA: Grosset/Putnam.

Damasio, A. R. (1999). *The feeling of what happens : Body and emotion in the making of consciousness*. New

York : Hartcourt Brace & Company.

Di Martino A, Shehzad Z, Kelly AMC, Roy AK, Gee DG, Uddin LQ, Gotimer K, Klein DF, Castellanos FX, Milham MP. (2009b). Autistic traits in neurotypical adults are related to cingulo-insular functional connectivity. Am. J. Psychiat.,

Dimberg, U., & Thunberg, M. (2000). Unconscious facial reactions to emotional facial expressions. *Psychological Science (Wiley-Blackwell)*, *11*(1), 86.

Duclos, S. E., & Laird, J. D. (2001). The deliberate control of emotional experience through control of expressions. *Cognition & Emotion*, *15*(1), 27–56. doi:10.1080/02699930126057

Ekman, P., Friesen, W. V., & Hager, J. C. (Eds.). (2002). Facial action coding system: Research

Nexus, Network Research Information, Salt Lake City, UT.

Förster, J., & Strack, F. (1996). Influence of overt head movements on memory for valenced words: a case of conceptual-motor compatibility. *Journal of Personality and Social Psychology*, *71*(3), 421.

Gallese, V. (2003). The roots of empathy: The shared manifold hypothesis and the neural basis of intersubjectivity. *Psychopathology*, *36*(4), 171–180. doi:http://dx.doi.org/10.1159/000072786

Häfner, M. (2013). When Body and Mind Are Talking: Interoception Moderates Embodied Cognition. *Experimental Psychology (formerly Zeitschrift Für Experimentelle Psychologie)*, *60*(4), 255–259. doi:10.1027/1618-3169/a000194

Havas, D. A., Glenberg, A. M., Gutowski, K. A., Lucarelli, M. J., & Davidson, R. J. (2010). Cosmetic Use of Botulinum Toxin-A Affects Processing of Emotional Language. *Psychological Science*, *21*(7), 895–900. doi:10.1177/0956797610374742

Havas, D. A., Glenberg, A. M., & Rinck, M. (2007). Emotion simulation during language comprehension. *Psychonomic Bulletin & Review*, *14*(3), 436–441. doi:http://dx.doi.org/10.3758/BF03194085

Hennenlotter, A., Dresel, C., Castrop, F., Ceballos-Baumann, A. O., Wohlschlager, A. M., & Haslinger, B. (2009). The Link between Facial Feedback and Neural Activity within Central Circuitries of Emotion--New Insights from Botulinum Toxin-Induced Denervation of Frown Muscles. *Cerebral Cortex*, *19*(3), 537–542. doi:10.1093/cercor/bhn104

Hermans, E.J., van Wingen, G., Bos, P.A., Putman, P., and van Honk, J. (2009). Reduced spontaneous facial mimicry in women with autistic traits. Biological Psychology 80, 348-353.

Hill, C. L. M., & Updegraff, J. A. (2012). Mindfulness and its relationship to emotional regulation. *Emotion, 12*(1), 81-90.

Hill, E., Berthoz, S., & Frith, U. (2004). Brief report: Cognitive processing of own emotions in individuals with autistic spectrum disorder and in their relatives. Journal of Autism and Developmental Disorders, 34(2), 229-235.

Hölzel, B. K., Lazar, S. W., Gard, T., Schuman-Olivier, Z., Vago, D. R., & Ott, U. (2011). How does mindfulness meditation work? Proposing mechanisms of action from a conceptual and neural perspective. *Perspectives on Psychological Science, 6*(6), 537-559.

Hooker, C. I., Bruce, L., Lincoln, S. H., Fisher, M., & Vinogradov, S. (2011). Theory of mind skills are related to gray matter volume in the ventromedial prefrontal cortex in schizophrenia. Biological psychiatry, 70(12), 1169-1178.

Kabat-Zinn, J. (2003). Mindfulness-based interventions in context: Past, present and future. *Clinical Psychology: Science and Practice, 10*, 144-156.

Kring, A. M., & Earnst, K. S. (1999). Stability of emotional responding in schizophrenia. Behavior Therapy, 30(3), 373-388.

Lane, R. D., Ahern, G. L., Schwartz, G. E., & Kaszniak, A. W. (1997). Is alexithymia the emotional equivalent of blindsight ? *Biological Psychiatry, 42*, 834-844.

LeDoux J.E., 2000, Emotion Circuits in the Brain, Annual Review of Neuroscience, 23:155-184.

Lombardo MV, Chakrabarti B, Baron-Cohen S (2009), “What neuroimaging and perceptions of self-other similarity can tell us about the mechanism underlying mentalizing.” Behav Brain Sci 32(2):152-153

Mathersul, D., McDonald, S., Rushby, J.A. (2013) Autonomic arousal explains social cognitive abilities in high-functioning adults with autism spectrum disorder, International Journal of Psychophysiology

McIntosh, D. N., Reichmann-Decker, A., Winkielman, P., & Wilbarger, J. L. (2006). When the social mirror breaks: Deficits in automatic, but not voluntary mimicry of emotional facial expressions in autism. Developmental Science, 9, 295-302.

Niedenthal, P., Winkielman, P., Mondillon, L., & Vermeulen, N. (2009). Embodiment of emotion concepts. *Journal of Personality and Social Psychology*, *96*(6), 1120–1136. doi:10.1037/a0015574

Oberman, L. M., Winkielman, P., & Ramachandran, V.S. (2009). Slow echo: Facial EMG evidence for the delay of spontaneous, but not voluntary emotional mimicry in children with autism spectrum disorders. Developmental Science, 12, 510–520.

Ohira, H., & Kurono, K. (1993). Facial feedback effects on impression formation. *Perceptual and Motor Skills*, *77*(3 Pt 2), 1251–1258.

Oosterwijk, S., Rotteveel, M., Fischer, A. H., & Hess, U. (2009). Embodied emotion concepts: How generating words about pride and disappointment influences posture. *European Journal of Social Psychology*, *39*(3), 457–466. doi:10.1002/ejsp.584

Ortner, C.N.M., Kilner, S.J., & Zelazo, P.D. (2007). Mindfulness meditation and reduced emotional interference on a cognitive task. *Motivation and Emotion, 31*, 271–283.

Pitcher, D., Garrido, L., Walsh, V., and Duchaine, B. C. (2008). Transcranial magnetic stimulation disrupts the perception and embodiment of facial expressions. The Journal of Neuroscience : The Official Journal of the Society for Neuroscience, 28(36), 8929-33.

Pollatos, O., Herbert, B. M., Matthias, E., & Schandry, R. (2007). Heart rate response after emotional picture presentation is modulated by interoceptive awareness. Int J Psychophysiol, 63(1), 117-124.

Pollatos, O., Herbert, B. M., Schandry, R., & Gramann, K. (2008). Impaired central processing of emotional faces in anorexia nervosa. Psychosomatic Medicine, 70(6), 701-708.

Pollatos, O., Kirsch, W., & Schandry, R. (2005). On the relationship between interoceptive awareness, emotional experience, and brain processes. Cognitive Brain Research, 25(3), 948-962.

Raymond, J. E., Shapiro, K. L., & Arnell, K. M. (1992). Temporary suppression of visual processing in an RSVP task: An attentional blink? *Journal of Experimental Psychology: Human Perception and Performance*, *18*(3), 849.

Rotteveel, M., & Phaf, R. H. (2004). Automatic Affective Evaluation Does Not Automatically Predispose for Arm Flexion and Extension. *Emotion*, *4*(2), 156–172. doi:http://dx.doi.org/10.1037/1528-3542.4.2.156

Rozga, A., King, T. Z., Vuduc, R. W. and Robins, D. L. (2013), Undifferentiated facial electromyography responses to dynamic, audio-visual emotion displays in individuals with autism spectrum disorders. Developmental Science, 16: 499–514.

Russell, T. A., Chu, E., & Phillips, M. L. (2006). A pilot study to investigate the effectiveness of emotion recognition remediation in schizophrenia using the micro‐expression training tool. British Journal of Clinical Psychology, 45(4), 579-583.

Schnall, S., & Laird, J. (2003). Keep smiling: Enduring effects of facial expressions and postures on emotional experience and memories. *Cognition & Emotion*, *17*(5), 787–797. doi:10.1080/02699930302286

Schubert, T. W. (2004). The Power in Your Hand: Gender Differences in Bodily Feedback From Making a Fist. *Personality and Social Psychology Bulletin*, *30*(6), 757–769. doi:10.1177/0146167204263780

Segal, Z. V., Williams, J. M. G., & Teasdale, J. D. (2002). *Mindfulness-based cognitive therapy for depression: A new approach to preventing relapse*. New York: Guilford Press.

Sergerie, K., Chochol, C., & Armony, J. L. (2008). The role of the amygdala in emotional processing: a quantitative meta-analysis of functional neuroimaging studies. Neuroscience and Biobehavioral Reviews, 32(4), 811-830

Sestito, M., Umilta, M. A., De Paola, G., Fortunati, R., Raballo, A., Leuci, E., . . . Gallese, V. (2013). Facial reactions in response to dynamic emotional stimuli in different modalities in patients suffering from schizophrenia: a behavioral and EMG study. Front Hum Neurosci, 7, 368.

Shamay-Tsoory, S. G., Shur, S., Harari, H., & Levkovitz, Y. (2007). Neurocognitive basis of impaired empathy in schizophrenia. Neuropsychology, 21(4), 431-438.

Soussignan, R. (2002). Duchenne smile, emotional experience, and autonomic reactivity: A test of the facial feedback hypothesis. *Emotion*, *2*(1), 52–74. doi:http://dx.doi.org/10.1037/1528-3542.2.1.52

Stel, M., van den Heuvel, C., & Smeets, R. C. (2008). Facial feedback mechanisms in Autistic Spectrum Disorders. Journal of Autism and Developmental Disorders, 38, 1250–1258

Strack, F., Martin, L. L., & Stepper, S. (1988). Inhibiting and facilitating conditions of the human smile: a nonobtrusive test of the facial feedback hypothesis. *Journal of Personality and Social Psychology*, *54*(5), 768.

Sugranyes G., Kyriakopoulos M., Corrigall R., Taylor E., Frangou S. Autism spectrum disorders and schizophrenia: meta-analysis of the neural correlates of social cognition. PLoS One. 2011;6:e25322.

Susskind, J. M., Lee, D. H., Cusi, A., Feiman, R., Grabski, W., & Anderson, A. K. (2008). Expressing fear enhances sensory acquisition. *Nature Neuroscience*, *11*(7), 843–850. doi:10.1038/nn.2138

Todarello, O., Porcelli, P., Grilletti, F., & Bellomo, A. (2005). Is Alexithymia related to negative symptoms of schizophrenia? A preliminary longitudinal study. Psychopathology, 38(6), 310-314.

Tourangeau, R., & Ellsworth, P. C. (1979). The role of facial response in the experience of emotion. Journal of Personality and Social Psychology. 37, 1519-1531

Uddin, L. Q., & Menon, V. (2009). The anterior insula in autism: under-connected and under-examined. Neurosci Biobehav Rev, 33(8), 1198-1203.

Uljarevic, M., & Hamilton, A. (2013). Recognition of emotions in autism: a formal meta-analysis. J Autism Dev Disord, 43(7), 1517-1526. doi: 10.1007/s10803-012-1695-5

Van Dantzig, S., Pecher, D., Zeelenberg, R., & Barsalou, L. (2008). Perceptual Processing Affects Conceptual Processing. *Cognitive Science: A Multidisciplinary Journal*, *32*(3), 579–590. doi:10.1080/03640210802035365

Vermeulen, N., Luminet, O., & Corneille, O. (2006). Alexithymia and the automatic processing of affective information: Evidence from the Affective Priming Paradigm. Cognition and Emotion, 20, 64–91.

Vermeulen, N., Mermillod, M., Godefroid, J., & Corneille, O. (2009). Unintended embodiment of concepts into percepts: Sensory activation boosts attention for same-modality concepts in the attentional blink paradigm. *Cognition*, *112*(3), 467–472. doi:10.1016/j.cognition.2009.06.003

Vieillard-Baron, J.-L. (Ed.). (1991). *Autour de Descartes: le problème de l'âme et du dualisme*. Paris: Vrin.

Winkielman, P., McIntosh, D. N., & Oberman, L. (2009). Embodied and disembodied emotion processing: Learning from and about typical and autistic individuals. Emotion Review, 2, 178-190.

Wolf, K., Mass, R., Kiefer, F., Wiedemann, K., & Naber, D. (2006). Characterization of the facial expression of emotions in schizophrenia patients: preliminary findings with a new electromyography method. Can J Psychiatry, 51(6), 335-341.

Wylie, K. P., & Tregellas, J. R. (2010). The role of the insula in schizophrenia. Schizophr Res, 123(2-3), 93-104.