The influence of bodily actions on social perception and behaviour : assessing effects of power postures

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The influence of bodily actions on social perception and behaviour: Assessing effects of power postures

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Abstract

Expansive and constrictive body postures serve a primary communicative function in humans and other animals by signalling power and dominance. Whether adopting such "power postures" influences the agent's own perception and behaviour is currently a subject of debate. In this PhD thesis, I explored effects of adopting power postures on behaviours closely related to the postures' primary function of social signalling by focusing on responses to faces as particularly salient social signals. In a series of experiments, I utilized reverse correlation methods to visualize mental representations of preferred facial traits. Mental representations of implicitly as well as explicitly preferred faces evoked an affiliative and slightly dominant impression, but revealed no replicable effects of power postures. Two further separate experiments investigated posture effects on the perception of threatening facial expressions, and approach vs. avoidance actions in response to such social signals. While postures did not influence explicit recognition of threatening facial expressions, they affected approach and avoidance actions in response to them. Specifically, adopting a constrictive posture increased the tendency to avoid individuals expressing anger. Finally, an attempt to replicate posture effects on levels of testosterone and cortisol demonstrated that even repeatedly adopting a power posture in a social context does not elicit hormonal changes. Altogether, these findings suggest that our body posture does not influence our mental representations and perception of other people's faces per se, but could influence our actions in response to social signals.

Keywords: body posture, power, social behaviour, facial expressions, mental representations, implicit vs. explicit processing

Résumé

Les postures corporelles signalant domination ou soumission servent une fonction de communication chez les humains et d'autres animaux. La question de savoir si l'adoption de telles "postures de pouvoir" influence la perception et le comportement de l'agent fait actuellement l'objet d'un débat. Le travail réalisé pendant cette thèse consistait à explorer les effets de ces postures sur des comportements étroitement liés à leur fonction primaire, à savoir la communication sociale, en se focalisant sur les réponses aux visages, signaux sociaux particulièrement saillants. Dans une série d'expériences, j'ai utilisé des méthodes de corrélation inverse pour visualiser les représentations mentales de traits préférés du visage. Les représentations mentales des visages préférés implicitement et explicitement évoquaient une impression affiliative et légèrement dominante, mais ne révélaient aucun effet reproductible des postures. Deux autres expériences distinctes ont étudié les effets de la posture sur la perception d'expressions faciales menaçantes et sur les comportements d'approche ou d'évitement en réponse à ces signaux. Bien que les postures n'aient pas d'influence sur la reconnaissance explicite d'expressions faciales menaçantes, elles ont un impact sur les décisions d'approcher ou d'éviter des signaux de menace. Plus précisément, l'adoption d'une posture de soumission augmentait la tendance à éviter les personnes exprimant la colère. Enfin, une tentative de réplication des effets des postures sur les niveaux de testostérone et de cortisol a démontré que même l'adoption répétée d'une posture de pouvoir en contexte social ne provoque pas de changements hormonaux. Dans l'ensemble, ces résultats suggèrent que notre posture corporelle n'influence pas nos représentations mentales et notre perception des autres individus, mais pourrait influencer nos actions en réponse aux signaux sociaux.

Mots-clés : posture corporelle, dominance, comportement social, expressions faciales, représentations mentales, traitement implicite vs. explicite

Foreword

Humans are an incredibly social species. From the beginning of our lives, social contact and communication are crucial for our survival. We communicate with each other in many different ways, and nonverbal forms of communication are among the most evolutionarily ancient. A large body of research, dating back to Darwin's investigations of emotional expressions in man and animals (Darwin, 1872), has investigated how we evaluate the different social signals others transmit through their bodily actions, such as their facial expressions, gaze, head and body positions and movements. Research on social cognition has not only shed a light on which judgements these different signals elicit in the observer, but also started to examine whether carrying out certain facial expressions or body movements impacts the acting individual itself (see e.g. Niedenthal, 2007).

A recent and particularly prominent example of bodily actions affecting the acting individual are the so-called "power poses" (Carney, Cuddy, & Yap, 2010). These are expansive and constrictive body postures that communicate high and low levels of social power, dominance and status, respectively (Harper, 1985). The study found that power posing induced changes in feelings of power along with endocrine and behavioural changes associated with power. These results seemed impressive, since power is a crucial determinant of any social interaction. It greatly affects what we can say and do, and which risks we can take in pursuit of our own needs and goals. Mostly inspired by this by now famous study of Carney et al. (2010), researchers started to explore posture effects on various other behaviours. Yet, although postural expansiveness is conserved across species as a social signal, and socially meaningful body actions impact the agent's own social perception (Niedenthal, 2007), no studies had investigated whether adopting such postures impacts on the agent's perception of other's social signals.

The aim of this thesis was thus to assess effects of adopting expansive and constrictive postures on behaviours closely related to the communicative function of these postures. Do we perceive other's differently when we are in a dominant or submissive posture? In a series of experiments, I explored posture effects on mental representations of other people's faces, the perception of facial expressions signalling threat, and approach and avoidance behaviours in response to such facial expressions. While I carried out these different experiments, repeated failures to replicate the initial findings of Carney et al. (2010), on which many, including us, had built their research projects, gave rise to an intense and still ongoing debate about the replicability of postural feedback effects. Given such controversy, caution is necessary in the interpretation of all the results I obtained. As the repeated replication failure of the power posing study has clearly demonstrated, one single study is never enough to claim or rule out the existence of an effect. Due to the exploratory nature of all experiments in my thesis, replication is thus required before definite conclusions can be drawn.

Conducting my thesis project in the midst of such controversies has taught me valuable and sometimes difficult lessons about the messy processes through which science advances, the uncertainty and fallibility of scientific knowledge, and finally, the importance of communicating scientific findings to the public in a reflected and careful manner. My understanding of research practices that foster replicability and advance cumulative science has deepened, and I have critically reflected upon which scientific questions we ask and the validity and reliability of the measures we use to answer them. I am tempted to say that these insights are the most valuable ones for me, besides the technical skills and scientific knowledge I have acquired.

Overview of the structure of the present thesis

The theoretical part of this thesis begins with an overview of the broader context of postural feedback effects on cognition. Chapter 1 first takes a close look at postural expansiveness as a social signal of power, dominance and social status and then summarizes research suggesting that bodily actions impact cognition and behaviour of the agent. This research inspired numerous investigations of postural feedback effects, including our own studies on social cognition and behaviour. Chapter 2, critically reviews studies that specifically investigated the impact of expansive and constrictive postures on the agent's behaviour and cognition. Chapter 3 specifies the core research questions of the present thesis, provides an overview of all conducted experiments and describes common aspects of their methodology.

Given that research on postural feedback effects has developed quickly in the last four years, a large part of the evidence presented in the first three chapters was not available when we planned the research projects presented in the experimental chapters. Some of the studies published while I conducted my project put some of the earlier evidence into question. Where this is relevant, I thus outline what was known at the time we started a study at the beginning of the chapter. The experimental chapters describe investigations of postural feedback effects on explicit processing of threat-related facial expressions (Chapter 4), levels of cortisol, testosterone and progesterone (Chapter 5), mental representations of other people's faces (Chapter 6) and approach and avoidance actions in response to social threat signals (Chapter 7).

Eventually, the general discussion (Chapter 8) summarizes the main findings of this thesis and deliberates on possible determinants of the observed posture effects, including the focus of attention and the presence of action opportunities. Setting my studies in a larger context, I then point out the importance of considering the contextual meaning of body postures and other neglected determinants of postural feedback effects in the current literature. After reflecting on the replicability debate more generally, I close by highlighting the role of postural expansiveness in real life interactions.

THEORETICAL BACKGROUND

Chapter 1
Why adopting a body posture might affect the agent's social perception and behaviour

Any form of communication necessarily implicates both a sender, and a receiver. In the domain of nonverbal communication, communicative signals emitted by the sender include for example facial expressions of emotion, gaze direction, gestures, movements or body postures. For the perceiver, individual traits, previous experiences, as well as their current state, needs and goals may affect the way in which they process and respond to such social signals. One central dimension of social relations that strongly shapes the way we perceive others and react to them is social hierarchy, which may manifest in the form of social power, dominance or status (Fiske & Dépret, 1996; Keltner, Gruenfeld, & Anderson, 2003). The perceiver's social power relative to the power of the sender greatly affects not only how they process incoming social signals, but also which social signals they will receive. Power determines an individual's ability to influence others, their access to resources and social support, and thus the range of action possibilities in social interactions (Galinsky, Magee, Gruenfeld, Whitson, & Liljenquist, 2008). Nonverbally, humans signal their power, dominance or status for example by expanding or constricting their body (Hall, Coats, & LeBeau, 2005): expansive postures convey "strength, comfort-relaxation, and fearlessness" whereas constrictive postures imply "weakness, smallness, discomfort, tension, and fearfulness" (Mehrabian, 1981, p. 47).

In most studies of social perception, the role of the sender and the receiver are clearly separate: while stimuli presented on the screen constitute the signals, participants usually take the role of a passive perceiver, observing, judging and reacting to the presented signals (Figure 1a). However, in real social interactions, the separation between sending and receiving is much more amorphous. Each individual taking part in an interaction is emitter and receiver of multiple social signals simultaneously. While perceiving and responding to social signals of others, individuals constantly emit signals themselves through each of their bodily actions and facial expressions. In brief, the processes of production and reception of social signals are intermingled.

Given that power is such a fundamental aspect of all social interactions, bodily actions that signal power have a social meaning for both the sender and the perceiver. Could bodily feedback[1] from actions that signal power therefore impact how an agent perceives and reacts to power-related social signals (Figure 1b)? Research on embodied cognition (M. Wilson, 2002), together with evidence for a pervasive impact of power on social perception and behaviour (Fiske, Cuddy, & Glick, 2007; Guinote, 2017; Keltner et al., 2003) suggests that they might. This thesis experimentally tackles the question of agency by exploring whether the bodily action of adopting an expansive or constrictive body posture affects mental imagery and perception of facial expressions, as well as approach and avoidance actions in response to facial expressions.

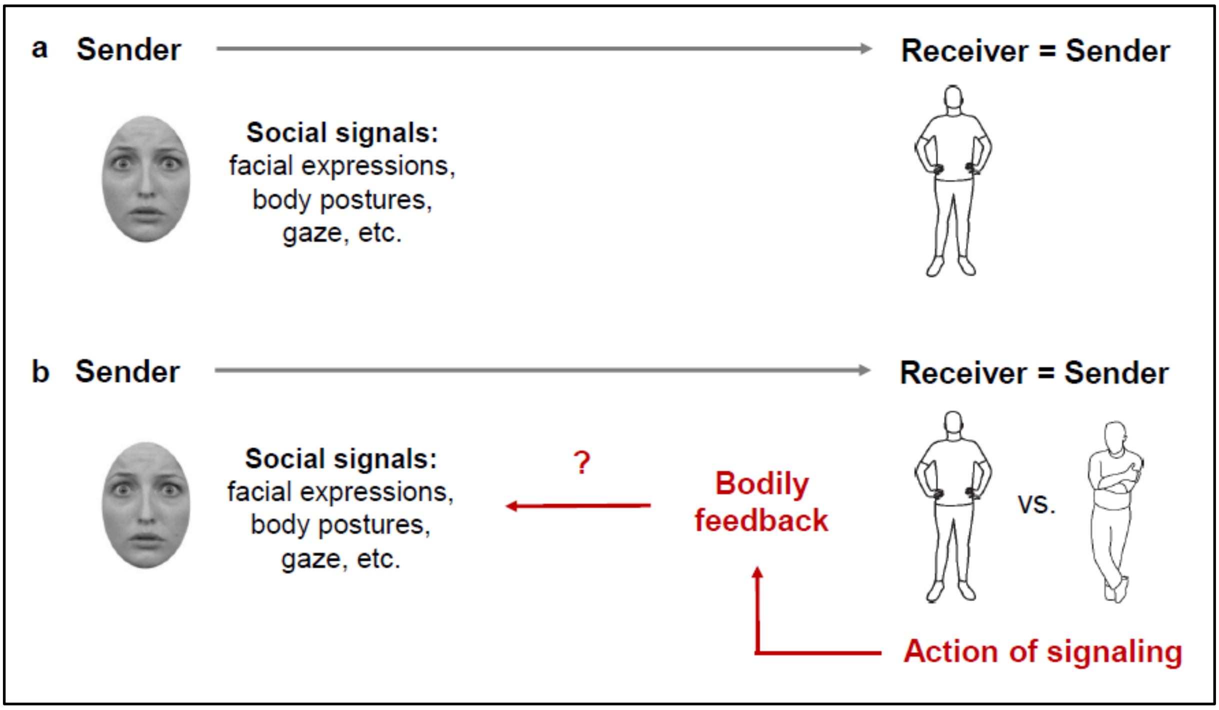

Figure 1. a) Clearly separate roles of sender and receiver of social signals in many studies on social perception**. b)** Receivers in real social interactions emit social signals themselves while processing the social signals of others. Could bodily feedback produced by the action of signalling influence how the perceive others?

Chapter overview

This chapter starts with a closer look at expansive and constrictive body postures as signals of power, dominance and status. Next, it summarizes theories and evidence for embodied

[1] Throughout this thesis, the expression *bodily feedback* is used to refer to the transmission of proprioceptive information about the body's posture to the central nervous system via afferent nerve fibres.

cognition to illustrate why adopting such postures might impact cognition and behaviour, in particular in the social domain.

1. Postural expansiveness as a social signal of power, dominance and status

Humans signal their level of social power, dominance and status via the space they occupy with their bodies. Expansive, erect body postures communicate power, dominance and high status, whereas constrictive, slumped body postures convey powerlessness, submissiveness and low status (Burgoon & Dunbar, 2006; Hall et al., 2005). Power, dominance and status are different but related constructs associated with social hierarchy (Ellyson & Dovidio, 1985b), which is a central organizing principle in many social species with important implications for survival and success (e.g. Sapolsky, 2005). For instance, hierarchy has been shown to reduce conflict and facilitate coordination and cooperation between individuals (Halevy, Chou, & Galinsky, 2011; Magee & Galinsky, 2008).

Definitions of **power** vary according to the level at which they are examined (Guinote, 2017). At the interpersonal level, power is in general defined as the control over valued resources or outcomes, which bestows an individual with the capacity to influence others and to control social interaction (Ellyson & Dovidio, 1985b; Fiske & Dépret, 1996; Keltner et al., 2003; Magee & Galinsky, 2008). Resources can be material, social or cognitive nature, and include food, protection, money, social support, information or expert knowledge (Ellyson & Dovidio, 1985b; Keltner et al., 2003). The term social power refers more explicitly to individual's relative capacity to control resources and therefore others, for example via rewards and punishments (Anderson & Berdahl, 2002; Galinsky, Gruenfeld, & Magee, 2003; Keltner et al., 2003).

Dominance is most often viewed as a personality trait related to the desire to achieve power and influence over others, and described in terms of behaviours that lead to this goal (e.g. Anderson & Berdahl, 2002; Guinote, 2017; Keltner et al., 2003). The term dominance is also used to describe an individuals' position or rank in a group hierarchy which emerges through social interactions (Ellyson & Dovidio, 1985b), particularly in the literature on nonhuman animals (see e.g. Sapolsky, 2005; F. Wang, Kessels, & Hu, 2014). With regard to dominance as an individual characteristic, the desire to achieve power and influence others is central

(Ellyson & Dovidio, 1985b; Guinote, 2017; Koski, Xie, & Olson, 2015), while the behaviour used to attain this goal may be assertive, forceful and aggressive as well as cooperative and pro-social (Guinote, 2017; Hawley, 1999; Kalma, Visser, & Peeters, 1993). The term submissive thus describes either individuals who occupy a low rank in a social hierarchy, or who have a low desire to achieve power and influence.

Social status describes the level of social respect, admiration and prestige an individual enjoys as a function of attributes that are broadly valued among members of a social group (Ellyson & Dovidio, 1985b; Fiske & Berdahl, 2007; Keltner et al., 2003; Magee & Galinsky, 2008). As both dominance and status facilitate access to resources, they have been described as determinants or antecedents of social power (Ellyson & Dovidio, 1985b; Keltner et al., 2003). In reality, these different concepts are often confounded with each other, although one may in some cases occur without the others (Ellyson & Dovidio, 1985b; Keltner et al., 2003). Importantly, whenever I use the terms power, dominance or status in the following, I refer to expressions along the entire dimension of social hierarchy, ranging from high power to lack of power, from dominance to submission, and from high to low social status.

In humans, **postural expansiveness** seems to be a signal for all these different expressions of social hierarchy. Numerous studies demonstrate that observers perceive individuals as more dominant, powerful, high in status, confident or competent when they are pictured in expansive as compared to constrictive postures (e.g. Carney et al., 2010; Gurney, Howlett, Pine, Tracey, & Moggridge, 2016; Rennung, Blum, & Göritz, 2016; Turan, 2015; see Figure 2). After only a brief glimpse of an expansive, constrictive or neutral posture humans are capable of accurately evaluating the corresponding level of dominance. Accuracy rises above chance at presentation times of only 40ms, increases again at 94ms, but shows no further significant improvement when time is unlimited (Rule, Adams, Ambady, & Freeman, 2012). This highly efficient perceptual ability hints at an evolutionary advantage of correctly recognizing another individual's dominance status even under challenging conditions.

Social impressions elicited by postural expansiveness in **actual social interactions** reflect a similar pattern. For example, participants in discussion groups who displayed more bodily openness received higher ratings on leadership and toughness by their peers (Cashdan, 1998), and confederates who adopted expansive as compared to constrictive postures during interactions in a laboratory setting were perceived as more dominant (Tiedens & Fragale, 2003). Relatedly, the degree to which high-school students' perceived the posture of their peers as erect correlates positively with perceived physical attractiveness as well as athletic ability – which are potential indicators of social status or success at the age of 14-18 years (Weisfeld & Beresford, 1982). These relationships seem to persist over long time periods: peer rankings of toughness in young boys (6-10 years) predicted perceived erect postures, physical attractiveness and athletic ability about 6-9 years later.

Figure 2. Examples for high- and low-power postures in humans; adapted from Figure 1 from Rennung et al. 2016.

The judgements of dominance or success elicited by postural expansiveness have actual **real-life consequences**, particularly in contexts where first impressions are crucial (Vacharkulksemsuk et al., 2016). During a speed dating session, individuals displaying more expansive postures were perceived as more attractive and received more 'yes' responses from their speed-dating partners, with both effects being mediated by judgements of dominance. Relatedly, profiles depicting a person in an expansive instead of a constrictive posture received more likes on an online dating platform. Such immediate consequences for mating success are another hint at the important evolutionary function of nonverbal signalling dominance, power and status.

Indeed, similar postural displays in various **other animal species**, first described by Darwin (1872), suggest that expansive and constrictive postures are an ancient signal from an evolutionary perspective (see Figure 3). Expansion of the body as a threat, fight or dominance display in contrast to constriction as a display of submission and defeat has for example been described in species such as crickets (Stevenson, Hofmann, Schoch, & Schildberger, 2000), lizards (Crews, 1975; Greenberg, 1977; Murphy & Mitchell, 1974), lobsters and crayfish (Livingstone, Harriswarrick, & Kravitz, 1980), various species of birds (Darwin, 1872; Hagelin, 2002) and rodents (Grant & Mackintosh, 1963), cats (Flynn, 1967; Turner, Bateson, & Bateson, 2000), wolfs and dogs (Darwin, 1872; Schenkel, 1967) as well as chimpanzees (de

Waal, 2007). That bodily expansion occurs across so many species confirms that it serves and **important evolutionary function**. An individuals' position in a social hierarchy has important consequences for their access to resources such as food and shelter, mating opportunities and success as well as experienced levels of stress (Cowlishaw & Dunbar, 1991; Cummins, 2005; Sapolsky, 2005). Postural displays of dominance and submission may thus constitute an evolutionary advantage by allowing the quick and correct recognition of another's position in relation to one's own, and to adjust one's behaviour accordingly, as for instance by avoiding the risk of a fight with a physically dominant or socially influential individual.

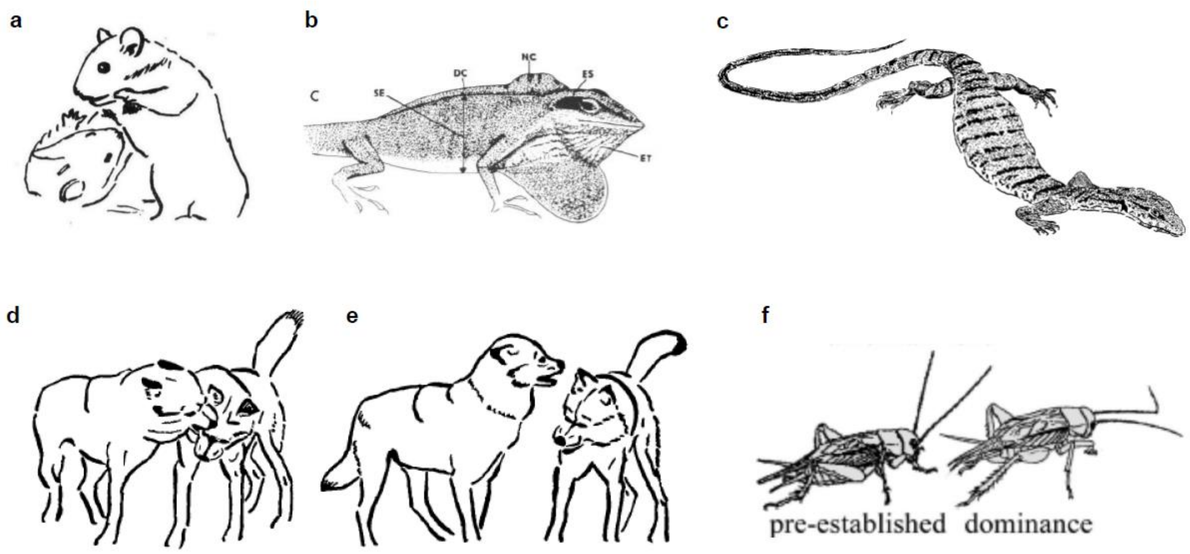

Figure 3. a) Submissive posture and offensive upright posture in the hamster (Figure 6 from Grant & Mackintosh 1963). **b)** Challenge display in the lizard (Figure 2C from Greenberg 1977). **c)** Male lizards flatten themselves dorsoventrally before fights, which increases the width of their trunks by about one third (Figure 1 from Murphy & Mitchell, 1974). **d)** Although the submissive wolf (on the left) tries to press the superior wolf (on the right) down, the superior wolf keeps his ears erected ears and his tail up. **e)** The submissive wolf cannot stand the challenge (Figure 2A & 2B from Schenkel 1967). **f)** Stereotyped displays in crickets with a pre-established dominance hierarchy: one cricket attacks, the other retreats (Figure 2.1 from Stevenson & Rillich, 2012).

Postural expansiveness might function as a signal of dominance, because it makes an organism appear larger and therefore stronger. In several nonhuman animal species, **physical size** is a reliable predictor of dominance rank since it is correlated with physical strength (Ellis, 1995; Jacob et al., 2007; Morgan et al., 2000; Schuett, 1997; Tokarz, 1985). Physical strength might also be one of the characteristics that allows an individual to achieve and maintain high status in humans, and cues of physical strength might therefore serve as dominance signals (Rueden, Gurven, & Kaplan, 2010; Sell et al., 2009; Toscano, Schubert, & Sell, 2014). Physical height, for example, is positively correlated with judgements of power and social esteem, and seems to be correlated with career success, as measured in terms of income (Judge & Cable, 2004).

Postural expansion and contraction are not the only nonverbal cues of high and low dominance, power and status in humans (Hall et al., 2005). However, they seem to be one of the few nonverbal behaviours that are not only perceived as a cues of dominance and submissiveness, but are **valid indicators of one's actual level of dominance, power and status**. In a comprehensive meta-analysis, Hall et al. (2005) identified a total of 17 different nonverbal behaviours that humans interpret as cues for a high or low position on the "vertical dimension" of human relations, under which these authors subsume the related, but not identical, constructs of power, dominance and status. Crucially, among these behaviours, bodily openness was one of only four which reliably signalled actual high verticality, with the three others being smaller interpersonal distance, louder voice and more frequent interruptions of conversation partners. Another reliable indicator of various manifestations of high verticality (see p. 899 in Hall et al., 2005 for an overview) is the proportion of time an individual looks at others while talking vs. listening, the so called visual dominance ratio (Dovidio & Ellyson, 1985).

Concerning postural expansion, examples for demonstrations of actual high verticality include correlations of erect postures with academic success in college students or with dominance measured as frequency of hitting the ball in a volleyball tournament in high school students (Weisfeld & Beresford, 1982). In total, however, there is only little research examining the accuracy of verticality judgements with regard to actual verticality, and some research suggests that postural expansion might be just one (and not necessarily the most important) nonverbal behaviour from which humans infer other's actual social status (Schmid Mast & Hall, 2004).

Importantly, as Hall et al. (2005) point out, the **meaning of nonverbal behaviour** is not "dictionary-like", but depends on the context in which it occurs, such as other concurring behaviours, the situation, the intentions and the internal state of an individual. Expansive and constrictive postures thus also have meanings that are related to but not identical with the high and low end of the dimensions dominance, power and social status. One example are associations of postural contraction with depression: Research has shown, for example, that observers ascribe depressive and helpless attitudes to people displaying a constrictive, slumped posture (Riskind & Gotay, 1982), and has further confirmed that depressed individuals do indeed adopt more slumped postures (Canales, Cordás, Fiquer, Cavalcante, & Moreno, 2010; Michalak et al., 2009). Slumped posture even represents a criterion in the diagnosis of depression (American Psychiatric Association, 2013). Importantly, the neurochemical, genetic and psychological parallels between depression and submission or the lack of power (Kroes, Panksepp, Burgdorf, Otto, & Moskal, 2006; Pillmann, 2001; Tse & Bond, 2002), illustrate that the different meanings of a particular body posture are related to each other in a coherent manner.

Conclusion

Expansive and constrictive postures function as signals of high and low dominance, power and status in many social species. In humans, perceptual processing of postural displays is highly efficient and has important consequences for everyday life. The experimental projects conducted in the course of this thesis were inspired by research which demonstrated that adopting such postures influences feelings, cognitive processes and behaviours associated with power. Therefore, the next section introduces the concept of embodied cognition that constitutes the theoretical framework for these studies.

2. How bodily actions affect social perception

All theories of embodied cognition emphasize the important role of the body for cognition and emotion (Barsalou, 1999; Glenberg, 2010; M. Wilson, 2002). Theories of embodied cognition can be traced back to William James (1890), who put forward the idea that emotion arises from the perception of signals from the body. He claimed, for example, that upon perception of danger, we are afraid because we tremble and our heart beats faster, and not the other way round. Modern embodiment theories are more nuanced, and propose instead that neural representations of bodily states (see reviews by Craig, 2002; Damasio & Carvalho, 2013), and not necessarily bodily states themselves, are an integral part of the complex mechanisms that cause cognitive and emotional experiences (Winkielman, Niedenthal, Wielgosz, Eelen, & Kavanagh, 2015).

With regard to the embodiment of social signals and affective states, it has been argued and empirically demonstrated that bodily states such as postures, arm movements or facial expressions of emotion do not just signal the sender's feelings and associated behavioural intentions, but may also affect how the sender feels and perceives others (Barsalou, Niedenthal, Barbey, & Ruppert, 2003; Niedenthal, 2007). In brief, the link between emotion and bodily states might be bidirectional. Concretely and with regard to the topic of this thesis, expansive and constrictive postures might not only serve to signal social power and dominance to conspecifics, but could also induce bodily states associated with power and dominance in the agent.

Below, I first introduce two approaches to embodied cognition that are of particular relevance for this thesis. The first concerns the role of simulation of previous sensory, motor and introspective experiences for cognition, and the second the situated nature of cognition and its functional relationship to action. Finally, I will provide some examples for the embodiment of emotional and social information processing.

2.1. Cognition is grounded in perceptual, motor and introspective experience

Barsalou's (1999, 2008) account of "perceptual symbol systems" describes one potential mechanism through which bodily states on the one side, and cognition and emotion on the other, might influence each other. The central tenet of this theory is that conceptual knowledge and cognitive processes are grounded in simulations of previous sensory, motor and introspective experiences (Barsalou, 1999). He refers to these simulations as perceptual symbols. During experiences with the world, information processed by the brain is partially stored in sensory and motor systems of the brain. When previous experiences become functionally relevant for a current situation or task, these neural representations are partially reactivated. For instance, the recall of a memory of an event involves a partial reactivation or reliving of the sensory, motor or introspective states that we experienced during that event (Barsalou, 1999). These partial simulations of previous sensorimotor experiences then inform, influence or even determine the cognitive processes in the current situation. In some cases, the perceptual experiences encoded and later simulated by the brain may consist of bodily states associated with emotions or feelings (Barsalou, 2008).

According to Barsalou (1999), simulations rarely involve a full reproduction of bodily states, but are often constrained to partial re-enactments of previous sensorimotor experiences at the level of neural representations. They may be mediated by any of the modal systems of the brain, depending on whether past perceptual experiences were of a visual, auditory, haptic, gustatory or olfactory, proprioceptive or introspective nature. Importantly, the reactivation of neural representations or bodily states seems to be an unconscious process, which can be, but is not necessarily, accompanied by a conscious experience (see also Damasio & Carvalho, 2013).

The grounding of cognitive processes in sensorimotor experiences has classically been illustrated with tasks that involve for example listing features of certain concepts, switching between different sensory modalities or understanding of sentences (Glenberg, 2010; Winkielman et al., 2015). For example, when listing features of the concept “half a water melon” instead of “a water melon”, individuals more frequently listed “seeds” and “red” as features of these concepts (Wu & Barsalou, 2009). This suggests that thinking about concepts triggers mental imagery of features of these objects, or in other words, re-activates mental representations of previous and in this case visual sensory experiences. Such perceptual simulations may contribute to the understanding of concepts, as the phenomenon of “switching costs” indicates. When verifying the properties of concepts (e.g., BLENDER-loud), participants are quicker if the previous concept belonged to the same sensory modality (e.g., LEAVES-rustling) rather than a different sensory modality (e.g., CRANBERRIES-tart) (Pecher, Zeelenberg, & Barsalou, 2003). Decreased processing time when both concept and property belong to the same modality may indicate that the activation of the sensory representation of the concept facilitates subsequent verification of the property. Ultimately, such sensory simulations may also contribute to language comprehension. For instance, the activation of neural representations associated with a particular spatial orientation during the reading of sentences facilitated subsequent recognition of objects presented with the same spatial orientation (Stanfield & Zwaan, 2001). Specifically, after reading sentences implying a particular spatial orientation of an object (e.g. “The carpenter hammered the nail into the floor/wall”), recognition of the object was quicker when it was depicted in the same as opposed to a different spatial orientation. The three above examples demonstrate that perceptual simulations of visual or other sensory experiences support the understanding of concepts and language.

Cognition is not only grounded in the perception of external sensory information, but also in the perception of motor signals associated with bodily actions. In a study by Glenberg and Kaschak (2002), participants categorized sensible and nonsense sentences by making a movement away from or towards their own body. Sentences described motor actions in a certain direction (“Open the drawer”), physical transfer (“Courtney handed you the notebook” or non-physical transfer (“Liz told you the story”). Response movements were quickest when their direction matched the direction implied by the sentence. Consistent with this, mental imagery of one-handed manual actions (“to throw”) usually performed with the dominant hand, as opposed to non-manual actions (“to kneel”), activated either right or left premotor and postcentral motor regions, depending on whether participants were left or right handers. This demonstrates that the grounding of cognitive processes associated with bodily actions is specific to how individuals usually perform these actions in the real world (Willems, Toni, Hagoort, & Casasanto, 2009).

Altogether, these examples illustrate that cognitive processes rely at least partially on modal and motor systems of the brain. Importantly, not all cognitive processes involve simulation of bodily states and/or their neural representations (Winkielman et al., 2015). Instead, simulation of sensorimotor experience occurs when it is relevant and useful for the task at hand (see e.g. Niedenthal, Mondillon, Winkielman, & Vermeulen, 2009). This might be particularly true for social perception: mapping other's nonverbal communicative signals onto representations of one's own body likely facilitates the prediction and understanding of other's behaviour (Knoblich & Sebanz, 2006; M. Wilson, 2002), which could result in more adaptive behavioural responses. Based on the "perceptual symbols" account of embodiment, one could hypothesize that proprioceptive information about a bodily action, such as a body posture, could indicate the current relevance of perceptual experiences that previously co-occurred together with these proprioceptive signals. Consequently, bodily actions could elicit simulations of the previous perceptual experiences, that is, they could partially reactivate the neural representations of these experiences, which might then inform and influence current perceptual processes.

2.2. Cognition serves to control bodily action in specific contexts

Other accounts of embodied cognition empathize the situated nature of cognition and its tight link with bodily action (e.g. Fiske, 1992; Gibson, 1979; Glenberg, 1997). In the words of Wilson (2002), the concept of situated cognition refers to the interaction of cognition with "task-relevant inputs and outputs. That is, while a cognitive process is being carried out, perceptual information continues to come in that affects processing, and motor activity is executed that affects the environment in task-relevant ways" (p. 626). Not all human cognition is situated, i.e., influenced by interactions with the immediate environment: for instance, humans are able to think about the past or the future, and mentally imagine things they have never experienced (M. Wilson, 2002). However, it makes sense to consider processes of social perception as situated, given that production and perception of social signals typically occur simultaneously and in real social interactions. To produce an adaptive response to a particular social signal, the brain needs to take into account information from the immediate environment, including the internal "environment" of the body, given that bodily states provide important information about one's own current needs and goals (Damasio & Carvalho, 2013).

A related, but broader notion of embodied cognition argues that main purpose of cognition is to control action, not necessarily action in the immediate environment as implied by the concept of situated cognition, but action at some point in the present or future (Barsalou, 2008; Gibson, 1979; Schubert & Semin, 2009; M. Wilson, 2002). Action is necessarily carried out through the body in its immediate environment. Brains capable of executing complex cognitive processes, including perception, only became necessary once organisms started to move through the world (Glenberg, 2010; Kaschak & Maner, 2009). Ultimately, the only reasons for developing brains and complex nervous systems is to more successfully navigate the body through the world, that is, to move towards certain objects and away from others depending on whether they are beneficial for survival (Wolpert, 2011). Thus, brains capable of implementing cognitive processes developed within the context of the body and in order to control body movement (Wolpert, Ghahramani, & Flanagan, 2001). Although not all cognition serves immediate bodily action, ultimately, only cognitive processes that result in some kind of bodily action in the future can lead to survival advantages and thus be selected for (Kaschak & Maner, 2009; M. Wilson, 2002).

Given that motor actions are the only way in which organisms can affect the environment, cognitive processes need to take into account the state and the capabilities of the body whenever it might be relevant to an upcoming action in response to external events (Glenberg, 2010; Wolpert et al., 2001). Muscular strength, physical energy and motor abilities determine whether we can carry out a certain action. Therefore, decisions about whether we can afford to fight against an opponent or are better of fleeing or signalling submission, or about whether we currently need food or physical protection cannot be made without taking into account information from the body.

Central to the understanding of cognition as serving action is the concept of affordances proposed by Gibson (1979) in his ecological approach to visual perception. In Gibson's own words, "the affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill" (1979, p. 127). That is, affordances are possibilities for interaction with the surrounding environment that an animal can perceive and act upon (Kaschak & Maner, 2009), or properties of objects in the environment that define how it could be used by a particular agent (Gibson, 1979). Crucially, affordances not only depend on properties of the environment, but also on characteristics of the organism. To illustrate, a chair affords the possibility of sitting and a cup affords the action of grasping for humans, but these same objects offer different affordances for other animals with different kinds of bodies, such as for example cats or dogs (see Kaschak & Maner, 2009). As Marsh, Johnston, Richardson, and Schmidt (2009) put it, "affordances exist in the relationship of the actor and the environment and can be detected and enacted by creatures with the right body and history" (p. 1218). Gibson's central assumption is that perception serves an adaptive function, that we therefore perceive things in terms of what they afford, or in short, that "perception is for doing" (Gibson, 1979).

To avoid misunderstandings, it is crucial to note here that Gibson's ecological theory did not include the concept of mental representations, which is central to the view of embodied cognition adopted for the current thesis. I nevertheless use his concept of affordances as the interactions it proposes between properties of the perceived environment and properties of the observer are fundamental for the research questions tackled in this project. However, I use it within a cognitive framework in which representations are seen as the link between perception and motor actions. Importantly, these representations may be activated even in the absence of overt action, simply while perceiving a certain object associated with certain opportunities for acting upon it (see Decety & Grèzes, 2006).

While objects signal possibilities for physical interaction, other people additionally signal opportunities for social interaction or potential social threats (Zebrowitz, 2006). Since humans are a highly social species, many of their interactions with the environment involve other people (Kaschak & Maner, 2009). Therefore, other individuals and the social signals they emit play a central role for the affordances humans perceive and act upon (Grèzes & Dezecache, 2014; McArthur & Baron, 1983). Indeed, the link between cognition and action seems to be particularly strong for cognitive processes pertaining to social perception and social behaviour (Zebrowitz, 2011). For example, findings of similar, although not identical, neural systems underlying the execution of own and the observation of other's motor actions speak for a direct link between action and perception in the social domain (Decety & Grèzes, 2006). This applies to motor actions in the wide sense, including production and perception of facial expressions of emotion.

Applying the idea that cognition is for action to social perception implies that social perception serves to guide adaptive behaviour (Zebrowitz, 2006, 2011). Given that such behaviour necessarily involves some kind of bodily action, the cognitive and neural processes underlying social perception and behavioural responses to social signals need to take into account neural representations of the body for the selection of the most appropriate response.

2.3. Causal impact of bodily states on the perception of social signals

Nonverbal social signals include bodily expressions of emotions and affective states, such as certain body postures or facial expressions. Production and perception of such social signals could more strongly activate neural representations of bodily states than other actions or stimuli, since changes in bodily states are a core component of emotions and affective states (Critchley & Nagai, 2012; Damasio & Carvalho, 2013). Perceiving affective and social content (e.g. Cacioppo, Petty, Losch, & Kim, 1986; Lang, Greenwald, Bradley, & Hamm, 1993; Weisfeld & Beresford, 1982), including nonverbal social signals (e.g. Dimberg, Thunberg, & Elmehed, 2000; Gelder, Snyder, Greve, Gerard, & Hadjikhani, 2004), has been shown to induce bodily changes. Building on these findings, researchers started to explore whether manipulating bodily states would also induce affective changes in the agent, or change how agents process social signals from others (for reviews, see Barsalou et al., 2003; Niedenthal, 2007; Niedenthal, Barsalou, Winkielman, Krauth-Gruber, & Ric, 2005; Price & Harmon-Jones, 2015; Winkielman et al., 2015). Typical manipulations of bodily states include the activation of facial muscles associated with certain facial expressions, arm and head movements as well as holding particular body postures.

One of the earliest studies that manipulated bodily states found that activating frowning or smiling muscles generated feelings of happiness and anger, respectively (Laird 1974). A later study suggested that unobtrusively activating or blocking smiling muscles by holding a pen with one's teeth or lips, respectively, affects the strength of the humorous response to cartoons (Strack, Martin, & Stepper, 1988)[2]. Furthermore, nodding as compared to shaking one's head was observed to increase agreement with the content of messages presented whilst moving (Wells & Petty, 1980), or to increase liking of an object placed in participants' view during the movement in comparison to a new object (Tom, Pettersen, Lau, Burton, & Cook, 1991). The first researchers experimenting with manipulations of body posture observed that slumped and upright postures influenced affective reactions to positive feedback, learned helplessness

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[2] Unsuccessful attempts to replicate these findings will be discussed in the General Discussion at the end of this thesis.

behaviour, as well as self-perceived locus of control and feelings of depression (Riskind, 1984; Riskind & Gotay, 1982). Similarly, Duclos et al. found that angry, fearful and sad body postures specifically enhanced self-reports of the emotion they expressed (1989).

More recent studies suggest that mimicry of **emotional expressions** facilitates their recognition, while blocking activation of muscles deteriorates recognition accuracy in an emotion-specific fashion (Niedenthal 2001, Oberman 2007). Correspondingly, the action of smiling biases the neural processing of neutral faces in direction of the processing of happy faces (Sel, Calvo-Merino, Tuettenberg, & Forster, 2015). Furthermore, temporary paralysations of frowning muscles by means of Botox injections slows down the understanding of emotional sentences expressing anger but not of sentences expressing other emotions (Havas 2010). This hints at a causal role for facial muscle activity for emotional understanding. Further causal evidence for the role of somatosensory representations for the understanding of other's emotions comes from a lesion study which observed deficits in visual emotion recognition in patients with lesions of somatosensory cortices (Adolph 2000). Particularly strong evidence for the causal role of somatosensory simulations for the correct processing of social signals come from a study applying repetitive transcranial magnetic stimulation (rTMS) to disrupt neural activity in different regions underpinning somatosensory and visual perception (Pitcher, Garrido, Walsh, & Duchaine, 2008). RTMS over the face but not the finger area of the right somatosensory cortex interfered with the discrimination of facial expressions of emotion, and this to a similar extent as rTMS over the right occipital face area.

Such somatosensory influences on the processing of facial emotion expressions do not appear to be limited to the specific emotion most directly associated with a particular bodily action, but more broadly impact social perception. For instance, uncomfortable arm movements biased the perception of faces in a negative direction along a continuum between happy and angry facial expressions (Fantoni & Gerbino, 2014). That is, slightly happy faces were perceived as neutral, and neutral faces were perceived as slightly angry, when they were presented during the execution of uncomfortable reaching actions, and the reverse was true for comfortable reaching actions. Furthermore, uncomfortable arm movements lowered the detection threshold for anger in facial expressions, while comfortable actions lowered the detection threshold for happy expressions (Fantoni, Rigutti, & Gerbino, 2016).

Conclusion and link to the next chapter

Altogether, the reviewed evidence from the field of embodied cognition demonstrates that the processing of sensory information, including social signals, is rooted in bodily states and bodily actions associated with affective experiences. Our body does not only express what we feel and intend to do. Instead, it is an integral part of our emotional experience, and thus also determines how we feel, perceive and interact with the world.

Based on these findings, researchers have begun to examine whether adopting expansive and constrictive postures affects cognition and behaviour of the agent. These body postures are socially meaningful body actions that signal high and low levels of power. Given that power crucially determines an agent's action opportunities, adopting such postures may indeed affect how they feel and behave. Chapter 2 critically reviews studies conducted in the area of research exploring effects of adopting such "power postures". As will become clear, research has almost entirely focused on feelings and behaviours associated with power (see Guinote, 2017; Keltner et al., 2003) and not yet investigated effects on social perception and related behaviours, although expansive and constrictive postures are themselves social signals.

Chapter 2
A critical review of power posture effects on human cognition and behaviour

The research field focussing on the embodiment of power, comprising investigations of feedback effects of adopting expansive or constrictive body postures on cognition and behaviour, is still quite young. It has gained momentum very recently, with only a few relevant studies published before the beginning of this thesis project and the majority of studies published afterwards. Most of the recent research interest was sparked off by a single study on the effects of the so-called "power poses" (Carney et al., 2010). It attracted a lot of attention in public media and the scientific community, and also inspired the present thesis project. Yet, the study's findings were soon contested by repeated failures to replicate, which gave rise to an intense and critical debate about whether they were reproducible (for excellent summaries, see: Schultheiss & Mehta, 2018; K. M. Smith & Apicella, 2017). As the debate continues, it becomes clear that there is no simple answer to the question whether the published studies actually reflect true effects of body posture on the actor's own cognition and behaviour. While some effects have already been shown not to be reproducible, others might actually be true.

Below, I provide an overview of research on feedback effects of adopting expansive and constrictive postures, starting with a summary of studies that have investigated the effects reported in Carney et al. (2010), including all non-replications up to 2017. I then outline reported effects on other behavioural measures before reviewing studies suggesting that the effect of postures is context dependent. Many of the described studies are one-time reports that need to be confirmed before clear conclusions are possible. Finally, an overview of two recently published meta-analyses offers some first hints about which of all published results might actually reflect true postural feedback effects.

It will become evident that this research field has evolved rapidly in the years since the now famous "power posing" study from 2010. Therefore, the evidence available at different time points entailed different conclusions. This is reflected in the different experiments presented as part of this thesis.

1. Initial findings on power posture effects on feelings of power, testosterone, cortisol, risk-taking and job interview performance

Combining the idea that expansive and constricted postures are perceived as powerful and dominant (Burgoon & Dunbar, 2006; Hall et al., 2005; Weisfeld & Beresford, 1982) with the notion that affective states are influenced by bodily actions (Brinol & Petty, 2003; Niedenthal, 2007; Stepper & Strack, 1993), Carney et al. (2010) were the first to explicitly investigate the effect of whole body expansion on behavioural and endocrine correlates of power and dominance. Their results suggested that holding expansive as compared to constrictive postures for merely two minutes leads to significantly higher feelings of power, higher probability of risky gambling decisions as well as higher levels of salivary testosterone and lower levels of cortisol (Figure 4). The large effects observed after such transient manipulations were striking and the results seemed to make intuitive sense, as they were coherent with the evidence on effects of hormones as well as the effects of social power on human behaviour. Evidence about hormones, on the one hand, shows that testosterone mediates behaviour with implications for social status or dominance (Archer, 2006; Eisenegger, Haushofer, & Fehr, 2011; Mazur & Booth, 1998), but this association only becomes evident when levels of cortisol, a hormone that is part of the body's reaction to stress, are low (Mehta & Josephs, 2010; Sapolsky, 1990). Furthermore, testosterone and cortisol, as well as social power, have been shown to influence risk-taking (Anderson & Galinsky, 2006; Mehta, Welker, Zilioli, & Carré, 2015).

Due to the effort and talent of Amy Cuddy with regard to science communication, this study has attained high popularity in the general public and lots of attention in the scientific community. A TED talk about the study (Cuddy, 2012), which is currently the second most viewed TED talk of all times (www.ted.com/playlists/171/the_most_popular_talks_of_all), confidently claims that adopting expansive postures can have meaningful real-life consequences. If only two minutes in such a posture increases your testosterone level, calms down your stress system, and makes you feel powerful, power posing would be an easy and effective means to cope with the challenges we confront every day. In support of this idea, another study by the same authors demonstrated that postures adopted before a job interview subsequently influence performance and success (Cuddy, Wilmuth, Yap, & Carney, 2015). Building on the simple and empowering message of these two studies, Cuddy became the author of a best-selling book (Cuddy, 2016) and a successful and popular speaker at various community and business events (Dominus, 2017).

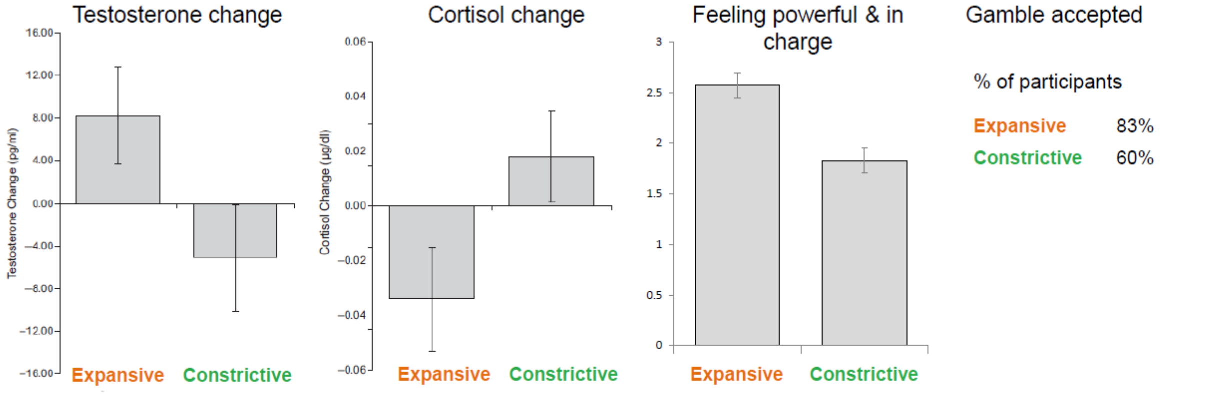

Figure 4. Posture effects on testosterone, cortisol, feelings of power and control and risky gambling in Carney et al. 2010. Testosterone and cortisol figures are Figures 3 and 4 from Carney et al. (2010) and depict mean changes in hormone levels following expansive or constrictive postures. Error bars in all figures represent standard errors of the mean. Reproduced from Carney et al. (2010).

2. How robust are the initial power posture findings?

While the empowering message in Cuddy's communications was impressive and remains important, many researchers were sceptical whether the short and subtle intervention of adopting a posture for two minutes could really induce changes in hormone levels as large as the ones reported. Much more intense interventions, such as actual competitions or intense stress induction protocols including a public speech and mental arithmetic under time-pressure and negative social evaluation (Kirschbaum, Pirke, & Hellhammer, 1993) typically yield smaller effects on cortisol and testosterone levels (Dickerson & Kemeny, 2004; Geniole, Bird, Ruddick, & Carre, 2017). Could adopting a posture for two minutes really have the similarly large effects? It seemed too good to be true.

2.1. Non-replications of hormonal and risk-taking effects and the following debate on replicability

When a first attempt to replicate Carney et al.'s findings in a considerably larger sample of participants yielded null-effects on all measures except feelings of power (Ranehill et al., 2015), a debate on the robustness of their findings started to unfold that has continued until today. At first, Carney, Cuddy & Yap (2015) responded with a review of 33 studies reporting embodied effects of expansive and constrictive postures, in which they argued that small methodological differences could be responsible for the non-replication of their original findings. For example, participants in Ranehill's posture held postures for a bit longer (6 minutes) and did not watch faces while doing so, whereas the initial study had presented faces and instructed participants to form an impression of the presented people (they refer to this as a social filler task).

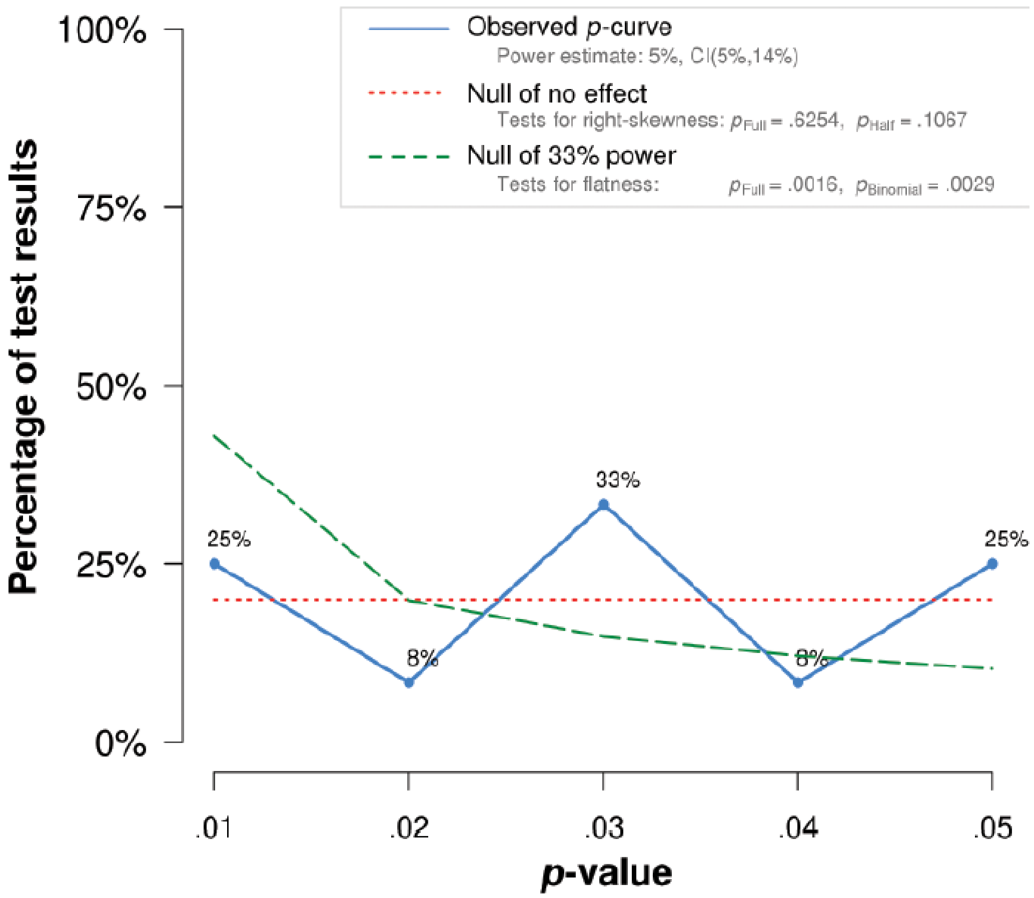

Figure 5. Figure 1 from Simmons & Simonsohn (2017): P-curve of 33 studies cited by Carney et al. (2015) as evidence for power posture effects. The solid line shows the distribution of actually observed p-values (7 p-values are not included because they were above p>.05).Average power of the included studies was 5% with a 90% confidence interval of (5%, 14%). The dotted line is the expected distribution of p-values if there was no true effect. The dashed line depicts the expected distribution in case there was a true effect and existing studies had a power of 33%.

Still, many other researchers held doubts at this point that the initial study reflected real effects (see Cesario, Jonas, & Carney, 2017), which soon seemed to be confirmed by a p-curve analysis (initially a blog-post, by now also available as a paper: Simmons & Simonsohn, 2015, 2017). The p-curve analysis by Simmons and Simonsohn, conducted on the subset of 24 studies, which (1) reported significant effects and (2) investigated effects other than those on feelings of power, did not provide evidence for a true effect of power postures (see Figure 5). Disregarding effects on feelings of power as a mere manipulation check, these authors thus concluded that all other previously published effects were merely the result of selective reporting. In their opinion, the available evidence did not justify further efforts and resources necessary to investigate the role of moderators of posture effects or posture effects on other outcome variables. Although their analysis was methodologically sound otherwise, it is unclear why these authors disregarded feelings of power as a mere manipulation check and did not include this variable into their analysis.

At this point, Dana Carney, the first author of the initial study, declared in a statement on her website that no longer believed that the reported effects were real, and admitted that she now recognized several problematic decisions she had taken during the analysis and the reporting of the original effects (Carney, 2016). She mentioned, for instance, selective reporting of significant results, running subjects in chunks and checking results intermittently, or stating results as hypotheses. While these practices were common in 2010, they had in the meantime become more broadly recognized as biases that contribute to the non-replicability of published results (Ferguson & Heene, 2012; Nosek, Spies, & Motyl, 2012). Additionally, a critical comment by Stanton (2011) remarked that the sample size of n=42 (26 women) of the study was small for human endocrinology, and that collapsing across gender for the analysis of testosterone was problematic for two reasons. First, it ignores fundamental biological differences with regard to testosterone production in men and women, and second, it violates the assumptions of the applied statistical tests because testosterone levels across both genders follow a bimodal distribution. Much later, a multiverse re-analysis of the data by independent researchers did indeed confirm that the specific data-analytic choices taken by Carney et al. in 2010, such as those regarding the exclusion of outliers or the inclusion of covariates such as gender and hormone baseline levels in the statistical models played a large role in producing the statistically significant findings reported in the initial study (Credé & Phillips, 2017). These researchers conclude that the analysis approach of the initial paper was not the most appropriate, but yields the highest effect-sizes compared with all other possible ways to analyse the data.

In the following years, additional non-replications of the effects on hormone levels as well as risk-taking favoured such critical opinions. One direct and pre-registered replication (Ronay, Tybur, Huijstee, & Morssinkhof, 2016), one study conducted in the ecologically valid context of winning or losing a competition (K. M. Smith & Apicella, 2017), and one study in which participants with social anxiety disorder underwent exposure therapy in the form of a public speaking exercise (Davis et al., 2017) investigated the reported hormonal effects. None of these studies found any differential impact of expansive and constrictive postures on testosterone and cortisol levels. With the exception of Davis et al. (2017), these replications all featured substantially larger sample sizes than the original study, providing higher statistical power to detect the hypothesized effects. With respect to risk-taking, there are currently a total of ten replication attempts, which all consist of studies with large sample sizes and high statistical power and include the direct and conceptual replications mentioned above (Bailey, LaFrance, & Dovidio, 2017; Bombari, Schmid Mast, Brosch, & Sander, 2013; Cesario & Johnson, 2017; Keller, Johnson, & Harder, 2017; Ranehill et al., 2015; Ronay et al., 2016; K. M. Smith & Apicella, 2017). All but one of them (study 4 in Cesario & Johnson, 2017) observed no effect.

These non-replications of hormone and risk-taking results assessed the role of many **moderators** mentioned by Carney et al. (2015): they included men and women, many used the exact posture manipulation, cover-story and social filler task as the initial study, and some assessed posture effects in ecologically valid social contexts (Cesario & Johnson, 2017; K. M. Smith & Apicella, 2017). Another study directly tested whether time in posture could influence the effects on the feelings of power (further discussed below) and reported that this was not the case (Bailey et al., 2017). In total, these studies provide strong evidence against an effect of postures on hormones and risk taking, and eliminate several of the moderators that have been mentioned as potential explanations for differences between the initial and later replication studies.

2.2. Non-replications of power posture effects on job interview performance

Two highly powered pre-registered studies (Keller et al., 2017; Klaschinski, Schnabel, & Schröder-Abé, 2017) have failed to replicate the positive effect of expansive postures on subsequent performance and hireability in a mock job interview (Cuddy et al., 2015). In the initial study, effects seemed mediated by nonverbal presence, that is, ratings as confident, enthusiastic, captivating, and awkward (reverse-scored). In addition, raters in the replication by Klaschinski et al. (2017) judged interviewees along other indicators of dominance and indicators of social competence. The results refute that adopting a posture before public speaking tasks affects others’ impressions along any of those dimensions.

2.3. A small but possibly robust postural feedback effect on feelings of power

In contrast to postural feedback effects on hormones and risk-taking, those on feelings of power have been partially supported. When one considers single studies, their results seem to partially contradict each other: some studies report significantly higher feelings of power in participants who adopted an expansive as compared to a constrictive posture (Fischer, Fischer, Englich, Aydin, & Frey, 2011; Huang, Galinsky, Gruenfeld, & Guillory, 2011 study 1; Park, Streamer, Huang, & Galinsky, 2013; Rotella & Richeson, 2013; Teh et al., 2016; Turan, 2015), while others report no significant difference (Cuddy et al., 2015; Hao, Xue, Yuan, Wang, & Runco, 2017; Huang et al., 2011 study 2; K. M. Smith & Apicella, 2017), and yet others even report an effect in the reverse direction (Garrison, Tang, & Schmeichel, 2016). Nevertheless, a p-curve analysis across all these studies (Cuddy, Schultz, & Fosse, 2018) shows that all available evidence taken together actually supports a differential effect of expansive and constrictive postures on feelings of power (see Figure 6). However, because p-values do not provide information about the direction or size of effects, conclusions from this p-curve analysis cannot distinguish between studies that observed an increase or a decrease of power feelings after the expansive posture. As the pool of analysed p-values included contradictory findings, the result only implies that expansive as compared to constrictive postures have an effect, but not that this effect is necessarily in the desired direction. Nevertheless, the fact that size and direction of the effect vary between studies, but is positive in most, could hint at a small true effect of postures on feelings of power. Consequently, the only way to detect it reliably would be to use very large sample sizes.

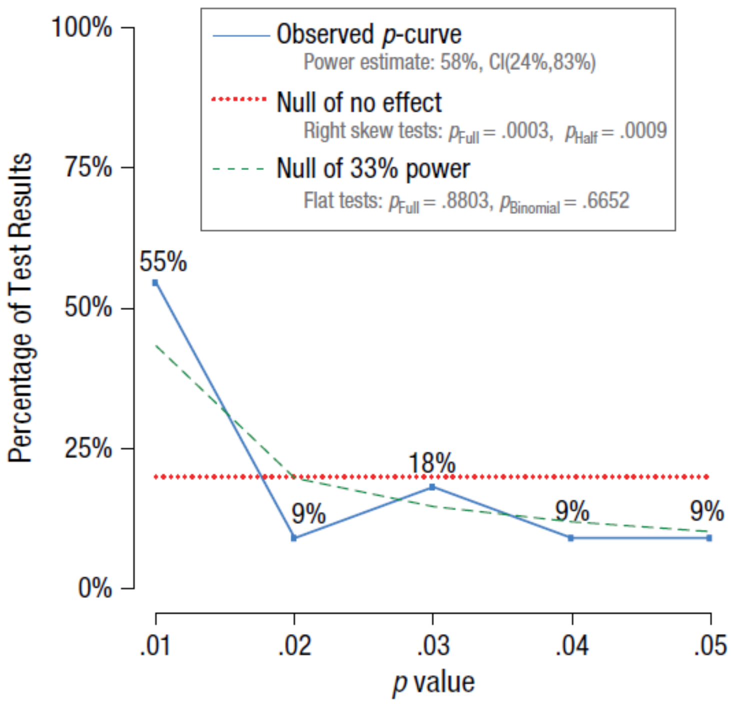

Figure 6. Figure 1b from Cuddy et al. (2018): P-curve for power posture effects on feelings of power, including 11 studies (p-values from 4 studies were excluded because they were p>.05).

Thanks to the coordinated effort of several researchers (including Dana Carney herself) to publish a special issue of highly-powered and pre-registered studies on power postures, a more convincing demonstration of the effect of postures on feelings of power is available (Cesario et al., 2017). Although the effect was only significant in two out of the six studies and this despite their consistently large sample size, assessing the combined effect across all studies with a Bayesian meta-analysis yielded clear evidence that expansive postures enhance feelings of power, with the strength of the evidence being either strong or moderate, depending on whether all or just participants still unfamiliar with the "power poses" were included in the analysis (Gronau et al., 2017).

With regard to feelings of power, some preliminary hints suggest that one moderator, namely **gender**, could influence the strength of the effect. Re-analysis of the data from Carney et al. (2010) and the first replication (Ranehill et al., 2015) showed that the effect is much stronger in men (Credé & Phillips, 2017). Furthermore, one study of the pre-registered special issue reported stronger effects on feelings of power along with less effort to hold the expansive posture in men than women, which could suggest that men might be more used to and therefore respond to expansive postures more strongly (Bombari, Mast, & Pulfrey, 2017).

Conclusion on replicability of initial power posture findings

In summary, re-investigations of the effects of expansive and constrictive postures reported by Carney et al. (2010) showed that the effects on hormones and risk-taking were not replicable, while there might be a small true effect on feelings of power, the strength of which could be influenced by gender as well as familiarity with the "power posing" concept.

3. Postural feedback effects on other feelings and behaviour

Although the "power posture" findings were the first to attain such popularity, they were not the first demonstrations of an impact of bodily expansion on feelings and behaviour. An independent body of research building on a several studies by Riskind in the 80ies used upright and slumped sitting postures as bodily feedback manipulations (Riskind, 1983, 1984; Riskind & Gotay, 1982). While most studies after Carney et al. (2010) consistently interpreted the whole body expansion exclusively in terms of power and dominance, interpretations of postures with an upright or slumped upper body postures vary more broadly. Their interpretations comprise different affective states related but not limited to power, such as strength, mood, valence, happiness vs. depression, stress vs. relaxation (Riskind, 1983, 1984; Riskind & Gotay, 1982), pride (Stepper & Strack, 1993) or confidence vs. doubt (Brinol, Petty, & Wagner, 2009). Given that the review and p-curve analyses by Cuddy and colleagues (Carney et al., 2015; Cuddy et al., 2018) have incorporated these studies, I also include them in the below review of all effects other than those on risk-taking, hormones and feelings of power, clearly labelling the type of posture used in each study.

3.1. Explicit mood and self-esteem

The most common finding regarding mood is enhanced positive mood or reduced negative mood for upright/expansive in relation to slumped/constrictive postures, although results vary with regard to which posture drives the effect (Kozak, Roberts, & Patterson, 2014; Nair, Sagar, Sollers, Consedine, & Broadbent, 2015; Roberts & Arefi-Afshar, 2007; Rossberg-Gempton & Poole, 1993; Zabetipour, Pishghadam, & Ghonsooly, 2015). Furthermore, merely adopting postures does not seem to impact self-esteem in general (Nielsen, 2017), although slumped postures appear to diminish self-esteem after a social stress task (Nair et al., 2015).

Most investigations of mood involved ratings across a collection of positive and negative affective words, which illustrate that postural expansion may influence a broad range of affective states. For instance, Nair et al. (2015) systematically studied affective states in terms of valence and arousal, and found that participants sitting upright reported feeling less quiet, still, passive, dull, sleepy and sluggish, and experienced reduced fear in social threat situations, whereas participants assuming slumped positions felt less enthusiastic, excited, strong, happy, satisfied, content, but more fearful, hostile, nervous, sad and lonely. In other studies, slumped compared with upright postures further brought on enhanced worry, shame, tension, discouragement and reduced anger (Roberts & Arefi-Afshar, 2007), higher depression scores along with lower locus of control (Riskind & Gotay, 1982), enhanced guilt and decreased pride (Rotella & Richeson, 2013; Stepper & Strack, 1993). In summary, a broad range of self-report measures suggest that expansive as compared to constrictive postures induce more positive affective states.

3.2. Implicit indicators of changes in mood and attitudes

To measure posture effects on mood and attitudes implicitly, studies have focused on the valence of recalled memories and the ease or speed of memory recall, learned helplessness behaviours, as well as valence and self-focus in spoken and written language. Specifically, slumped and upright postures have been shown to induce memory biases for positive and negative words, thoughts and memories, respectively, and make recall of positive and negative memories more efficient and easy (Michalak, Mischnat, & Teismann, 2014; Peper, Lin, Harvey, & Perez, 2017; Riskind, 1983; Tsai, Peper, & Lin, 2016; V. E. Wilson & Peper, 2004). Overall, slumped postures induce similar behaviours as those known to be associated with depression, such as the negative memory biases just described, reduced persistence in unsolvable or difficult tasks as an indicator of greater learned helplessness (Nair et al., 2015; Riskind & Gotay, 1982), increased frequency of negative and self-focused words in word patterns during speech tasks (Nair et al., 2015; Wilkes, Kydd, Sagar, & Broadbent, 2017) or written thought listing tasks (Veenstra, Schneider, & Koole, 2016), whereas upright postures shift all of these outcomes in the positive direction.

Furthermore, two studies assessed implicit attitudes associated with power. In the first, participants chose one of several seats along a table, and upright vs. slumped postures biased choice towards the seat at the head of the table, which was interpreted as an enhanced sense of leadership (Arnette & Pettijohn II, 2012). The second study let older adults try out gerontechnology, and interpreted increased ease of use and intention to use the software after expansive vs. constrictive postures as a sign for an increased sense of control (Teh et al., 2016).

In short, implicit measures of mood and attitudes confirm explicit self-report findings: expansive postures evoke more positive moods and attitudes than constrictive postures, including stronger implicit attitudes associated with power and control.

3.3. Self-evaluation and self-concept

Changes in self-evaluation, on the one hand, have been investigated in terms of confidence individuals have in their own thoughts, decisions, opinions and performance. Upright postures increased thought confidence when participants reflected upon their best or worst qualities concerning future professional performance (Brinol et al., 2009). Similarly, participants who imagined having to take decisions as the leader of a small business tended to search for and believe more in information that confirmed their decision when they had previously adopted an expansive posture (Fischer et al., 2011). How confident individuals are in their own thoughts determines how open they are to persuasion by others. However, assessing this idea in a large pre-registered study, Latu, Duffy, Pardal & Ardal (2017) found no differences in attitudes towards persuasive messages between expansive and constrictive posture conditions. This could imply that contextual power cues (e.g. persuade others about one's qualities, or assuming the role of a business leader) are necessary for expansive postures to activate power associations and thus enhance confidence in one's own thoughts and decisions. Another large, pre-registered study investigated a related question by examining whether expansive vs. constrictive postures enhanced overconfidence in terms of over-estimation of performance in a general knowledge questionnaire (Ronay et al., 2016), and also observed no posture difference. Similarly, Nielsen (2017) found no effects on problem-solving confidence reported via a questionnaire.

Investigations of self-concept have focused on beliefs about the self, preferred perspective about the self in relation to time, and mental representation of the self. Positive emotional states broaden people's perspective on the world and their behavioural repertoire and increase their ability to think flexibly and abstractly (Fredrickson, 2001). Given that expansive postures enhance positive emotions, a pre-registered and highly powered study (Jackson, Nault, Richman, LaBelle, & Rohleder, 2017) therefore hypothesized that adopting expansive postures might expand self-concept, that is, increase the number of beliefs about the self. Although expansive postures did not enhance size of self-concept as predicted, exploratory analyses revealed an effect on psychological flexibility defined as self-reported commitment to goals in the face of stress or failure. In terms of temporal perspective, expansive postures induced a preference for metaphorical expressions describing the self as moving through time towards a specific event ("We are approaching the deadline."), over those describing an event moving towards the self ("Christmas is approaching"; Duffy & Feist, 2017). This suggests a preference for more active rather than passive self-conceptions. Assessing self-concept in a more implicit manner, Toscano used reverse correlation methods to visualize how postural expansion influences the mental representation of one's own face (2014; experiment 4). The resulting self-representation image, averaged across participants, appeared more dominant, strong and emotionally stable after expansive than constrictive postures.

To summarize, it is not yet entirely clear whether expansive postures increase the confidence in self-evaluations, due to mixed findings for different but still related outcomes. Furthermore, while expansive postures do not impact self-concept size, they might induce more active and dominant self-perceptions.

3.4. Physical strength and pain tolerance

In support of the notion that expansive postures lead to stronger and more dominant self-perception, a study reports an increase of pain threshold after adopting expansive postures (Bohns & Wiltermuth, 2012). Additionally, perceived weight of a lifted object reduced from before to after adopting an expansive posture, while no such change occurred for constrictive postures (Lee & Schnall, 2014). The fact that a similar reduction in weight estimation was observed in a control group hints that lacking power actively impacts on weight perception, while having power does not. Finally, one study reported that standing in an upright posture lead to an increased perceived arm strength (Peper, Booiman, Lin, & Harvey, 2016). However, one major caveat is that standing in an erect or slouched posture changes biomechanical capacity to resist downward pressure on one's arm. The effect on perceived power reported by this study is therefore questionable.

3.5. Social behaviour

Given that several studies suggest that postures affect how we feel and think about ourselves, could they also influence how we relate to others? With regard to more aggressive or assertive behaviour, a collection of studies suggests in increase of dishonest social behaviour in association with expansive postures, in terms of stealing, cheating and violating rules (Yap, Wazlawek, Lucas, Cuddy, & Carney, 2013). Furthermore, when individuals with a low general sense of power imagined a friend who unnecessarily put them at a disadvantage, adopting an expansive posture lead them to report stronger inclinations for revenge (Strelan, Weick, & Vasiljevic, 2014). In contrast, four large studies on behaviour during sale negotiations observed no impact of adopted posture on any parameter (decision to make the first offer, price of first offer and final price) (Cesario & Johnson, 2017).

With respect to pro-social behaviour, one study finds that constrictive postures increase feelings of guilt and reparative intentions for imagined personal wrongdoings as well as actual collective wrongdoings (Rotella & Richeson, 2013), while another study found no significant posture effect on intention to volunteer at a non-profit organization or on helping behaviour towards the experimenter (Peña & Chen, 2017).

Notably, all above-mentioned types of social behaviour involve high-level cognitive processing. So far, only one study (Jamnik & Zvelc, 2017)has focused on a lower level of social behaviour, which may more directly be related to the elementary social signalling function of postural expansiveness. The study investigated whether adopting an expansive posture during a conversation with a familiar other person induces changes in nonverbal dominance behaviour, such as the time spent looking at others while speaking compared to listening (Dovidio & Ellyson, 1985) and speaking time of the acting or the observing individual, but observed no effects on either side. However, Jamnik & Zvelc (2017) note that the sample they tested was relatively small, which means that effects on such nonverbal behaviours cannot be ruled out.

3.6. Abstract, logical and creative thinking

One of the first power posture studies demonstrated a considerable posture effect on abstract thinking (Huang et al., 2011), showing that expansive postures can increase object recognition in fragmented pictures similarly to other power manipulations (P. K. Smith & Trope, 2006; Stel, Dijk, Smith, Dijk, & Djalal, 2012). Yet, Cesario and Johnson (2017) failed to replicate this posture effect in four separate studies. Furthermore, two studies found no effect of open vs. closed sitting postures on logical reasoning, but found that open postures were associated with higher scores in two different creative thinking tasks (Andolfi, Di Nuzzo, & Antonietti, 2017).

4. Postural feedback effects are context dependent

Postural feedback effects have been found to be sensitive to context in several studies. This includes investigations of risk-taking and other power-related behaviours directly inspired by the initial power-posing study by Carney et al. (2010). These studies investigated posture effects on risky gambling decisions, explicit feelings of power, implicit activation of power, and reported willingness to take risky but necessary actions in hypothetical scenarios, specifically testing if these effects depend on congruency with one's current power role or with cultural norms about body postures. Huang et al. (2011) assigned people to a high or low power role as procedure frequently used in research on social power, that consists of by announcing an upcoming puzzle task during which the "manager" would direct, evaluate and reward the "subordinate" (Galinsky et al., 2003). Their results suggest that posture effects surpass or even erase the effects of power roles on the recall of power-related memories. In contrast, two other studies imply that congruency of the adopted posture with one's current power role (Cesario & McDonald, 2013) or cultural norms about respectful nonverbal behaviour (Park et al., 2013) is a necessary condition for postural feedback effects to manifest. Importantly, the latter study implied that effects of expansive and constrictive postures on behaviour are not direct and automatic, but rather depend on characteristics of the situation in which they are adopted.

For example, affective responses to positive or negative feedback have been shown to depend on whether the adopted posture is appropriate to the situation: upright postures increased feelings of pride and motivation while decreasing learned helplessness behaviour and depression only in a context of success, whereas slumped postures had the same effects in a situation of failure (Riskind, 1984; Stepper & Strack, 1993). Thus, it was the posture most appropriate to the context instead of the type of posture itself that yielded the best outcomes, i.e. the upright posture during success, and the slumped posture during failure. Similarly, a study on creativity observed better performance when individuals held either an expansive or constrictive posture, depending on whether the preceding emotional mood induction was positive or negative (Hao et al., 2017).

Two other studies demonstrate unfavourable effects of expansive postures in stressful situations. Turan (2015) tested postural feedback effects during a stress manipulation which combines performance pressure with negative social feedback (Kirschbaum et al., 1993). In a sample of 85 male participants, cortisol levels did not change after adopting a sitting expansive or constrictive posture for 2 minutes, which is consistent with the non-replications of power postures on hormone levels. Yet, after the stress task, throughout which participants again assumed their assigned posture, cortisol levels did increase in the expansive posture condition only, an effect in the opposite direction of what Carney at al. (2010) originally reported. This occurred although the expansive posture resulted in higher self-perceived state dominance. On the one hand, this suggests, consistent with the appropriateness-hypothesis, that constrictive postures might be more adaptive when receiving negative feedback. Moreover, it raises the possibility that postures could have effects on cortisol levels in the context of stress, and/ or when adopted for a longer duration (here about 15 minutes).

Similarly, participants who adopted an upright vs. slouched posture during a stressful experience of social exclusion reported greater threat to basic needs and more negative mood (Welker, Oberleitner, Cain, & Carré, 2013). This appears contradictory at first, given that social rejection raises the need for affiliation (Maner, DeWall, Baumeister, & Schaller, 2007), which is in general assumed to be stronger in powerless individuals (Magee & Smith, 2013). Although the authors label the postures as dominant and submissive, this contradiction dissolves if one considers that a posture must be appropriate to a context to have beneficial consequences, or that the effect of upright postures is context dependent: in a context where affiliative needs are threatened, they might signal openness and desire for social contact rather than power.

Whether a context is simply positive or negative is not the only dimension of importance with regard to postural feedback effects. Several studies reveal that the specific emotional, learned or cultural meaning of a posture also matter, raising the question whether simply dividing postures into upright/slumped or expansive/constrictive is sufficient to capture the variations between body postures and their effects. Duclos et al. (1989) show that angry, sad and fearful postures cause people to feel that specific emotion most strongly, and that the effects are more pronounced in individuals who interpreted the posture as showing that particular emotion.

An interesting study (Bialobrzeska & Parzuchowski, 2016) reflects upon what exactly constitutes an expansive and upright physical posture, by contrasting the effects of an upright posture with closed limbs (for example, standing-at-attention in the military) with a naturally adopted control posture ("standing at ease"). Consistent with the perception of these postures as tense and subordinate vs. calm and open by independent raters, the standing-at-attention vs. control posture led participants to put their chair at a greater distance from the experimenter, to imagine a described person as larger, and to comply more when the experimenter asked them for a favour. This demonstrates that a strongly upright posture can actually embody submissiveness, due to its learned meaning or the physical tension associated with it.

Such learned associations might also contribute to gender differences in postural feedback effects. When receiving positive feedback about a previous task in an upright posture, men felt more proud and went on to perform better in a math test, whereas women showed the opposite changes (Roberts & Arefi-Afshar, 2007). The authors suggested that this could be linked to learned gender-stereotypes and habits; it could also be due to feelings of self-objectification which women have learnt to associate with upright postures (Kozak et al., 2014). It has been shown (Kozak et al., 2014) that women can feel more self-conscious in upright than slumped postures when they wear a tight top compared to sweatshirt, i.e. when attention was drawn toward their breasts and body form.

In conclusion, studies of postures as a function of context in terms of feedback, stress, and innate or learned cultural associations suggest that the effect of a posture is not necessarily straightforward, and that one needs to carefully consider the experimental as well as the larger cultural context to fully understand postural feedback effects. One major caveat of studies demonstrating context-effects is that some of the posture effects they investigated have turned out not to be robust (risk-taking and hormone levels). This cannot be ruled out for effects that have not yet been replicated. Thus, it is possible that effects randomly occur in some but not other conditions, and that this is interpreted as a context-effect. Nonetheless, it is conceivable that any consequences of adopting a posture might depend on contextual information.

5. Disentangling true from false effects and possible reasons for the replicability debate

The myriad of different findings described above may appear to confirm that postural feedback effects truly exist. However, for most of them, the challenge to disentangle true from false positive effects by means of (ideally pre-registered) replication studies still remains to be tackled before strong conclusions are possible. Cuddy et al. (2018)'s p-curve analysis reports the strongest evidential value for posture effects on emotions, affective states and self-evaluations (other than feelings of power and control). Most of the 16 studies that Cuddy et al. subsumed under this category found main effects of posture in the expected direction, while only four report context-dependent effects. It is interesting that 13 out of these 16 effects were induced by upright vs. slumped upper body positions that were held for an extended period of time and while outcome measures were acquired. In contrast, whole body expansive vs. constrictive postures that Carney et al. (2010) called "power postures" are usually adopted only briefly and before outcome variables are assessed.

For the heterogeneous subset of postural feedback effects on other types of behaviour, the results of the p-curve analysis (Cuddy et al., 2018) provide no evidence for a true effect. Which of them are reliable will have to be discerned by means of replication efforts, for which a special issue of pre-registered and highly-powered studies (Jonas et al., 2017) serves as an excellent example. While some exploratory analyses in these studies observed effects of expansive and constrictive postures, none of the pre-registered analyses except those on feelings of power yielded a significant result. In addition to ruling out effects on risk-taking, interview performance and hormone levels, these studies also report null-effects on self-concept and overconfidence (Jackson et al., 2017; Ronay et al., 2016). Including these studies in their p-curve analysis may have changed Cuddy et al. (2018)'s conclusion that there is strong evidential value for a posture effect on self-evaluation measures.

Thus, from today's viewpoint, after publication of several non-replications of most of the initial and some other findings, one could conclude that most of the reported effects of postures were false positives or originated from methodological issues (Credé & Phillips, 2017; Schultheiss & Mehta, 2018), and that the scientific journals' publication bias towards significant findings prevented reports of null-findings before non-replications of the most famous finding. Some authors have argued that it remains to be clarified whether the confirmed effects on feelings of power reflect true effects of bodily feedback rather than demand effects (Jonas et al., 2017). A larger effect on feelings of power in individuals who knew about the supposed effects of "power posing" (Gronau et al., 2017), as well as an effect that is more strongly influenced by the self-reported posture, rather than the actually adopted posture (Jackson et al., 2017), are hints that demand or placebo effects may at least partially explain results observed with explicit self-reports. It heavily suggests that the interpretation of posture, which is influenced by the context, would matter.

Another possible reason for the debate could be that the initial focus of behaviours had limited relevance to nonverbal communication, yielding contradictory findings. However, there is unequivocal evidence that expansive as opposed to constrictive postures are perceived as signals of dominance, power and competence (Burgoon & Dunbar, 2006; Carney, Hall, & LeBeau, 2005; de Waal, 2007; Ellyson & Dovidio, 1985; Hall et al., 2005; Rennung, Blum, & Göritz, 2016), and that these judgments are ecologically valid, since successful and dominant individuals do indeed display more expansive and erect postures (Weisfeld & Beresford, 1982). Furthermore, it has clearly been demonstrated that posture as a social signal has implications for social interactions (Bohns & Wiltermuth, 2012; study 2; Tiedens & Fragale, 2003; Vacharkulksemsuk et al., 2016). Nevertheless, the large majority of studies on feedback effects of postural expansiveness have not focused on social cognition and behaviour, that is, cognitive processes and behaviour in response to the actions of others, but have instead focused on behaviours commonly assessed in the research field on social power (Guinote, 2017). However, enacting expansive or constrictive postures in contexts devoid of valid cues that signal that one actually has or lacks power might simply not affect these power-related behaviours.

While many postural feedback studies have focused on feelings that have social aspects, they have only evaluated how enactors of bodily postures perceive themselves, not how they perceive and consequently interact with others. The few social types of behaviour that were studied, comprising dishonest behaviour, reparative intention, revenge, negotiation and prosocial behaviour, have all involved high-level cognitive processes. However, postural expansion itself occurs in multiple species with limited cognitive capacities (see chapter 1) and serves the very basic social function of signalling dominance status. Only one single recent study (Jamnik & Zvelc, 2017) has investigated postural effects on nonverbal social behaviour, namely, on visual dominance and speaking time. Yet, it remains unexplored whether adopting postures affects how we perceive and react to social signals from others, as research on embodiment of social cognition would suggest (Niedenthal, 2007).

This thesis project aimed to investigate basic mechanisms of social perception and behaviour. To this end, we set out to explore postural feedback effects on the perception and reaction to others' nonverbal social signals, including gaze direction, facial traits associated with dominance and affiliation, and emotional expressions signalling threat.

Conclusion

In summary, expansive and constrictive postures do not affect risk-taking, hormonal levels, job interview performance, negotiation, self-concept expansion and overconfidence, while they impact mood and affective states, including feelings of power. For all remaining findings, strong conclusions are not yet possible. Although postural expansiveness serves to nonverbally signal social power, no studies have investigated whether it impacts the actor's social perception and responses to other's social signals. The present thesis therefore aimed at exploring postural feedback effects on three levels, comprising mental representations of other's faces, perception of facial expressions signalling threat, and approach and avoidance actions in response to such facial expressions. Chapter 3 will introduce the objectives of the present thesis in more detail, and outline the research process across studies investigating these different levels of social cognition and behaviour.

Chapter 3
Power posture effects on social perception and behaviour: The research questions and methodological approach of the present thesis

Although expansive and constrictive postures unequivocally serve to communicate important social information, none of the studies investigating postural feedback published at the beginning of this thesis project had looked at behaviours corresponding to this core function. Given that postural expansiveness is a low-level social signal of dominance in many animal species, we started by exploring postural feedback effects on the processing of basic social signals, namely facial expressions of anger and fear. A first study I participated in (Chadwick, Metzler, Tijus, Armony, & Grèzes, 2018)[3] demonstrated power posture effects on the processing of these threat-related facial expressions. Generally, facial expressions of anger are recognized better when they are paired with direct as compared to averted gaze, since gaze towards the observer implies that they are the target of the expressed anger (Sander, Grandjean, Kaiser, Wehrle, & Scherer, 2007). In contrast, fearful expressions are recognized better when paired with averted rather than direct gaze, since averted gaze implies that the emitter might have spotted a source of danger in the environment that could also threaten the observer. Our study demonstrated that the same effects of gaze on emotion processing can be found when individuals do not attend to the facial expression. Specifically, we found increased performances for direct anger and averted fear as participants focused on discriminating exterior from interior scenes in face-scene composite images (Figure 7a). This demonstrates that these threat-signalling facial expressions were salient enough to enhance visual processing (Figure 7b).

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[3] Data for this study was already collected when I joined the research team. Yet, I substantially contributed to the data analysis and writing of the paper. For this reason, the publication is included in the Appendix of this thesis.

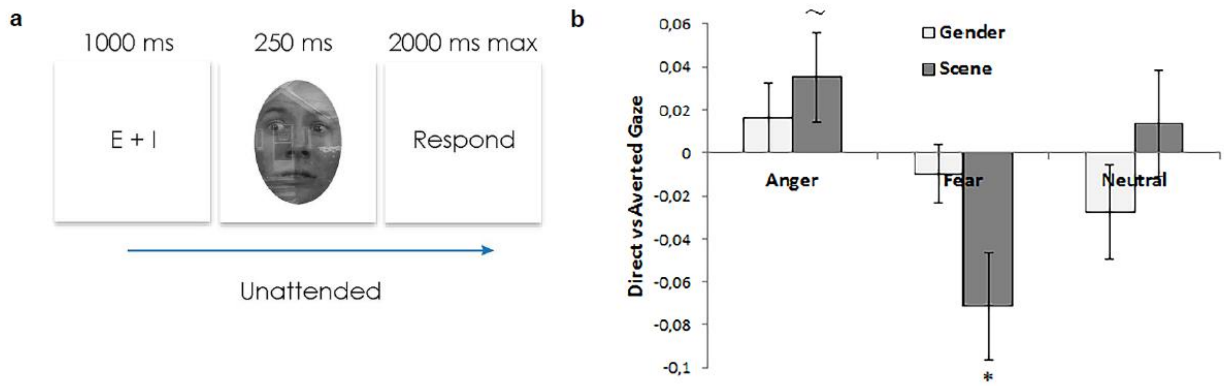

Figure 7. **a)** Adapted from Figure 1 from Chadwick et al. (2018). 1 trial of the scene discrimination task: participants had to determine whether the scene superimposed on the face was exterior or interior. **b)** Figure 2 from Chadwick et al. (2018): Mean difference in accuracy (% ± SEM) between direct and averted gaze for angry, fearful, and neutral faces in Experiment 1. (~ $p < 0.10$ * $p < 0.05$)

Crucially, we further found that adopting expansive postures before performing this scene discrimination task abolished the gaze effect for fear, whereas constrictive postures eliminated the gaze effect for anger (Figure 8). This suggests that the observer's body posture determines the salience of these threat-related facial expressions. Building on this study, I explored whether power postures would similarly impact explicit emotion recognition in Study 1 of my PhD project (see Chapter 4). I observed no impact of expansive and constrictive postures on emotion recognition accuracy of angry, and fearful expressions with direct or averted gaze. As Chapter 4 discusses in more detail, it seemed as if the focus of attention could consistently explain the difference between these two studies. In parallel to findings regarding the impact of trait dominance or anxiety on the salience of angry and fearful expressions (e.g. Putman, Hermans, Koppeschaar, van Schijndel, & van Honk, 2007; Terburg, Hooiveld, Aarts, Kenemans, & van Honk, 2011), body postures related to dominance and submission seemed to only affect emotion processing when faces were unattended. I continued to explore the possibility that the focus of attention was a determining factor for the occurrence of posture effects in subsequent experiments of my PhD. In the following, I will use the terms explicit and implicit processing to distinguish between tasks or situations in which the relevant dimensions of a stimulus are inside or outside the focus of attention.

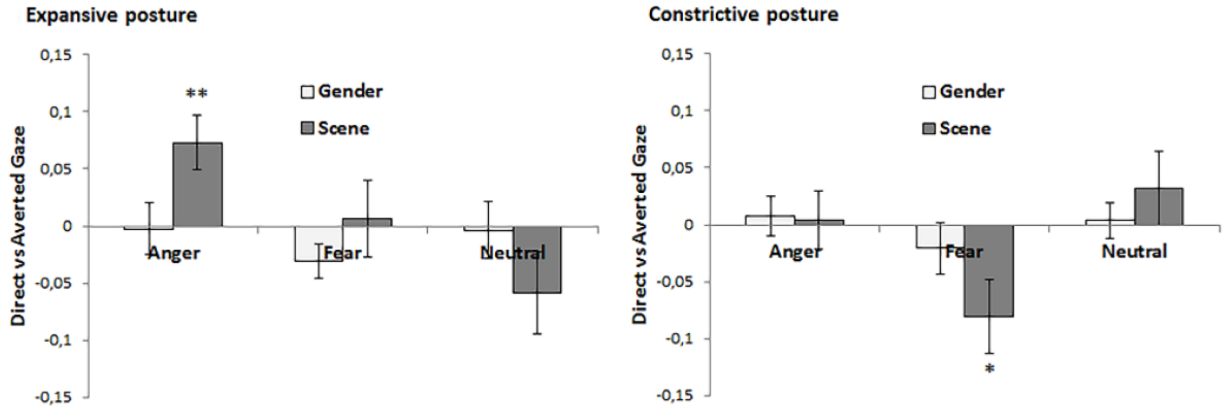

Figure 8. Mean difference in accuracy (% ± SEM) between direct and averted gaze for angry, fearful, and neutral faces split by expansive and constrictive poses in Experiment 2 – Session 1 by Chadwick et al. (2018). (*p <0.05, **p <0.01)

1. Objectives and research questions

The primary objective of the present thesis was to further explore the impact of adopting expansive and constrictive body postures on behaviours relevant to the core function of these postures, that is, social signalling. More specifically, I aimed at elucidating the mechanisms of the power posture effects on implicit processing of facial threat in our first study (Chadwick et al., 2018). On a physiological level, a posture effect on levels of the steroid hormones testosterone and cortisol (Carney et al., 2010) could have mediated the effects we observed, since they remarkably resembled typical effects of testosterone and cortisol baseline levels or administration on social threat processing (for a review, see Montoya, Terburg, Bos, & van Honk, 2012).

On a cognitive level, posture effects on attention to social signals of threat could arise from an influence on participants' social preferences and expectations about others and/or their evaluation of available action possibilities. To elaborate on this further, adopting a certain posture may activate representations of previous experiences in which one had or lacked power, which may in turn be associated with particular representations of other people in these situations. For example, we may represent others as more powerful when we experience ourselves as powerless, and vice versa. How we mentally represent others could shape social expectations or preferences towards others (see e.g. Ratner, Dotsch, Wigboldus, van Knippenberg, & Amodio, 2014), which may subsequently bias the perception of actually perceived social signals (L. Brinkman, Todorov, & Dotsch, 2017). For instance, attention may be more strongly captured by social signals which we prefer or expect.

The second (either alternative or additional) cognitive explanation for postural feedback effects on the implicit processing of social signals is a potential influence on the agent's evaluation of action opportunities in response to others. Power crucially determines the range of behaviours that are available in response to other people's actions (e.g. Galinsky et al., 2008). By activating representations associated with power, postures may thus alter a crucial characteristic of the observer that determines which action opportunities he perceives in response to other's social signals. Thus, postures may impact which social signals we attend to depending on which action opportunity is most adaptive given our current level of power.

Based on these considerations, I conceptualize power posture effects on social perception and behaviour on three different levels, including effects (A) on mental representations of faces of others, (B) on perception of and attention to social signals of others, and (C) on action decisions in response to such signals. The research questions I explored in the present thesis thus assessed these three core questions (see Figure 9):

A. Does adopting an expansive or constrictive body posture, in the absence of particular social signals from others, influence the agent's own mental representations of others?
B. Does adopting an expansive or constrictive body posture influence how the agent processes social signals from others?
C. Does adopting an expansive or constrictive body posture influence the agent's action decisions in response to social signals from others?

The first two studies we conducted focused on question B, investigating posture effects on implicit processing of social threat signals (Chadwick et al., 2018; see Appendix), and explicit recognition of social threat signals (Chapter 4, Figure 9 B). My next study assessed whether the posture effects on hormone levels reported by Carney et al. (2010) were reproducible (Chapter 5), and could thus potentially explain the effect on implicit processing of social threat. The study in which I collected hormone samples was at the same time the first of a series of studies assessing posture effects on mental representations of faces. The reason for collecting hormones in this study was that it did not involve any emotional expressions, which have been shown to induce testosterone and cortisol responses on their own (van Honk et al., 2000; Zilioli, Caldbick, & Watson, 2014).

Addressing question A, I used reverse correlation methods (Dotsch & Todorov, 2012) in a series of experiments to investigate posture effects on mental representations of faces. To shed light on possible posture effects on implicit and explicit social preferences and expectations, I assessed mental representations of faces one likes in both an implicit and an explicit manner (Chapter 6, Figure 9 A). Regarding question C, a final study examined posture effects on approach and avoidance actions in response to social threat signals (Chapter 7, Figure 9 C). In the following, I describe common features in the design of all these studies.

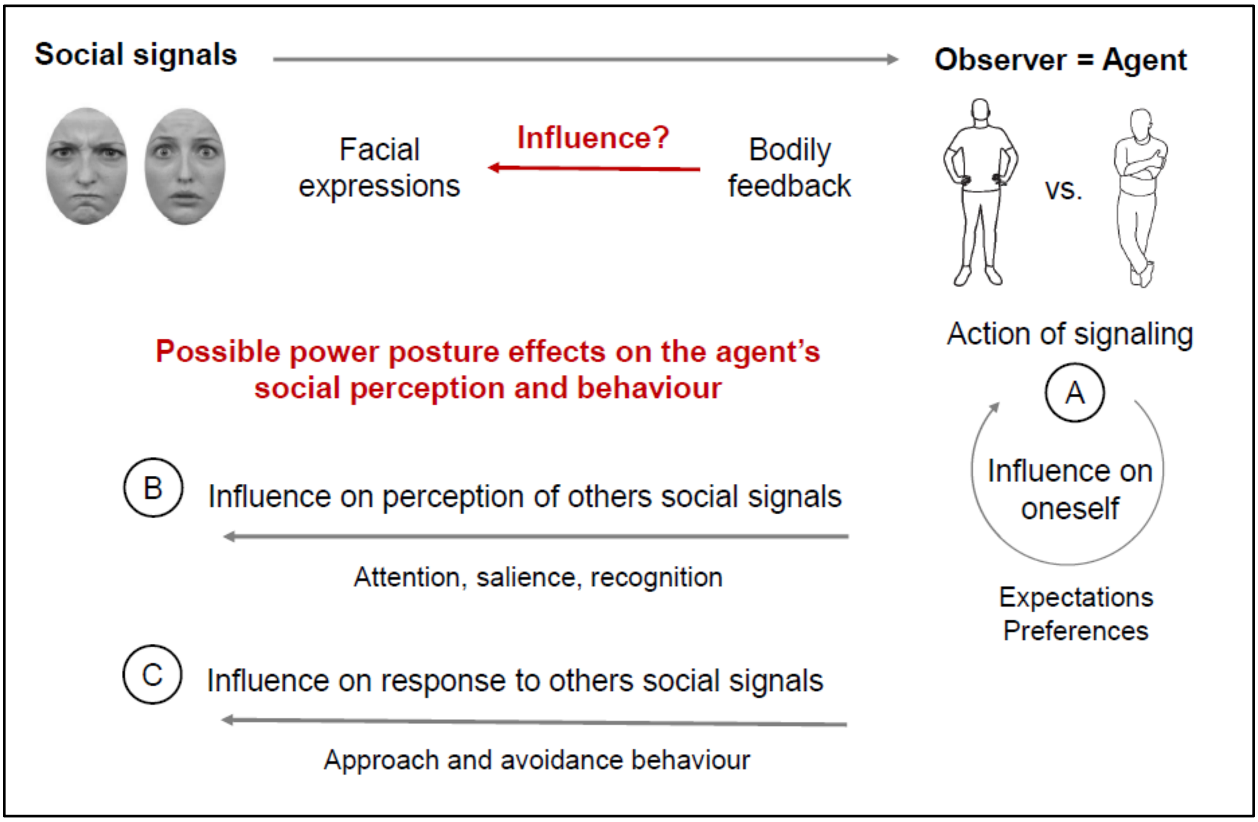

Figure 9. Levels of social cognition and behaviour at which power posture effects may take place.

2. General methodological approach

All studies in the present thesis involved both a posture manipulation and a categorization or decision task on the computer which included faces as social stimuli. The different tasks varied in whether attention was directed to the social signals of interest (i.e. the facial expression or trait), or to another irrelevant aspect of the stimuli. This section describes these different features of the studies' design (posture manipulation, faces, and focus of attention) in more detail.

2.1. Posture manipulation

The experimental task (face categorization or action-decision) was always separated in several blocks, before each of which participants were instructed to adopt either an expansive or constrictive posture for 2 or 3 minutes. In all but the study on action decisions, effects of posture were assessed in a between-subject design, that is, participants performed the task only once and adopted either an expansive or a constrictive posture. We opted for between-subject designs since posture effects in our first study (Chadwick et al., 2018) had only occurred in the first session in which participants adopted one type of posture, but then disappeared in the second session in which they adopted the other type of posture. In the study on action decisions, we again applied a within-subject design in order to reduce between-subject variability and achieve higher statistical power. Yet, this time participants adopted no posture in the first session, and only adopted one type of posture in the second session (see Chapter 7).

Participants were always told that the posture manipulation and the face perception or action decision task belonged to two separate studies. One was supposedly investigating effects of body posture on heart rate parameters, and the other either face perception or spontaneous action decisions. This cover-story was chosen to make sure that potential posture effects could be attributed to bodily feedback itself, and not to beliefs or reflections about how the postures could influence behaviour in the subsequent task. Data analysis was in general done with and without the few participants (max. two per study) who still suspected a link between the postures and the task, to verify whether this would yield different results.

2.2. Faces as social signals

We chose to focus on faces as social signals because they are likely the most salient social stimuli for humans and express a variety of social dimensions. For instance, faces evoke automatic trait inferences along the two fundamental social dimensions of dominance and trustworthiness (Todorov, Said, Engell, & Oosterhof, 2008). Furthermore, facial expressions communicate many different emotional states as well as behavioural intentions (Keltner & Haidt, 1999). For the studies on perception of social signals (Chapter 4) and on action decisions in response to social signals (Chapter 7) we selected the facial expressions anger and fear, given that such threat signals are specifically relevant with regard to bodily feedback from postures that express dominance or submissiveness. First, angry and fearful facial expressions are perceived as dominant and submissive, respectively (Hess, Blairy, & Kleck, 2000; Knutson, 1996). Second, postural expansion often occurs in threatening contexts, since it functions as a threat and victory display in agonistic encounters and competitive interactions (e.g. Grant & Mackintosh, 1963; Hagelin, 2002; Hwang & Matsumoto, 2014; Stevenson et al., 2000).

With regard to mental representations (Chapter 6), faces offered the possibility of assessing social preferences using an established reverse correlation method (Dotsch & Todorov, 2012; Dotsch, Wigboldus, Langner, & Knippenberg, 2008), with which the features of representations can be visualized unbiased by the researchers' a priori assumptions. Visualizing mental representations by means of this data-driven approach allows their features to vary freely as a function of participants choices. In contrast, the social dimensions on which the visual renderings of mental representations are to be evaluated need to be chosen by the researcher. We chose to evaluate them on the broad and fundamental dimensions that structure human social perception and behaviour: Dominance and affiliation (Fiske et al., 2007; Paulhus & Trapnell, 2008)[4]. The Interpersonal Circumplex Model (Kiesler, 1996; Wiggins, 1991) conceptualized them as two axes spanning a "social" vector space: a vertical dimension representing dominance, power, status, control and competence and a horizontal dimension embodying affiliation, warmth, friendliness, love, cooperation and solidarity. Evaluating mental representations along these two dimensions thus allowed assessing social trait impressions anywhere in this social space.

2.3. Varying the focus of attention

Usually, individuals do not directly focus their attention on their body posture. Instead, posture is regulated implicitly and automatically adapts to ongoing social interactions (Tiedens & Fragale, 2003). Similarly, the processing of nonverbal social signals such as facial expressions

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[4] Although these dimensions have been referred to with different names, empirical evidence reveals a broad overlap between the different concepts (Abele & Wojciszke, 2014). Research on interpersonal personality traits and motives (e.g. Horowitz et al., 2006; McAdams, 1980; Wiggins, 1991) refers to them as agency and communion, research on the content of stereotypes about social groups as *warmth* and *competence* (Fiske, Cuddy, Glick, & Xu, 2002), and research on face perception and evaluation typically as *dominance* and *trustworthiness* (Todorov, Said, Engell, & Oosterhof, 2008). I used these dimensions to measure impressions from facial traits, but focused on various affiliative traits rather than specifically trustworthiness. Therefore, I refer to them as *dominance* and *affiliation*, following other studies investigating the evaluation of facial expressions on these broad dimensions (Hess, Blairy, & Kleck, 2000; Knutson, 1996).

typically occurs outside of the focus of attention (Ambady & Weisbuch, 2010). Nevertheless, expansive and constrictive postures have been shown to impact explicit feelings of power (Cesario & Johnson, 2017; Gronau et al., 2017) and possibly on various other explicitly assessed self-report measures (see Carney et al., 2015; Cuddy et al., 2018). Therefore, we investigated postural feedback effects on implicit as well as explicit measures when focusing on perception and mental representations of faces.

First, regarding perception of faces, I complemented the study on implicit emotion processing by Chadwick et al. (2018) with a study on explicit emotion discrimination. Second, regarding mental representations, I investigated implicit social preferences using an in-out-group categorization task (Ratner et al., 2014) without explicitly directing participants attention to the group context. To investigate explicit preferences, I used a task in which participants directly selected faces they preferred. In one of the studies on mental representations (Study 4 in Chapter 6), I further tested whether postures affect explicit self-reports of feelings of power and of the need for affiliation, as well as implicit needs for power and affiliation. In the study on action decisions, finally, facial emotion expressions were never mentioned explicitly. In general, we expected stronger effects of postures on implicit than explicit measures, given that posture and social perception are mostly regulated without conscious awareness in everyday life.

Summary of Chapter 3

The experiments presented in this thesis investigated postural feedback effects on the recognition of threat-signalling facial expressions (Chapter 4), on hormone levels (Chapter 5), on mental representations of other people’s faces (Chapter 6), and on approach and avoidance actions in response to threat-signalling facial expressions (Chapter 7). They always included a cover-story regarding the posture manipulation, which consisted of repeatedly adopting an expansive or constrictive posture for a few minutes. The experimental tasks varied with regard to whether participants’ attention was explicitly directed to the respective relevant feature of presented face stimuli (i.e. the expressed emotion or preferred facial traits). To put it briefly, relevant features were processed either inside or outside the focus of attention. The following experimental section of this thesis will present each of these experiments in detail.

EXPERIMENTAL STUDIES

Chapter 4
Does your body affect what you see?
No power posture effects on explicit recognition of threat-related facial expressions

When I joined the research team of Julie Grèzes, a former PhD student, Michèle Chadwick, had already begun to investigate the impact of body postures on the perception of social signals like emotion and gaze (Chadwick, 2015). More specifically, she focused on how postural feedback influenced the agent's appraisal of relevance of different threat-related facial expressions. As I started working with Michèle, the data for one central study on implicit processing of threat-related expressions had already been collected and revealed promising results (Chadwick et al., 2018). I originally aimed at identifying the cognitive and neural mechanisms of postural feedback effects on both implicit and explicit processing of social signals during my PhD. I began by investigating whether posture effects on explicit processing of threat-related expressions would be similar to those identified by Michèle. To do so, I used an explicit emotion discrimination task designed for EEG-experiments by Marwa El Zein (El Zein, Wyart, & Grèzes, 2015) which would have further allowed to characterise cognitive mechanisms by means of computational models. As the following chapter will illustrate, I found no posture effects on explicit emotion discrimination. This, together with publication of the first non-replication of the posture effects described by Carney et al. (2010), eventually led us to change my research plans. Nevertheless, the following study on explicit emotion processing offered important insights with regard to the focus of attention, task difficulty and statistical power as factors to take into account in future studies on postural feedback effects.

Abstract

Facial expressions of emotions convey crucial social signals, notably in threatening situations. The degree to which an emotional face signals a threat can vary considerably as a function of contextual elements such as co-emitted gaze direction as well as of the observer's characteristics. For instance, observers' power-related body posture has been reported to modify the salience of unattended gaze-emotion combinations (Chadwick et al., 2018). Here, we address whether these posture effects persist when threatening facial expressions are directly attended to. Participants (n=102) adopted either an expansive- or a constrictive body posture before performing an explicit anger vs. fear discrimination task. The salience of fearful and angry displays was varied using gaze direction. Results revealed best performance in explicit emotion recognition for threat-signalling gaze-emotion combinations (direct anger and averted fear), but no difference between posture groups. These results might imply that the focus of attention is a crucial factor for the emergence of posture effects on the processing of threat, with postural feedback occurring only when faces are unattended. However, in view of the current controversy on the replicability of postural feedback effects, we also discuss alternative explanations.

Keywords: body posture, power, threat, emotion, gaze direction, facial expression

Introduction

Facial expressions of emotion provide crucial information about other's emotional states, current needs and behavioural intentions. The visual processing of facial expressions depends not only on the type of emotion, but also on the context in which they appear, as well as characteristics of observer themselves (Wieser & Brosch, 2012). Other nonverbal behaviours emitted together with a facial expression, such as gaze direction or posture, constitute a reliably available source of contextual information that helps to decode the meaning of a particular display. Gaze direction, for example, indicates who or what may have elicited an expressed emotion (Graham & Labar, 2012). This information is particularly pertinent for emotional expressions that convey threat, such as anger and fear, which require rapid reaction in case the danger is relevant for the self. These threat-related expressions imply higher threat to the self when co-emitted with a specific gaze direction (Sander et al., 2007). Specifically, anger signals higher threat to the self when the emitter gazes directly at the observer, since this suggests that the observer is the target of the emotion. In contrast, fear with gaze away from rather than toward the observer implies higher threat since it signals that the emitter may have noticed a source of danger in the environment. Indeed, anger with direct and fear with averted gaze (called Threat+ combinations from now on) are processed more efficiently, better recognized and rated as more intense and negative than anger with averted and fear with direct gaze (Threat- combinations), and remain salient even when they are irrelevant to the task at hand (Adams & Kleck, 2003; Chadwick et al., 2018; Cristinzio, N'Diaye, Seeck, Vuilleumier, & Sander, 2010; El Zein et al., 2015; Hess, Adams, & Kleck, 2007; N'Diaye, Sander, & Vuilleumier, 2009).

The processing of facial emotion expressions further depends on characteristics of the observer. Concerning threat-related expressions, a particularly relevant characteristic is the observer's power, dominance or social status. In general, having power heightens approach motivation (Guinote, 2017; Keltner et al., 2003) and decreases vigilance towards threat (Anderson & Berdahl, 2002; Willis, Rodríguez-Bailón, & Lupiáñez, 2011). More powerful individuals are motivated to maintain their position and achieve their own goals and have better resources to cope with threat than less powerful individuals (Guinote, 2017; Keltner et al., 2003). Accordingly, dominant individuals are slower than submissive individuals to avert their gaze from angry faces and bodies, particularly but not only when these stimuli are masked, which indicates increased attention to such dominance cues (Hortensius, van Honk, de Gelder, &

Terburg, 2014; Terburg, Aarts, & van Honk, 2012; Terburg et al., 2011). Furthermore, unattended and attended angry faces elicited a stronger P3-component in individuals with higher implicit power motives in two studies using event-related potentials, which further underlines the enhanced salience of angry faces with increased power (J. Wang, Liu, & Yan, 2014; J. Wang, Liu, & Zheng, 2011). In contrast, more anxious (and thus presumably more submissive) individuals allocate more attention to fearful faces and the location indicated by the moving gaze of a fearful face, which suggests that they are more vigilant towards cues of danger in the environment (Putman et al., 2007; Putman, Hermans, & Van Honk, 2006). Even transient manipulations of power have been shown to bias visual processing of dominance cues, namely body size, as well as approach and avoidance behaviour towards others (Weick, McCall, & Blascovich, 2017; Yap, Mason, & Ames, 2013).

Altogether, previous research implies that more powerful individuals should allocate more attention towards angry faces with direct gaze, perceiving them as a dominance challenge rather than a threat to avoid. Yet, they should not be particularly vigilant towards fear with averted gaze. In contrast, less powerful individuals should avert their attention from angry faces with direct gaze, but be particularly alert when perceiving fear with averted gaze. Using expansive (dominant) and constrictive (submissive) postures as a transient power manipulation, Chadwick et al. (2018) indeed observed results in line with these predictions. In a visual discrimination task in which angry and fearful faces with direct or averted gaze were superimposed on images of in- and outdoor scenes, participants who adopted an expansive posture were better at discriminating scenes superimposed on direct vs. averted angry expressions, but similarly accurate for averted vs. direct fearful expressions. Constrictive postures produced the opposite result, that is, higher accuracy for averted vs. direct fear, but no difference between direct and averted anger. These posture effects seemed to be driven by a reduction in the salience of one emotion/gaze combination, as participants who did not adopt any posture showed better performance for both Threat+ compared to both Threat- combinations. In short, expansive and constrictive body postures determined the salience of threat-related facial expressions when faces were unattended.

Expansive and constrictive postures have been used as power manipulations in various other studies, given that they function as nonverbal social signals of high and low power and dominance in many social species (e.g. de Waal, 2007; Grant & Mackintosh, 1963; Hall et al., 2005). As theories of embodiment propose, body actions such as body postures may impact cognition and behaviour by re-activating representations of sensorimotor and affective experiences associated with these body actions (see M. Wilson, 2002). Based on this idea, numerous studies have investigated whether adopting postural displays of power influences an individual's own power-related feelings and behaviours. Yet, with the exception of a reliable small effect on feelings of power and control (Cesario & Johnson, 2017; Gronau et al., 2017), the replicability of other reported effects is currently a subject of debate (see Cesario et al., 2017). Since these postures are social signals themselves, bodily feedback from these postures seems more likely to impact perception of social signals and associated behavioural responses than on other cognitive processes and behaviours less related to nonverbal communication. Postural feedback effects on the salience of threat-related facial expressions (Chadwick et al., 2018) seem to support this idea.

In the present study, we examined whether the posture effects observed by Chadwick et al. (2018) when faces were unattended persist when participants explicitly focus on the facial expressions. More precisely, we tested whether the specific emotion-gaze combination that most improved performance in the visual scene discrimination task in each posture group would also be more accurately recognized than all other combinations during explicit emotion discrimination. For this purpose, we used an emotion discrimination task developed by El Zein et al. (2015). Participants adopted an expansive or constrictive posture for three minutes before each block of the emotion discrimination task. In line with the literature summarized above, El Zein et al. (2015) found higher accuracy for direct vs. averted anger and averted vs. direct fear. We predicted that posture would modulate this pattern in parallel to the findings by Chadwick et al. (2018), expecting a stronger effect of gaze on anger recognition in participants who adopted expansive postures, and a stronger effect on fear recognition for constrictive postures.

Methods

Participants and power analysis

Based on data from the study that had developed the task we used (El Zein et al., 2015), we expected an overall effect size of partial eta-squared (η^2_p) = 0.45 for the emotion by gaze interaction. G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) indicated a necessary sample size of 13 to detect this interaction with 80% power in a two-way repeated measures ANOVA (entered in G*Power as one-way repeated-measures ANOVA on the direct-averted difference in accuracy with the factor emotion). We were mainly interested in an effect of posture on this interaction, but also wanted to be able to account for possible gender differences in the postural feedback effect, given observations of differences in nonverbal dominance behaviour in social interactions (Cashdan, 1998; Dovidio, Heltman, Brown, Ellyson, & Keating, 1988; Dovidio, Keating, Heltman, Ellyson, & Brown, 1988) as well as in the processing of threat (Kret & De Gelder, 2012). Therefore, we needed to at least multiply this sample size by four (total n = 52) to have sufficient power to detect the emotion by gaze interaction in each posture by gender group (Simonsohn, 2015). Yet, this would only provide sufficient power for the highest order interaction (emotion*gaze*posture*gender) in case of a complete suppression of the emotion by gaze interaction in one of the groups. Therefore, we again doubled this sample size, resulting in n=26 per group and n=104 in total.

We recruited a total of 107 healthy, right-handed participants via a mailing list and online student job platforms. They had normal or corrected vision, were not currently under medical treatment and reported no dependency to alcohol or other drugs or any history of neurological or psychiatric disorders. Data of 102 participants (51 women), with a mean age of 22.10 years ± 3.04 SD were included in the analysis, of which 53 (27 women) had been assigned to the expansive and 49 (24 women) to the constrictive posture group. Of the remaining five participants, one had always pressed the same response button, another repeatedly put on headphones and sang during the experiment despite of being told not to and data of three others was lost due to a technical problem. All participants signed written informed consent, were treated according to the declaration of Helsinki and paid for participation.

Stimuli and task

We used a forced-choice emotion discrimination task designed by El Zein et al. (2015 see for details on stimuli creation) programmed in Matlab (MathWorks, Inc., 2014), using Psychophysics Toolbox 3 (Brainard, 1997; Kleiner et al., 2007). Stimuli consisted of 20 identities from the Radboud Faces Database (Langner et al., 2010) chosen for best anger-fear recognition rate in the study by El Zein et al. They varied in gaze direction (direct or averted 45° to the left or right), facial emotion expression (neutral, angry or fearful) and emotion intensity (7 levels of morphs per emotion, from neutral to the full emotional expression). This resulted in 30 conditions per identity: 2 gaze directions * 2 emotions * 7 intensities =28 + 2 gaze directions * 1 neutral face. Faces of two additional identities were used during a training session of the task.

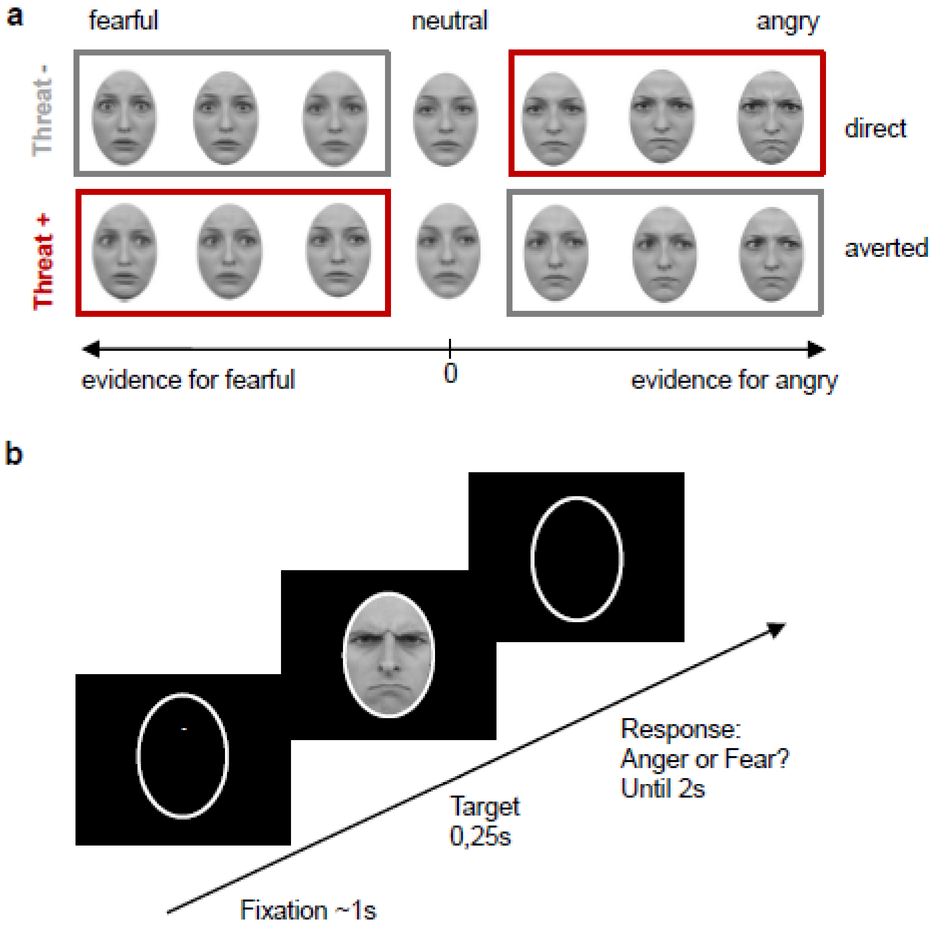

Figure 1. a) Examples of stimuli for one identity: Morphs from neutral to full fear or anger (3 out of 7 morphs depicted), with either direct or averted gaze. Threat + conditions (in red) signal higher threat to the observer than Threat - conditions (in grey). **b)** Timing of stimulus presentation: Following fixation, the stimulus was presented for 250ms. Participants had 2s to respond after stimulus onset.

At the beginning of each trial, a white oval delimitating the face appeared on the black screen for approximately 500ms, followed by a white fixation point at the level of the eyes for approximately 1000ms and finally a stimulus face for 250ms. The white oval stayed on screen throughout the trial. Participants had to press one of two buttons to indicate if the presented emotion was fear or anger within a response window of 2s after stimulus onset (see Figure 1 for an example of stimuli and task design). They were told to respond as quickly as possible. Each stimulus was presented once, resulting in a total of 600 trials divided in 5 blocks. While no feedback was provided after response, percentage of correct responses and average reaction time were presented at the end of each block to keep participants motivated. Gender, gaze direction, emotion and intensity of stimuli was balanced across blocks.

Procedure

To check and possibly control for group differences, participants were asked to complete the French version of the scale assessing the behavioural inhibition and activation systems (Caci, Deschaux & Baylé, 2007), the Liebowitz Social Anxiety Scale (Yao et al., 1999) and the trait version of the State-Trait Anxiety Inventory (STAI, Spielberger, 1983) prior to the testing day. At the start of the testing session, they additionally completed the state version of the STAI. As a cover story for adopting the posture, they were told they were participating in two independent experiments, of which the first investigated body posture effects on heart rate and the second the perception of emotions. This was crucial to ensure that any potential posture effects were really due to bodily feedback, and did not reflect demand or placebo effects induced by reflections about the posture. Participants underwent a short training session, which was repeated if they failed to achieve at least 60% of correct responses. Thereafter, the experimenter explained that they would adopt their assigned posture for 3 min before every block of the emotion discrimination task (5-6 min), attached adhesive electrodes to their hand wrists and demonstratively turned on the heart rate recording system. After mentioning that she would verify via a camera whether they correctly adopted the posture each time since this was crucial for heart rate recording, she verbally provided instructions for the respective posture without demonstrating the posture herself. If necessary, she additionally indicated the correct position for the arms or legs by pointing at the respective location (see Figure 2 for the postures and Supplementary Information for posture instructions).

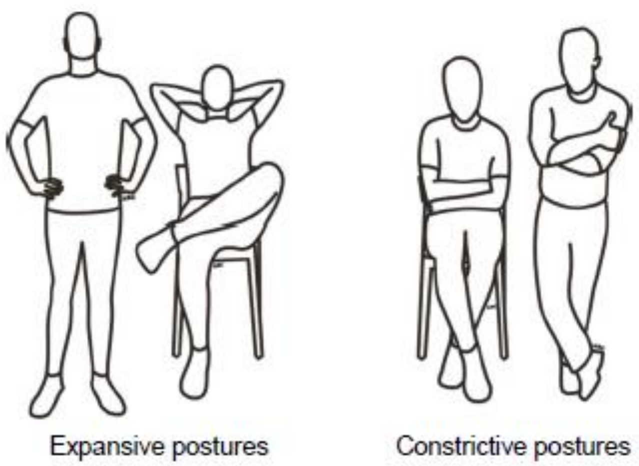

Figure 2. Expansive and constrictive body postures (Images created by Antoine Balouka-Chadwick).

Each participant adopted the same expansive or constrictive posture before each of the five task blocks. Instructions on screen then guided participants through the experiment, and the experimenter did not enter anymore until debriefing unless this was necessary to adjust the posture. At the end of the experiment, she enquired about participants' ideas regarding the objective of the two experiments to verify whether they suspected a link between the two supposedly unrelated studies or recognized the purpose of the posture manipulation. Only one participant suspected that we were interested in an effect of posture on emotion perception, and a second new the TED-talk on power-posing by Amy Cuddy (Cuddy, 2012). Excluding them from analysis did not alter the significance (above or below p=0.05) of any effect. Finally, participants were debriefed about the real purpose of the experiment and paid for participation.

Data analysis

Statistical analysis was performed in R version 3.4.4 (R Core Team, 2018) using the packages dplyr, tidyr, ez, ggplot2 and psych (Lawrence, 2016; Revelle, 2017; Wickham, 2009; Wickham, Francois, Henry, & Müller, 2017; Wickham & Henry, 2018). The distribution of reaction times was right-skewed and further revealed a small peak close to zero. Therefore, we log-transformed reaction times and filtered for trials with reaction times below 200ms (%) to exclude unintentional early button presses. After filtering for neutral trials (in which no correct response was possible) we calculated accuracy scores as the percentage of correct responses. Total accuracy scores across all conditions ranged from 68.65 to 95.90, with a mean of 87.50 ± 6.25 SD and no outliers outside a ± 3SD window around the mean. Only correct trials were used for reaction time analyses. Accuracy scores as well as log-transformed reaction times were subjected to a 2 x 2 x 2 x 2 mixed effects ANOVA with posture (expansive vs. constrictive) and gender as between-subject factors, and emotion (anger vs. fear) and gaze direction (direct vs. averted) as within-subject factors. Emotion intensity was not analysed given that we were already investigating the interaction of up to four factors. As effect-sizes, we provide partial (η_p^2) as well as generalized eta-squared (η_G^2) for mixed-effect ANOVAs to allow for comparison with between-subject designs (Lakens, 2013) and Cohen's d or d_z for independent and dependent t-tests.

Results

The two posture groups did not differ significantly on behavioural activation or inhibition, social anxiety, and trait or state anxiety neither as a whole (all p-values of pose main effects >.383) nor within each gender (all p-values of posture*gender interactions >.346). We thus conducted all further analyses without controlling for any of these trait and state measures.

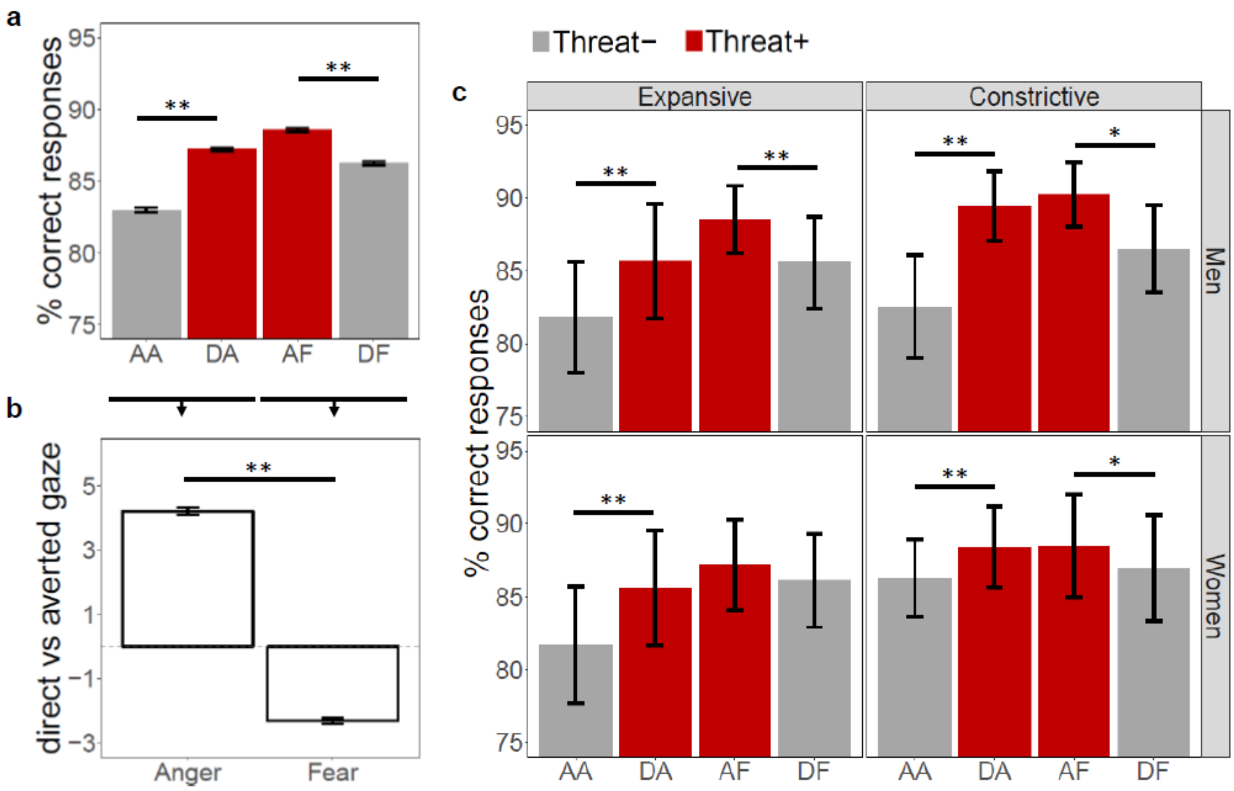

Figure 3. Accuracy in emotion recognition for each emotion by gaze combination: AA = averted anger, DA = direct anger, AF = averted Fear, DF = direct fear. Asterisks indicate significance in within-subject t-tests at ** p<.005 and * p<.05. Error-bars represent within- or between-subject confidence intervals. **a)** Accuracy in the whole sample, error-bars are within-subject. **b)** Difference in accuracy for direct minus averted gaze in the whole sample, error-bars are within-subject. **c)** Accuracy per posture by gender group, error-bars are between-subject to allow for comparison between different groups.

The ANOVA on accuracy revealed better emotion recognition of fear than anger F(1,98)=4.70, p=.033, η_G^2=0.018, η_p^2 =0.046) and for faces presented with direct as opposed to averted gaze (F(1,98)=10.01, p=.002, η_G^2=0.003, η_p^2 =0.093). As predicted, a significant interaction (F(1, 98)= 85.82, p<.001, η_G^2=0.037, η_p^2 =0.467) indicated that anger was better recognized when paired with direct than averted gaze (t(101)=8.26, p<.001, d_z=0.81), whereas fear was more accurately recognized when paired with averted than direct gaze (t(101)=-5.332, p<.001, d_z=-0.53). In short, accuracy was higher for Threat+ than for Threat- combinations. The size of this effect was as large as we had anticipated in our power analysis (η^2_p = 0.45). Most crucially, however, this interaction was not modulated by posture (emotion x gaze x posture: F(1, 98)= 0.77 , p=.382, η_G^2=0.003, η_p^2 =0.008, see Figure 3a and b), nor was there a different effect of posture as a function of gender (emotion x gaze x posture x gender: F(1, 98)= 3.37, p=.070, η_G^2=0.002, η_p^2 =0.033, see Figure 3c).

In contrast to posture, gender did significantly modulate the emotion by gaze interaction (F(1, 98)= 9.67, p=.002, η_G^2=0.004, η_p^2 =0.091). Specifically, the emotion by gaze interaction was stronger in men (F(1,50)=65.97, p<.001, η_G^2=0.069, η_p^2=0.569) than in women (1,50)=21.67, p<.001, η_G^2= 0.015, η_p^2=0.302), despite of being large in both genders. In other words, the difference in accuracy between Threat+ and Threat- combinations was larger in men than in women. Nonetheless, removing gender as a factor in the ANOVA did not change the size or the significance of the posture effect (emotion x gaze x posture: F(1,100)=0.80, p=.373, η_G^2=0.000, η_p^2=0.008). Refer to Table 1 for descriptive statistics, and Table S1 for all other main effects and interactions of the ANOVA including both posture and gender as factors.

Table 1. Descriptive statistics for accuracy for emotion by gaze direction conditions within each posture by gender group. CIs are within-subject CIs to allow for comparisons between emotion-gaze combinations.

Posture	Gender	N	Emotion	Gaze	Mean	SD	95% CI	
Expansive	Men	26	Anger	Direct	85.67	10.20	85.15	88.31
				Averted	81.83	9.93	81.25	84.78
			Fear	Direct	85.55	8.15	84.94	88.66
				Averted	88.52	6.02	88.02	91.05
	Women	27	Anger	Direct	85.62	10.44	85.16	87.98
				Averted	81.70	10.61	81.10	84.78
			Fear	Direct	86.13	8.53	85.63	88.74
				Averted	87.20	8.25	86.67	89.94
Constrictive	Men	25	Anger	Direct	89.43	6.11	89.05	91.35
				Averted	82.52	9.00	81.97	85.30
			Fear	Direct	86.52	7.57	86.05	88.85
				Averted	90.23	5.66	89.79	92.40
	Women	24	Anger	Direct	88.40	6.92	87.99	90.42
				Averted	86.29	6.70	85.73	89.03
			Fear	Direct	86.96	9.02	86.44	89.48
				Averted	88.49	8.76	88.06	90.56

Concerning reaction times, the largest effects were main effects of emotion and gaze, indicating quicker responses for anger than fear (F(1,98)= 25.56, p<.001, η_G^2=0.013 η_p^2 =0.207) and direct than averted gaze (F(1,98)=16.41, p<.001, η_G^2=0.001, η_p^2 =0.143). The interaction of emotion and gaze was significant but much smaller than for accuracy ($F(1,98)= 5.47$, $p=.021$, $\eta_G^{2=}0.000$ $\eta_p^2 =0.053$), and driven merely by significantly quicker responses for direct vs. averted anger ($t(101)=-4-40$, $p<.001$, $d_z=-0.44$) in the absence of a significant gaze effect for fear ($t(101)= -1.11$, $p=0.272$, d_z -0.11). As for accuracy, there was neither a posture nor a posture by gender effect on the emotion by gaze interaction. The interaction was further not modulated by gender (see Table S2 for further details, and Table S3 for descriptive statistics of reaction time).

Discussion

Building on the observation of a postural feedback effect on the salience of threat-related facial expressions when faces were unattended (Chadwick et al., 2018), the current study set out to investigate whether adopting expansive and constrictive postures would similarly impact explicit emotion discrimination. In line with previous research (e.g. Adams & Kleck, 2005; El Zein et al., 2015; Sander et al., 2007), combinations of emotion and gaze direction that signal higher threat to the self, namely direct anger and averted fear (Threat+ combinations), were better recognized than combinations that imply less threat to the self. Additionally, responses were more rapid for direct than averted anger. Yet, this threat-signalling effect on emotion recognition accuracy or reaction time was not modulated by posture. Thus, the change in salience of these combinations after adopting expansive and constrictive postures when faces are unattended (Chadwick et al. 2018) does not seem to translate into explicit recognition abilities. When faces were unattended, expansive postures eliminated the influence of averted fear (a signal of danger in the environment) on performance in a scene discrimination task, whereas constrictive postures erased the influence of direct anger (Chadwick et al. 2018). In contrast, when facial emotion expressions were themselves the focus of attention in the current study, both Threat+ combinations were better recognized than Threat- combinations in both posture groups. Altogether, we directly replicate all findings of El Zein et al. (2015), a study without any posture manipulation.

The design of our study was quite similar to the one of Chadwick et al. (2018): we used identical posture instructions, posture duration, stimulus and response timing, and obtained facial expression stimuli from the same Face Database. Given these similarities, it seems likely that the different focus of attention in the two studies could explain why we did not observe effects of postural feedback on explicit processing of facial threat in contrast to Chadwick et al. (2018). These authors observed such effects during implicit emotion processing (used in the following to indicate that faces were unattended). Since body posture is itself mostly regulated without conscious attention (see e.g. Tiedens, Unzueta, & Young, 2007), and occurs in various animal species (de Waal, 2007; Grant & Mackintosh, 1963; Schenkel, 1967; Stevenson & Rillich, 2012), it may only influence unconscious and automatic perceptual processes. In contrast, its effects may disappear when attention is explicitly focused on the stimulus. In line with such an interpretation, trait dominance, trait anger and social anxiety more strongly correlate with attention to angry faces and gaze aversion from angry faces or bodies when these stimuli are masked as opposed to unmasked (Hortensius et al., 2014; Putman, Hermans, & van Honk, 2004; Terburg et al., 2011). Additionally, masked as opposed to unmasked angry faces elicit stronger physiological responses (van Honk et al. 2000). These associations with trait dispositions and bodily reactions could more strongly emerge during implicit threat-processing due to reduced interference of conscious control mechanisms (Putman, Hermans, Koppeschaar, Schindjel, van Honk 2007). Thus, if postural feedback activates representations of dominance or submission, these may only affect the processing of unattended, but not attended social signals of threat.

In addition to the focus of attention, task difficulty may determine whether postural feedback effects can be detected. Accuracy scores ranged from 80 to 90% (SEM 1%) in the emotion discrimination task as compared to 60 to 70% (SEM 3%) in the scene discrimination task of Chadwick et al. (2018). The fact that posture effects occurred only in the scene task may indicate that only more difficult tasks in which performance varies more strongly may be sensitive enough to detect subtle effects of posture. The absence of posture effects on the easier gender discrimination task also used by Chadwick et al. (2018) further corroborates this interpretation. Yet, given that discriminating gender required focusing on the facial expression, this finding is also compatible with interpretations that attribute a crucial role to the focus of attention. In other words, task difficulty could, but does not necessarily, fully explain why posture effects occurred only when faces were unattended.

Although focus of attention and task difficulty may seem to provide explanations for why we did not observe postural feedback effects in contrast to Chadwick et al. (2018), it is important to also consider statistical power as an alternative explanation. This is especially true in the context of the current controversy around the replicability of postural feedback effects (see Cesario et al., 2017). Statistical power is fundamental particularly when interpreting the absence of an effect as a consequence of an experimental manipulation. The postural feedback effect on implicit emotion processing did indeed arise from the absence of a gaze effect for either anger or fear, respectively, in the two posture groups (Chadwick et al., 2018). However, without a posture manipulation, the explicit task we used yields a much stronger emotion by gaze effect on performance (η^2_p=0.45) (El Zein et al., 2015) than the implicit task used by Chadwick et al. (η^2_p=0.12) (Study 1; 2018). Therefore, even assuming equal sample sizes, the explicit task provides higher statistical power and thus better chances to detect small posture effects. In fact, the explicit and implicit task were tested on 102 and 44 participants, respectively, resulting in even higher power for the explicit relative to the implicit study. If calculating power exactly as we did, the implicit study would have required 61*4=224 participants to achieve the same statistical power (assuming similarly large effects of posture on implicit and explicit processing). The striking difference between the tested (n=44) and the necessary sample size (n=224) arises from the fact that Chadwick et al. (2018) planned to assess posture effects within-subject across two consecutive sessions. Eventually, they observed posture effects only in the first and not the second session, which resulted in between-subject assessment of the posture effect. Hence, if we consider evidence for a posture effect on the processing of threat-related expressions as a whole, regardless of the focus of attention, what is current state of evidence for such an effect? As the current study achieved a much higher statistical power and the previous study found a posture effect only in one of two sessions, there is currently more evidence against than for such an effect.

In conclusion, we did not observe a posture effect on the explicit recognition of angry and fearful facial expressions with direct or averted gaze, although a previous study observed posture effects on the salience of these threat-related expressions when faces were unattended (Chadwick et al. 2018). Previous research provides explanations for why posture effects may only occur under certain conditions, namely when faces are unattended or when tasks are difficult. Yet, it is also possible that a lack of power the study by Chadwick et al. (2018) did not allow to detect the effects that would have been expected in the absence of postural feedback. To provide a more informed answer to the question as to whether posture effects on the processing of threat signals occur only under certain conditions or resulted only from a lack of statistical power, future studies should replicate the study by Chadwick et al. (2018).

Supplementary Information

Supplementary methods

Posture instructions

Instructions for the expansive postures were: (1) Sit down on this chair, advance a bit and lean back to make yourself comfortable, now put one leg on the knee of the other, put your hands behind your neck, look upwards and let your head rest in your hands. It would be good if your arms were approximately parallel, but you really need to be comfortable to be able to keep the posture for 3 min." and (2) "Spread your feet at the width of your shoulders and turn your feet outwards. Place your hands on your hips with the thumb backwards and keep your elbows approximately parallel. Look straight ahead and don't tilt your head downwards. The posture needs to be comfortable." Instructions for the constrictive postures were: (1) "Sit down on this chair and put your legs next to each other, one close to the other, put one hand next to your neck and the other on your knee, relax your shoulders and look at the floor in front of you." (2) "Cross your legs and put one foot next to the other. Now, lay one arm across your belly and place the other one on top, but do not cross your arms. Look at the floor in front of you and relax your back and shoulders."

Supplementary results

Table S1. Full results of mixed-effects ANOVA on accuracy. Significant p-values are highlighted in bold.

Effect	df n	df d	F	p	η^2_G	η^2_p
Gender	1	98	0.00	0.958	0.000	0.000
Posture	1	98	2.91	0.091	0.016	0.029
Emotion	1	98	4.70	0.033	0.018	0.046
Gaze	1	98	10.01	0.002	0.003	0.093
Gender x Posture	1	98	0.06	0.809	0.000	0.001
Gender x Emotion	1	98	0.30	0.583	0.001	0.003
Posture x Emotion	1	98	0.71	0.401	0.003	0.007
Gender x Gaze	1	98	0.07	0.794	0.000	0.001
Posture x Gaze	1	98	0.00	0.983	0.000	0.000
Emotion x Gaze	1	98	85.82	0.000	0.037	0.467
Gender x Posture x Emotion	1	98	0.17	0.678	0.001	0.002
Gender x Posture x Gaze	1	98	3.75	0.056	0.001	0.037
Gender x Emotion x Gaze	1	98	9.76	0.002	0.004	0.091

Posture x Emotion x Gaze	1	98	0.77	0.382	0.000	0.008
Gender x Posture x Emotion x Gaze	1	98	3.37	0.070	0.002	0.033

Table S2. Full results of mixed-effects ANOVA on reaction time. Significant p-values are highlighted in bold.

Effect	**df n**	**df d**	**F**	**p**	η^2_G	η^2_p
Gender	1	98	2.28	0.134	0.021	0.023
Posture	1	98	0.45	0.504	0.004	0.005
Emotion	1	98	25.56	0.000	0.013	0.207
Gaze	1	98	16.41	0.000	0.001	0.143
Gender x Posture	1	98	5.13	0.026	0.047	0.05
Gender x Emotion	1	98	0.04	0.844	0.000	0.000
Posture x Emotion	1	98	0.08	0.775	0.000	0.001
Gender x Gaze	1	98	0.01	0.923	0.000	0.000
Posture x Gaze	1	98	0.32	0.575	0.000	0.003
Emotion x Gaze	1	98	5.22	0.024	0.000	0.051
Gender x Posture x Emotion	1	98	0.01	0.941	0.000	0.000
Gender x Posture x Gaze	1	98	0.01	0.909	0.000	0.000
Gender x Emotion x Gaze	1	98	2.13	0.147	0.000	0.021
Posture x Emotion x Gaze	1	98	0.01	0.913	0.000	0.000
Gender x Posture x Emotion x Gaze	1	98	0.13	0.723	0.000	0.001

Table S3. Descriptive statistics for reaction times in ms for emotion by gaze direction conditions within each posture by gender group. CIs are within-subject CIs to allow for comparisons between emotion-gaze combinations.

Posture	**Gender**	**N**	**Emotion**	**Gaze**	**Mean**	**SD**	**95% CI**	
Expansive	Men	26	Anger	Direct	792	127	789	809
				Averted	816	141	812	833
			Fear	Direct	836	148	833	856
				Averted	836	144	833	853
	Women	27	Anger	Direct	692	114	689	705
				Averted	705	120	702	721
			Fear	Direct	729	129	727	742
				Averted	740	130	736	756
Constrictive	Men	25	Anger	Direct	752	142	749	772
				Averted	771	164	767	790
			Fear	Direct	791	163	787	810
				Averted	791	161	788	807
	Women	24	Anger	Direct	776	148	773	789
				Averted	787	166	783	806
			Fear	Direct	810	145	806	828
				Averted	815	150	812	831

Chapter 5
Assessing physiological mechanisms: Repeatedly adopting power postures does not affect hormonal correlates of dominance and affiliative behaviour

At the beginning of this thesis project, only one study on the impact of power postures on testosterone and cortisol levels (Carney et al., 2010) had been published. While cortisol is part of the body's reaction to stress, testosterone is associated to behaviours with implications for social status (Mehta & Josephs, 2011). The study seemed to suggest that adopting constrictive postures elicits a corticoid stress response and a decrease of testosterone levels, while expansive postures would boost testosterone levels together with the experience of power and control, and dampen activity of the stress system. It seemed to make sense that constrictive postures activate the stress response, given that animals adopt such postures to signal submission for example to prevent a looming attack and that humans interpret them as signals of low self-esteem and power. Likewise, it appeared consistent that expansive postures, which signal high status and dominance, increase testosterone.

Additionally, posture effects on these hormone levels seemed to offer a straightforward explanation for their effects on the salience of implicitly processed threat-related expressions (Chadwick et al., 2018). These effects looked like they were mediated by a posture effect on hormone levels, since they remarkably resembled effects of testosterone and cortisol administration or baseline levels on social threat processing (for a review, see Montoya et al., 2012). Akin to high testosterone baseline levels or testosterone administration, expansive postures seemed to increase salience and decrease avoidance of angry facial expressions, particularly if paired with direct gaze. In contrast, individuals who had adopted a constrictive posture seemed to avoid angry expressions with direct gaze and become more vigilant towards fear as a signal of threat in the environment, similarly to effects observed in anxious individuals or individuals with high baseline levels of cortisol.

On the one hand, manipulations of postural expansiveness and constrictiveness thus seemed like a unique opportunity to test the effect of endogenous variations of testosterone and cortisol levels on emotion processing, especially because they simultaneously induced changes in both hormones. Coinciding changes of testosterone and cortisol are particularly relevant as the interaction between the two hormones is crucial for the display of dominance behaviour (Mehta & Josephs, 2010; Terburg, Morgan, & van Honk, 2009). On the other hand, it seemed striking that two minutes of holding a posture would have such large effects on hormone levels, in comparison to the smaller effects in response to much more intense and longer competition or stress induction procedures (Dickerson & Kemeny, 2004; Geniole et al., 2017). In addition, Carney et al.'s study (2010) had several methodological shortcomings. First, its sample was small, particularly with regard to the endocrine measures, which vary considerably between and even within subject (Stanton, 2011). Second, the study did not consider menstrual cycle and oral contraceptive use and instead simply controlled for gender statistically, which is invalid given the inherent biological sex differences concerning the production of testosterone (Stanton, 2011). Before systematically exploring postural feedback effects on the processing of facial threat, it thus seemed necessary to verify whether they actually affected endocrine levels. This would either allow to discard hormones as an explanation for posture effects on the salience of threat-related expressions, or give us an idea about the duration of hormonal effects and thereby provide a temporal framework for the design of future studies. [5]

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[5] This is a draft manuscript to be submitted for publication as: Hannah Metzler & Julie Grèzes. Repeatedly adopting power postures does not affect hormonal correlates of dominance and affiliative behavior.

Abstract

Adopting expansive versus constrictive postures related to high versus low levels of social power has been suggested to induce changes in testosterone and cortisol levels, and thereby to mimic hormonal correlates of dominance behaviour. However, these findings have been challenged by several non-replications recently. Although there is thus more evidence against than for such posture effects on hormones, the question remains as to whether repeatedly holding postures over time and/or assessing hormonal responses at different time points would yield different outcomes. The current study assesses these methodological characteristics as possible reasons for previous null-findings. By testing effects of repeated but short posture manipulations in a social context while using a cover-story, it further fulfills the conditions previously raised as potentially necessary for the effects to occur. 82 male participants repeatedly adopted an expansive or constrictive posture for 2 minutes in between blocks of a task that consisted in categorizing faces based on first impressions. Saliva samples were taken at two different time points in a time window in which hormonal responses to stress, competition and other manipulations are known to be strongest. Neither testosterone and cortisol levels linked to dominance behaviours, nor progesterone levels related to affiliative tendencies, changed from before to after adopting expansive or constrictive postures. The present results establish that even repeated power posing in a context where social stimuli are task-relevant does not elicit changes in hormone levels.

Keywords: body posture, power, testosterone, cortisol, progesterone, dominance, affiliation

Introduction

Individuals' position in a social hierarchy greatly determines their response to stressful situations as well as their opportunities for social contact and relationships (de Waal, 1986; Sapolsky, 2005). Because individuals' social power changes over time and across different contexts, the physiological mechanisms underlying power-related behaviour need to allow flexible adaptation to new situations. Steroid hormone levels, including cortisol, testosterone and progesterone are key players in the implementation of this behavioural flexibility: not only do their baseline levels influence individuals' tendencies for certain behaviours, but their levels also change in situations that involve stress, opportunities for gaining social status or affiliating with others, or threats to social status and affiliative needs (Mehta & Josephs, 2011; Schultheiss, 2013). Although there are complex interactions between these three steroid hormones and the behaviours they modulate (Mehta & Josephs, 2011), cortisol is predominantly involved in the regulation of stress responses (Sapolsky, 1990), testosterone mediates behaviours that serve to achieve or maintain social status (Archer, 2006; Mehta & Josephs, 2011; Eisenegger, Haushofer & Fehr, 2011), and progesterone contributes to the regulation of affiliative behaviour (Schultheiss, Wirth & Stanton, 2004; Wirth, 2011).

Positions of high and low power are associated with distinct endocrine profiles: while high-ranking individuals have higher baseline testosterone levels and lower cortisol levels, the reverse is observed in low-ranking individuals (Sapolsky, 1990; Virgin & Sapolsky, 1997; Mehta & Josephs, 2010). Building on theories of embodiment, which postulate that many aspects of cognition are shaped by representations of body actions, Carney, Cuddy and Yap (2010) assessed whether exhibiting non-verbal dominant or submissive behaviour, namely expanding or constricting one's body, would induce corresponding changes in testosterone and cortisol levels. They did indeed observe an increase of testosterone and a decrease of cortisol in individuals who had adopted an expansive posture and the reverse changes in individuals who had adopted a constrictive posture. Although these findings seemed consistent with the hormonal correlates of status and power, four subsequent studies could not replicate them despite of large sample sizes that ensured high statistical power in three of the replications (Ranehill et al., 2015; Ronay et al., 2016; Smith & Apicella, 2017; Davis et al., 2017).

In response to the first non-replication, Carney, Cuddy and Yap (2015) pointed out several methodological differences that could possibly account for the contradicting results. For example, Ranehill et al. (2015) had not used a cover story or a social filler task (later referred to as “social context” in power-posing studies) while participants held the posture. Furthermore, they had provided instructions via computer instead of having an experimenter explain the postures, and chose a longer duration for the posture manipulation. The three following replication studies addressed some of these concerns and even improved the original study’s setting, for instance by testing effects in social contexts with implications for power, status and dominance, such as competition or public speaking (Smith & Apicella, 2017; Davis et al., 2017). Eventually, the direct replication of Ronay and colleagues (2016) addressed all these points and still observed no effect on hormone levels.

While expansive and constrictive postures’ effects on hormones were not replicated, their effect on feelings of power and control, also originally reported by Carney et al. (2010), has been confirmed by a meta-analysis of several pre-registered, highly powered studies (Gronau et al., 2017). A p-curve analysis further suggests that the existing literature contains evidence for such an effect on feelings of power (Cuddy, Schultz & Fosse, 2018), although this analysis remains unspecific about the direction of the effect (see Credé, 2018). Regardless of the null-findings for hormones, this evidence for posture effects on feelings of power and other emotional and affective self-report measures have led Cuddy et al. (2018) to call for more studies on psychophysiological outcomes. Specifically, they suggest that future experiments should apply more precise hormone methods or assess incremental effects of adopting a posture several times. Davis et al. (2017) have also raised the question of whether null-effects for hormones could be related to the timing and dose of the posture manipulation. They speculated that larger doses of posture or collection of samples at different time points after the posture could yield different outcomes. Indeed, adopting expansive postures for about 15 minutes throughout a stressful experience boosted the cortisol response to stress (Turan, 2015). This suggests that expansive postures are maladaptive in certain contexts, but also illustrates that adopting postures for longer durations may induce hormonal changes. Altogether, it appears that additional empirical evidence is necessary to reach final conclusions about whether expansive and constrictive postures do or do not induce changes in hormone levels at different time points than assessed previously or when adopted for longer durations.

In 2015, before the publication of the first non-replication of the power posing effect on hormone levels, we collected data which we believe can contribute to the ongoing discussion about whether expansive and constrictive postures induce changes in hormone levels. The design of our study meets most of the criteria Carney et al. (2015) listed as potentially necessary conditions to observe postural feedback effects. First, postural effects on hormones were measured in a social context: saliva samples were collected as part of another study (Metzler et al., unpublished data - see Chapter 6) during which participants had to categorize faces according to their first impression while repeatedly adopting postures between task blocks. This task resembles the social filler task in the original study (Carney et al., 2010), in which subjects also formed impressions by looking at people's faces. Second, this setting provided a credible cover story, i.e. that the saliva samples were collected to assess associations between face categorization and physiological indices. None of the participants associated the collection of saliva samples to the posture manipulation. Third, we did not use computerized instructions, but instead kept the experimenter blind to participant's posture condition for as long as possible during the instructions in order to minimize experimenter biases. Fourth, participants adopted the expansive or constrictive posture for maximum two minutes at a time, which avoids discomfort that might lessen the posture's effect.

Moreover, our study is the first to provide an answer to questions regarding the "dose" of posture and the timing of hormone measurement recently raised by Cuddy et al. (2018) and Davis et al. (2017). It investigated the incremental effects of repeatedly adopting the same posture, by having participants adopt their assigned posture three times, with 10-12 minutes in between during which they performed the face categorization task. Participants were further encouraged to adopt an open or closed sitting position, similar to their assigned posture, while performing the task. Together, the repeated 2 minute periods in which participants adapted one of two postures chosen from Carney et al. (2010), together with the encouragement of a similar, but freely adaptable sitting position during the face categorization task, add up to a "larger dose" of posture while avoiding discomfort. Finally, we measured hormone levels at longer time intervals than previous studies, collecting two post-posture saliva samples at approximately 23 and 36 minutes after the beginning of the first posture.

Finally, we evaluated the possible effect of postures on affiliation motivation as evident in progesterone levels. Indeed, the existing and above-mentioned literature on postural feedback effects has so far focused on power-related behaviour and hormones. Yet, there is considerable evidence that power also impacts on individuals affiliative tendencies (Magee & Smith, 2013; Guinote, 2017). For instance, lack of power enhances motivation to connect with others (Lammers et al., 2012; Case, Conlon & Maner, 2015) and cues of low social status have positive effects on pro-social behaviour (Guinote et al., 2015). Moreover, facing threats and stressful situations can enhance affiliative motivation and behaviour (Schachter, 1959; Gump & Kulik, 1997; Dezecache, Grèzes & Dahl, 2017), as bonding with others represents an efficient coping strategy (Taylor, 2006; Dezecache, 2015). The display of constrictive and submissive postures generally occurs in threatening situations and serves to appease aggressive conspecifics by signaling friendly intentions (Schenkel, 1967; de Waal, 1986). Adopting constrictive postures may thus be linked with affiliative tendencies. Progesterone is known to be released together with cortisol in response to stress in general, but particularly social stress (Wirth, 2011). It correlates with both naturally fluctuating (Schultheiss, Dargel & Rohde, 2003) and experimentally induced affiliative motivation (Schultheiss, Wirth & Stanton, 2004; Wirth & Schultheiss, 2006) and may promote social bonding as a coping behaviour in response to stress (Wirth, 2011). A change in salivary progesterone after adopting constrictive postures would therefore indicate an increase of affiliation motivation. In summary, the current study investigated changes in salivary testosterone, cortisol and progesterone levels in response to a repeated posture manipulation in a social context.

Methods

Participants

Carney et al. (2010) reported effect-sizes of r=.34 for testosterone and r=.43 cortisol. We performed a power-analysis in G-Power (Faul et al., 2007) based on the smaller one of these two effect-sizes, i.e. r=.34. This yielded a minimal necessary sample of n=63 to achieve 80% power to detect effects as large as those of Carney et al. (2010). These were the only available effect sizes for posture effects on hormone levels when we conducted our study. Given inherent biological differences in testosterone and progesterone production between men and women, analyses of these hormones need to be done separately for each sex (Stanton, 2011). Therefore, we included only male participants to achieve sufficient power with the maximum sample size possible under our feasibility constraints.

We recruited a total of 82 male participants via a participant pool mailing list and student job advertisement websites. Participants were between 17 and 32 years old, reported not to be regular smokers or under medical treatment, and to not have a history of endocrine illness, neurological and psychiatric disorders, or dependency to alcohol or other drugs. All participants provided written informed consent and were paid for their participation. The experimental protocol was approved by INSERM and licensed by the local research ethics committee (Comité de protection des personnes Ile de France III - Project CO7-28, N° Eudract: 207-A01125-48) and carried out in accordance with the Declaration of Helsinki.

Measures

Questionnaires. For assessing potential differences between posture groups, we administered the French version of the State-Trait Anxiety Inventory (STAI, Spielberger, 1983), the BIS/BAS Scales (Caci, Deschaux & Baylé, 2007) and the Rosenberg Self-Esteem Scale (Vallières et Vallerand, 1990). Participants completed the trait measures prior to the testing session in the lab, but filled out the state version of the STAI after arrival at the laboratory. In addition, questions regarding compliance with behavioural restrictions before saliva collection and the dominance scale from the International Personality Item Pool (Goldberg et al. 2006, scale representing the California Psychological Inventory: http://ipip.ori.org/newCPIKey.htm#Dominance) were administered at the end of the experiment to avoid raising suspicion about the real purpose of the posture manipulation.

Saliva collection. We collected three saliva samples (1ml each) per participant using small tubes and stored them below -20°C immediately after collection. After completion of the study (duration: 51 days), they were packed in dry ice and shipped to the laboratory of Clemens Kirschbaum in Dresden, where they were analyzed with commercially available chemiluminescence immunoassays with high sensitivity (IBL International, Hamburg, Germany). For a more detailed description of the assay methods used by this laboratory, see for example Ronay et al. (2016). To exclude the possible influence of external factors on hormone levels, participants were requested to refrain from drinking alcohol and exercising intensively within 24 hours before the session, from smoking or taking medical drugs on the testing day, and from eating, drinking anything except water, and tooth brushing 1.5 hours before the session. The debriefing questionnaire after the experiment showed that they largely complied with these instructions (5 exceptions for alcohol, 2 for smoking).

Procedure

All testing sessions took place between 13h and 19h to attenuate effects of diurnal variation of hormone levels. Upon arrival, participants signed consent forms and completed the STAI state questionnaire. Participants were part of a larger sample taking part in a study on mental representations of in- and outgroup faces (Metzler et al., unpublished data - see Chapter 6). We used a well-established “number estimation style” procedure to induce minimal group membership, assigning participants to either the group of over- or under-estimators. Next, participant’s task was to guess, based on their first impression, which of two presented faces was an over- or under-estimator (Ratner et al., 2014). The cover story for collecting saliva samples consisted in telling participants that we were interested in the physiological makers associated with the tendency to over- or underestimate numbers. The cover story for the postures was that a second, unrelated project on the impact of body posture on heart rate was conducted simultaneously. At this point of the instructions, approximately 15 min after arrival, participants provided a first saliva sample.

Thereafter, the female experimenter determined the posture condition using a randomizing function and provided corresponding instructions for either the expansive (n=42) or the constrictive (n=40) posture. Participants would adopt this posture three times for 2 min each time in between the blocks of the face categorization task. This supposedly served to acquire heart-rate data for a total of 6 min while avoiding discomfort from holding the same posture for too long, and offered breaks during the visually demanding task (see Dotsch & Todorov, 2012 for an example of the noisy stimuli used for reverse correlation of mental representations). The experimenter placed electrodes on participant’s wrists and hooked them up to the acquisition system, which she demonstratively turned on afterwards. She verbally provided instructions on how to place each body part without demonstrating the posture herself. The expansive and constrictive posture involved open or closed limbs, erect or slumped upper body and straight or downward head tilt, respectively. The experimenter informed participants that she would check whether they correctly adopted the standing posture each time via a camera. Depending on the participant’s posture condition, she finally instructed participants to (1) sit upright with feet apart or (2) keep back and shoulders slumped and legs parallel or crossed during the task as far as comfortable for them, which supposedly served to “stabilize” the effect of postures on heart rate. This short instruction was repeated on screen at the beginning of each task block. Although allowing participants to freely adjust their posture for their own comfort during the task constitutes a less controlled posture manipulation, it ensures higher ecological validity, as it corresponds to what we typically do in everyday life. Participants were alone while they adopted the postures and performed the task. The experimenter only briefly re-entered the room for the collection of two more saliva samples.

In total, participants thus adopted the standing posture three times, i.e., before task block 1, 3 and 5. Saliva samples were collected before the first posture and block and after block 4 and 6. Participants had thus adopted the posture twice before sample 2, and three times before sample 3. Median block duration was 4.58 minutes (interquartile range [3.46-6.25]) depending on participants' speed in the face categorization task. This resulted in collection of saliva samples 2 and 3 approximately 23 and 36 minutes after the first posture, respectively, although the exact timing varied between participants (min. 14 minutes, max. 50). This corresponds to collection of samples 2 and 3 approximately 11 and 24 minutes after the second posture, respectively, and collection of sample 3 approximately 10 minutes after the third posture. Figure 1A and B depict the timing of postures and saliva samples, and Figure 1C depicts the posture adopted in each of the two experimental groups.

At the end of the experiment, participants were carefully debriefed regarding suspicions about the postures. None of them had suspected a link between the posture manipulation and the saliva samples and only one participant raised doubts about our interest in a posture effect on heart-rate. Excluding him from analyses did not affect the results.

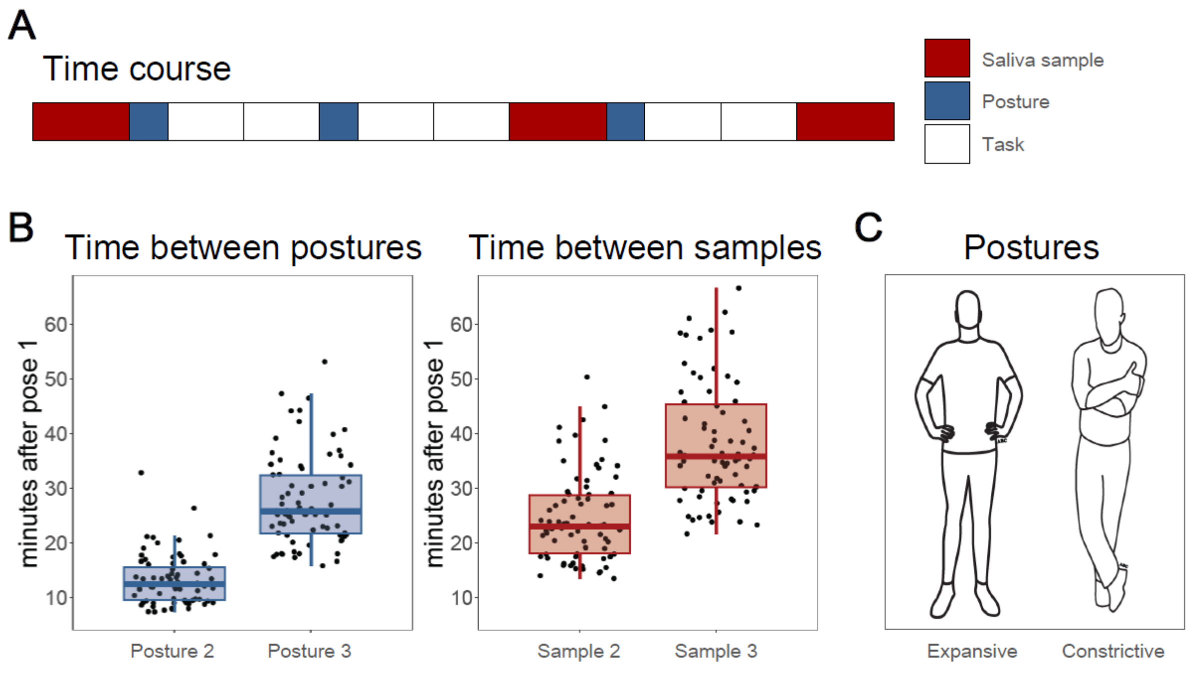

Figure 1. Time course of the experiment and adopted body postures. **A)** Time course of posture, saliva sample and task blocks. **B)** Time intervals between postures and saliva samples from the beginning of posture 1 on. **C)** Postures adopted by each of the experimental groups (Images created by Antoine Balouka-Chadwick).

Data analysis

Outliers were determined per time point using a conservative threshold of three times the absolute deviation from the median (Leys et al., 2013), given that mean ± SD rules are problematic for endocrine data which are rarely normally distributed (Pollet & Meij, 2017). First, we excluded one participant from all time points and hormones due to extreme progesterone values (around 1500pg/ml, (outside of normal range even for women, see Liening et al., 2010), clearly indicating a problem with his salivary samples. Within the remaining sample of 81 participants (age 21.36 ± 2.78, expansive n=41, constrictive n=40), there were six outliers above the median plus three absolute deviations for cortisol, seven for testosterone and nine for progesterone. Results calculated without outliers did not differ from results with the full sample (see Supplementary Table S1), i.e., the same effects yielded significant or non-significant p-values with and without outlier exclusion. All hormone levels were log-transformed to correct for right-skewed distributions and subjected to a mixed-effects ANOVA with posture (expansive, constrictive) as a between-subject and time (T1, T2, T3) as a within-subject factor. In addition to partial eta-squared, we report generalized eta-squared as an effect-size to allow for comparison with between-subject designs (Lakens, 2013). All analysis were done in R (R Core Team, 2018) using the packages ez, psych, latticeExtra, ggplot2 and dplyr (Wickham, 2009; Lawrence, 2016; Sarkar & Andrews, 2016; Revelle, 2017; Wickham et al., 2017). Data and analysis scripts are available at https://osf.io/3nrsy/.

Results

Descriptive statistics for raw levels of cortisol, testosterone and progesterone are presented in Table 1, and results are depicted in Figure 2.

Cortisol

Cortisol levels similarly decreased over time ($F(2,148)=79.40$, $p<.001$, $\eta^2_p = 0.51$, $\eta^2_G = 0.16$) in both posture groups (time*posture: $F(2,148)=1.17$, $p=.313$, $\eta^2_p = 0.00$, $\eta^2_G = 0.00$), in the absence of any overall difference between the groups ($F(1,74)=0.32$, $p=.576$, $\eta^2_p = 0.00$, $\eta^2_G = 0.00$). Both the decrease from T1 to T2, i.e. from before the first posture to after adopting the posture twice, and the decrease from T2 to T3, i.e. from after the first two postures to after the third posture, were significant (T1-T2: $t(75)=-10.67$, $p<.001$, $d_z=-1.22$), T2-T3: $t(75)=-3.78$, p<.001, d_z=-.43). Cortisol baseline levels at T1 did not significantly differ between postures t(74)=0.95, p = 0.346).

Testosterone

Levels of testosterone also decreased throughout the experiment (F(2,146)=19.76, p<.001, η^2_p = 0.21, η^2_G= 0.03) with no different changes as a function of posture (time*posture: F(2,146)= 1.09, p=.340, η^2_p = 0.01, η^2_G= 0.00), and no main effect of posture (F(1,73)=0.13, p=.721, η^2_p = 0.00, η^2_G= 0.00). The decrease over time was significant from the first to the second (t(74)=-3.53, p=.001, d_z=-.41), as well as the second to the third time point (t(74)=-3.19, p=.002, d_z=-.37). Testosterone baseline levels did not differ significantly between the groups (t(73)=0.83, p=0.411).

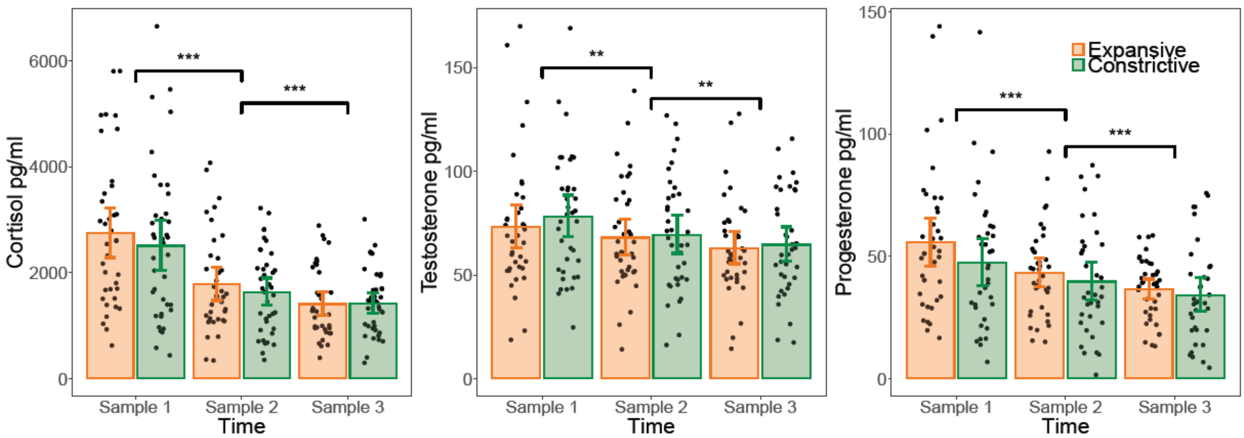

Figure 2. Changes in hormone levels from before to after the posture manipulation. Means, between-subject confidence intervals and individual data points for cortisol, testosterone and progesterone samples in pg/ml. Sample 1 was collected before the first posture. Sample 2 and 3 reflect the effect of adopting the same posture twice and three times, respectively. Asterisks indicate significance in t-tests between time points at *** = p<.001 and ** p<.01.

Progesterone

As the two other hormones, progesterone levels declined over time (F(2,142)=33.07, p<.001, η^2_p = 0.32, η^2_G= 0.06) in the same manner in both posture groups (time*posture: F(2,142)=0.04, p=.965, η^2_p = 0.00, η^2_G= 0.00). There was no general difference between the two postures (F(1,71)=2.52, p=.117, η^2_p = 0.00, η^2_G= 0.03). Declines between both pairs of time points were significant (T1-T2: t(72)=-4.63, p<.001, d_z=-.54; T2-T3: t(72)=-3.92, p<.001, d_z=-.46). Progesterone baseline levels were not significantly different between the two postures (t(71)= 1.52, p = 0.132).

Self-report questionnaires

Participants from the two posture groups did not rate themselves as significantly different on self-esteem (t(77)= -0.73, p=.469, d=-0.08), trait anxiety (t(77)=0.02, p=.99, d=0.00), behavioural activation (t(77)=-0.15, p=.88, d=-0.02) and inhibition (t(77)=0.58, p=.562, d=0.07) prior to the testing day, nor on state anxiety at the beginning (t(79)=0.40, p=.689, d=0.045) or trait dominance at the end of the experiment (t(79)=-0.90, p=.372, d=-0.10).

Table 1. Descriptive statistics for cortisol, testosterone and progesterone in samples without outliers. Confidence intervals are between-subject to allow for between-posture comparisons.

	Posture	N	Time	Mean	Median	SD	95% CI	
Cortisol	Expansive	37	1	2755,88	2599,13	1416,89	2299,33	3212,44
			2	1788,89	1555,13	930,94	1488,92	2088,86
			3	1421,20	1268,75	665,40	1206,79	1635,60
	Constrictive	39	1	2518,72	2562,88	1453,86	2062,43	2975,02
			2	1647,33	1638,50	775,28	1404,01	1890,65
			3	1428,06	1439,13	608,28	1237,16	1618,97
Testosterone	Expansive	38	1	73,52	69,05	31,96	63,35	83,68
			2	68,37	60,95	25,90	60,13	76,60
			3	63,23	59,60	23,32	55,81	70,64
	Constrictive	37	1	78,51	79,30	30,14	68,79	88,22
			2	69,64	67,90	27,59	60,74	78,53
			3	64,92	62,30	24,97	56,87	72,96
Progesterone	Expansive	38	1	55,93	51,20	29,89	46,42	65,43
			2	43,43	43,35	17,76	37,79	49,08
			3	36,69	38,95	12,59	32,69	40,70
	Constrictive	35	1	47,70	45,30	27,87	38,47	56,94
			2	39,97	34,30	22,63	32,47	47,46
			3	34,49	31,20	20,05	27,84	41,13

Discussion

The present experiment investigated whether adopting expansive and constrictive postures, associated with high and low social power, respectively, impacts on salivary levels of hormones related to power, stress and affiliation. Although there is currently more evidence against than for a posture effect on hormones, several factors have been raised as explanations for why initial findings of Carney et al. (2010) did not replicate. Our design met most of the conditions which Carney et al. (2015) suspected to be necessary for observing postural feedback effects: first, we assessed postural effects on hormones in a social context during a face categorization experiment, second, we used a cover story, third, the instructions were given by an experimenter, and fourth, participants adopted postures for maximum two minutes at a time. Moreover, following up on hypotheses raised by Cuddy et al. (2018) and Davis et al. (2017), we investigated the possibility that repeatedly holding postures over time (i.e. larger doses of posture) and/or assessing hormonal responses at longer time intervals than previous studies would induce hormonal changes.

Under these specific experimental conditions, neither testosterone and cortisol levels linked to dominance behaviours and stress reactions, nor progesterone levels related to affiliative tendencies, changed from before to after adopting expansive or constrictive postures. Salivary levels of testosterone, cortisol and progesterone declined from baseline to two later post-posture samples, and did so similarly in the expansive and constrictive posture group. The first post-posture sample captured the potential incremental effect of adopting a posture twice, at approximately 23 and 11 minutes before sample collection. The second post-posture sample reflected the effect of adopting the same posture three times, at approximately 36, 24, and 10 minutes before sample collection.

Akin to four previous studies using a single posture manipulation (Ranehill et al., 2015; Ronay et al., 2016; Smith & Apicella, 2017; Davis et al., 2017), we did not replicate the effects reported by Carney et al. (2010), and thereby add to the evidence against an effect of postures on testosterone and cortisol levels. Our results demonstrate that even repeated adoption of expansive and constrictive postures while providing a cover story and a social context, each time for a short period of time to avoid discomfort, does not trigger hormonal changes. Thus, all the experimental characteristics listed by Carney et al. (2015) as possible reasons for null-results in Ranehill et al.'s replication (2015) were respected in the present study. An insufficient dose of posture as well as the collection of hormone samples at inappropriate time points after the posture manipulation (see Davis et al., 2017) therefore seem unlikely explanations for previous non-replications. The time points at which we collected saliva samples after onset of the first posture fell into the time window (20 to 40 minutes) in which experimentally induced cortisol responses are strongest (Dickerson & Kemeny, 2004). Testosterone and progesterone responses to arousal of power and affiliation motives have been observed in a similar time window (e.g. Schultheiss, Wirth & Stanton, 2004; Seidel et al., 2013). Still, our study shows together with previous non-replications that power postures do not elicit physiological changes associated with the experience of power and stress or the need for affiliation (Mehta & Josephs, 2011; Wirth, 2011; Schultheiss, 2013).

Three methodological differences with previous studies merit a more detailed discussion: First, we collected three samples in total in contrast to two in all previous studies, both with a longer delay after the onset of the first posture manipulation. This procedure revealed a decline from the first to the last time point for all three hormones. This decline may either simply reflect the diurnal pattern of these hormones (Faiman & Winter, 1971; Delfs et al., 1994; Brambilla et al., 2009; Liening et al., 2010), and/or a reduction in arousal from the start to the end of the experiment as far as cortisol is concerned. Second, we examined an exclusively male sample, whereas previous studies included mostly women (with the exception of Smith & Apicella, 2016). If anything, this reduced variation of our dependent variables and should hence have facilitated the detection of posture effects. Moreover, in the initial study (Carney, Cuddy & Yap, 2010) and one of its replications (Ranehill et al., 2015), effects on testosterone and feelings of power were stronger in men than in women (see Credé & Phillips, 2017). Nevertheless, we did not observe any effect in an exclusively male sample. Third, and this is a potential limitation of our study, hormone samples were not collected at exactly the same time points for all participants as in previous studies, but after participants had finished a fixed number of blocks from the face categorization task at their own speed. Yet, the distribution of sampling time points was very similar in both posture groups and all samples were collected in a time window in which hormonal responses generally occur (Dickerson & Kemeny, 2004; Schultheiss et al., 2012).

Conclusions

The current study assessed whether repeatedly adopting expansive and constrictive postures known as power postures induces endocrine responses that resemble the hormonal correlates of dominance and affiliative behaviour. In doing so, it assessed whether larger doses of posture or collection of saliva samples at longer time intervals than previous studies would produce similar findings as the study by Carney et al. (2010) in contrast to previous non-replications. Participants adopted an expansive or constrictive posture three times for two minutes each, in between the blocks of a face categorization task. Salivary testosterone, cortisol and progesterone levels did not differ between posture groups within a time window of 14 to 50 minutes from the beginning of the first posture. Together with results from four previous non-replications, our study thus suggests that it is unlikely that short-term manipulations of postural expansiveness and constrictiveness elicit hormonal responses, even when postures are adopted repeatedly and within social contexts. While effects on other outcome variables described as promising by Cuddy et al. (2018) might be reproducible, the available evidence against an effect on hormone samples begins to clearly outweigh evidence for such an effect.

Supplementary Results

Table S1. Results of mixed effects ANOVAs with the full sample. Posture, Time and Posture*Time effects in ANOVAs conducted on the full sample before exclusion of outliers more than three absolute deviations above the median. η^2_{p}: partial eta-squared, η^2_{G}: generalized eta-squared.

	Effect	**df n**	**df d**	**F**	**p**	**$\eta 2_p$**	**$\eta 2_G$**
Cortisol	Posture	1	80	1,17	0,283	0,01	0,01
	Time	2	160	49,73	0,000	0,38	0,11
	Posture*Time	2	160	0,57	0,567	0,01	0,00
Testosterone	Posture	1	80	0,31	0,582	0,00	0,00
	Time	2	160	16,60	0,000	0,17	0,02
	Posture*Time	2	160	1,14	0,322	0,01	0,00
Progesterone	Posture	1	80	1,56	0,215	0,02	0,02
	Time	2	160	32,17	0,000	0,29	0,04
	Posture*Time	2	160	0,35	0,703	0,00	0,00

Chapter 6
Does your body affect your mental images?
Facing a controversy: Assessing the robustness of power posture effects on mental representations of faces

Assessing mental representations is probably the most direct way to investigate whether body postures activate representations of previous experiences, as the perceptual symbols theory of embodied cognition would postulate (Barsalou, 1999; see Chapter 1, section 2.1.). According to this perspective, expansive and constrictive postures would impact cognition and behaviour by re-activating representations of previous sensorimotor and affective experiences associated with high or low power. Since these postures have an important signalling function in social interactions, we wanted to focus on mental representations of potential interaction partners. We first aimed at assessing mental representations implicitly, since we had only observed posture effects on implicit but not explicit processing of threat-related facial expressions. An excellent reverse correlation study by Ratner et al. (2014) inspired us to investigate posture effects on implicit mental representations of in- and out-group members, given that in-group members represent potential interaction partners. This first study revealed strikingly strong effects of postures on in-group representations. Yet, while I was running the study, the first non-replication of the initial power-posing study was published (Ranehill et al., 2015), and the debate on replicability of postural feedback effects started to unfold. Still, effects on social cognition seemed much more plausible than effects on risk taking in gambling games, or large effects on hormone levels after only briefly adopting a posture. We decided to verify whether postural feedback would also impact explicit mental representations of people one likes. Null-findings in this second study, together with the publication of further non-replications of the initial power-posing study (Garrison et al., 2016; K. M. Smith & Apicella, 2017) let me doubt that the large posture effects on in-group representations indeed represented true postural feedback effects. Rigorous examination of my reverse correlation data further fuelled my doubts, as it revealed that implicitly assessed mental representation images were very variable. I concluded that using them as a dependent variable to investigate the (most likely) small effect of postural feedback had not been an ideal choice. To verify whether the strong effects on in-group representations could have resulted from chance alone, I conducted a permutation experiment, and found they might indeed be the result of random variability. Next, I attempted to replicate the effect on in-group representations and obtained null-results.

In order to draw a conclusion across these two contradictory studies, I conducted a final experiment to evaluate the mental representation images including data from both studies. The result of this study revealed no impact of postural feedback on implicit mental representations of in-group members. The following Chapter describes this series of experiments in more detail.

[6]

[6] This is a draft manuscript to be submitted for publication as: Hannah Metzler, Jorge Armony & Julie Grèzes. Facing a controversy: Assessing the robustness of power posture effects on mental representations of faces.

Abstract

Expansive and constrictive body postures, by signalling power and dominance, have a fundamentally social function. Yet, past studies that examined the effects of adopting such postures mainly focused on non-social or high-level social behaviour and yielded mixed results. We therefore assessed whether postural feedback impacts on social preferences, by visualizing mental representations of preferred facial traits using reverse correlation methods. While expansive and constrictive postures distinctively impacted mental representations of the faces of implicitly preferred in-group members, they did not affect representations of explicitly preferred faces. These findings appeared to suggest that posture effects depend on the implicit assessment of in-group representations or the social implications of the group context. However, considering the ongoing controversy regarding the replicability of postural feedback effects and the higher variability of implicitly vs. explicitly assessed mental representations, we verified whether the significant posture effect on in-group representations could have arisen from chance alone. Indeed, an additional experiment revealed similarly large differences for randomly shuffled groups of participants as for the actual posture groups. A final study could not replicate the initially observed posture effects on in-group representations. Taking all studies together, our findings demonstrate that mental representations of implicitly as well as explicitly preferred faces evoke affiliative and slightly dominant impressions. However, they are not conclusive regarding an effect of postural feedback on mental representations of other people's faces. Nevertheless, they have implications for the use of reverse-correlation methods in implicit tasks and highlight the crucial role of replication and reliability assessments of dependent measures for avoiding preliminary conclusions.

Keywords: body posture, power, mental representations, faces, replicability

Introduction

In social contexts, individuals' very first impressions about others determine whether they will interact with them. Subtle facial morphological features reliably influence our social judgements of dominance and affiliation (Todorov et al., 2008), two core dimensions of interpersonal perception and behaviour (Fiske et al., 2007; Paulhus & Trapnell, 2008; Wiggins, 1991). For example, masculine faces are perceived as dominant and aggressive whereas 'baby faces' are judged as weak and submissive (A. A. Marsh, Adams, & Kleck, 2005). Furthermore, changes in facial expressions evoke different judgements along the dominance and affiliation dimension. For instance, individuals infer high dominance and low affiliation from happy expressions, and high dominance but low affiliation from angry expressions (Hess et al., 2000; Knutson, 1996). In addition to facial features, postural expansiveness is used by various social species, including humans, not only to communicate but also to infer dominance status and associated behavioural intentions (e.g. de Waal, 2007; Hall et al., 2005; Schenkel, 1967). In humans, evidence shows unequivocally that perceivers interpret expansive and constrictive postures as signals of high and low dominance, power and status, respectively (e.g. Hall et al., 2005; Rule et al., 2012). Similarly to facial features, postural expansiveness influence individuals' first impressions for example in online and speed dating contexts (Vacharkulksemsuk et al., 2016). Interestingly, individuals' preferences for nonverbal social cues of dominance and affiliation traits are prone to changes as a function of life experience (e.g. Safra et al., 2017) as well as recent experience (e.g. losers or winners of a confrontation - Watkins & Jones, 2012).

Social power, a strong determinant of what individuals can and cannot do in social interactions, is one of the factors that modulate spontaneous evaluation of social cues and associated responses. Although the impact of power on preferences for facial cues has not been tested directly, lack of power was shown to increase the salience of affiliative personality traits (Toma, Yzerbyt, Corneille, & Demoulin, 2017), motivation to affiliate (Case et al., 2015) and prosocial behaviour (Guinote et al., 2015). In contrast, power has been shown to increase social distance and decrease motivation to work with others (Lammers et al., 2012). For instance, when perceiving an affiliative signal such as a smile, low power individuals will always reciprocate the smile, irrespective of the emitter's power status, whereas high power individuals will adapt their response as a function of the emitter's power status and only reciprocate the smile of low but not high power emitters (Carr, Winkielman, and Oveis 2014).

With regard to dominance traits, power has been shown to impact the salience and evaluation of dominance cues (Schultheiss & Hale, 2007; Yap, Mason, et al., 2013), as well as behavioural responses to such cues. Some evidence suggests a preference for individuals displaying opposite and complementary dominance signals (Tiedens et al., 2007; Toma et al., 2017; Yap, Mason, et al., 2013). When interacting with a friendly individual displaying an expansive or constrictive posture, individuals adapt their own body's expansion in the opposite direction spontaneously and without noticing (Tiedens & Fragale, 2003). In parallel, they prefer interaction partners who display the opposite posture. Moreover, high power facilitates attention toward faces signaling low dominance but away from faces signaling high dominance (Schultheiss & Hale, 2007). Power can even lead individuals to misperceive others' dominance cues in a complementary direction: low and high power individuals were shown to overestimate and underestimate the size of others, respectively (Yap et al. 2013). Preference for complementarity is however not always the rule. For instance, facing a dominance signal from unfamilar others such as sustained direct gaze leads high power individuals to reciprocate dominance with approach behaviours while low power individuals will complement by avoidance behaviours (Weick et al., 2017).

Altogether, past research strongly suggests that power modulates individuals' preferences for social cues of dominance and affiliation. We therefore set out to investigate whether postural feedback from expansive and constrictive postures influences basic social preferences along interpersonal dominance and affiliation dimensions. We conducted two studies to visualize how people mentally represent preferred facial traits using an established reverse-correlation image classification technique (Dotsch and Todorov (2012): study 1 assessed whether expansive and constrictive postures impact mental representations of faces one prefers implicitly, by instructing participants to classify faces according to their minimal group membership (Ratner et al., 2014). In contrast, Study 2 investigated interpersonal preferences explicitly by having participants select their preferred face from face pairs. Given that people seem unaware of the interpersonal preferences that drive their behaviour (Tiedens et al., 2007), we made sure that dominance and affiliation traits as well as the power manipulation remained covert throughout both studies. Specifically, we neither selected stimuli with regard to dominant or affiliative facial features, nor mentioned these dimensions to the participants who chose their preferred, in- or out-group faces. Furthermore, as we were interested in bottom-up effects of postural feedback on social cognition, we kept participants unaware about the investigated posture effect by providing a convincing cover story. To reveal mental representations, faces selected as in-and out-group members (Study 1) or as preferred (Study 2) were averaged all chosen faces per posture condition. Next, a sample of participants naïve about the image creation process was asked to rate the average mental representation images on items assessing dominance and affiliation traits.

Postural feedback had a large effect on implicitly assessed in-group representations (Study 1), but did not affect representations of explicitly preferred faces (Study 2). Acknowledging the debate on replicability of postural feedback effects, which evolves around whether adopting such postures affects an individual's own cognition and behaviour (Cesario et al., 2017, 2017; Cuddy et al., 2018; Simmons & Simonsohn, 2017), we further considered alternative explanations for the divergent findings between implicit and explicit preferences. We first assessed the probability of observing a significant posture effect on in-group representations by chance using a permutation approach (Study 3), and then attempted to replicate the effect on implicit preferences (Study 4). Given that Study 3 indicated high variability of in-group representations, we conducted a final experiment (Study 5) to evaluate the combined in-group representations from Study 1 and Study 4.

Study 1: Power posture effects on mental representations of implicitly preferred in-group faces

Study 1 investigated whether postures would affect preferences for interpersonal traits when mental representations are assessed implicitly. To prompt an implicit preference for some individuals as opposed to others, we implemented the minimal group design used by Ratner, Dotsch, Wigboldus, van Knippenberg and Amodio (2014). By means of reverse correlation methods, the authors revealed that people's pervasive tendency to prefer in- over out-group members (Tajfel, 1982; Tajfel, Billig, Bundy, & Flament, 1971) also manifests in how they mentally represent the faces of others. Mean mental images of in-group members prompted more favourable trait impressions (more attractive, intelligent, responsible, confident, trustworthy, caring, sociable and emotionally stable) and more closely resembled the mental representation of a trustworthy face. Individual in-group images further induced more positive implicit attitudes in a priming experiment. Altogether, these findings indicate that participants' were consistently driven by their implicit preference for in- over out-group members.

To investigate whether postural feedback would modulate these implicit preferences, we instructed participants to hold an expansive or constrictive posture before they underwent the procedure used by Ratner et al. (2014). Specifically, participants were assigned to an arbitrary group using a classical minimal paradigm (Tajfel, 1982) and then requested to categorize faces according to their group membership in a 2-image forced choice reverse-correlation task (Dotsch & Todorov, 2012; Dotsch et al., 2008). The faces were created by superimposing random noise patterns on two images of the same base face, which distorts the features of the base face and lets the two faces appear different. For each trial, another set of noise patterns produced a new variation of the facial features of the underlying base face. The average across all selected noise patterns represents the so-called classification image (CI) and reveals the key features of participants' mental representation of the social construct of interest, here features of faces of in- and out-group members. In a second step, an independent group of participants rated the average in- and out-group CIs from both posture conditions on 16 adjectives measuring the dimensions dominance and affiliation, which allowed to statistically evaluate the interpersonal trait impressions elicited by these mental representations.

This reverse correlation approach takes advantage of people's ability to intuitively select the one out of two faces that best resembles their mental image of a social construct. If participants were classifying faces randomly, the resulting average CI would be identical to the base face, as noise patterns would cancel each other out after a sufficiently large number of trials. If, however, participants select faces based on systematic preferences, the features forming the basis for their choices will become visible in the average CI. Thus, comparing trait impressions elicited by the in-group CIs from the expansive and constrictive condition would reveal whether the adopted posture influences implicit preferences for facial features signalling interpersonal dominance or affiliation traits.

We predicted an impact of posture only for in-group images, as in-group members are more motivationally salient (Van Bavel, Packer, & Cunningham, 2008), represent promising targets for affiliative strategies (White et al., 2012) and intergroup preferences in mental images only emerge as a positive bias towards the in-group, but not as a negative bias against the out-group (Ratner et al. 2014). While people in general prefer affiliative faces (Safra, Baumard, Wyart, & Chevallier, in revision), lack of power increases affiliation motives and behaviour (Case et al., 2015; Guinote et al., 2015; Toma et al., 2017), in contrast to having power (Lammers et al., 2012; Magee & Smith, 2013). Therefore, we expected a general preference for affiliative faces, which should be reinforced in individuals adopting a constrictive (submissive) posture. With regard to dominance traits, research in primates suggests a general preference for dominant individuals, but evidence in humans has mostly revealed preferences for individuals displaying complementary dominance behaviour (Tiedens & Fragale, 2003; Tiedens et al., 2007; Toma et al., 2017; Yap, Mason, et al., 2013). Taken together, all of these findings predict preferences for dominant facial traits after adopting a constrictive (submissive) posture. However, they do not allow specific predictions regarding the influence of expansive (dominant) postures on representations of in-group members.

Methods

Part 1: Reverse correlation of in- and out-group faces after a posture manipulation

Participants.73 healthy, male participants (age: 21.30 ± 2.85 years) were recruited via a participant mailing list and student job advertisement websites. For sample size calculations and further methodological details, see supplementary methods. Inclusion criteria for all experiments reported in the current paper were age between 18 and 35 years, fluency in French, normal or corrected vision, no medical treatment, no history of neurological or psychiatric disorders and no dependency to alcohol or other drugs. Participants were randomly assigned to the expansive (n= 37) or the constrictive posture condition (n=36). All participants gave written informed consent, were treated in accordance with the Declaration of Helsinki and paid for their participation.

Questionnaires. Participants filled out questionnaires prior to the testing session in the lab, which served to assess possible personality differences between posture groups. These included the French version of the State-Trait Anxiety Inventory (STAI, Spielberger, 1983), the BIS/BAS Scales (Caci, Deschaux & Baylé, 2007), and the Rosenberg Self-Esteem Scale (Vallières et Vallerand, 1990). In addition, they rated themselves on four adjectives assessing dominance and affiliation (dominant, self-confident, warm-hearted and considerate) selected from the Interpersonal Adjective List – Short Version (Jacobs & Scholl, 2016). After arrival at the laboratory, participants completed the state version of the STAI. None of the self-report measures differed significantly between posture conditions (all p-values >.158).

Group induction and face selection task. The female experimenter told participants that they would take part in two separate studies, investigating whether bodily postures influence cardiac frequency, and face perception, respectively. We use the same group induction procedure and cover-story as Ratner et al. (2014): after first being told that about half of the general population had a tendency to over- or under-estimate the number of perceived objects, respectively, participants were requested to estimate the number of dots appearing on a screen in what we presented as a short version of the "well-established" Number Estimation Style Test, and were randomly assigned to either the over- or under-estimator group. Participants were then told that, according to recent research, one can recognize people's estimation style from their face, and that the present study aimed at determining whether this was still possible given blurry perceptual information, which corresponds to everyday situations of judging others from a distance or at night. For that purpose, black and white noise patterns had been superimposed on photos of students who previously participated in our studies on estimation-style, and participants were requested to choose intuitively and according to their first impression, for many different pairs of faces which always including both an over- and an under-estimator, which of the two was the over- or the under-estimator.

Half of the participants were requested to choose the over- or under-estimator on all trials, which implies that half of them chose their in-group while the others selected their out-group. The chosen face was assigned to the participant's in-group if its estimation style was shared with the participant and to his out-group otherwise. To ensure that participants' group membership would remain salient throughout the face categorization task, participants had (1) to report the result of the Number Estimation Style Test after its completion; (2) to type their estimation style in a box opening on screen while the experimenter was allegedly busy with paper work; and (3) during the main experiment, the instruction screen appearing before each task block reminded participants of their own estimation style. Finally, participants adopted an expansive or constrictive for 2 minutes before the 1st, 3rd and 5th task block and were encouraged to stay in a similar sitting posture throughout the task. Within each posture group, there were two groups of participants, i.e., those who selected their own or the other estimation style, respectively.

Posture manipulation and cover story. Participants adopted an expansive or constrictive standing posture (each n=24) for 2 minutes before the first, third and fifth out of six task blocks, and subsequently stayed in an expansive or constrictive sitting posture while performing the reverse correlation task. In order to minimize possible experimenter biases, both experimenters remained unaware of the posture condition the participant would be assigned to for as long as possible. We randomly determined the condition only at the end of all other procedures, just before providing posture instructions (see below), thereby reducing interaction time after posture assignment as much as possible.

Participants were led to believe that an unrelated posture study had been combined with the face perception task as this offered several advantages. We needed to collect heart rate data for six minutes during which participants comfortably remained in the same posture. Inserting 2 minutes of posture between the blocks of the face perception task minimized physical discomfort during the posture and allowed for breaks during the demanding perceptual task with noisy images. To bolster this cover story, the experimenter attached two adhesive surface electrodes to participants' hand-wrists and demonstratively turned on the acquisition system. In reality, no heart-rate data was collected. The expansive and constrictive postures were taken from Chadwick et al. (2018) and are depicted Figure 1.

After providing all above instructions, the experimenter randomly assigned participants to a posture condition using MATLAB. He then and verbally provided instructions about how to place each body part while neither demonstrating the posture nor referring to any words associating the postures with meaning (see Supplemental Information). The experimenter informed participants that a camera would allow to make sure the standing posture was adopted correctly, from outside the testing room. Finally, depending on participants' posture condition, they were instructed to (1) sit upright with feet apart or (2) keep back and shoulders slumped and legs parallel or crossed during the task as best as they could, in order to "stabilize the effect of postures on heart rate parameters". This short instruction was repeated on screen at the beginning of each task block. At the end of the study, participants were carefully debriefed. We specifically enquired for suspicions about unmentioned objectives of the study. No participant suspected a link between the posture manipulation and the face categorization task, or guessed the purpose of the group induction procedure, which confirms the effectiveness of the cover story.

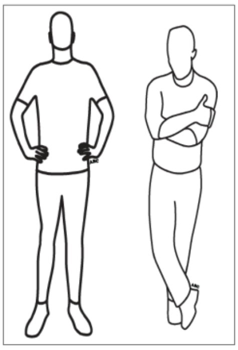

Figure 1. Expansive and constrictive body postures adopted in Study 1, 2 and 4. (Images created by Antoine Balouka-Chadwick).

Stimuli. On screen instructions and stimulus presentation for all experiments in this paper were programmed in MATLAB (MathWorks, Inc., 2014), using Psychophysics Toolbox 3 (Brainard, 1997; Kleiner et al., 2007). We used a typical 2-image-forced-choice-task (Dotsch & Todorov, 2012; Dotsch et al., 2008) with 600 trials in total, separated in six blocks. After a fixation-cross of 500ms (jitter: 250ms), two face images appeared adjacent to each other and remained on screen until the participants' response. Participants were however encouraged to make their choice after 2 to 3 seconds, i.e. the approximate time other participants needed for intuitive decisions. We created face image pairs using the RCICR toolbox in R (Dotsch, 2015) which generates stimuli for reverse correlation tasks by superimposing two sinusoid noise patterns on the same base face for each trial, with the second pattern being the inverse or negative image of the first (see Dotsch & Todorov, 2012 for details). This results in two faces with distinct facial features, since pixels that are dark in one face are bright in the other. As the base face, we used the grey scaled average of all male faces in the Karolinska Face Database (Lundqvist & Litton, 1998). The order of face pairs and the side on which the original noise pattern was presented were randomized. Image size was 512x512 pixels, and the distance between images 20 pixels.

Image processing. We removed trials with response times below 300ms based on previous reverse correlation studies (e.g. Dotsch, Wigboldus, & van Knippenberg, 2011; Imhoff, Dotsch, Bianchi, Banse, & Wigboldus, 2011), as low reaction times are associated with low informational value in the resulting classification images (Loek Brinkman et al., 2018). Across all studies in this paper, we further excluded participants entirely if they responded in less than 300ms in more than 40% of the trials, suggesting that they pressed buttons without actually looking at the images. This concerned none of the participants in Study 1. In 4 subjects, some trials (44, 82, 100 & 219) were lost due to technical issue. For all remaining trials, the noise patterns which the participant had assigned to his own estimation style were averaged to calculate the average in-group CIs. Since participants knew that each stimulus pair presented an over- and an under-estimator, we included noise patterns of participants who had directly selected their in-group and of those who had chosen their out-group, thereby indirectly assigning the adjacent image to their in-group. The other noise pattern of each stimulus pair was assigned to the out-group. As the two noise patterns are negatives of each other, the each average out-group CI represents the anti-CI or mathematical opposite of the in-group CI. The resulting in- and out-group CIs of both posture conditions are depicted in Figure 2.

Part 2: Rating the in-out-group images on dominance and affiliation

Participants and task. An independent group of 35 male participants (age: 23.65 ± 3.8), unaware of how the faces were generated, rated the in- and out-group CIs on 16 traits descriptions, coming from four scales that assess the high and low end of the dominance and affiliation dimension, respectively: (1) direct, dominant, assertive, self-confident; (2) avoids conflict, shy, silent, inconspicuous; (3) warm-hearted, empathic, attentive to social harmony, considerate; (4) inconsiderate, emotionally cold, indifferent, ruthless (descriptions from the short version of the German Interpersonal Adjective List (Jacobs & Scholl, 2016); see Supplementary Information for translations). They had indicate to what extent each of the 16 trait descriptions corresponded to each presented CI on a visual analogue scale ranging from “not at all” to “completely”. An overview of all faces and trait descriptions (with clarifications where necessary) was presented to participants as part of the on-screen instructions before the task. At the start of each trial, the upcoming trait was presented for one second, before the face and the scale appeared. . The position of the cursor on the scale at the beginning of each trial varied randomly, making responses in the centre of the scale an active neutral judgement. The face disappeared after four seconds, but scale and trait remained on screen until response. We encouraged participants to answer according to their first impression as long as the face was visible, but pointed out that they could still answer after the face had disappeared if necessary. The order of face stimuli and traits was randomized, never allowing more than two repetitions of the same face or trait.

Analysis of face ratings. Analysis and figures were done in R version 3.2.5 with the packages data.table, dplyr, ez, ggplot2 and tidyr (Dowle & Srinivasan, 2017; Lawrence, 2016; R Core Team, 2018; Wickham, 2009; Wickham et al., 2017; Wickham & Henry, 2018) and in MATLAB (MathWorks, Inc., 2014). First, total dominance and affiliation scores were calculated by averaging the scores of the eight adjectives per scale, after reversing scores of the four negative adjectives. Since all CIs were rated by the same subjects, we used two-way mixed ANOVAs with posture (expansive/constrictive) and group (in/out) as within-subject factors. As we predicted an impact of posture only on in-group and not out-group images, we examined the interaction of posture and group for dominance and affiliation ratings. To correct for these two tests, we applied a threshold of $\alpha=0.05/2$ to determine significance of each interaction. In case of a significant interaction, we conducted paired post-hoc t-tests with Bonferroni correction (i.e. $\alpha=.05/4=0.0125$) to compare in- and out-group between postures (expansive vs. constrictive), and in- and out-group within each posture. When an interaction was not significant, we reported in- and out-group comparisons within each posture to validate whether we replicate Ratner et al. in both posture conditions. As effect sizes, we always report Cohen's d_{av} for post-hoc comparisons and generalized eta-squared η_G^2 for repeated-measures designs to allow comparability with partial eta-squared from between-subject designs (Lakens, 2013).

Results

Dominance ratings of in- and out-group faces (see Figure 2) revealed a significant main effects of posture ($F(1,34) =16.40$, $p<.001$, $\eta_G^2=0.06$), no effect of group ($F(1,34) =2.74$, $p=.107$, $\eta_G^2=0.02$), but a significant interaction ($F(1,34) =10.49$, $p=.002$, $\eta_G^2=0.06$). Post-hoc t-tests indicated higher dominance ratings for the in-group of the constrictive posture, compared both with the in-group of the expansive posture and the out-group of the constrictive posture (see Table 1 for t-test results and Table S1 in the supplementary information).

Affiliation ratings showed significant main effects for posture ($F(1,34) =44.67$, $p<.001$, $\eta_G^2=0.21$) and group ($F(1,34) =35.54$, $p<.001$, $\eta_G^2=0.24$), further characterised by a significant interaction ($F(1,34) =86.22$, $p<.001$, $\eta_G^2=0.23$). T-tests results mirrored the pattern found for dominance, with the in-group of the constrictive posture receiving high affiliation ratings, in contrast to low ratings for the out-group of the constrictive posture and the in-group of the expansive posture. All significant t-tests remain significant at $p<.001$ after multiple comparison correction. Taken together, the in-group representation of participants who adopted a constrictive posture was rated as highly affiliative and moderately dominant, while all other in- and out-group CIs received lower ratings on both dimensions.

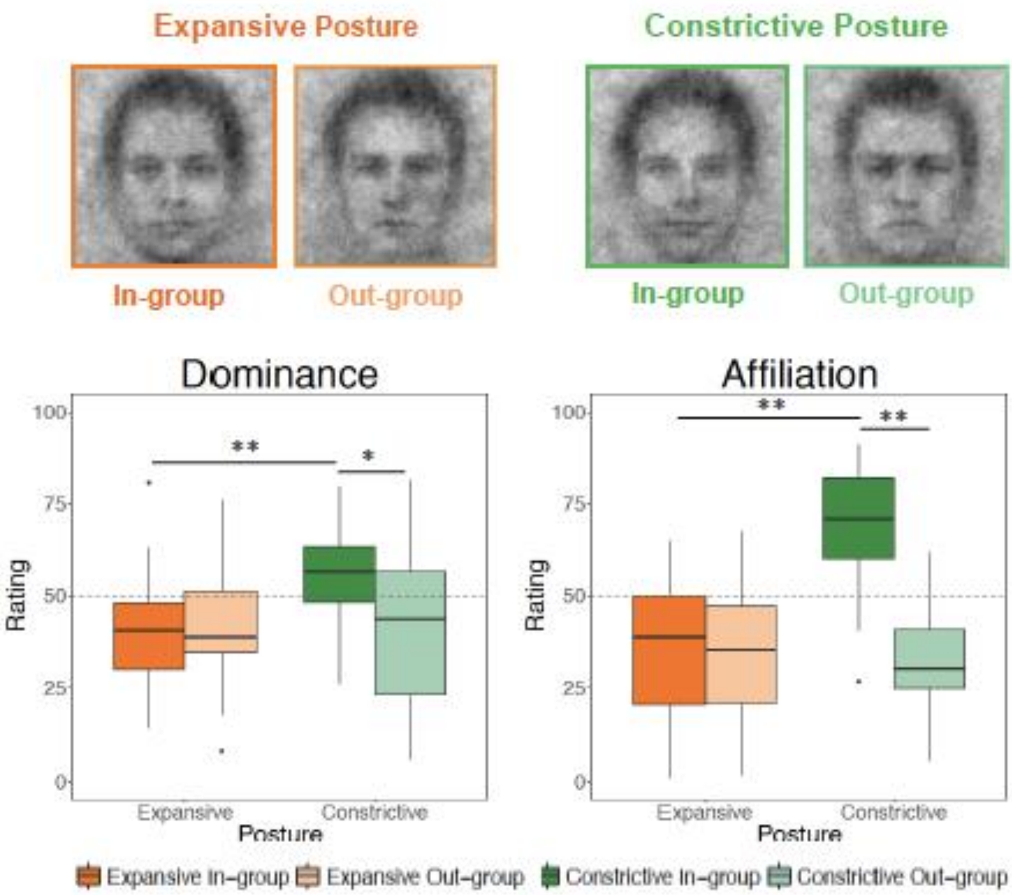

Figure 2. In- and out-group CI of participants in the expansive and constrictive posture condition in Study 1, and total rating scores of these CIs on the dominance and affiliation dimension. ** = p<.001, * = p<.01. The dashed line at 50 represents a neutral trait judgement.

Table 1. Paired t-tests for Study 1 ratings of in- and out-group CIs. P-values are uncorrected, unless associated with an asterisk, which indicates that the t-test remains significant after Bonferroni-Holm correction.

Trait	Comparison		df	t	p		d
Dominance	In-group	E vs C	34	-4.68	<.001	*	-0.99
	Out-group	E vs C	34	0.03	.976		0.00
	Expansive	In vs Out	34	-0.93	359		0.19
	Constrictive	In vs Out	34	2.88	.007	*	0.71
Affiliation	In-group	E vs C	34	-9.79	<.001	*	-1.45
	Out-group	E vs C	34	0.35	.725		0.06
	Expansive	In vs Out	34	0.36	.800		0.04
	Constrictive	In vs Out	34	8.22	<.001	*	1.51

Discussion

Study 1 assessed whether postural expansiveness impacts on how we mentally imagine the faces of in- and out-group members and whether these mental representations elicit different social trait impressions. Participants adopted either an expansive or constrictive posture before and while categorizing faces as in- and out-group members. Using reverse correlation techniques, we then created visual renderings of in- and out-group representations for each posture condition, which evoked distinct social impressions in independent observers that were largely in line with our hypotheses. The in-group representation of participants adopting a constrictive posture was evaluated as highly affiliative and moderately dominant. Ratings of the out-group representation were significantly lower on both dimensions. In contrast, both the in- and the out-group representation of participants who adopted an expansive posture received low dominance and affiliation ratings.

Since mere in-group categorization evokes in-group preferences (Tajfel et al., 1971), in-group choices could reveal postural influences on implicit interpersonal preferences. In-group members are more motivationally relevant (Van Bavel et al., 2008) and are promising allies for affiliative strategies (White et al., 2012). In-group representations would thus embody individuals we prefer to affiliate and interact with when adopting a specific postural dominance display. The observed differences between mental representations of in-group members from the expansive and the constrictive condition thus appeared to demonstrate that postures considerably influence implicit interpersonal preferences along the dominance and affiliation dimension. They suggested that constrictive postures, associated with a vulnerable and submissive stance, induced complementary preferences for rather self-confident, and very empathic and warm-hearted interaction partners, possibly by enhancing tendencies to seek reassurance and protection from friendly and powerful in-group members. The in-group representation of participants who adopted an expansive posture received relatively low ratings on both the dominance and the affiliation dimension. Furthermore, these ratings did not differ from ratings of the out-group representation. As dominant individuals can more flexibly respond to social behaviour (Orford, 1986), this may indicate that individuals felt able to deal with any individual when their body signalled a dominant state. Nevertheless, it is striking that expansive postures completely eliminated the inter-group bias for affiliative traits, which Ratner et al. (2014) observed without manipulating posture.

Study 2: Power posture effects on mental representations of explicitly preferred faces

Findings of Study 1 suggest that constrictive postures induce preferences for affiliative and dominant in-group members, while expansive postures elicit no specific preferences, and even eliminate the usual preference for affiliative traits in in-group members. In other words, our body posture may impact which kind of traits we prefer in social interaction partners. Study 2 investigated whether postures would also affect explicit preferences for facial features. In contrast to Study 1, which implicitly assessed participants' social preferences in a group context, Study 2 implied no particular social context.

Methods

Instead of the group induction and categorization task used in Study 1, participants simply selected the face they preferred in Study 2. All other procedures were identical to Study 1.

Part 1. Reverse correlation of faces with preferred features and posture manipulation

Participants. 52 healthy, male participants (age: 22.75 ± 3.16 years for 48 included subjects) were randomly assigned to the expansive (n=24) or constrictive (n=24) posture condition. While no participant had to be excluded due to reaction time criteria, the data of three participants was lost due to technical error, and a fourth had to be excluded due to a psychomotor handicap. As in Study 1, participants' trait and state self-report measures didn't differ significantly between postures (all p-values >.252).

Procedure and task. The experimenter explained that the objective of the study was to identify facial traits that lead us to prefer one face over another. Participants' task was to always choose the face they preferred in a series of pairs of faces. We mentioned that the face images were blurry due to superimposed noise patterns, and that participants should trust their first impression while making their choice. All other aspects of the face categorization task, including stimulus presentation, number of trials and blocks, and intermediate posture sessions remained as described in Study 1. Again, no participant suspected a link between the posture manipulation and face categorization task during debriefing.

Image processing. After removing trials with response times below 300ms (1%) we averaged noise patterns of selected faces across all participants per posture condition.

Part 2: Rating the preferred CIs on dominance and affiliation

Participants. The preferred CIs were rated by the sample of participants described in Study 1. Although we had conducted preliminary ratings of in- and out-group CIs that had shown the same results, we included all CIs again in Part 2 of Study 2 to directly compare results between studies.

Results

Ratings of the preferred CI from the expansive and constrictive condition resembled each other on both dominance ($t(34)=1.29$, $p=.207$, $d=.17$) and affiliation dimensions ($t(34)=1.46$, $p=.15$, $d=.12$, see Figure 3). Both CIs created a highly affiliative (expansive: 74.21 [68.29, 80.13], constrictive: 72.14 [66.32, 77.96]) and moderately dominant impression (expansive: 60.28 [56.30, 64.26], constrictive: 58.32 [54.62, 62.02]).

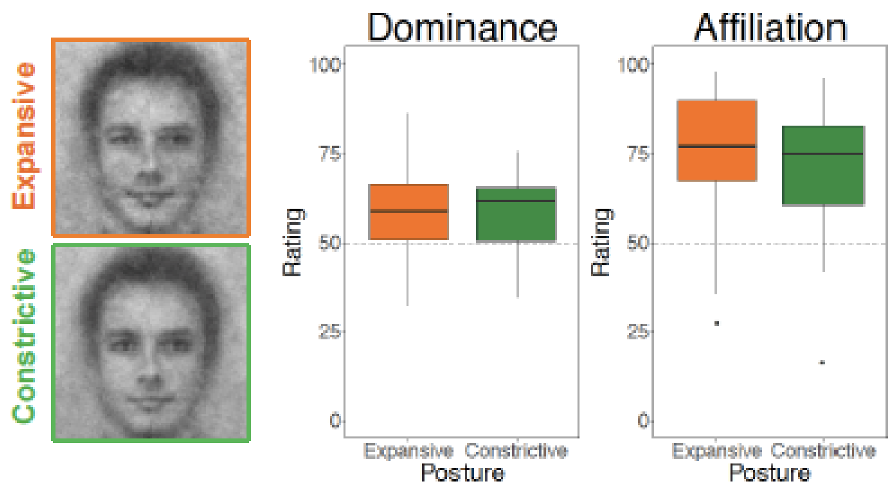

Figure 3. Preferred CI of participants in the expansive and constrictive posture condition in Study 2, and total rating scores of these CIs on the dominance and affiliation dimension. The dashed line at 50 represents a neutral trait judgement.

Discussion

In contrast to effects on mental representations of the faces of in-group members, postural expansiveness did not affect explicit preferences for facial features. Regardless of their posture, participants seemed to prefer faces with highly affiliative and reasonably dominant features.

From these findings, we could conclude that postures implicitly affect how we mentally represent other's faces when the context implies potential social interaction, but do not affect explicit preferences for individuals with specific social traits. Postural expansiveness, mostly regulated unconsciously (Tiedens & Fragale, 2003; Tiedens et al., 2007), might only influence social perception when relevant features are processed outside the focus of attention. Indeed, postures have been found to modulate attention to threat-related expressions only when faces are unattended, (Chadwick et al., 2018) and do not seem to impact explicit emotion recognition (Metzler et al. unpublished data - see Chapter 5). This fits nicely with research on motivation which shows that implicit motives shape spontaneous behavioural tendencies and rarely correlate with explicit motives (McClelland, Koestner, & Weinberger, 1989).

However, another potential explanation is related to the fact that Study 2 used a more direct and reliable dependent measure than Study 1. Considering the debate about replicability of postural feedback effects, we set out to test whether this second interpretation could account for the contrast between Study 1 and 2.

Study 3: Could power posture effects on in-group representations arise from chance?

While the difference between findings of Study 1 and 2 can easily be made sense of given previous literature, it is also possible that lower reliability of the implicit dependent measure in Study 1 gave rise to the observed posture effect. Classification images of preferred faces are averages of faces that all participants selected according to the same criterion, whereas classification images of in- and out-group members are averages of faces selected according to two different criteria, namely, two expressions of a rather abstract personality trait linked to number estimation. While it is easy to form a mental image of a face one likes, it may be hard to imagine a face of someone who tends to under-estimate numbers. Consequently, different participants likely attributed different facial traits to their in- or out-group, even if they selected the same estimator type, which increased variability in- and out-group CIs. Using such a variable measure in a between-subject design may yield distinct outcomes between two groups even in the absence of an effective experimental manipulation.

We therefore assessed similarity of individual CIs within each posture condition by calculating pixel-wise luminance correlations (see Dotsch & Todorov, 2012) of the CI of each participant with the n-1 average of his posture condition (mean CI including all but this participant's individual CI). Similarity of individual CIs within each posture condition was indeed much lower in Study 1 than in Study 2. Correlations were close to zero for in-group CIs (expansive: r=0.04, constrictive: r=0.06), but around .30 for preferred CIs (expansive: r=0.37, constrictive: r=.0.29). Thus, higher between-subject variability of in-group as compared to preferred CIs could potentially explain why we observed a difference between posture groups in Study one but not Study 2.

Study 3 tested whether the stronger variability of the in-group CIs could produce effects as large as the posture effect observed in Study 1. For this, we shuffled and split the total sample of Study 1 in two random groups a hundred times and calculated mean in-group CIs for both groups each time. As the posture effect on in-group CIs was largest for the affiliation rating in Study 1, we tested if an effect this large could occur by chance alone by counting how many of the shuffled mean CIs would yield an even larger absolute difference in affiliation ratings. For the actually observed effect to be considered significant at $\alpha = 0.05$, the difference of the original in-group CI pair (i.e. the expansive and constrictive in-group CI) from Study 1 would need to fall within the first five percent of differences between shuffled mean CI pairs.

Methods

Calculating shuffled mean CIs. We first shuffled and split participants of Study 1 into two random groups, and then calculated mean in-group CIs for each group. Repeating this process a 100 times yielded a 100 pairs of shuffled mean in-group CIs. We applied two constraints during this shuffling procedure: The proportion of participants from each posture was 50% in each random group, and the average luminance difference of two shuffled mean CIs was allowed to vary at most 1% of the difference of the original in-group CI pair. Because each shuffled mean CI would have to be rated on several adjectives, the rating approach was limited to 100 shuffled mean CI pairs. For this reason, we also calculated the difference in luminance scores for a sample of 1000 shuffled mean CI pairs to see where the difference between the original expansive and constrictive in-group CI would fall in the distribution of luminance differences of this much larger sample of shuffled mean CIs.

Participants and task. 31 healthy volunteers (15 women, age: 24.13 ± 4.15 years) participated in the experiment. Due to the high number of shuffled mean CIs to be rated, we chose to present four instead of eight adjectives per dimension as rating scales. Specifically, we used the four adjectives representing high affiliation and dominance, respectively (see Study 1 Methods). Total scores calculated from eight and four respective adjectives per dimension yielded the same results in Study 1. Participants were first requested to rate the mean preferred CIs and mean group CIs from Study 1 and 2 on both dimensions, to verify if they rated these CIs in the same manner as those in the earlier studies. This resulted in 6 CIs x 4 adjectives x 2 dimensions = 96 trials. Given that one participant indicated having misunderstood the adjective conciliatory after completing the mean CI rating, affiliation scores for these mean CIs include only 30 participants. Next, participants rated the 200 shuffled mean in-group CIs on the four adjectives of the affiliation dimension, which amounted to 800 trials.

Results

Ratings for mean CIs from Study 1 and 2 were replicated exactly, indicating reliability of our rating scales (see supplementary information). Importantly, 26 out of 100 differences in affiliation ratings between shuffled mean CI pairs were larger than the difference in affiliation ratings found for the original expansive and constrictive in-group CI in Study 1 (difference: 39.65). Similarly, 15 out of 100 differences between shuffled mean CI pairs were larger than the difference in affiliation ratings found for the original expansive and constrictive in-group CI when using the replicated ratings from the present study (difference: 44.35, see Figure 4). The difference in affiliation ratings of the original expansive and constrictive in-group CI from both Study 1 and Study 3 did not fall within the first 5% of differences between shuffled mean CI pairs. The posture effect on affiliation ratings of in-group faces could therefore have resulted from chance alone. Differences in luminance scores for a sample of 1000 shuffled mean CI pairs implied the same conclusions: 441 out of 1000 luminance differences were higher than the luminance difference found for the original expansive and constrictive in-group CI pair. The luminance difference between the original expansive and constrictive CIs could therefore have occurred by chance.

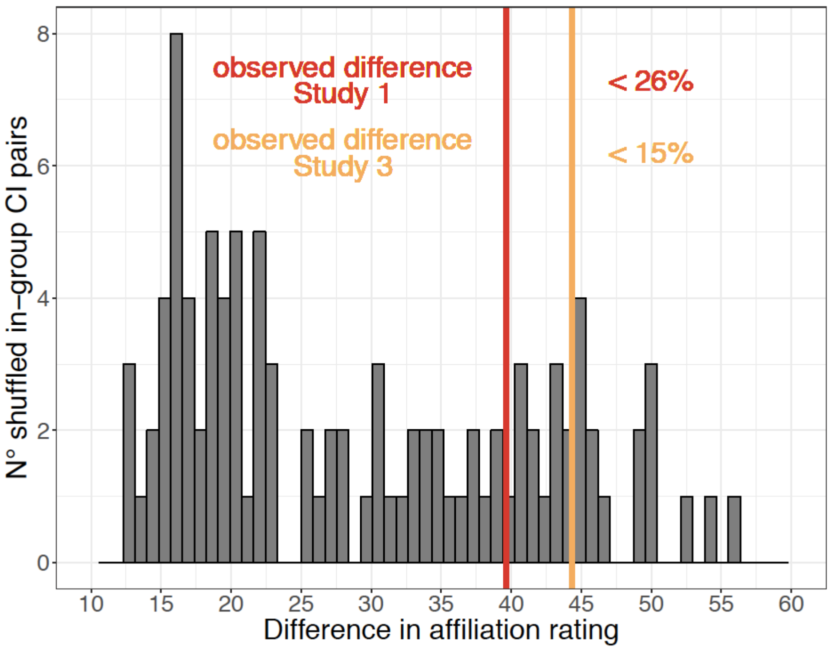

Figure 4. Distribution of differences in affiliation ratings between the two shuffled in-group CIs calculated after shuffling and randomly splitting the total sample of participants from Study 1 in two. The red (dark) and orange (bright) lines represent the rating difference between the expansive and constrictive in-group CI in Study 1 and Study 3, respectively. Affiliation ratings are total scores of 4 positive affiliation adjectives.

Discussion

In Study 3, we assessed whether random variability of in-group CIs or ratings could have produced the posture effects observed in Study 1. An exact replication of ratings for in-, out-group and preferred faces from Study 1 and 2 confirmed the reliability of CI ratings, excluding random variability in ratings as a reason for differences between posture groups. Yet, a permutation approach indicated a 15-26% probability that the apparent impact of posture on affiliative traits of mental in-group representations arose from random variability of individual in-group CIs. Similarly, there was a 44.1 % probability to detect random differences in average luminance larger than the one between the two in-group representations. If the large effect of posture on affiliation ratings (d = -1.45) in Study 1 could have occurred by chance, the same has to be assumed for the smaller effect on dominance ratings (d=-0.99). Therefore, we set out to replicate Study 1 to verify whether the large posture effects on dominance and affiliative trait representations of in- and out-group members were reproducible despite of high variability of the implicitly assessed CIs.

Study 4: Replication of Study 1

Study 4 is a direct replication of Study 1. In short, participants adopted an expansive or constrictive posture before and while engaging in an in-out-group face classification task. Group membership was assigned based on the tendency to either over- or under-estimate numbers. We used reverse correlation techniques to visualize mean in- and out-group representations, averaging across individual in- and out-group representations within the expansive and constrictive posture condition. A sample of independent participants rated these representations on trait adjectives measuring the dominance and affiliation dimension.

Methods

Methods closely followed those described in Study 1 apart from two improvements: First, to minimise experimenter biases, a male experimenter naïve about results and predictions of Study 1 and the literature about posture and group membership conducted the experiments. Second, we added both an explicit and an implicit measure of subjective power and affiliation to better capture possible effects of postures, at the beginning and at the end of the experiment.

Part 1: Reverse correlation of in- and out-group faces after a posture manipulation

Participants. 79 healthy, male volunteers participated in the experiment. We stopped testing at 36 valid participants per posture condition according to criteria defined in Study 1. Four participants had to be excluded due to responses below 300ms in more than 40% of trials and three participants guessed the real purpose of the study. Mean age of the included 72 participants was 22.0972 ± 3.74 years.

Implicit and explicit measures of affiliation and power feelings. At home, in addition to the questionnaires used in Study 1, participants rated themselves on the 16 adjectives from the Interpersonal Adjective List – Short Version (IAL-K) also used for the CI ratings. At the start of the experiment, after filling out the STAI state as in Study 1, participants explicitly rated their current feelings of affiliation and power on visual analogue scales using 10 items of the Need to Belong Scale (NTB, Leary, Kelly, Cottrell, & Schreindorfer, 2013) and self-ratings of feeling confident and in control in a social interaction. They then proceeded to an adapted version of the Implicit Concerns Test (Quirin, Droste, Kazen, & Kuhl, in preparation), which assessed their implicit affiliation and power motivation. In this test, participants are requested to intuitively interpret the meaning of six artificial words by judging how much the sound of each word expressed four personality traits (adjectives from the IAL-K: assertive, self-confident, warm-hearted & empathic). At the end of the experiment, they completed the same measures of explicit feelings and implicit motives associated with power and affiliation. Total scores of each of these measures were analysed with a 2 (time) by 2 (posture) mixed ANOVA, testing whether expansive postures as compared to constrictive postures would increase explicit feelings and implicit motives of power and decrease explicit feelings and implicit motives of affiliation from T1 to T2. Explicit measures were not available for the first six participants, resulting in a sample size of 64.

Part 2: Rating the in-out-group images on dominance and affiliation

36 participants (18 women, age: 22.75 ± 4.20 years) rated the in- and out-group CIs from both posture conditions. All other methods were exactly as reported in Study 1.

Results

Measures of trait and state-anxiety, behavioural inhibition and activation, self-esteem or dominance and affiliation traits did not differ between postures (all p-values >.214). We further found no significant changes in explicit feelings or implicit motives from before to after adopting an expansive or constrictive posture: explicit affiliation: F(1,64)=2.32, p=0.133, η_G^2=0, explicit power: F(1,64)=0.15, p=.703, η_G^2=0, implicit affiliation: F(1,70)=.52, p=.473, η_G^2=0 and implicit power: F(1,70)= 2.07, p=.155, η_G^2=0. Means and confidence intervals can be found in Supplementary Table S4.

For dominance ratings, we did not find the predicted group by posture interaction (F(1,35) =1.93 , p=. 173, η_G^2=0.01; Figure 5). Instead, the in-group was much more dominant than the out-group in both posture conditions (F(1,35)=108.55, p<.001, η_G^2=0.45), with slightly higher ratings for CIs from the constrictive posture (F(1,35)=6.03, p=.019, η_G^2=0.02,). In contrast, there was a trend for an interaction (F(1,35) =4.55, p=0.040**,** η_G^2=0.02) for affiliation scores (Figure 5), but it did not result from the predicted differences. Rather, the out-group of the expansive compared to the constrictive condition elicited more affiliative impressions (t(35) =2.15., p=.039, d=0.37). Critically, the two in-group representations (t(35) =-1.18, p=.250., d =-0.17) did not differ. Instead, the in-group was much more affiliative than the out-group in both posture conditions ($F(1,35)=36.41$, $p<.001$, $\eta_G^2=0.27$). Finally, there was no main effect of posture ($F(1,35)=0.87$, $p=.357$, $\eta_G^2=0$). In short, the ratings did not replicate results of Study 1.

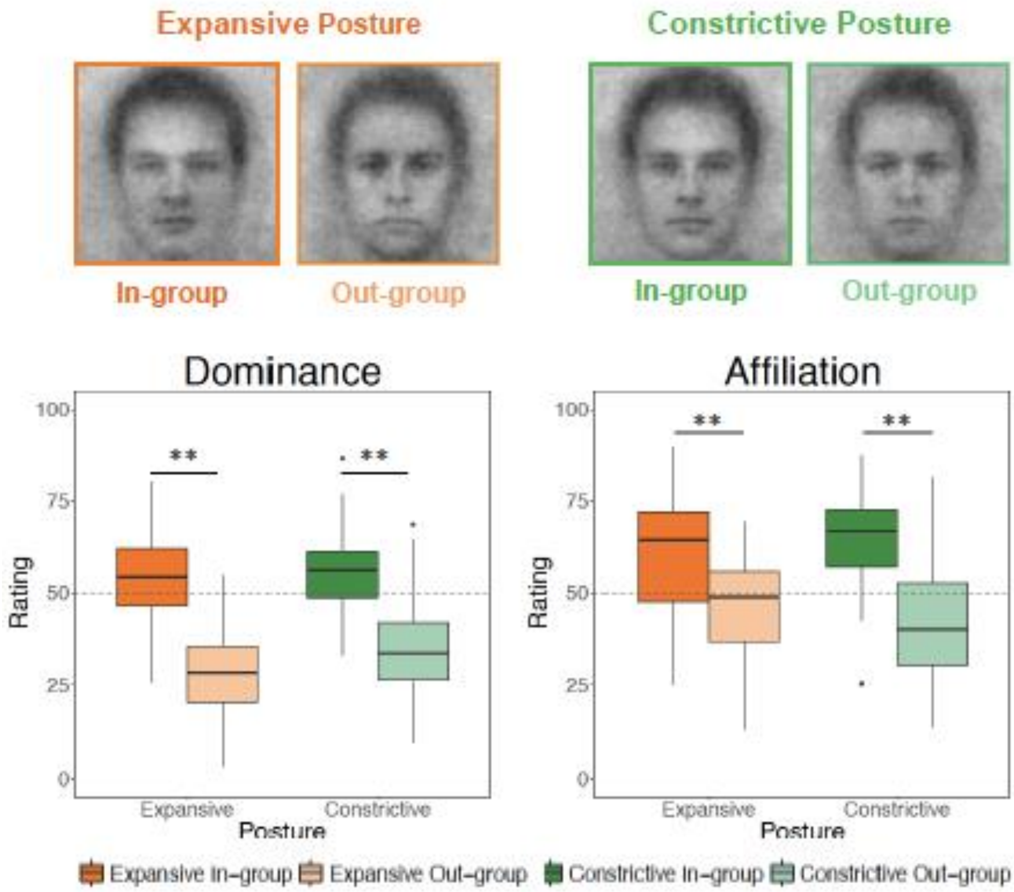

Figure 5. In- and out-group CIs of participants in the expansive and constrictive posture condition in Study 4, and total rating scores of these CIs on the dominance and affiliation dimension. ** = p<.001, * = p<.01. The dashed line at 50 represents a neutral trait judgement.

Discussion

Study 4 did not replicate any of the posture effects on group representations we observed in Study 1. Social trait impressions evoked by the in-group representations of both posture conditions closely matched each other. Together with Study 3, Study 4 could thus imply that the large effects observed in Study 1 may have actually resulted from high variability of in-group CIs.

Moreover, Study 4 was the first in the literature to assess an impact of postures on implicit motives of affiliation and power. Using a word interpretation task, we could not observe such effects, nor did we observe an effect on the explicitly rated need to belong or on explicit feelings of power. Some studies have reported effects of postural expansiveness on explicit power feelings (Cesario & Johnson, 2017; Gronau et al., 2017). Yet, as non-significant effects in four out of six highly-powered studies in the meta-analysis by Gronau et al. (2017) demonstrate, these effects are small. When participants are unfamiliar with power postures, they are even smaller. Hence, we might not have observed effects on explicit feelings of power since participants were naïve about power postures, since they rated their explicit feelings only 10 minutes after the posture, or simply because we lacked the statistical power to detect small effects.

Study 5: Combining in- and out-group representations from Study 1 and 4

Given the contradicting results obtained with a highly variable measure in Studies 1 and 4, we decided to combine the CIs of in- and out-group representations from both studies to achieve a larger sample size and thus possibly a more precise result. Additionally, we changed which data we included when calculating average CIs to exactly match the methods of Ratner et al. (2014). In Studies 1 and 4, half of participants had directly chosen the noise pattern assigned to their in-group CI (i.e. they selected the over-estimator and were over-estimators themselves). The other half chose the in-group indirectly by selecting the other noise pattern as out-group (i.e. they chose the over-estimator but were under-estimators themselves). Based on previous evidence that CIs resulting from direct and indirect choices are equivalent in explicit tasks (Dotsch & Todorov, 2012), we had decided to average across all individual CIs regardless of whether participants had chosen their in-group (or out-group) directly or indirectly. In Study 5, as it has not been formally demonstrated that direct and indirect choice CIs are equivalent in implicit tasks, we only averaged across individual CIs from participants who had directly selected their in- or out-group exactly as in Ratner et al. (2014).

For the purpose of comparison between our different studies, it is nevertheless important to point out that mixed CIs (including directly and indirectly chosen individual CIs such as in Study 1 and 4) and direct choice CIs (including only directly chosen CIs such as in Study 5) looked very similar (see Figure 6). This suggests that the indirectly selected noise patterns included in mixed CIs did not contribute any additional signal value to the average CIs. This makes sense given that they are simply negative images of the directly selected noise patterns.

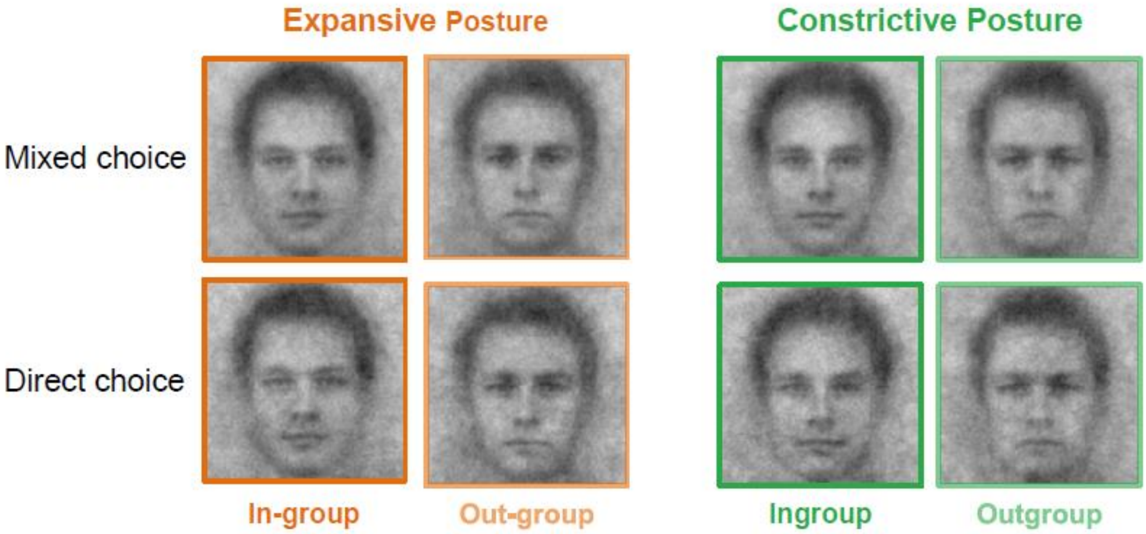

Figure 6. Comparison of mixed choice and direct choice CIs in Study 5 (combining data from Study 1 and 4). Mixed choice CIs were calculated by averaging across individual CIs from participants who chose the in- or out-group directly or indirectly. Direct choice CIs include only individual CIs from participants who chose the in- or out-group directly. Apart from slightly increased noise in direct choice CIs, which results from a twofold reduction of the number of included individual CIs in comparison to mixed CIs, these CIs are highly similar.

Methods

Part 1. Combining in- and out-group representations from Study 1 and 4

Participants from Study 1 and 4 combined. Mental representation images were calculated with the data of the 145 participants included in Study 1 and 4 (mean age 21.7 ± 3.33 years). Participants adopted either an expansive or constrictive posture and selected either in- or out-group faces. There were 37 participants in the expansive in-group condition, and 36 in the expansive out-group, constrictive in-group and constrictive out-group condition, respectively.

Image processing. Trials with reaction times below 300ms were excluded (1.3%). The selected noise patterns were averaged to calculate either the in-group or the out-group CI per posture, depending on whether participants chose their own or the other estimation style. As Ratner et al. (2014), we did not use the unselected noise pattern to visualize classification images. The resulting mean in- and out-group CIs for each posture condition and are depicted in Figure 7.

Part 2: Rating the combined in- and out-group CIs on dominance and affiliation

Participants. An independent group of 41 participants (21 women, age: 24.65 +- 5.23), rated the combined in- and out-group CIs. One participant was excluded because his age (47 years) lay outside the defined age range.

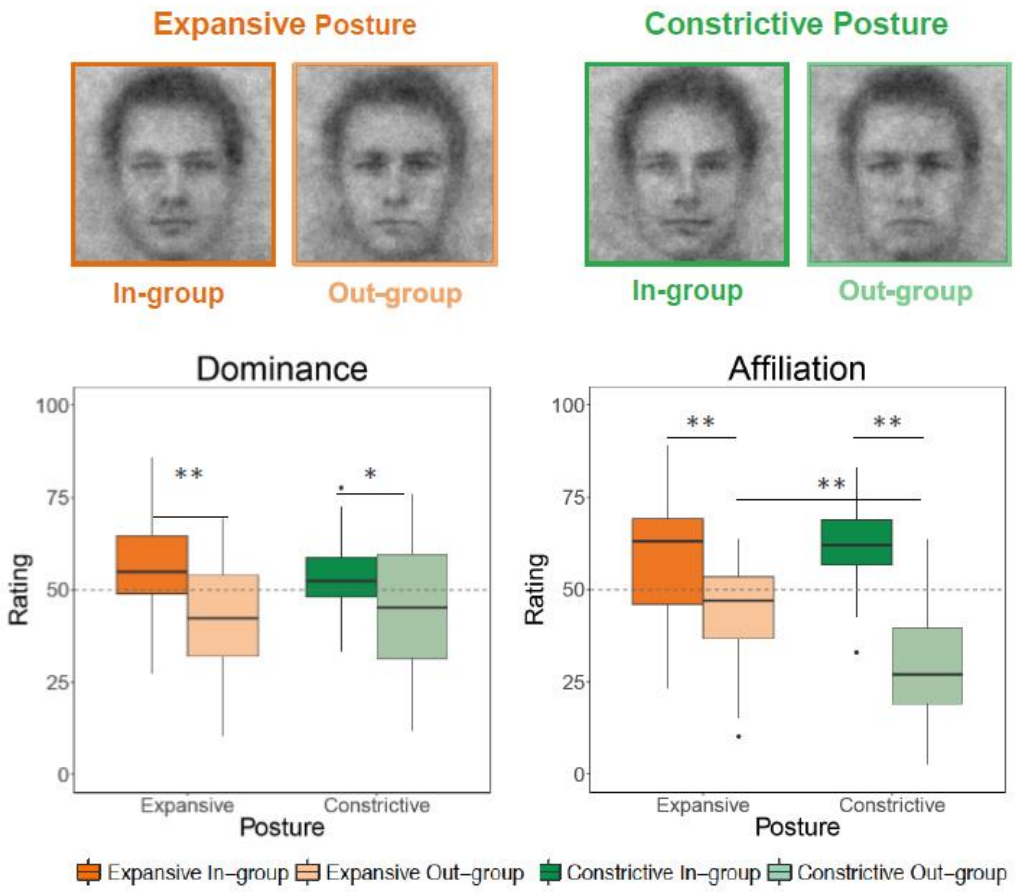

Figure 7. Combined in- and out-group CIs from the expansive and constrictive condition including data from Study 1 and 4, and rating scores of these combined CIs on the dominance and affiliation dimension. ** = p<.001, * = p<.05. The dashed line at 50 represents a neutral trait judgement.

Results

Analyses of dominance ratings showed that in-group faces were rated as more dominant than out-group faces ($F(1,39)=20.35$, $p<.001$, $\eta_G^2=.14$). A non-significant interaction indicated that this effect did not differ between posture conditions ($F(1,39)=2.58$, $p=.117$, $\eta_G^2=.01$, expansive: $t(39)=4.54$, $p<.001$, $d=0.93$, constrictive ($t(39)= 2.66$, $p=.011$, $d=0.54$). On the affiliation dimension, in-group faces received much higher ratings than out-group faces (Group: $F(1,39)=98.62$, $p<.001$, $\eta_G^2=.45$). This comparison was significant in both postures (expansive:

t(39)=5.45, p<.001, d=0.94; constrictive: t(39)=11.50, p<.001 d=1.58). Against our prediction however, this intergroup difference was larger in the constrictive than the expansive posture condition ($F(1,39)=40.87$, $p<.001$, $\eta_G^2=.11$), due to more affiliative ratings for the out-group CI from the expansive than the constrictive condition t(39)=6.86, p<.001, d=0.95). The in-group CIs were not rated differently (t(39)=1.41, p=.166, d=-0.25). Ratings of the mean group CIs are depicted in Figure 7, and means and confidence intervals for ratings scores are reported in Table S5.

Discussion

Ratings of combined CIs from Study 1 and 4 revealed clear group effects, which were larger on the affiliation than the dominance dimension. These results replicate the intergroup bias in mental representations described by Ratner and colleagues (2014) and confirm that mere assignment to an arbitrary group elicits more positive representations of in-group members. Most importantly, in-group images received equally high ratings on affiliation and equally moderate ratings on dominance for both posture conditions, suggesting that the adopted posture did not influence implicit interpersonal preferences. Unexpectedly, the out-group representation from the expansive posture condition was judged as more affiliative than the one of the constrictive condition. We had not observed this effect in any of the studies that were combined for this meta-analysis. In addition, the literature would, if anything, predict stronger out-group prejudice in individuals with high social power (Goodwin, Operario, & Fiske, 2010; Guinote, Willis, & Martellotta, 2010; Hewstone, Rubin, & Willis, 2002). From this, one would expect a larger rather than a smaller intergroup difference on the affiliation dimension in the expansive condition. This unexpected result might simply constitute further evidence for the high variability implicitly assessed mental representations. Yet, additional evidence would be needed to definitively prove that the out-group difference on affiliation does not reflect a true postural feedback effect.

In conclusion, combining CIs from Studies 1 and 4 revealed no postural feedback effect on mental representations of in-group faces. This suggests that the strikingly strong effects on in-group representations in Study 1 were more likely the result of random variability than the result of a true postural feedback effect.

General Discussion

The present series of five studies illustrates how seemingly large and coherent effects do not necessarily indicate robust effects, particularly if the dependent measure is highly variable. A first study had shown that constrictive postures induced affiliative and self-confident mental representations of in-group members' faces, while expansive postures eliminated such implicit in-group preferences. The fact that a second study revealed no influence on mental representations of explicitly preferred faces appeared to suggest that postures may only affect implicit and not explicit social preferences, or only affect preferences in particular social contexts. We could have concluded that postures affect how we imagine others only if we anticipate interacting with them, but not when we explicitly focus on their social traits. However, a permutation experiment and a non-replication demonstrated that such interpretations would have relied on inconclusive evidence. Moreover, we did not observe any postural feedback effect on implicit needs for power and affiliation or the explicit need to belong, and did not replicate previously reported effects on explicit feelings of power. Altogether, these findings provide more evidence against (Study 2 and 4) than for (Study 1) an impact of postural feedback on mental representations of other's faces, although definite conclusions are not possible yet. A sort of meta-analysis of Study 1 and 4, in which combined in- and out-group representations from both studies were rated by another sample, entails the same conclusion: postural feedback does not seem to impact mental representations of in-group faces, and thus on implicit social preferences.

The present series of studies has two main methodological implications. First, regarding reverse correlation, the difference between in- and out-group representations in the first study and its replication raise concerns about the reliability of classification images generated with implicit tasks. Both the images themselves and their ratings showed that group CIs from the two studies did not resemble each other. In contrast, the preferred face images of both participant groups in Study 2 looked almost perfectly alike. We assume that the variability of implicitly assessed classification images matters less for large and robust effects such as intergroup bias. We observed higher affiliation ratings for the in-group than the out-group in five out of six group CI pairs acquired in our studies (all except the expansive CI pair in Study 1), which demonstrates a relatively robust intergroup effect. Thus, for large effects, testing sample sizes larger than ours (see e.g. Ratner et al. 2014) seems to be a reasonable solution. Yet, reverse correlation studies addressing smaller or less robust effects with an implicit task design should cautiously consider the high variability of implicit mental representation images.

Second, the present paper suggests ways for progress in the ongoing debate about replicability regarding postural feedback effects (see Cesario et al., 2017). The fact that the effects of Study 1 did not replicate in Study 4 underlines the importance of replication even when effects seem large and predicted. A permutation approach helped to identify high variability of the dependent measure as a potential reason for these conflicting results. Since the likelihood of false positives increases with reduced reliability of dependent measures, such assessments of variability may be useful to better target replication efforts towards studies that may represent true postural feedback effects. For instance, high variability of salivary testosterone levels (Wood, 2009) and of risk-taking assessed with one single trial could for example explain why the initial study on power postures (Carney et al., 2010) found significant effects which later failed to replicate (Cesario & Johnson, 2017; Davis et al., 2017; Garrison et al., 2016; Ranehill et al., 2015; Ronay et al., 2016; K. M. Smith & Apicella, 2017). Assessing the variability of dependent measures via permutation approaches on existing datasets in the posture literature may be an efficient way to identify reliable dependent measures and then direct replication efforts towards promising studies. Finally, between-subject variability might have increased the rate of false positive results in posture research, which typically used between-subject designs with small sample sizes. Adopting within-subject designs in future studies would circumvent this problem and simultaneously increase statistical power and thus replicability (Open Science Collaboration, 2015).

In conclusion, our results demonstrate that adopting power-related body postures does not impact explicit interpersonal preferences assessed by visualizing mental representations of faces of people one likes. Regarding implicit interpersonal preferences, adopting a rigorous methodological approach avoided drawing conclusions when these were not actually warranted given empirical evidence. Based on our results, we can currently neither assume nor rule out an effect of power postures on implicit preferences assessed by visualizing mental representations of in-group faces. Overall, our results provide more evidence against than for an impact mental representations of in-group faces. However, mental representation images created with reverse correlation methods might not have been an ideal measure to assess posture effects on explicit and implicit interpersonal preferences. Therefore, given that postural expansiveness has a fundamentally social function, we believe that postural feedback effects on elementary social behaviours merit further investigation. Assessing effects on implicit social behaviours seems more promising, first because implicit measures are less susceptible to demand effects and second because preliminary findings suggest an impact implicit but not explicit processing of threat-related expressions (Chadwick et al., 2018; Chapter 4 of the current thesis)

Supplementary Information

Sample Size determination

In-out-group and preferred face selection task

Since the reverse-correlation technique requires a two-step procedure for statistical evaluation of results, a power-analysis can only indicate the necessary sample size for the second part, namely the rating of the CIs. For the first part, i.e. the face selection task, the necessary number of noise patterns to obtain a grand average CI with characteristic features strongly depends on the mental representation of interest. For basic social traits such as trustworthiness or dominance, of which most people possess clear mental representations, 6000 noise patterns were sufficient (Dotsch & Todorov, 2012; Ratner et al., 2014). Since in- and out-group representations are likely more vague, we determined a minimal number of 35 participants per posture condition (total n=70) and a trial number of 600, to reach a total of 21000 noise patterns per average group CI. We chose 35 participants per posture as this was as high as the largest sample sizes per posture used in studies using similar body manipulations published prior to recruitment for Study 1. The studies available at that time included in between 18 and 38 participants (Bohns & Wiltermuth, 2012; Carney et al., 2010; Cesario & McDonald, 2013; Cuddy et al., 2015; Fischer et al., 2011; Huang et al., 2011; Park et al., 2013). We eventually included noise patterns of 73 and 72 participants in the average in- and out-group CIs in Study 1 and 4, respectively. Concerning Study 2, we assumed mental representations of faces one prefers explicitly to be as easy accessible as those of basic social traits. We thus targeted a sample size of 25 participants (total n=50) per posture condition to achieve 600 x 25 = 15000 noise images per average CI. The final sample includes 48 participants.

Part 2: Face Ratings in Study 1, 2, 3 and 4 and 5

We performed a power-analysis with the pwr-package in R (Champely, 2015) based on Ratner et al. (2014), who compared online ratings of in- and out-group CI on various single adjectives. Effect sizes for the adjectives yielding significant in-out-group differences lay between 0.43 and 1.23, which corresponds to sample sizes between 8 for the largest and 44 for the smallest effects to reach a statistical power of 80%. In contrast to Ratner et al., we performed the rating experiment in the laboratory to create optimal conditions for stimulus presentation, participant motivation and attention. In order to maximize the precision of our measure, we performed statistical tests on total scores calculated from ratings on 8 different adjectives, instead of analysing ratings on single adjectives. Under these optimized conditions, we thus aimed at a sample size of 35, which should be large enough to detect small effects on the total scores between in-out-group representations within each posture condition. Eventually, 35 participants rated the CIs form Study 1 and 2. Replication of the resulting effects on ratings in Study 3 with 31 indicated that this sample size was sufficiently large. In- and out-group CIs in Study 4 and 5 were rated by 36 and 40 participants, respectively.

Posture instructions

Expansive condition: "Spread your feet at the width of your shoulders and turn your feet outwards. Place your hands on your hips with the thumb backwards and keep your elbows approximately parallel. Look straight ahead and don't tilt your head downwards. The posture needs to be comfortable." Constrictive condition: "Cross your legs and put one foot next to the other. Now, lay one arm across your belly and place the other one on top, but do not cross your arms. Look at the floor in front of you and relax your back and shoulders."

Study 1

Table S1. Means and Confidence intervals for Study 1 ratings of in- and out-group CIs.

Trait	Image	Posture	
		Expansive	**Constrictive**
Dominance	In-group	39.32 [34.22, 44.42]	54.97 [50.95,58.99]
	Out-group	42.25 [37.21,47.29]	42.16 [35.30,49.02]
Affiliation	In-group	34.71 [29.18,40.24]	68.98 [63.79,74.17]
	Out-group	34.03 [28.19,39.87]	33.07 [27.97,38.17]

Study 3

Replication of Study 1 and 2 CI ratings

Mean in-group and preferred CIs from Study 1 and 2 were again rated in Study 3 to assess the reliability of our rating scales, and check whether four adjectives would yield the same pattern of total scores as eight adjectives per dimension. Dominance ratings of in- and out-group CIs suggested an effect of group ($F(1,30)=6.26$, $p=.018$, $\eta G2=0.05$), no effect of posture ($F(1,30)=1.22$, $p=.278$, $\eta G2=0$) and revealed a significant group by posture interaction

(F(1,30)=11.8, p=.002, ηG2=0.06). Exactly as in Study 1, post-hoc comparisons indicated a significantly higher dominance rating for the in-group CI from the constrictive condition, as compared to the out-group CI of the same condition and to the in-group CI from the expansive condition. Dominance scores of the in- and out-group CI from the expansive condition did not differ significantly (see Supplementary Table S2 & S3 for t-tests, means and confidence intervals).

Affiliation ratings yielded significant main effects of posture F(1,29)=41.85, p<.001, ηG2= 0.22) and group (F(1,29)=130.13, p<.001, ηG2=0.55) and a significant interaction (F(1,29)=214.25, p<.001, ηG2=0.56). The interaction was characterised by high affiliation ratings for the in-group CI from the constrictive condition, and lower ratings for the other three CIs as in Study 1 (see Table S2 & S3 for further details). There was only one minor difference to the results in Study 1 calculated based on eight adjectives: Affiliation ratings of out-group CIs were similar in Study 1, but higher for the out-group CI of the expansive vs. the constrictive condition. Yet, the identical effect occurred in Study 1 when calculating affiliation scores with only four adjectives. Hence, in both studies, high affiliation words captured a difference between out-group CIs from the two posture conditions, while low affiliation words did not. In conclusion, we exactly replicated the results of Study 1, indicating that rating measures we obtained were reliable.

Preferred CIs from the expansive and constrictive condition were both rated as highly affiliative (expansive: 81.01 [76.44, 85.58], constrictive: 79.90 [76.25, 83.55], t(29)=0.56, p=.581, d=0.10) and moderately dominant (expansive: 59.71 [55.10, 64.32], constrictive: 62.89 [58.15, 67.63], t(30)=-1.44, p=.160, d=-0.24).

Table S2. Paired t-tests for in- and out-group CIs. T-tests with asterisks remain significant after Bonferroni-Holm correction.

Trait	Comparison		df	t	p		d
Dominance	In-group	E vs C	30	-3.18	.003	*	-0.66
	Out-group	E vs C	30	1.97	.055		0.31
	Expansive	In vs Out	30	-0.17	.869		-0.03
	Constrictive	In vs Out	30	3.75	.001	*	0.87
Affiliation	In-group	E vs C	29	-13.26	<.001	*	-1.72
	Out-group	E vs C	29	5.93	<.001	*	0.97
	Expansive	In vs Out	29	-1.11	.275		-0.23
	Constrictive	In vs Out	29	16.73	<.001	*	1.80

Table S3. Means and confidence intervals for in- and out-group CI ratings in Study 3.

Trait	Image	Posture	
		Expansive	Constrictive
Dominance	In-group	45.40 [38.79, 52.01]	56.35 [52.18, 60.52]
	Out-group	46.00 [39.67, 52.33]	39.77 [32.26, 47.28]
Affiliation	In-group	31.80 [27.17, 36.43]	76.15 [71.54, 80.76]
	Out-group	34.94 [29.77, 40.11]	19.21 [14.15, 17.31]

Study 4

Implicit and explicit measures of affiliation and power feelings or needs

Table S4: Means and Confidence intervals of subjective explicit and implicit power and affiliation measures before and after the posture manipulation

Feeling or need	Type of Measure	Time	Expansive posture	Constrictive posture
Power	Explicit	Pre	66.02 [57.79, 74.25]	70.65 [62.59, 78.71]
		Post	66.55 [58.65, 74.45]	69.65 [62.24, 77.06]
	Implicit	Pre	50.55 [46.65, 54.45]	53.73 [49.56, 57.90]
		Post	51.15 [47.50, 54.80]	51.29 [46.70, 55.88]
Affiliation	Explicit	Pre	55.37 [49.04, 61.70]	49.15 [42.88, 55.42]
		Post	53.30 [47.58, 59.02]	49.94 [44.18, 55.70]
	Implicit	Pre	39.53 [35.59, 43.47]	38.08 [33.30, 42.86]
		Post	40.36 [37.30, 43.42]	37.57 [31.91, 43.23]

Study 5

Table S5. Means and confidence intervals for ratings of in- and out-group CIs, and Cohen's dav effect sizes for between-posture comparisons.

Trait	CI	Expansive	Constrictive	d_{av} posture
Dominance	In-group	56.64 [52.78, 60.50]	52.73 [49.83, 55.63]	0.35
	Out-group	42.74 [38.37, 47.11]	44.70 [39.09, 50.31]	-0.12
Affiliation	In-group	58.88 [54.25, 63.51]	62.20 [58.85, 65.55]	-0.25
	Out-group	43.76 [39.53, 47.99]	28.58 [24.01, 33.15]	0.95

Chapter 7
Does your body affect your actions? Power posture effects on approach and avoidance actions under social threat

When I was about to run the study on action decisions, I had become sceptical about whether any postural feedback effects were reproducible. Yet, I also believed that bodily feedback was most likely to have an effect when the agent actually makes decisions about bodily actions. Given that postures that express power only unfold their full meaning in relation to others, their effects may further only emerge when agents actually interact with others. Emma Vilarem, a former PhD student in the team, had developed task that depicted a realistic social context in which participants had to make actual action decisions in response to social threat signals (Vilarem, Armony, & Grèzes, under review). We therefore decided to use this task in a last study on postural feedback effects with a particularly sound methodological approach. To exclude the possibility that effects would arise from pre-existing group differences and reduce the likelihood of false positive results, we used a within-subject design and tested a large sample to achieve high statistical power.

With regard to different accounts of embodied cognition, the question about whether power-related body postures impact approach and avoidance actions in response to social threat signals is most tightly related to the view that cognition serves to control action. Building on Gibson's ecological approach to visual perception (Gibson, 1979), facial emotion expressions have been conceptualized as social affordances, that is, social signals that communicate opportunities for action (Grèzes & Dezecache, 2014; McArthur & Baron, 1983; Zebrowitz, 2006, 2011). For instance, anger conveys the possibilities to either avoid conflict or seek confrontation, while fear signals an opportunity to flee from danger or to affiliate with a potential ally. If emotions communicate opportunities for action, both characteristics of the signal and the observer determine what constitutes an adaptive action (Gibson, 1979; Zebrowitz, 2006). Hence, the observers' characteristics, such as his state, needs, body shape or motor capacities, constrain which out of all available action opportunities in response to a given social signal should be selected. If the brain's function is to successfully navigate the body through the world, that is, to select the appropriate bodily actions, then the body's posture provides essential information for decisions about impending actions (Cesario & McDonald, 2013). Dominance rank is one of the most crucial characteristics to determine which action opportunities are available to an observer upon perception of an angry or fearful conspecific. Additionally, expansive and constrictive postures are valid social signals of an individuals' dominance rank, given their display corresponds to individual's actual dominance level (Hall et al., 2005). Thus, within the framework of emotions as social affordances, adopting an expansive or constrictive posture may impact approach and avoidance in response to other's emotional displays by activating representations of dominance and submissiveness, respectively. [7]

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[7] This is a draft manuscript to be submitted for publication as: Hannah Metzler, Emma Vilarem, Adrian Petschen, Julie Grèzes. Power posture effects on approach and avoidance actions under social threat.

Abstract

Individuals' opportunities for action in threatening social contexts largely depend on their power or dominance status. While powerful individuals can afford to fight off aggressors and confront dangers, powerless individuals are better off avoiding direct challenges and searching for allies for social protection. Here, we investigate if adopting expansive or constrictive postures, which function as social signals of power, impacts on individuals approach and avoidance decisions in response to the threat signals of others. Given the current debate on the replicability of postural feedback effects, it is crucial to test effects on elementary social behaviour congruent with the social signalling function of postural expansiveness. Participants performed approach or avoidance actions by choosing one of two free chairs in a scene depicting a realistic social context, of which one was next to an individual expressing anger or fear and the other next to a neutral individual. While a first task session served as within-subject baseline, participants adopted an expansive or constrictive posture between the blocks of a second session. Overall, participants more frequently avoided angry displays, which communicate strength and potential imminent aggression, but showed no clear approach or avoidance preference for fearful displays, which are more ambiguous threat signals and further convey a potential opportunity to affiliate. Constrictive postures considerably increased avoidance of angry individuals, whereas expansive postures induced no significant changes. This finding suggests that bodily feedback from one's own posture impacts on implicit social decisions in a manner related to the power it embodies.

Keywords: body posture, power, approach, avoidance, emotion, threat

Introduction

Efficient detection and reaction to threat clearly provide survival advantages. Which action is most adaptive when responding to threat signals emitted by others largely depends on the relative dominance rank or social power of the interacting individuals. While more powerful individuals can afford to confront others and fight off aggressors, less powerful individuals are better off avoiding conflicts and seeking social support as a means of protection. In other words, individuals' opportunities for action in social threat contexts are constrained by their power and dominance status. Nonverbal threat dominance displays involve expansion of the body in many social species, such as for example chimpanzees, rodents, birds, wolfs, dogs, and crickets (de Waal, 2007; Grant & Mackintosh, 1963; Hagelin, 2002; Schenkel, 1967; Stevenson et al., 2000). Large bodies imply physical strength and thus signal threat, while small bodies signal submission and vulnerability (Mehrabian, 1981; Schuett, 1997; Sell et al., 2009; Tokarz, 1985). Humans use analogous nonverbal displays to express social power and dominance, for example following competitive interactions (Hwang and Matsumoto 2014). Expansive body postures signal high dominance, power and social status (Hall et al. 2005) and success (Tracy & Matsumoto, 2008; Weisfeld & Beresford, 1982), while constrictive postures convey low dominance, power, status and defeat. Here, we investigate whether adopting expansive or constrictive postures, which function as social signals of power, impacts on individuals' decisions in response to the threat signals emitted by others.

Building on theories of embodiment, which posit that many features of cognition and motivation are shaped by representations of body actions, a number of studies (Duclos et al., 1989; Riskind, 1984; Riskind & Gotay, 1982; Stepper & Strack, 1993) examined whether body posture influences the individuals' own feelings, moods and behaviour. Applying this idea to the domain of power, Carney, Cuddy and Yap (2010) tested whether adopting expansive or constrictive postures for only two minutes could significantly affect subjective feelings of power and control, risk-taking behaviour and levels of testosterone and cortisol, two hormones associated with social status and stress, respectively (Mehta & Josephs, 2011). Although the study found evidence in favour of these hypotheses, later studies could not reproduce its results (Bailey et al., 2017; Bombari et al., 2013; Cesario & Johnson, 2017; Davis et al., 2017; Garrison et al., 2016; Keller et al., 2017; Ranehill et al., 2015; Ronay et al., 2016; K. M. Smith & Apicella, 2017), which gave rise to an ongoing debate about the replicability of the postural feedback effects reported in this and many follow-up studies. Given the small sample sizes and between-subject designs in many past studies (for references, see Carney et al., 2015; Cuddy et al., 2018), some posture effects could indeed result from random between-group variability. Additionally, the studies used primarily explicit self-report measures which are susceptible to experimental demand effects (Gronau et al., 2017; Jonas et al., 2017). Most importantly, however, the existing studies mainly investigated posture effects on non-social or high-level cognitive behaviours, thereby underestimating the fundamentally social and communicative nature of these dominance displays in various animal species. Although past research illustrates that both current power status (Schultheiss and Hale 2007, Yap et al. 2013) and socially meaningful body actions (Niedenthal, 2007) have the potential to distort our perception of the social world, only one recent study has so far investigated effects of expansive and constrictive postures on social perception (Chadwick et al., 2018). Findings suggest that the observers' body posture determines which social threat signal becomes most salient to them: while angry expressions with direct gaze (signalling a dominance challenge towards the observer) improved performance in a scene discrimination task after expansive postures, fearful expressions with averted gaze (a signal of danger in the environment) improved performance after constrictive postures. The question remains however as to whether adopting such postures also impact the agent's action-related decisions in response to other's social signals. Like Chadkwick et al. (2018), we focus on responses to social signals of threat, given that power most crucially determines individuals' action opportunities in threatening contexts.

One of the most fundamental decisions individuals take in social contexts is whether to approach or to avoid others, depending on the social displays they emit. We investigated approach and avoidance actions towards individuals that express threat-related facial expressions of anger and fear. While these two emotional expressions are both of negative valence, they convey different social meanings (Sander et al., 2007; Springer, Rosas, McGetrick, & Bowers, 2007). Facial expressions of anger are thought to have evolved to enhance cues of strength and dominance (Sell, Cosmides, & Tooby, 2014) and communicate the emitter's aggressive intent (Reed, DeScioli, & Pinker, 2014).Being perceived as a direct threat to the observer (Sander et al., 2007), anger displays should thus clearly elicit avoidance (e.g. Enter, Spinhoven, & Roelofs, 2014; E.-M. Seidel, Habel, Kirschner, Gur, & Derntl, 2010). Fearful displays, in contrast, are more ambiguous in terms of avoidance and approach behaviours. On the one hand, by signalling the presence of an imminent danger in the observer's environment, they should prompt avoidance behaviours (Paulus & Wentura, 2016). Yet, by enhancing facial cues of vulnerability and affiliation which appease social interactions and inhibit aggression (Hess et al., 2000; Knutson, 1996; A. A. Marsh, Adams, et al., 2005; Sell et al., 2014), fearful displays could also elicit approach behaviours (Hammer & Marsh, 2015; Marsh, Ambady, & Kleck, 2005). Approach and avoidance actions towards individuals expressing anger or fear in a realistic social context corroborate these predictions (Vilarem et al., under review). In a scene depicting a waiting room with two free chairs, of which one is next to an individual displaying an angry facial expression, the other next to a neutral individual, participants more often chose the chair away from the angry individual, although they did not perceive the emotion explicitly. In contrast, when one individual expressed fear, approach and avoidance decisions were balanced.

To assess posture effects on approach and avoidance decisions in response to angry and fearful displays, we used the above-described task developed by Vilarem et al. (under review) in two consecutive sessions: the first session, without posture, served as within-subject baseline, while in the second session, participants adopted either an expansive or a constrictive posture before each task block. This resulted in a study design with emotion and session as within-subject factors and posture as a between-subject factor. We expected that adopting expansive and constrictive postures would impact approach and avoidance decisions in response to social threat signals as a function of the level of power they embody. Greater physical and social resources (Keltner et al., 2003) enable powerful individuals to better cope with social threat, such as an angry opponent. Moreover, power increases approach motivation in general (Guinote, 2017; Keltner et al., 2003) and decreases vigilance towards threat (Anderson & Berdahl, 2002; Willis et al., 2011). Correspondingly, manipulations of power induced opposite approach and avoidance tendencies in response to sustained direct eye gaze, another social threat and dominance signal. While a staring onlooker elicited approach tendencies in high-power individuals, it triggered avoidance in low-power individuals (Weick et al., 2017). Consequently, if expansive postures activate representations of power, they should decrease avoidance while constrictive postures should increase avoidance of an angry individual. Our predictions for fearful displays were more speculative, given that they are both a threat and an affiliation signal. If participants were more sensitive to the threat aspect, stronger avoidance after a constrictive than an expansive posture should be expected, akin to anger displays. If, however, participants focused more on the affiliative aspect of fearful displays, a different pattern should be expected. Lack of power increases affiliation motivation (Case et al., 2015) and subtle cues of low as compared to high social status increase pro-social behaviour (Guinote et al., 2015). Hence, constrictive (low-power) postures should increase approach towards fearful individuals, who signal a need for help and represent potential allies in the defence against threat.

Methods

Stimuli and task

Stimuli (see Vilarem et al., under review for more details) were presented using Psychophysics Toolbox 3 (Brainard, 1997; Kleiner et al., 2007) in MATLAB (MathWorks, Inc., 2014), using. Upon presentation of a scene depicting a realistic social environment consisting of a waiting room with four seats, participants choose on which of the two outer seats they want to sit, given the two middle ones are already occupied (Figure 1). The faces of the individuals sitting on the two middle seats consisted of 10 pairs of individuals matched for gender, and face ratings of threat and trustworthiness. While one of them always displayed a neutral facial expression, the second individual displayed either a neutral, angry, or fearful expression in one third of the trials, respectively. Expressions of anger and fear varied along 4 levels of intensity (morphs between the neutral and the full emotional expression, equalized for perceived emotion intensity, for details see El Zein et al., 2015). However, we did not investigate the effect of intensity, since investigation of posture effects in a within-subject design already requires a complex design with 3- and 4-fold interactions. We fully counterbalanced which individual expressed the emotion and the side on which it was presented. This resulted in a total of 480 trials per session (10 pairs x (2 emotions x 4 intensity levels + 1 neutral expression x 4 repetitions) x 2 identities displaying the emotion x 2 side of the emotional individual.

Each trial started with a grey screen of 1000ms, onto which a fixation cross was then superimposed for 500ms, followed by the scene with the mouse cursor at the bottom centre. Participants were instructed to keep their eyes on the fixation-cross located between the faces throughout the trial. As soon as the scene appeared, they were to click the left mouse button and move it onto the chair of their choice, where they were to release the click. If they managed to release the click within the chair area within 1400ms after scene onset, a tick appeared for 300ms at the release location to indicate a successful movement. The next trial was initiated by the release of the mouse button or after 1400ms if no response occurred. We recorded the choice of chair (moving away or toward the emotional individual), initiation time (time from presentation of the scene to mouse click) and movement duration (time from mouse click at the bottom centre to release on top of a chair).

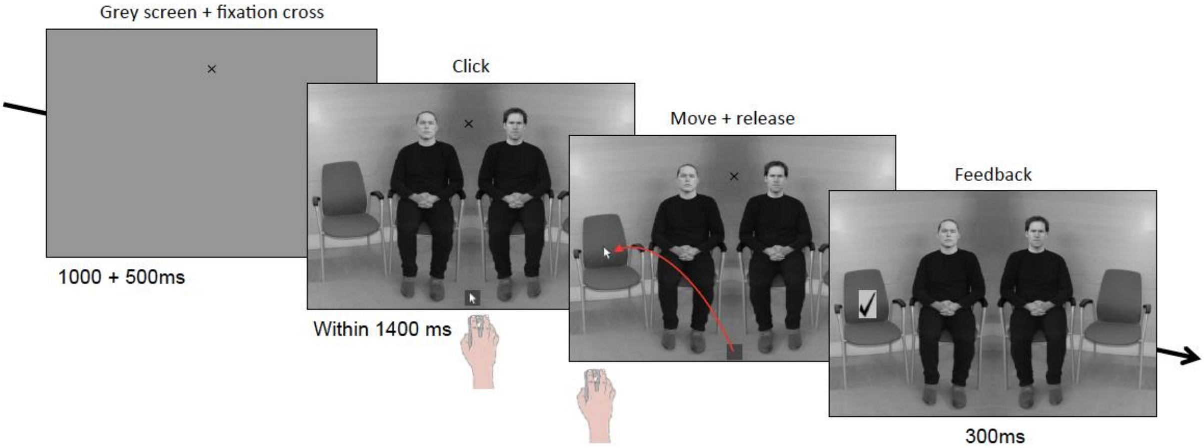

Figure 1. Stimuli, timing and task of participants

Participants and power analysis

We used a partial eta-squared (η^2_p) of 0.30 as an estimate for the main effect of emotion on the proportion of away choices, which was the smaller effect size from two previous experiments using the same task (Study 1 in Vilarem et al., under review, η^2_p = 0.36, and Menella, Vilarem & Grèzes, in preparation, η^2_p= 0.30). Entering η^2_p= 0.30 (corresponding to f=0.65, option "as in SPSS") in a power-analysis for a repeated-measures one-way ANOVA in G-Power (Faul et al., 2007) indicated a minimal sample size of n=22 to detect the effect of emotion with 80% power. As we were interested in testing an interaction with posture, we needed to at least double this number (Simonsohn, 2015), i.e. to test 22 participants in each posture group. However, simply doubling sample size is only sufficient if one anticipates complete suppression of the effect in one group, which we did not. Instead we expected the emotion effect to get larger in the constrictive posture and smaller in the expansive posture, with the real extent of this change being unknown. Given that no effect size estimates for similar implicit social behaviours were available in the literature, we again doubled this number, aiming at 44 participants per posture group, assuming that multiplying the estimated sample size by 4 should provide sufficient power to detect a significant posture (between-subject) by emotion (within-subject) interaction on the change in proportion of choices from the first to the second session. Additionally, we conducted a sensitivity analysis to determine the minimal effect-size we could reliably detect with a power of 80% using the final sample size of n=79 after exclusion. This yielded a minimal effect size η^2_p=0.10 (f=0.33 in G-Power), meaning we had at least 80% power for effects larger than this, and less than 80% for smaller effects.

We recruited a total of 88 healthy, right-handed, fluently French speaking men between 17 and 35 participants via a mailing list and online student job platforms. All had normal or corrected vision, were not currently under medical treatment, and did not suffer from ocular pathologies or ocular fatigue in front of a screen. Due to a technical error, data of 2 participants was lost. Another participant was excluded because he did not achieve 60% accuracy (see procedure for explanations) after repeating the training three times. Six additional participants had to be excluded because their click and movement duration distribution indicated that they did not perform the mouse movement as instructed in at least 50% of all trials (see section data analysis for details), resulting in a final sample of 79 participants with a mean age of 22.70 ± 3.64 years. Out of these, 40 participants had been randomly assigned to the expansive and 39 to the constrictive posture condition. All participants were treated in accordance with the Declaration of Helsinki, provided written informed consent and were paid for participation.

Questionnaires

Participants completed the French version of the State-Trait Anxiety Inventory (STAI, Spielberger, 1983), the Behavioural Inhibition and Activation System Scales (BIS/BAS, Caci, Deschaux, & Baylé, 2007), the Rosenberg Self-Esteem Scale (Vallières & Vallerand, 1990), and four scales (PA, LM, HI, DE) from the Interpersonal Adjective List – Short Version (Jacobs & Scholl, 2016). For the latter, a dominance and affiliation score were calculated as (PA + reversed HI)/2 and (LM + reversed DE)/2, respectively. All questionnaires except the state version of the STAI were filled out online prior to the testing day.

Procedure

After arrival, participants signed consent forms and completed the STAI state questionnaire. The male experimenter informed them that they were going to participate in two separate studies, the first investigating spontaneous action choices and the second effects of body postures on heart rate. During instructions for the spontaneous action choice task, participants were told to choose the chair as if they had to make the choice in a real situation, and that there was no good or bad answer, as long as they managed to correctly release the cursor within one of the chair areas. The experimenter emphasized the importance of fixating the cross throughout the trial instead of exploring the rest of the scene, claiming that we were interested about the capacity to make action choices in the periphery of the visual field. They underwent a short training session with neutral facial expressions only, during which the area on top of each chair was indicated with a blue rectangle, until they accurately landed on the chair in at least 60% of trials. Participants were asked to maximize the number of correct trials, and their accuracy score was displayed at the end of each block throughout the experiment. In total, there were 10 blocks à 96 trials with a mean duration of 6.5 ± 1.95 SD minutes and participants reached mean accuracy scores of 91.3% ± 5.37 SD.

Regarding the second study, we claimed that we needed to register heart rate data for a total duration of 10 minutes while they held the same posture. Supposedly in order to avoid discomfort, we had decided to divide this total duration in five separate 2-minute intervals, inserted between the blocks of the action choice task. To allow them to fully focus on the relatively difficult task at the beginning, they would first perform the 5 blocks without posture. Thereafter, they would adopt the posture for 2 minutes before each of the last 5 blocks, which offered the additional advantage of short breaks for the eyes, avoiding tiredness from fixating the cross on the screen towards the end of the experiment.

After receiving these instructions, participants performed the first 5 blocks of the experiment (session 1). Thereafter, the experimenter attached electrodes to their hand-wrists and demonstratively turned on the acquisition system, although we did not record any heart-rate data in reality. He informed participants that he would observe their posture via a small camera to verify that it was correct and similar each time. Finally, after randomly determining the posture condition via a MATLAB function, he verbally provided instructions (see Supplementary Information) for either the expansive or constrictive posture (Figure 2), taking care not to demonstrate it himself, and left the room. Ensuring that the experimenter did not know the participant’s posture condition until the last minute of the instructions was meant to minimize possible experimenter biases. At the end of the experiment, participants were carefully debriefed regarding their decisions strategies during the action choice task and their ideas about the purpose of both studies. Only 12 participants mentioned facial expressions as one of the factors influencing their decisions, but none of them specifically mentioned anger and fear when directly asked which expressions they had recognized. Around half of participants listed a range of negative and positive emotions or simply noticed changes of eyebrows and the mouth. Finally, only two participants correctly suspected a link between the action and the posture study. Excluding them from the analysis did not alter the results.

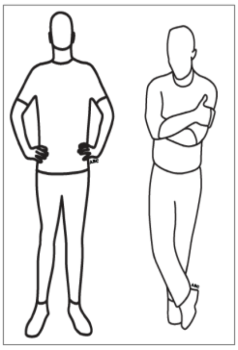

Figure 2. Expansive and constrictive body postures (Images created by Antoine Balouka-Chadwick).

Data analysis

After exporting data from Matlab, all analyses were conducted in R version 3.4.4 (R Core Team, 2018) using the packages dplyr, tidyr, ez, ggplot2 and psych (Lawrence, 2016; Revelle, 2017; Wickham, 2009; Wickham et al., 2017; Wickham & Henry, 2018) in addition to those mentioned separately below. Only correct trials (landing inside one of the chair areas within 1400ms after scene onset) were included in the analysis. For correct trials, inspection of the frequency distribution of initiation time revealed a small peak around 50-100ms in addition to the main peak around 400-500ms, suggesting that participants anticipated scene onset in a certain number of trials due to the fixed duration of the inter-trial interval, instead of waiting until scene onset as instructed. We therefore excluded trials with initiation times below the 5th percentile, that is, below 95ms. Furthermore, the distribution of movement duration, together with coordinates of click and release location, revealed a certain number of trials in which some participants had started moving the mouse before clicking contrary to the instructions. Instead of holding the mouse button while moving, they both clicked and released within the chair area, which resulted in very short movement durations. As for initiation time, we thus filtered trials for movement durations below the 5th percentile, corresponding to movement durations shorter than 184ms. To ensure a sufficient number of trials per participant, we required at least 50% of valid trials per session above the respective 5th percentile threshold for both initiation time and movement duration, which entailed the exclusion of 6 participants. Mean trial number per emotion condition (anger, fear, neutral) for all remaining 79 participants was 132.6 ±17.22 with a range of 65-158 trials. Finally, initiation time and movement duration were log-transformed to correct for the obvious right skew typically observed in reaction time distributions.

To analyse choice (away vs. toward) and movement kinematics we used generalized linear mixed models with a logit link function and linear mixed models, respectively, as implemented in the lme4 package (Bates, Mächler, Bolker, & Walker, 2015). In contrast to ordinary logistic and linear regression, mixed-effect models (also known as multilevel models) allow accounting for repeated-measures. In our design, the factors emotion (anger, fear), side (moving away or toward the motional individual; only for kinematics analyses), and session (session 1 no posture, session 2 with posture) were within-subject factors, while posture (expansive, constrictive) was a between-subject factor. The baseline level for each factor was set to fear, toward, session 1 and expansive, respectively, so that parameter estimates describe the change from this to the other level of each factor. All models were run with a random intercept per participant and all main effects and interactions as fixed effects. We further tried to include random slopes for the highest within-subject factor interaction of interest (e.g. emotion by session for choice) in each model in order to avoid inflated Type 1 error rates. However, none of the random effect structures including random slopes converged. Significance of fixed effects was assessed using model comparison, and alpha was set to $p<.05$.

Mixed-effects models offer several advantages over traditional ANOVA approaches (Baayen, Davidson, & Bates, 2008; Jaeger, 2008). Of interest here is that they perform well on imbalanced data, which enabled us to handle the unequal sample size per posture after exclusion (expansive: 40, constrictive: 39), and the varying number of trials per condition after filtering. Furthermore, these models do not require averaging per condition and participant, but use data at the single-trial level, which is particularly relevant for binomial outcome variables such as choice, where averaging can produce hard-to-interpret results in ANOVAs (Jaeger, 2008). To allow comparison with previous studies and conclusions regarding our power analysis, and to facilitate inclusion into prospective meta-analyses on postural feedback effects, we nevertheless report results of a mixed-ANOVA on proportion of choice, with session and emotion as within-subject factors and posture as a between-subject factor. For these, we provide partial eta-squared (η^2_p) as well as generalized eta-squared (η^2_g) as effect sizes to allow comparison with effect-sizes from other designs (see Lakens, 2013). To disentangle significant interactions with session and posture, we conducted t-tests on the change of proportion of choice from the first to the second session per emotion against zero, as well as dependent and independent t-tests between emotions and postures, respectively. We provide Cohen's d and $_{dz}$ as effect sizes for independent and dependent t-tests, respectively.

While we ran the **mixed logit model** choice ~ (1 | participant) + emotion*session*posture only on emotional trials (choice away or toward the emotional actor is not meaningful in neutral trials), we ran two types of linear mixed models on initiation and movement time: First, the model time ~ (1 | participant) + emotion*side*session*posture on only emotional trials, and second, the model time ~ (1 | participant) + threat (anger + fear vs. neutral)*session*posture on all trials. For the latter, we grouped anger and fear together in order to compare response times in threat vs. neutral trials, since the first model did not reveal any difference between angry and fearful trials for neither initiation nor movement time.

Results

Proportion of choice

Mixed logit model. The model choice ~ (1 | subject) + emotion*session*posture, revealed a significant effect of emotion ($\beta=0.08$, 95% CI=[0.01, 0.16]; $\chi^2(1)=25.1$, $p<.001$), indicating that it was 2% more likely to avoid anger than to avoid fear (odds ratio = 1.09). None of the other main effects and two-fold interactions were significant, suggesting that there were no significant general differences between groups or sessions (see Supplementary Table S1 for odds ratios, and S2 for parameters and significance tests). In contrast, the predicted three-fold interaction emotion*session*posture was significant ($\beta=0.17$, 95% CI=[0.02, 0.32]; $\chi^2(1)=4.77$, $p=.029$), indicating that the effect of emotion on action choices (more avoidance for anger than fear) changed between sessions as a function of adopted posture (odds ratio = 1.19). Specifically, it was larger in the second session compared to the first in the constrictive compared to the expansive posture group. Follow-up regressions (choice ~ (1 | subject) + emotion*posture) for each session separately showed that the effect of emotion in the two groups was similar in the first session (emotion*posture: $\beta=-0.02$, 95% CI=[-0.12, 0.09]; $\chi^2(1)=0.08$, $p=.784$), but differed in the second session, in which participants adopted the respective posture ($\beta=0.16$, 95% CI=[0.05, 0.26]; $\chi^2(1)=7.90$, $p=.005$). Separate regressions within each posture (choice ~ (1 | subject) + emotion*session) demonstrated that the difference in session 2 was due to a significant increase in the effect of emotion on action choices in the constrictive group (emotion*session: $\beta=0.13$, 95% CI=[0.02, 0.24]; $\chi^2(1)=5.28$, $p=.022$), but no change in the expansive group (emotion*session: $\beta=-0.04$, 95% CI=[-0.15, 0.06]; $\chi^2(1)=0.62$, $p=.430$).

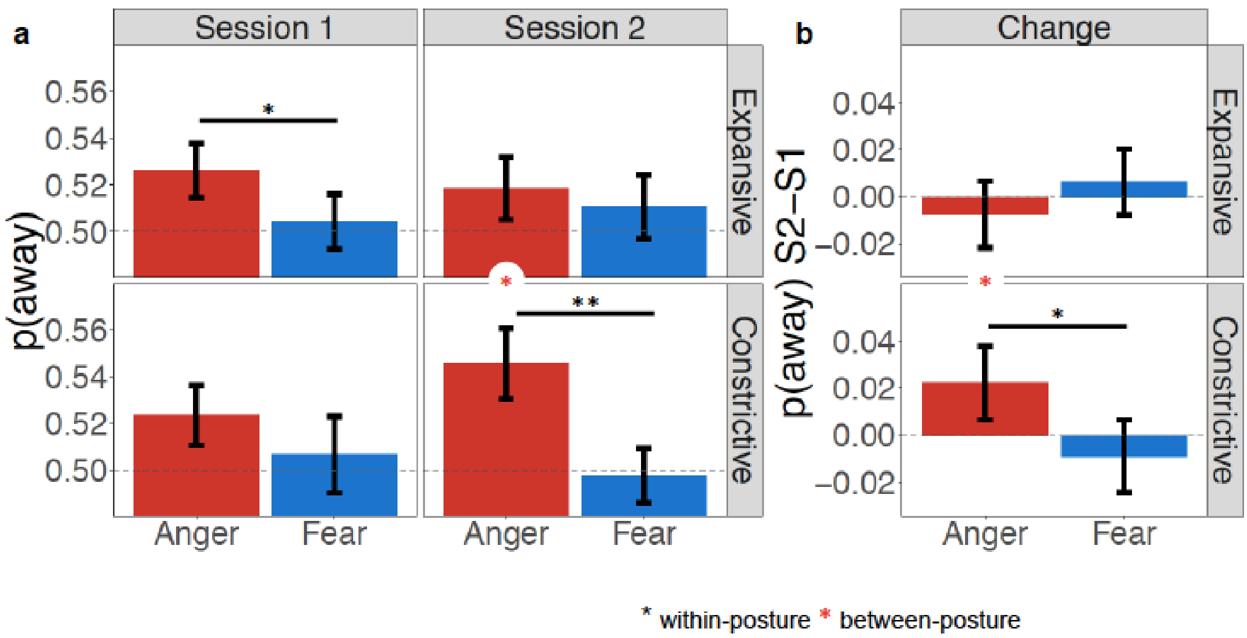

Figure 3. a) Proportion of choices to move away as opposed to toward the emotional individual**. b)** Change in proportion of choice from session 1 to session 2. Error bars represent within-subject confidence intervals; those not overlapping with 50 or 0 indicate significance at p<0.05. * p<0.05 | ** p<.001 t-tests between-groups or conditions

Regressions in each session and each posture separately demonstrated that the difference in action choices in response to anger and fear increased significantly from before (β=0.07, 95% CI=[-0.01, 0.15]; $\chi^2(1)=3.17$, p=0.075) to after (β=0.20, 95% CI=[0.12, 0.28]; $\chi^2(1)=25.23$, p<0.001) when adopting the constrictive posture, and decreased (though not significantly) from before (β=0.09, 95% CI=[0.01, 0.16]; $\chi^2(1)=4.85$, p=0.028) to after (β=0.04, 95% CI=[-0.04, 0.12]; $\chi^2(1)=1.14$, p=0.286) when adopting an expansive posture. In other words, the effect of emotion on action choices (more avoidance for anger than fear) became significantly larger after a constrictive posture, but did not change after an expansive posture. To test whether this effect was driven by responses to anger, to fear or to both emotions, we continued by running a model on angry trials only. It revealed significantly stronger avoidance of angry individuals after adopting a constrictive as compared to an expansive posture (session*posture: β=0.12, 95% CI=[0.01, 0.23]; $\chi^2(1)=4.79$, p=0.029). In contrast, action choices in response to fear did not change significantly in the two posture groups (session*posture: β=-0.05, 95% CI=[-0.16, 0.06]; $\chi^2(1)=0.86$, p=0.352, see Supplementary Table S3 for main effects). This indicates that the larger emotion effect after a constrictive posture resulted mainly from stronger avoidance of anger.

In summary, approach and avoidance decisions in response to angry and fearful individuals did not differ between the two groups before participants adopted a posture. All participants avoided angry individuals more than fearful individuals, with a 2% higher probability to avoid anger as compared to fear. After adopting a constrictive posture, this higher probability to avoid anger as compared to fear became even larger (it increased by 4%, see Table S1). In contrast, expansive postures induced no significant changes in action choices in response to angry and fearful individuals. Figure 3a illustrates the results as proportion of choices away vs. toward per emotion, session and posture and Table 1 includes means, confidence intervals and effect sizes against chance level (50%).

Table 1. Means and within-participant confidence intervals of proportion of choices away

Session	Posture	Emotion	n	Mean	95% CI		d against 50%
1	Expansive	Anger	40	0.53	0.51	0.54	0.64
1	Expansive	Fear	40	0.50	0.49	0.52	0.11
1	Constrictive	Anger	39	0.52	0.51	0.54	0.42
1	Constrictive	Fear	39	0.51	0.49	0.52	0.15
2	Expansive	Anger	40	0.52	0.51	0.53	0.36
2	Expansive	Fear	40	0.51	0.50	0.52	0.26
2	Constrictive	Anger	39	0.55	0.53	0.56	0.71
2	Constrictive	Fear	39	0.50	0.49	0.51	-0.06

ANOVA. In parallel to the results of the mixed logit model, the ANOVA on proportion of choice revealed an effect of emotion ($F(1,77) = 19.63$, $p<.001$, $\eta^2_p = 0.203$, $\eta^2_G = 0.060$), and a significant three-fold interaction emotion*session*posture ($F(1, 77) = 7.05$, $p=.010$, $\eta^2_p = 0.084$, $\eta^2_G = 0.014$), with no other significant effects. This observed effect size was slightly smaller than the minimal effect-size of $\eta^2_p = 0.10$ which we could detect with 80% power with our sample size according to the sensitivity analysis. This implies that we achieved a power of approximately 75% to detect a different behavioural change in response to the two emotions in the two posture groups, assuming that the detected effect size corresponds to the true effect-size. Follow-up ANOVAs per posture and post-hoc comparisons reflect the results reported above for the mixed logit model (see supplementary information for details).

Self-report questionnaires

Scores from participants in the expansive and constrictive group did not differ significantly on any of the personality trait or state measures (all p-values >.109, all effect sizes d >0.36). Since the absence of a significant difference does not imply actual equivalence, we conducted equivalence tests (Lakens, 2016) with d = -0.3 and d=0.3 as equivalence bounds for the smallest meaningful difference. None of the equivalence tests was significant (all p-values >.130), i.e.

the confidence intervals of all measures crossed one of the equivalence bounds, which implies that we could not assume statistical equivalence of the two groups on any of the measures. We thus included all measures as covariates into the model predicting choice as a function of emotion, session and posture. This did not change the result pattern, that is, previously significant effects remained the only significant effects.

Movement kinematics

Initiation time. In the mixed linear model log(initiation time) ~ 1 | subject + emotion*side*session*posture on log-transformed initiation time (time from appearance of scene to first click) in angry and fearful trials only revealed slower initiation times for away than toward responses (β=-0.16, 95% CI=[-0.17, -0.14]; $\chi^2(1)$=11.84, p=.001), but no effect of or interaction with emotion (both >0.01, both p <.308), nor any interaction with side or emotion with any of the other factors (see Table S4). Consequently, we examined all other effects in the model log(initiation time) ~ 1 | subject + threat*session*posture including all trials, contrasting threat-related facial expressions with neutral ones. This revealed quicker initiation times in session 2 as compared to session 1 (β=-0.17, 95% CI=[-0.18, -0.16]; $\chi^2(1)$=2836.11, p<.001), which might indicate a learning effect across sessions. Although the reduction of initiation time in session 2 was more pronounced in the expansive group (session*posture: β=0.05, 95% CI=[0.04, 0.07]; $\chi^2(1)$=157.76, p<.001), it was significant in both posture groups (see Table S5 for separate regressions per posture).

Additionally, the model revealed quicker initiation time for threat vs. neutral displays (β=-0.08, 95% CI=[-0.09, -0.07]; $\chi^2(1)$=423.91, p<.0.001), which suggests that threat-related facial expressions significantly reduced the time needed to initiate an action. While being slightly reduced in the second session (threat*session: β=0.03, 95% CI=[0.01, 0.04]; $\chi^2(1)$=44.62, p<.001), this threat effect remained highly significant in session 2 (see Table S5 for separate regressions per session). In addition, and although it was also highly significant in both postures (see Table S5), participants who adopted an expansive posture showed a larger threat effect in both sessions than those who adopted a constrictive posture (threat*posture: β=0.02, 95% CI=[0.002, 0.03]; $\chi^2(1)$=18.22, p<.001). Yet, the fact that neither the main effect of posture nor the threat*session*posture interaction were significant (p>.279, see Table S5) suggests that posture did not induce a change in threat detection. Means and confidence intervals of initiation time per emotion and side for each session and posture are depicted in Figure 4a.

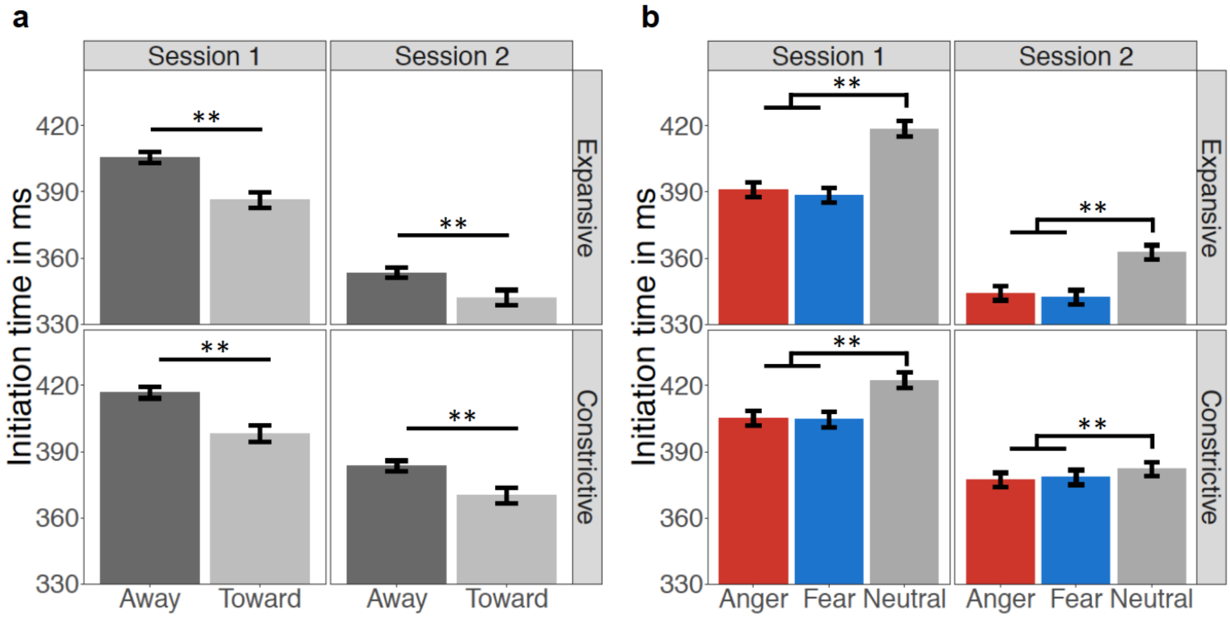

Figure 4. Means and within-subject confidence intervals for initiation time in ms per session and posture for each side (a), and for each emotion (b). * p<0.05 | ** = p<.001 form model comparisons

Movement duration. We next ran the same two linear mixed regressions on log transformed movement duration, that is, time from click to release on top of a chair. Given that neither emotion or side nor their interaction had a significant effect (all β <0.89, all p's > 0.345, see Table S5) when running the model on angry and fearful trials, we examined all other effects in the model including all trials. Exactly as for initiation time, there were significant main effects of threat (β=0.01, 95% CI=[0.00, 0.02]; $\chi^2(1)$=34.25, p<.001) and session (β=0.02, 95% CI=[0.01, 0.03]; $\chi^2(1)$=43.93, p<.001). However, these effects were smaller overall, and went into the opposite direction to initiation time: Movement duration was slower for threat displays and in the second session. The effect of session was driven merely by the expansive group, as movement duration in the constrictive group did not change (session*posture: β=-0.02, 95% CI=[-0.03, 0.00]; $\chi^2(1)$=23.81, p<.001, see Table S7 for separate regressions per posture and session). Movement duration results are depicted in Figure 5.

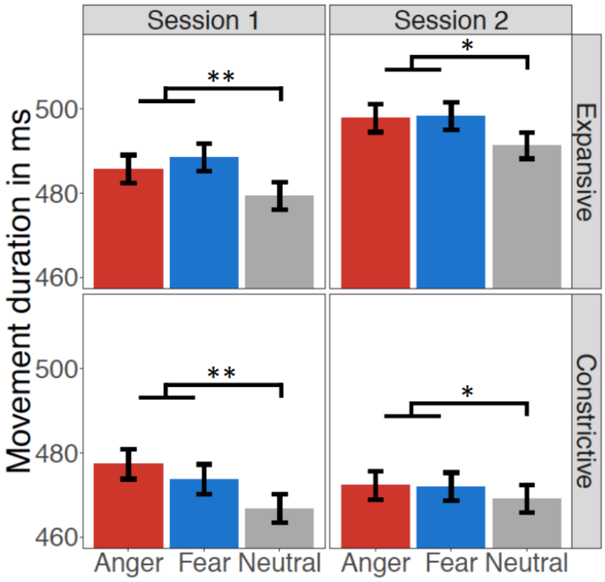

Figure 5. Means and within-subject confidence intervals for movement duration in ms per emotion, session and posture

Discussion

The current study assessed whether bodily feedback from adopting expansive or constrictive postures, which function as social signals of power, impacts on individuals approach and avoidance decisions in response to threat signals emitted by other individuals. More specifically, we investigated free action choices in the presence of task-irrelevant individuals who displayed angry or fearful facial expressions. Without knowing about or explicitly noticing the emotional expressions, participants chose where to sit in a realistic scene by moving the mouse cursor on top of the chair of their choice, thereby either approaching or avoiding the emotional individual. After a first session without posture, participants repeatedly adopted either an expansive or constrictive posture in between task blocks of a second session. In contrast to the outcome measures used in most previous studies assessing postural feedback effects, approach and avoidance decisions in response to social threat signals constitute an implicit social behaviour. Importantly, such behaviour is less susceptible to experimental demand effects than explicit self-reports and requires no high-level cognitive processes, which corresponds to the elementary social signalling function of postural expansiveness.

Replicating previous studies that used the same approach-avoidance task (Mennella, Vilarem, & Grèzes, in preparation; Vilarem et al., under review), we found that facial expressions of anger, which signal direct threat towards the observer (Sander et al., 2007; Sell et al., 2014), elicit more avoidance than approach decisions, while expressions of fear, which simultaneously signal potential danger in the environment and an opportunity to affiliate (A. A. Marsh & Ambady, 2007), prompted avoidance and approach behaviour to the same extent. Of interest here, postures modulated these decisions in a manner that corresponds to the level of dominance or power they signal. Specifically, constrictive postures considerably enhanced individuals' tendency to avoid angry individuals (d_z=0.38), while expansive postures induced no significant changes (d_z=-0.13, medium between-posture effect of d=0.51). This result is in line with previous findings of increased avoidance of dominance or threat signals in individuals with low power (Weick et al., 2017). Hence, it could indicate that constrictive postures induced a submissive, powerless state, in which it becomes crucial to avoid conflict with aggressive conspecifics. Changes in responses to fearful individuals were small and non-significant, but occurred in opposite directions in the two posture groups: avoidance decreased in the constrictive (d_z=-0.15) and increased in the expansive posture group (d_z=0.11, small between-posture effect of d=-0.26). While we had reasonably high statistical power to detect the observed difference between angry and fearful displays (approximately 75%), larger samples would be needed to test whether these small changes in response to fearful displays are reliable. In this case they might reflect increased motivation to affiliate with potential allies as a means of social protection when adopting constrictive postures.

Importantly, the impact of postures on approach and avoidance decisions were not mediated by differences in the ability to process threat-related displays. As in previous studies using the same task (Mennella et al., in preparation; Vilarem et al., under review), time to initiate approach or avoidance actions was shorter for threatening as compared to neutral scenes in both posture groups. There was no difference between fearful and angry displays, which might indicate speeded motor preparation in the face of threat. In addition, movement duration was longer for threatening than neutral scenes, which is likely associated with the fixed total time interval available to execute the movement: when clicking earlier, one has more time to move, and vice versa. This general threat effect on kinematic measures suggests that angry and fearful facial expressions were implicitly processed to a similar extent, and this in both posture groups. Thus, the stronger tendency to avoid angry as compared to fearful displays, and the even stronger tendency to do so after a constrictive posture, cannot be explained by improved or quicker perceptual processing of anger, but rather seems to reflect its social meaning (Hess et al., 2000; Springer et al., 2007; Vilarem et al., under review). In other words, the presence of task-irrelevant angry displays more strongly facilitates avoidance than fearful displays because anger poses a direct threat and challenge to the observer (Sell et al., 2014), not because it is detected more quickly. In the same vein, adopting a constrictive as compared to an expansive posture induces stronger avoidance of angry displays not because they are detected more rapidly, but because the threat they communicate is even more relevant when one's body signals a submissive as compared to a dominant state.

In addition to similarly detecting angry and fearful displays, both posture groups also took more time to initiate an action when deciding to avoid rather than to approach the emotional individual. This difference in initiation time as a function of participants' choice seems to suggest that participants made the decision before starting to move. Second, it could indicate that taking longer to initiate an action left more time to fully process the social threat signals present in the environment, and thereby increased the probability of taking the more adaptive decision to avoid, rather than to approach. Kinematic measures further revealed general changes from session 1 to session 2, independent from emotion and choice, which were more pronounced in the expansive group. Specifically, all participants and particularly those who adopted the expansive posture more quickly initiated movement in session 2, which may demonstrate that they became more fluent in correctly performing the task. Effects on movement duration were again opposite to those on initiation time, with duration increasing in session 2 in the expansive posture group. One could speculate that the even shorter initiation time in the expansive posture condition indicates increased certainty about the ability to correctly perform the movement.

In summary, the current study provides evidence suggesting that briefly adopting a constrictive posture enhances avoidance of angry individuals, while expansive postures did not seem to alter participants' approach and avoidance decisions. Hence, it seems that postural feedback, by modulating the relevance of certain threat signals to the perceiver, does not only affect visual attention (Chadwick et al., 2018), but also the decisions taken in response to such threat signals. Thanks to a within-subject design that revealed similar behaviour before postures were adopted, we can be relatively sure that this posture effect does not originate from between-group differences in approach and avoidance tendencies. The overall tendency to avoid angry individuals more than fearful individuals, as well as the posture effect on these tendencies, were independent from perceptual processing of threat, and rather reflected the social function of each emotional expression. While anger signals a social threat directed at the observer, which is particularly threatening in a state of low power, fear is a more ambiguous threat signal, and simultaneously conveys a potential opportunity to affiliate (Hammer & Marsh, 2015b; Sander et al., 2007). Within the view of expressions of emotion as communicating action opportunities (Gibson, 1979; McArthur & Baron, 1983; Zebrowitz, 2006), postures embodying different levels of social power could be one relevant characteristic of the observer that impacts on action selection.

By demonstrating postural feedback effects on a primary and implicit social behaviour with reasonable statistical power, the present study makes a valuable contribution to the posture literature discussed in the current debate on the replicability of power-posing effects. Most previous studies which yielded significant effects tested small samples, while studies with large samples mostly reported null-effects (Cesario & Johnson, 2017; Jonas et al., 2017). So far, conclusive evidence is only available for a posture effect on explicit feelings of power assessed in a meta-analyses of six pre-registered and highly-powered studies (Gronau et al., 2017). However, as a larger effect on feelings of power in subjects familiar with the idea of "power posing" underlines, explicit self-reports are susceptible to demand effects. Still, the majority of studies on other outcome measures also used explicit self-reports (e.g. Kozak et al., 2014; Nielsen, 2017; Peña & Chen, 2017; Rotella & Richeson, 2013; Strelan et al., 2014). The implicit social behaviour assessed in this study is much less likely to be influenced by demand effects. Furthermore, despite the posture's primary social signalling function, most earlier studies focused on non-social behaviour such as risky gambling, abstract or creative thinking (Andolfi et al., 2017; Huang et al., 2011), or behaviour that requires high-level cognitive processes, such as sales negotiation, cheating or planning to take revenge or to volunteer (Cesario & Johnson, 2017; Peña & Chen, 2017; Strelan et al., 2014; Yap, Wazlawek, et al., 2013). The only existing study on low-level and implicit social behaviour, namely visual dominance behaviour and speaking time, reported no significant effects, but was statistically underpowered (Jamnik & Zvelc, 2017). The results of the present study suggest that investigating low-level social behaviour that corresponds to the posture's function of signalling social dominance is a promising direction for future research.

Additionally, the present study attempted to overcome some of the methodological limitations of previous studies on bodily feedback effects of expansive and constrictive postures. Only two out of about 60 studies in total (for references, see Carney et al., 2015; Cuddy et al., 2018; Jonas et al., 2017) used within-subject designs, and observed a change only after expansive postures (Bohns & Wiltermuth, 2012; Lee & Schnall, 2014), or no significant effect (Jamnik & Zvelc, 2017), respectively. Similarly, only four studies included a control group, and observed a significant difference only for the constrictive posture (Cesario & McDonald, 2013) or no significant effects (Davis et al., 2017; Nielsen, 2017; K. M. Smith & Apicella, 2017). Thus, most previous studies did not provide an answer about which posture drives the observed effects. In contrast, the present study can attribute the observed effects to changes in the constrictive posture group.

Within the current context of the controversy around the replicability of previously published posture effects (see Jonas et al., 2017; or K. M. Smith & Apicella, 2017), the present results need to be replicated before any strong conclusions can be drawn. Yet, postural feedback effects on approach and avoidance decisions in response to other's threat signals might be more likely to replicate than some of the previously assessed outcome measures, such as risky gambling or abstract thinking (e.g. Carney et al., 2010; Cesario & Johnson, 2017; Huang et al., 2011), because such implicit and primary social decisions correspond to the posture's core function as a social signal of dominance and power. In conclusion, while many of the previously published effects might not be robust effects, behaviours that are conceptually linked to the social meaning of expansive and constrictive postures could turn out to be sensitive to postural feedback effects.

Supplementary Information

Methods

Posture instructions

Expansive condition: “Spread your feet at the width of your shoulders and turn your feet outwards. Place your hands on your hips with the thumb backwards and keep your elbows approximately parallel. Look straight ahead and don’t tilt your head downwards. The posture needs to be comfortable.” Constrictive condition: “Cross your legs and put one foot next to the other. Now, lay one arm across your belly and place the other one on top, but do not cross your arms. Look at the floor in front of you and relax your back and shoulders.”

Results

Mixed logit models on proportion of choice

Table S1. Odds ratios and probabilities for full model on choice.

	Odds ratio	Probability	95% CI odds ratio	
(Intercept)	1,02	0,51	0,96	1,08
Emotion Anger	1,09	0,52	1,01	1,17
Session 2	1,02	0,50	0,94	1,10
Posture Constrictive	1,00	0,50	0,92	1,09
Session x Posture	0,95	0,49	0,85	1,06
Emotion x Posture	0,99	0,50	0,88	1,10
Emotion x Session	0,96	0,49	0,86	1,07
Emotion x Session x Posture	1,19	0,54	1,02	1,38

Table S2. Parameter estimates and model comparison for proportion of choice on all trials and separately per session, posture and session by posture combination.

Full Model	**β**	**95% CI**		**χ^2**	**df**	**p**
(Intercept)	0.02	-0.04	0.08			
Emotion	0.08	0.01	0.16	25.1	1	0.000
Session	0.02	-0.06	0.09	0.48	1	0.490
Posture	0	-0.08	0.09	0.31	1	0.580
Session x Posture	-0.05	-0.16	0.06	0.74	1	0.390
Emotion x Posture	-0.01	-0.12	0.09	3.22	1	0.070
Emotion x Session	-0.04	-0.15	0.06	1.11	1	0.290
Emotion x Session x Posture	0.17	0.02	0.32	4.77	1	0.030

Session 1	**β**	**95% CI**		**χ²**	**df**	**p**
(Intercept)	0.02	-0.04	0.07			
Emotion	0.09	0.01	0.16	7.94	1	0.000
Posture	0.01	-0.07	0.09	0	1	0.970
Emotion x Posture	-0.02	-0.12	0.09	0.07	1	0.780
Session 2	**β**	**95% CI**		**χ²**	**df**	**p**
(Intercept)	0.04	-0.02	0.10			
Emotion	0.04	-0.03	0.12	18.39	1	0.000
Posture	-0.05	-0.13	0.04	0.78	1	0.376
Emotion x Posture	0.16	0.05	0.27	7.90	1	0.005
Expansive	**β**	**95% CI**		**χ²**	**df**	**p**
(Intercept)	0.02	-0.04	0.08			
Emotion	0.09	0.01	0.16	5.34	1	0.021
Session	0.02	-0.06	0.10	0.00	1	0.959
Emotion x Session	-0.04	-0.15	0.06	0.62	1	0.430
Constrictive	**β**	**95% CI**		**χ²**	**df**	**p**
(Intercept)	0.03	-0.04	0.09			
Emotion	0.07	-0.01	0.15	23.03	1	0.000
Session	-0.03	-0.11	0.04	1.15	1	0.283
Emotion x Session	0.13	0.02	0.24	5.28	1	0.022
Session 1 Expansive	**β**	**95% CI**		**χ²**	**df**	**p**
(Intercept)	0.02	-0.04	0.07			
Emotion	0.09	0.01	0.16	4.85	1	0.028
Session 1 Constrictive	**β**	**95% CI**		**χ²**	**χ²**	**df**
(Intercept)	0.03	-0.03	0.08			
Emotion	0.07	-0.01	0.15	3.17	1	0.075
Session 2 Expansive	**β**	**95% CI**		**χ²**	**df**	**p**
(Intercept)	0.04	-0.02	0.10			
Emotion	0.04	-0.04	0.12	1.14	1	0.286
Session 2 Constrictive	**β**	**95% CI**		**χ²**	**df**	**p**
(Intercept)	-0.01	-0.07	0.06			
Emotion	0.20	0.12	0.28	25.23	1	0.000

Table S3. Parameter estimates and model comparison for proportion of choice separately per emotion.

Anger	**β**	**95% CI**		**χ²**	**df**	**p**
(Intercept)	0.11	0.04	0.17			
Session	-0.03	-0.10	0.05	1.33	1	0.249
Posture	-0.01	-0.11	0.09	1.43	1	0.232
Session x Posture	0.12	0.01	0.23	4.79	1	0.029
Fear	**β**	**95% CI**		**χ²**	**df**	**p**
(Intercept)	0.02	-0.03	0.07			
Session	0.02	-0.05	0.10	0.02	1	0.898
Posture	0.01	-0.07	0.08	0.49	1	0.485
Session x Posture	-0.05	-0.16	0.06	0.86	1	0.352

ANOVAs and post-hoc comparisons on proportion of choice

Due to a significant three-fold interaction emotion*session*posture (F(1, 77) = 7.05, p=.010, η^2_p = 0.084, η^2_G= 0.014), we assessed the effect of session and emotion separately in each posture group. The ANOVAs per posture group showed no significant emotion*session interaction in the expansive group (F(1,39)= 1.47, p=.233, η^2_p = 0.04, η^2_G= 0.006), in contrast to a significant interaction in the constrictive group (F(1 ,38)= 6.17, p=.018, η^2_p = 0.140, η^2_G=0.024). This interaction was driven by an increased tendency to avoid anger after holding a constrictive posture (t-test on change S2-S1 against 0, see Figure 3b: t(38)=2.40, p=.022, d=0.38), with no significant change for fear (t(38)=-0.94, p=.349, d= -0.15). In the expansive group, proportion of choice did not change significantly for neither anger (t(39)=-0.82, p=.416, d= -0.13) nor fear (t(39)=0.67, p=.507, d=0.11). The change in proportion of choice significantly differed between the postures for anger (t(77)=2.28, p= 0.026, d=0.51), but not for fear t(77)=-1.14, p=0.256, d=-0.26). Finally, although there was no significant change for fear, the difference in responses to anger vs. fear became larger after a constrictive posture (t-test on change anger vs. fear: t(38)=2.48, p = 0.017, d= 0.40), while it became smaller but not significantly so after an expansive posture (t(39)= -1.21, p = 0.23, d= -0.19). The effect sizes for the mean change in proportion of choices against 50% (Table 1) illustrate that this is due a large change for anger, but also a small change in the opposite direction for fear in both postures: While avoidance of anger increased from d=0.42 to d=0.71 after adopting a constrictive posture, avoidance of fear decreased from d=0.15 to d=-0.06, thus making the difference between the two emotions larger. In contrast, avoidance of anger decreased from d=0.64 to d=0.36 after an expansive posture and avoidance of fear increased from d=0.11 to d=0.26, thus making the responses to the two emotions more similar.

Movement kinematics

Table S4. Parameter estimates and model comparison for click time in angry and fearful trials.

Full model angry and fearful trials	β	95% CI		χ^2	df	p
(Intercept)	-1.01	-1.08	-0.93			
Emotion	0.00	-0.02	0.01	0.89	1	0.345
Side	0.01	-0.01	0.03	11.84	1	0.001
Emotion x Side	-0.01	-0.03	0.01	1.04	1	0.308
Session	-0.16	-0.17	-0.14	1679.66	1	0.000
Posture	0.02	-0.08	0.13	1.31	1	0.252
Session x Posture	0.07	0.05	0.09	116.75	1	0.000
Emotion x Posture	0.00	-0.02	0.02	1.18	1	0.277
Side x Posture	0.01	-0.02	0.03	2.99	1	0.084

Emotion x Session	0.01	-0.01	0.03	0.15	1	0.695
Side x Session	0.01	-0.01	0.03	0.00	1	0.955
Emotion x Side x Session	-0.01	-0.04	0.02	0.13	1	0.720
Emotion x Side x Posture	0.01	-0.02	0.04	2.25	1	0.134
Emotion x Session x Posture	-0.01	-0.04	0.02	0.00	1	0.969
Side x Session x Posture	-0.01	-0.05	0.02	0.21	1	0.649
Emotion x Side x Session x Posture	0.01	-0.03	0.06	0.41	1	0.522

Table S5. Parameter estimates and model comparison for click time in all trials.

Full model all trials	β	95% CI		χ^2	df	p
(Intercept)	-0.93	-1.00	-0.86			
Threat	-0.08	-0.09	-0.07	423.91	1	0.000
Session	-0.17	-0.18	-0.16	2836.11	1	0.000
Posture	0.00	-0.10	0.11	0.94	1	0.333
Session x Posture	0.05	0.04	0.07	157.76	1	0.000
Threat x Posture	0.02	0.00	0.03	18.22	1	0.000
Threat x Session	0.03	0.01	0.04	44.62	1	0.000
Threat x Session x Posture	0.01	-0.01	0.03	1.17	1	0.279
Session 1	**β**	**95% CI**		**χ^2**	**df**	**p**
(Intercept)	-0.93	-1.00	-0.86			
Threat	-0.08	-0.09	-0.07	362.20	1	0.000
Posture	0.00	-0.10	0.11	0.18	1	0.675
Threat x Posture	0.03	0.02	0.04	17.81	1	0.000
Session 2	**β**	**95% CI**		**χ^2**	**df**	**p**
(Intercept)	-1.10	-1.18	-1.02			
Threat	-0.06	-0.07	-0.05	148.20	1	0.000
Posture	0.06	-0.06	0.17	1.90	1	0.168
Threat x Posture	0.04	0.02	0.05	28.92	1	0.000
Expansive	**β**	**95% CI**		**χ^2**	**df**	**p**
(Intercept)	-0.93	-1.00	-0.86			
Threat	-0.08	-0.09	-0.07	350.57	1	0.000
Session	-0.17	-0.18	-0.16	2084.16	1	0.000
Threat x Session	0.02	0.00	0.03	4.90	1	0.027
Constrictive	**β**	**95% CI**		**χ^2**	**df**	**p**
(Intercept)	-0.93	-1.01	-0.84			
Threat	-0.05	-0.06	-0.04	102.46	1	0.000
Session	-0.12	-0.13	-0.10	858.44	1	0.000
Threat x Session	0.03	0.01	0.04	14.56	1	0.000

Table S6. Parameter estimates and model comparison for movement time in angry and neutral trials.

Full model angry and fearful trials	β	95% CI		χ^2	df	p
(Intercept)	-0.80	-0.88	-0.71			
Emotion	0.01	-0.01	0.02	0.13	1	0.716
Side	0.00	-0.01	0.01	0.89	1	0.345

Emotion x Side	0.00	-0.02	0.02	0.20	1	0.656
Session	0.02	0.01	0.04	25.21	1	0.000
Posture	-0.02	-0.14	0.10	0.24	1	0.627
Session x Posture	-0.03	-0.05	-0.01	16.70	1	0.000
Emotion x Posture	-0.01	-0.03	0.01	1.19	1	0.276
Side x Posture	0.00	-0.02	0.02	0.05	1	0.819
Emotion x Session	-0.01	-0.03	0.01	0.18	1	0.670
Side x Session	0.00	-0.02	0.02	0.12	1	0.727
Emotion x Side x Session	0.00	-0.02	0.03	0.68	1	0.408
Emotion x Side x Posture	0.00	-0.02	0.03	1.10	1	0.294
Emotion x Session x Posture	0.02	-0.01	0.04	0.42	1	0.518
Side x Session x Posture	0.01	-0.02	0.03	0.08	1	0.776
Emotion x Side x Session x Posture	-0.02	-0.06	0.01	1.64	1	0.200

Table S7. Parameter estimates and model comparison for click time in all trials

Full model all trials	β	95% CI		χ^2	df	p
(Intercept)	-0.80	-0.89	-0.72			
Threat	0.01	0.00	0.02	34.25	1	0.000
Session	0.02	0.01	0.03	43.93	1	0.000
Posture	-0.02	-0.14	0.10	0.23	1	0.628
Session x Posture	-0.02	-0.03	0.00	23.81	1	0.000
Threat x Posture	0.00	-0.01	0.01	0.45	1	0.501
Threat x Session	0.00	-0.01	0.01	0.00	1	0.961
Threat x Session x Posture	0.00	-0.02	0.01	0.04	1	0.840
Session 1	β	95% CI		χ^2	df	p
(Intercept)	-0.81	-0.89	-0.72			
Threat	0.01	0.01	0.02	24.29	1	0.000
Posture	-0.02	-0.14	0.10	0.09	1	0.769
Threat x Posture	0.00	-0.01	0.01	0.08	1	0.772
Session 2	β	95% CI		χ^2	df	p
(Intercept)	-0.78	-0.87	-0.69			
Threat	0.01	0.00	0.02	14.17	1	0.000
Posture	-0.04	-0.17	0.09	0.44	1	0.505
Threat x Posture	0.00	-0.01	0.01	0.11	1	0.742
Expansive	β	95% CI		χ^2	df	p
(Intercept)	-0.80	-0.90	-0.71			
Threat	0.01	0.01	0.02	18.35	1	0.000
Session	0.02	0.01	0.03	69.28	1	0.000
Threat x Session	0.00	-0.01	0.01	0.12	1	0.731
Constrictive	β	95% CI		χ^2	df	p
(Intercept)	-0.83	-0.90	-0.75			
Threat	0.01	0.01	0.02	15.98	1	0.000
Session	0.01	0.00	0.01	1.36	1	0.244
Threat x Session	0.00	-0.01	0.01	0.36	1	0.546

GENERAL DISCUSSION

Chapter 8
Do power postures influence social perception and behaviour?

The present thesis explored whether adopting expansive and constrictive postures impacts on the agent's social perception and behaviour. Although these postures are nonverbal signals of high and low social power and dominance, and are thus referred to as power postures, previous research has not addressed effects on **behaviours that are congruent with their social signalling function**. Building on embodiment theories, research on power posture effects has so far mainly examined non-social and high-level cognitive behaviours. Yet, expansive and constrictive postures serve as dominance and submission displays in many social animal species, which demonstrates that they are an ancient and elementary social signal and underlines their evolutionary importance. Relying on research which demonstrates that both power and bodily actions influence social perception and behaviour, this thesis therefore set out to explore effects of power postures in this domain. Specifically, it investigated potential effects of power postures on **three levels of the agent's social cognition and behaviour**:

1) Posture effects on mental representations of faces of others
2) Posture effects on perception of social threat signals
3) Posture effects on action decisions in response to social threat signals

Furthermore, it attempted to replicate and extend previous findings regarding the effect of power postures on levels of testosterone and cortisol, **hormones** centrally involved in regulating behaviours associated with social status and stress.

In the course of this thesis, a **debate on the replicability** of previous power posture findings has started to unfold (Cesario et al., 2017). It was sparked off by several non-replications of a study central to this research field (Carney et al., 2010) and is still ongoing. So far, reasonably clear conclusions are only possible for a few behaviours. Specifically, replication efforts (including our own) have confirmed a small effect on self-reports of feeling powerful and in control (Gronau et al., 2017), and made a strong case against effects on risky gambling decisions, testosterone and cortisol levels and job interview performance (Bailey et al., 2017;

Bombari et al., 2013; Cesario & Johnson, 2017; Davis et al., 2017; Garrison et al., 2016; Keller et al., 2017; Ranehill et al., 2015; Ronay et al., 2016; K. M. Smith & Apicella, 2017). Furthermore, a few studies with high statistical power provide relatively strong evidence against effects on openness to persuasion by others, behaviour in sales negotiations, self-concept expansion and overconfidence (Cesario & Johnson, 2017; Jackson et al., 2017; Latu et al., 2017; Ronay et al., 2016).

As this short overview demonstrates, research efforts have mainly focused on behaviours that involve high-level cognitive processes. Elementary behaviours such as perception of and responses to social threat signals are more closely related to the postures core function of signalling social power and dominance. Furthermore, the only consistent evidence for posture effects derives from studies using explicit self-reports of feelings and emotions (see Cuddy et al., 2018; Gronau et al., 2017). By **measuring actual behavioural responses, and focusing on elementary social behaviours**, this thesis therefore makes a strong contribution to the current debate. Nevertheless, given the debate on the replicability of power posture effects and of psychological findings more generally (Camerer et al., 2018; Open Science Collaboration, 2015), it became increasingly important in the course of this thesis to verify whether effects on social perception and behaviour were more robust. I could only begin to do so. The findings below would therefore require replication before any clear conclusions can be drawn.

1. Summary of findings

This thesis built on the promising results of a first study on posture effects on the salience of threat-related facial expressions (Chadwick et al., 2018; see Appendix). Its results suggested that briefly adopting expansive postures reduced the salience of fear with averted gaze as a signal of potential threat in the environment. In contrast, adopting constrictive postures diminished the salience of anger with direct gaze, which signals intentions to challenge the observer. This pattern of results emerged in a scene discrimination task in which faces were unattended. A second study on explicit emotion discrimination (**Chapter 4**) demonstrated that these effects vanish when the agent directly focuses on the angry or fearful facial expression. This seemed to hint that power postures only affect implicit but not explicit **processing of threatening facial expressions**.

Testosterone and cortisol effects on implicit processing of angry and fearful expressions appeared to mirror the results we observed in the first study. To verify whether these hormones may be part of the physiological mechanism by which postures impact the agent's behaviour, I examined whether repeatedly adopting a posture in a social context elicited hormonal responses (**Chapter 5**). Extending the initial study on a posture effect on hormone levels (Carney et al., 2010), we included progesterone as a potential physiological correlate of affiliative motivation (Schultheiss et al., 2004; Wirth, 2011). We additionally assessed hormonal responses at a later delay to cover the time window in which they have been shown to be largest. Together with other non-replications of the posture effect on testosterone and cortisol, the results of this study **discarded hormones as a potential mechanism** underlying the impact of postures on implicit processing of threatening facial expressions.

We concluded that cognitive mechanisms in line with accounts of embodied cognition might instead provide plausible explanations. On the one hand, partial reactivations of mental representations of previous sensorimotor and affective experiences associated with having or lacking power may prompt changes in the processing of social signals after adopting an expansive or constrictive posture. On the other hand, the bodily action of adopting a power posture may induce changes in the evaluation of action opportunities in response to other's social signals. A series of reverse correlation studies assessed the first cognitive mechanism, that is, a power posture effect on mental representations of other's faces (**Chapter 6**), while a final study investigated the second, by testing effects on approach and avoidance actions in response to threatening facial expressions (**Chapter 7**).

Concerning **mental representations**, we focused on faces of in- and out-group members, since in-group members represent potential social interaction partners (**Chapter 6**). As assignment to a minimal group induces a more positive representation of in- compared to out-group members(Ratner et al., 2014), we expected in-group representations to reveal whether power postures impact implicit social preferences and expectations. The **first reverse correlation study** suggested that this was the case, as the in-group representation from participants who adopted a constrictive compared to an expansive posture elicited a more affiliative and dominant impression. Yet, a **second study** showed no posture effect on mental representations of explicitly preferred faces. Again, it seemed as if postures only impact social perception when the social dimensions of interest are processed implicitly.

However, rigorous examination of the data of these two reverse correlation experiments hinted at an alternative explanation. Actually, the considerably higher variability of implicitly compared to explicitly assessed mental representation images enhances the chance of a false positive, namely, here a difference between posture groups that only originates from random noise. An evaluation of in-group representation images created by shuffling participants from both posture groups confirmed that there was a 15-26% probability to detect the posture effect on in-group representations by chance alone (**Study 3**). Indeed, a **fourth study** did not replicate the effect. A **meta-analysis** (**Study 5**), in this case consisting of an evaluation of combined in-group representation images including data from the first study and its replication, also revealed no posture effect on in-group representations. Altogether, the reverse correlation studies thus provide more evidence against than for an effect of postures on mental representations of faces.

The most conclusive study in the current thesis suggests that power postures may impact **approach and avoidance decisions in response to social threat signals (Chapter 7)**. In a realistic social context, participants spontaneously chose on which seat they wanted to sit by executing a mouse movement. Two task-irrelevant individuals were occupying the two middle seats, leaving the two outer ones as available “action opportunities”. Since participants focused on a central fixation cross, they could not attend to the facial expressions in the peripheral visual field. Adopting a constrictive posture increased the tendency to avoid individuals that express anger, whereas adopting an expansive posture did not significantly impact action decisions. Importantly, behaviour of participants in the two groups did not differ before they adopted the posture. This may indicate that bodily actions associated with power may indeed change the implicit appraisal of action opportunities: While powerful individuals can afford to approach and possibly confront an angry individuals, powerless individuals are better off avoiding them.

This study so far provides the strongest empirical evidence for a posture effect on social behaviour for several reasons. First, it focused on an elementary social behaviour, namely approaching or avoiding others, that corresponds to the evolutionarily ancient social signalling function of postures. Second, it measured actual and implicit social behaviour, as the threatening facial expressions were never mentioned and went largely unnoticed. This behavioural measure was less variable than the implicit mental representations that revealed a posture effect in one of the studies in Chapter 6. Third, reasonable statistical power and a within-subject design that minimized between-group variation reduced the likelihood of a false positive.

2. Potential determinants of posture effects on social perception and behaviour

2.1. Posture effects may only occur when social signals are processed implicitly or when faces are entirely unattended

This section critically evaluates the argument that posture effects occur only when relevant social signals remain implicit, and disappear when attention is explicitly directed towards them. Difference in the focus of attention could indeed partially account for why effects occurred in some but not other studies on threat processing and mental representations of faces.

A first version of the focus of attention argument is that posture effects only emerge when the social signal of interest (i.e. the facial expression or trait) is **processed implicitly**, that is, not directly attended to. However, concerning threat processing, postures impacted performance when facial expressions were unattended only in a first and not a second session (Chadwick et al., 2018). Additionally, they did not affect performance when participants focused on the gender of the face, although the emotional expression remained implicit in that task. Concerning implicit mental representations of faces (i.e. in-group representations), a posture effect occurred only in one of two studies and did not emerge in a meta-analysis across both of them. Leaving the study on action decisions aside for the moment, there are thus strictly speaking more cases where implicit tasks revealed no effect, than cases in which they did[8].

A second version of the focus of attention argument could claim the **extent of attention** directed to the social signal of interest matters. Posture effects would in this case only occur when attentional resources are fully captured by something else and social signals really remain unattended. The scene discrimination task in Chadwick et al. (2018) was indeed the only task in which faces were actually unattended, contrary to the gender discrimination task and the implicit in- vs. out-group categorization task. The results obtained with the scene discrimination task may still turn out to be replicable, which does not seem to be the case for the effect on mental in-group representations. However, **replication of the posture effect on threat processing** when faces are unattended is essential to uphold this argument, given that the study was exploratory and lacked the statistical power to interpret the absence of an effect as positive

[8] Namely: no effect in one session in the scene task, the gender task, one in-out-group experiment and the meta-analysis vs. an effect in one session in the scene task and one in-out-group experiment.

evidence for postural feedback. All existing pre-registered and highly powered studies on posture effects did not replicate earlier findings of smaller exploratory studies (see Jonas et al., 2017 and Chapter 2). Thus, caution is warranted until replication of the posture effect on the salience of implicitly processed threatening expressions with a larger sample.

In contrast, the evidence for an effect of constrictive postures on **avoidance of angry individuals** remains relatively convincing despite all above considerations. Both emotions and faces were task-irrelevant and thus relatively unattended in that study and statistical power was reasonably high. One could thus conclude that expansive and constrictive postures impact behaviour in response to social threat signals only when faces are unattended and explicit attention is directed elsewhere. Yet, there is also another more plausible explanation for why this study yielded stronger evidence for a posture effect than all previous studies: it involved actual action opportunities.

2.2. Posture effects may only occur in the presence of actual action opportunities

Expansive and constrictive postures, as nonverbal signals of power and dominance, are all about actual behaviour in social interactions. First, **power** crucially determines an agent's action opportunities in response to the behaviour of interaction partners or opponents. Second, the **body** plays a direct role for action planning when we are actually about to execute a motor action. Bodily actions associated with power may therefore exert a stronger influence on social perception and behaviour when actual action opportunities are available. In contrast, its influence could be weaker when we merely perceive or imagine social signals, but do not need to take any action. Given these considerations and its robust methodology, the study on approach and avoidance actions in response to social threat thus provides the most compelling evidence for a posture effect on social behaviour. It therefore most clearly warrants replication efforts in comparison to the other studies reported in this thesis.

3. Setting my studies in context: A critical discussion of the research on power postures

3.1. Contextual meaning influences bodily feedback effects

As I have described in the introduction (Chapter 2 Section 4), the meaning agents attribute to their posture may determine how adopting a posture influences their feelings and behaviour. Importantly, nonverbal behaviours, including body postures, **convey different meanings and have different functions depending on the context** in which they are expressed (Harper, 1985). As Hall et al. (2005) put it, “NVB [nonverbal behaviour] does not have dictionary-like meanings, but rather the meaning of a given NVB depends heavily on contextual factors such as concurrent verbal behaviour, other NVBs, intentions, antecedent events, and the situational and interpersonal context” (p.916). According to these authors, even describing a nonverbal behaviour very precisely will not suffice to clearly decode its meaning, “because the different meanings and functions may not be detectable in the morphology of the behaviour alone but only in relation to contextual factors and inner states that are hard to measure” (p. 916).

Consequently, participants’ interpretation of the posture they adopt in a scientific study depends both on their previous experiences and the situational context in which they find themselves. This context is at least in part determined by the **experimental procedures**, which researchers choose based on the meaning they themselves associate with the postures. The type of posture, the chosen cover story, the experimental task and the outcome measures might therefore all shape postural feedback effects. This has direct implications for research on postural feedback effects: Researchers manipulating erectness of the **upper body** interpreted the meaning of postures differently than those manipulating expansion of the **whole body**. Studies working with slumped vs. upright torso have mostly considered the postures as sad/depressed and happy/confident (Duclos et al., 1989; Michalak et al., 2014; Nair et al., 2015; Riskind, 1984; Riskind & Gotay, 1982). In contrast, studies manipulating expansion and constriction including the limbs have typically focused on high and low power and related feelings such as pride and guilt (e.g. Carney et al., 2010; Fischer et al., 2011; Huang et al., 2011; Rotella & Richeson, 2013).

Carney et al. (2010) were among the first to interpret expansive and constrictive postures **exclusively in terms of power** and to test outcome variables typically investigated in research on social power. This exclusive focus on power and dominance has been criticised, given that the meaning of postures might vary according to the context in which they are adopted. Latu et al. (2017) plausibly argue that postural expansion may only embody power when participants "are asked to give a persuasive speech, make risky decisions, or imagine being a business owner" (p. 70). However, in situations in which participants listen to persuasive messages by others (such as in a church), postural expansion might signal openness to new ideas. Consequently, in contrast to previous findings that expansive postures enhance confidence in one's own thoughts (Brinol et al., 2009; Fischer et al., 2011), expansive postures may increase confidence in other people's thoughts when one listens to persuasive messages (Latu et al., 2017).

The literature on postural feedback thus also demonstrates that a particular nonverbal behaviour can embody a variety of meanings. In addition, **power, dominance and social status are themselves very broad and abstract concepts**, which may concretely manifest in different social roles and psychological states, including goals, motives, needs, emotions and so forth (Hall et al., 2005). Such broad concepts allow to interpret the same outcome as a consequence of high as well as low power, which may contribute to the heterogeneity of findings regarding power-related nonverbal behaviours (Hall et al., 2005).

The **flexibility in interpretation** resulting from the ambiguity of these concepts as well as nonverbal behaviour itself may be illustrated by means of the study by Welker et al. (2013). It found that an upright posture increased negative feelings in response to social exclusion. The authors concluded that dominant individuals are more sensitive to social rejection as this poses a threat to their social status. While this is a plausible interpretation, various other interpretations are possible. If the slouched posture had elicited stronger negative feelings, a straightforward explanation would have been increased needs for affiliation in submissive individuals. Thus, it would be equally plausible to interpret the study's actual outcome as an increased need for affiliation after dominant postures. Alternatively, adopting an upright vs. a slouched posture while playing a ball tossing game may imply and thus induce stronger interest to participate in the social interaction rather than a power-related affective state. In this case, stronger negative affect following upright postures may indicate stronger disappointment about being excluded. Given this interpretation, it would be more appropriate to label the postures as sociable and withdrawn.

This example demonstrates that whatever the result of a study, it is easy to develop a story that is perfectly compatibly with researchers' a priori assumptions. To avoid this kind of story-telling, the experimental context needs to be carefully analysed and considered in the interpretation of results. Ideally, such reflections should be made before data collection and take the form of a pre-registration of the study's hypotheses. In any case, simply referring to expansive and constrictive postures as high-power/dominant and low-power submissive fails to take into account the complexity of nonverbal social behaviour.

Context in the experiments of the present thesis

Although the posture manipulation and cover-story were identical across all experiments in the present thesis, the experimental tasks and stimuli may have created distinct social contexts. The studies on emotion recognition and action decisions both used threatening facial expressions, and participants were required to respond rapidly. In contrast, in all reverse correlation studies participants chose between neutral faces either based on their implicit group membership or their interpersonal preferences, and could further take time to make their choice. While expansive and constrictive postures may thus have evoked meanings linked to dominance and submission in the **context of social threat** and rapid responses, the face selection tasks likely conveyed a more **affiliative context**. Choosing group members or people one likes could for instance have induced processes of social comparison and self-reflection, or openness to social contact. Hence, to assess whether posture effects on the processing of social threat could originate from changes in mental representations, one would maybe have to conduct reverse correlation studies that evoke a threatening rather than an affiliative context.

3.2. Determinants of postural feedback effects neglected in the review and meta-analysis of research on power postures

The authors of the first power-posing study (Carney et al., 2010) may themselves have been aware of the difference in **meanings** of upright and slumped torso vs. expansive and constrictive body postures, since they did not reference the literature on upright and slumped torso manipulations. Nevertheless, they later combined these two sets of studies in their review, when defending their findings in response to the first non-replication (Carney et al., 2015). In their recent p-curve analysis, Cuddy et al. (2018) addressed this explicitly for the first time, stating that all included studies modified expansion of the upper body. Thereby, they implicitly assume that upper body expansion is the only crucial feature of power posturing and discard contextual meaning as well as other important determinants.

One further determinant that may even determine whether erect postures are perceived as confident and proud or nervous and polite, and thus as signals of high or low power, seems to be **physical relaxation vs. tension** (Hall et al., 2005). Relaxation has been recognized as an important feature of nonverbal dominance behaviour for a long time (Harper, 1985; Mehrabian, 1981). Certain results indicate that relaxation may in fact be more vital than expansion, as upright postures with full extension of the spinal cord were experienced as more unpleasant, arousing and uncomfortable and less dominant than relaxed upright postures (Ceunen, Zaman, Vlaeyen, Dankaerts, & Diest, 2014). In the same vein, expansive but tense standing-at-attention postures induced subordinate attitudes and behaviour (Bialobrzeska & Parzuchowski, 2016).

In my opinion, the validity of combining the all studies included in the review and meta-analysis under the heading of "power postures" (Carney et al., 2015; Cuddy et al., 2018) is questionable. Given the inclusion of a variety of different postural manipulations in various different contexts, the statement that postural feedback has an effect on feelings, affective states and self-evaluations (Cuddy et al. 2018) is a very general one. It further says nothing about the **direction of the effect**, nor the circumstances under which the direction of an effect reverses. In fact, the p-curving method used by Cuddy et al. (2018) did not take into account that expansive postures had positive or negative effects depending on the context, but simply counted each significant result as a further confirmation of a postural feedback effect. However, quite a proportion of these significant results actually were opposite to what one imagines when thinking of power posing. As Credé (2018) puts it in his commentary on the p-curve analysis, "A negative effect of a contractive pose is not evidence for the positive effect of an expansive pose."

Results pointing in the **opposite direction**, revealed for example a decrease of feelings of power and pride, creativity, and mathematical abilities either in general or under certain conditions (Garrison et al., 2016; Hao et al., 2017; Riskind, 1984; Roberts & Arefi-Afshar, 2007). Still other results demonstrated an increase of obedience, sensitivity to social exclusion and cortisol levels after expansive postures in contexts in which one would usually rather constrict one's body (Bialobrzeska & Parzuchowski, 2016; Turan, 2015; Welker et al., 2013). All of these results obviously speak against a benefit of simply adopting a high-power posture in any challenging situation in everyday life. Instead, posture might have to be appropriate to one's particular immediate circumstances.

Finally, combining effects of upright vs. slumped and expansive vs. constrictive postures overlooks another fundamental difference between these different manipulations: **the moment**

and the duration for which postures were adopted. In almost all studies using whole body expansion or constriction the postures were only briefly adopted before the experimental task like in the initial power-posing study (Carney et al. (2010). In contrast, upright and slumped sitting positions are always adopted during and throughout the task. Only the first set of studies relies on postural feedback effects to last beyond the actual posture manipulation. Therefore, slumped and upright upper body effects may not necessarily provide evidence for effects of power postures.

In a certain sense, expecting postural feedback effects to last and influence subsequent behaviours assumes that holding expansive and constrictive postures constitutes a power induction akin to other **mood induction procedures**. However, theories concerning embodied cognition do not typically assume that bodily actions induce full affective experiences, and most evidence does not demonstrate consciously experienced mood changes (Damasio & Carvalho, 2013; Niedenthal et al., 2009; Winkielman et al., 2015). For instance, re-activations of neural representations are rarely full simulations of previously experienced bodily states according to perceptual symbol theory (Barsalou, 1999). Furthermore, studies focusing on perception-action links typically investigate feedback effects during the execution of bodily actions (e.g. Fantoni & Gerbino, 2014; Sel et al., 2015).

I tried to address this issue in the revers correlation studies (one of them included the hormone collection). In order to maximize postural feedback effects, participants were instructed to adopt an expansive or constrictive sitting posture while performing the task, in addition to adopting standing postures before every other block. Yet, in hindsight, this combination of postural manipulations before and during the task does not allow clear conclusions about which part exerted an effect (in any case, there were no effects in all but one of these studies).

Given all of the above points, Cuddy et al.'s (2018) claim that there is strong empirical evidence for postural feedback effects on affective, emotional and self-evaluative variables should be considered with caution. So far, only the effect on feelings of power is backed up by sufficient empirical evidence (Gronau et al., 2017). Yet, given that this effect is stronger in participants who knew how the postures were supposed to make them feel, there is reason to believe that this effect is partially explained by a demand or placebo effect.

4. A personal note on the current replicability debate

The results of the power posing study by Carney et al. (2010) are not the only ones in the field of embodied cognition that have turned out not to be replicable. First, a prominent study which demonstrated that people walked slower after having been primed with the stereotype of old age (Bargh, Chen, & Burrows, 1996) did not be replicate (Doyen, Klein, Pichon, & Cleeremans, 2012). Instead of priming, experimenter beliefs seemed to account for the originally observed effects. Second, the seminal study which put forward the facial feedback hypothesis has recently failed to replicate in 17 studies by independent laboratories (Wagenmakers et al., 2016). In the original study, participants held a pen either between their teeth, which activates smiling muscles, or in between their lips, which inhibits smiling muscles (Strack et al., 1988). While participants in this study found cartoons funnier if they held the pen with their teeth, no single replication study observed a significant result, and half of them even observed results in the opposite direction (Wagenmakers et al., 2016).

Debates on the replicability of research findings extend far beyond the field of embodied cognition. The Open Science Collaboration, for example, raises the possibility that only around 40% of famous findings in psychology are replicable (Open Science Collaboration, 2015). Another recent replication project subsuming 21 experiments in the social sciences published in Nature and Science between 2010 and 2015 yields replicability rates between 57 and 67% (Camerer et al., 2018). The “power posing” study, presumably due to the large success of Amy Cuddy in science communication to the general public, has become one prominent example for a larger problem with replicability of scientific findings (Gelman, Fung, & Engber, 2016; Schultheiss & Mehta, 2018). This problem affects not only psychology, but also other scientific fields, such as pharmacology (Lancee, Lemmens, Kahn, Vinkers, & Luykx, 2017), biomedicine (Begley & Ioannidis, 2015), epigenetics (Francis, 2014) and economics (Camerer et al., 2016).

Conducting my thesis in the midst of such controversies taught me valuable lessons about the critical role of replication and transparent scientific practices for scientific progress. I am convinced that the principles of Open Science and practices including pre-registration, full reporting of all conducted studies, disclosure of all measures and experimental conditions (see Nelson, Simmons, & Simonsohn, 2018) or registered replication reports (Nosek & Lakens, 2014) point out a way forward for research on power postures, as well as psychology more generally. As far as it was possible, I have tried to implement these practices into my projects as I was discovering them, and hope that this has improved to the quality of the studies reported in this thesis.

A failure to replicate neither discredits the scientific skills nor the honesty of the authors of the original study. Undoubtedly, the authors of successful original studies that turn out not to replicate face personal challenges which need to be acknowledged. A New York Times article thoughtfully describes these personal challenges from Amy Cuddy’s perspective (Dominus, 2017). Nevertheless, the reactions of some of the original researchers (see Gelman, 2016; Schimmack, 2016; Simons, 2012; Yong, 2012) show the necessity of a shift in thinking about replications. Replication offers the possibility to disentangle robust effects from potential false positives and to identify possible methodological constraints and necessary conditions for effects to occur (Nelson et al., 2018). It thereby creates a stable ground for both future research as well as practical applications.

As evidence against effects of power postures accumulated, I increasingly doubted the validity of my own research questions and methodology. Although this was at times a personal challenge, I now appreciate this opportunity to learn about possibilities to improve scientific methods and practices. I cherish having discovered a growing community of researchers who work on changing science for the better, such as the Society for the Improvement of Psychological Science (https://improvingpsych.org/) or the Open Science Framework (https://osf.io/). They advocate for research practices that foster replicability (e.g. preregistration, appropriate statistical analyses), transparency and openness (e.g. open access, sharing materials) and strengthen the self-corrective nature of science (e.g. replication, critical but kind discussion, changing publication criteria). I am optimistic that these efforts will make science more solid, and a more gratifying endeavour for everyone involved.

5. Final conclusions

Concluding that most existing findings in the power posture literature are false positives or demand effects does not mean that body posture does not impact an agent’s perception and behaviour. Repeated failures to replicate findings in the laboratory may reduce confidence in original findings, but do not imply that postural expansiveness is irrelevant in real-life social interactions. They merely show that briefly adopting a posture, in most studies in the absence of another person, will not automatically impact perception, behaviour and physiology of the poser. Laboratory experiments, in which the individuals do not actually possess or lack social power likely do not constitute an ecologically valid social context (see also Cesario & Johnson, 2017). The few studies that studied postural feedback in more ecologically valid contexts did not focus on the most relevant social behaviours (Cesario & Johnson, 2017; Davis et al., 2017; K. M. Smith & Apicella, 2017), or suffered from low statistical power (Jamnik & Zvelc, 2017).

For future studies concerning postural feedback effects, social signalling is undoubtedly the most promising domain to explore. However, even the currently available evidence for posture effects on social behaviour is not very strong, given that all but one of the studies in this thesis do not allow clear conclusions. The focus of attention may provide an explanation for why only some studies yield significant results. However, considering evidence on posture effects as a whole hints that lack of power and resulting false positives are the more likely explanation. The most conclusive evidence comes from the study on approach and avoidance behaviour in response to social threat signals. Given that the body is most relevant when we are actually about to execute an action, a pre-registered replication of this study would probably be a reasonable next step.

In real life situations, one's own posture is just one of many factors that our brain takes into account when preparing an appropriate response to another individual's actions. Mere postural bottom-up feedback, without the usual physiological, cognitive and situational correlates of a certain posture, might not be strong enough to induce visible changes in behaviour. Instead, postural feedback effects might need to be studied in a more integral manner. In any case, postural expansiveness is highly relevant in real social interactions: it strongly influences how others perceive and approach us, which in turn affects our feelings, perception and responses to them.

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Appendix

Article: Stimulus and observer characteristics jointly determine the relevance of threatening facial expressions and their interaction with attention

Motivation and Emotion
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ORIGINAL PAPER

Stimulus and observer characteristics jointly determine the relevance of threatening facial expressions and their interaction with attention

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Abstract

Most emotional stimuli, including facial expressions, are judged not only by their intrinsic characteristics, but also by the context in which they appear. Gaze direction, for example, modifies the salience of explicitly presented facial displays. Yet, it is unknown whether this effect persists when facial displays are no longer task-relevant. Here, we first varied the salience of fearful, angry or neutral displays using gaze direction, while participants performed a gender (attended faces) or a scene discrimination task (unattended faces). Best performance occurred when faces were unattended and emotional expressions were highly salient (direct anger and averted fear), suggesting that these combinations are sufficiently important to capture attention and enhance visual processing. In a second experiment, we transiently changed participants' individual characteristics by instructing them to hold either expansive or constrictive postures. Best performance occurred for direct anger and averted fear following expansive and constrictive postures, respectively, demonstrating that stimulus and observer characteristics jointly determine the attribution of relevance of threatening facial expressions and their interaction with attention.

Keywords Emotion · Gaze · Threat · Body posture · Object-based attention

Michèle Chadwick and Hannah Metzler have contributed equally to this work. Jorge L. Armony and Julie Grèzes have jointly supervised this work.

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Introduction

Our survival depends on the ability to rapidly detect and attend to what is most important in our immediate environment. Some stimuli can have biological significance in and of themselves, with their survival value dictating their importance (Panksepp and Biven 2012). These are salient stimuli and are said to capture attention involuntarily (Mohanty and Sussman 2013). For others, instead, the attribution of relevance may exist in the person-environment relationship, which can change over time and circumstances (Lazarus 1991, 2006; Speisman et al. 1964) and can alter how these objects are processed (Fecteau and Munoz 2006).

Among the most salient stimuli having a direct bearing on one's goals, needs or well-being (Lazarus 1991; Ohman and Mineka 2001; Sander et al. 2003), are facial expressions of emotion and especially those signaling potential threat (Hansen and Hansen 1988). Yet, their salience appears to be neither fixed nor exclusively dependent upon facial features alone, as the context in which they appear can influence how we judge them (Aviezer et al. 2008; Righart and de Gelder 2006). For example, co-emitted social cues, such as eye gaze direction, act as contextual information which modulates an observer's appraisal of the emotional expression:

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an angry face with eyes gazing towards the observer signals the observer is the target of that hostility while a fearful face with eyes gazing away from the observer signals a potential danger in the observer's immediate environment. Both these emotion-gaze combinations (direct anger and averted fear) have been shown to be more efficiently processed (El Zein et al. 2015), more quickly categorized (Adams and Kleck 2003, 2005; Hess et al. 2007), rated as more intense (Cristinzio et al. 2010; N'Diaye et al. 2009) and negative (Ewbank et al. 2010), and perceived to signal greater danger than anger with averted gaze and fear with direct gaze (Sander et al. 2007). Together, these findings clearly established that these emotion-gaze combinations (direct anger and averted fear, which we will call Threat+) are more salient than averted anger and direct fear combinations (henceforth, Threat−).

Given the limited capacity of our attentional system to process visual information, the prioritized processing of salient stimuli classically results in the capture of attention to the detriment of other ongoing behaviour (Desimone and Duncan 1995). Accordingly, in the presence of salient distracters such as threat-related displays, most studies have found a deterioration in performance in an ongoing task in the form of slower reaction times (Eastwood et al. 2003; Vuilleumier and Schwartz 2001; see; Carretié 2014 for a review; but see; Phelps et al. 2006 for opposite results). So far, the processing of threat-related stimuli has been shown to be prioritized independently of whether or not the stimulus is attended to (e.g. Dolan and Vuilleumier 2003; Ohman 2002; Vuilleumier et al. 2001). Yet, and although gaze direction is known to modulate the salience of threat-related displays, it remains to be demonstrated whether this influence of gaze persists when threat-related displays are no longer relevant to the task, i.e. presented simultaneously with task-relevant information competing for attention. For these reasons, we investigated the impact of emotional salience on task performances, both when faces were task-relevant and task-irrelevant. To do so, we manipulated, in an orthogonal fashion, the salience of the stimuli and participants' object-based attention; the former by presenting different combinations of facial expressions of emotion and gaze direction, and the latter by changing the task relevance of the faces in face-scene composite images.

Further, if the attribution of relevance depends on the person-environment relationship, our perception of the world must also be constrained by our potential to interact with it. Such constraint has been demonstrated, for example, as participants make lower estimations of hill slant following the unwitting consumption of a caloric, as opposed to a non-caloric beverage (Schnall et al. 2010), and judge distance differently according to whether or not they are carrying a heavy backpack (Proffitt et al. 2003). Such findings suggest that perception is the result of the observer's appraisal of their environment (Proffitt 2006).

Perception has also been shown to be dependent upon the context within which the observers find themselves, notably the context of their own body. Comfortable, as contrasted with uncomfortable, body postures increase the likelihood that neutral faces are judged as happy rather than angry (Fantoni and Gerbino 2014). However, it might be argued that socially meaningful body postures should even more greatly impact our perception of social stimuli. Socially relevant body postures such as expansive or constrictive postures signal dominance or submissiveness, respectively, across a wide variety of species (e.g. de Waal 2007; Hagelin 2002; Grant and Mackintosh 1963). Of interest here, these postures have been shown to alter behaviour in a manner related to the status they embody (see Carney et al. 2015 for a review). To our knowledge, only two studies addressed the influence of power on social perception. Schultheiss and Hale (2007) showed that power-motivated individuals directed their attention towards faces signaling submissiveness but away from faces signaling high dominance. Similarly, Yap et al. (2013) revealed that individuals who currently hold a powerful role under-estimate the others' size, another dominance signal, while individuals in a powerless role over-estimate it. These results suggest that current power status has the potential to distort our perception of the social world.

The questions arise as to whether this influence is still present when the stimulus is competing for attention with task-relevant information, and whether context enters into this competition to further modulate performance. We therefore examined, in Experiment 2, the interactive effect of stimulus and observer characteristics; i.e. whether transient characteristics of dominance modulate the impact of emotional salience on task performance, both when faces are task-relevant and task-irrelevant. We did so by manipulating the posture held by participants using either expansive (dominant) or constrictive (submissive) postures as they completed the same tasks used in Experiment 1.

Experiment 1

Experiment 1 aimed at addressing the impact of emotional salience on task performance under different attention conditions; i.e. whether Threat+ stimuli are sufficiently salient to influence performance of an ongoing task, even when they are task irrelevant. To do so, we manipulated (1) emotional displays and eye gaze direction to vary the intrinsic salience of the stimuli, and (2) the attention of the observer by making the face stimuli portraying emotional displays task-relevant or task-irrelevant, by having participants attend either to scenes or to faces presented in a single overlapping display.

Given the prioritized treatment of threat-related stimuli whether attended or not (e.g. Dolan and Vuilleumier 2003; Ohman 2002; Vuilleumier et al. 2001) we expected threat-related stimuli to impair performance overall. Further, the expression-by-gaze factorial design could yield three possible outcomes: (1) no effect of gaze, suggesting it is the salience of the expression itself, and not of the relation between emotion and gaze direction, which influences performance (2) a main effects of gaze, which would mean that being looked at or not alters the observer's performance, regardless of the face's emotional expression, and (3) an interaction between gaze and expression. Based on the findings from the literature described in the "General Introduction" section, we expected this third outcome; specifically, a difference in performance (possibly modulated by attention) between Threat+ and Threat− displays.

Methods and materials

Participants

Forty-one healthy volunteers (22 males; mean age 24.4 ± 4.2 years) participated in the experiment. All participants had normal or corrected-to-normal vision, were naive to the aim of the experiment and had no neurological or psychiatric history. All individual participants included in the study provided written informed consent according to institutional guidelines of the local research ethics committee and were treated in accordance with the declaration of Helsinki. At the end of the experiment, participants were debriefed and paid for their participation.

Stimuli

A total of 324 face stimuli were created from the Radboud Faces Database (Langner et al. 2010). This consisted of 36 actors (18 male), expressing three emotions: anger, fear and neutral and either a direct or an averted gaze (half left/half right). Using Adobe Photoshop CS5.1 (Adobe Systems, San Jose, CA), faces were modified to remove any visible hair, resized and repositioned so that eyes, nose and mouth appeared at the same level within the same circumference for all face stimuli. All images were then converted to greyscale and adjusted to be of equal contrast and cropped into a 280 × 406 pixel oval centred within a 780 × 1024 pixel black screen.

We created composite face-scene stimuli, similarly to those described in Dickie and Armony (2008). A total of 648 stimuli were created. They consisted of the 36 different actors described above with 3 emotional expressions (neutral, angry and fearful) and 3 gaze directions (direct, left and right) which were then superimposed upon non-copyrighted stock photos of outdoor and indoor scenes consisting primarily of buildings and streets, and rooms with furniture, respectively, without any social information (i.e., no people were present). A total of 36 scenes (18 indoor) were randomized across sex/emotion/gaze direction. Before superimposition, all faces and scenes were adjusted for contrast and luminosity such that no significant differences between emotions or between faces and scenes remained. Both face and scene stimuli were then reduced to 50% transparency and superimposed.

Procedures

An instruction screen presented for 1 s, comprising the letters M + F or E + I, indicated whether participants were cued to attend to the face or to the scene, judging if the face was male or female, or if the scene was exterior or interior. Moreover, the order of the letters was a reminder about which mouse button (left/right) represented which response option. Order of letters and thus mouse clicks was counterbalanced across subjects. The central "+" served as a fixation cross, such that participants had their field of vision located on the centre of the stimuli. Stimuli were 19 cm high × 15 cm wide, presented at a distance of 50 cm (visual angle: 21° h × 17° w).

Immediately following the instruction screen, the composite face-scene stimulus was presented centrally for 250 ms followed by a response screen marked "Respond". Although subjects were allowed a maximum of 2 s to respond, the instruction screen for the subsequent trial appeared as soon as a response was made. Each face-scene composite image was presented twice during the experiment, once with the gender task and once with the scene task for a total of 432 trials. Half the stimuli (216 trials) were presented to each participant and this assignment was counterbalanced across participants. After 72 trials and then again after 144 trials, a "Pause" screen appeared allowing participants to take a break for as long as they wished. During these two breaks, participants were advised to take a pause of at least a few seconds to close their eyes or look away from the screen to avoid excess fatigue.

Training

Prior to testing, participants completed three practice exercises using stimuli created uniquely for the training session. The first training exercise consisted of 15 trials where the participant was only to identify the gender of the face. The second training exercise consisted of 15 trials where the participant was only to identify the type of the scene. Finally, the third training exercise consisted of 15 trials where the participant was only to identify either the gender of the face or the type of scene in mixed order. When participants reached a minimum score of 60% on each of the three exercises they could proceed to the actual experiment, otherwise all three exercises were repeated. All participants obtained at least 60% in all three exercises in either 1 or 2 training sessions.

Data analysis

The data were cleaned so that only responses with a reaction time superior to 200 ms were included in analyses. Reaction times inferior to 200 ms were excluded as they were considered to constitute anticipatory or erroneous key presses rather than actual reaction times. These represented 2.5% of all responses, and including them in the analysis did not alter the findings (i.e., all significant effects remained significant and no new ones arose). The data was analysed using a factorial repeated measures analysis of variance (ANOVA) with task (gender or scene), emotion (angry, fearful or neutral) and gaze (direct, averted) as within-subject factors and sex of subject as a between-subject factor. Reaction time analyses were conducted using only correct responses. Participant's sex was included as a factor given that there are several reports in the literature of sex differences in emotional processing, particularly in processing threat-related stimuli (see review by Kret and De Gelder 2012), as well as in the literature on dominance (Del Giudice 2015). However, it should be noted that results are the same if we remove sex as factor in the analysis. All ANOVAs used Greenhouse–Geisser adjusted degrees of freedom. The threshold for statistical significance in all analyses was set at a p value of .05 (two-tailed in the case of t-tests). Partial eta-squared was used as the effect size estimate for ANOVAs. Planned comparisons were used only where main effects or significant interactions were observed and Cohen's d_{av} was used to report effect sizes for dependent t-tests as recommended by Lakens (2013), calculated as the standardized mean difference between conditions divided by the average standard deviation (Fig. 1).

Results

Accuracy collapsed across tasks was 76.7 (SEM = 0.1%), indicating that participants both understood instructions and could correctly perform the task. Importantly, our manipulations were successful in generating sufficiently high percentage of errors to allow accuracy-based analyses. The repeated-measures ANOVA across tasks revealed a main effect of Task ($F(1,39) = 30.89$, $p < .001$, $\eta_p^2 = 0.44$), related to the fact that the Scene task (71%) was more difficult than the gender task (81%), as in previous studies using similar stimuli (Dickie and Armony 2008). A significant emotion × gaze interaction across tasks ($F(2,78) = 4.294$, $p = .017$, Greenhouse–Geisser corrected $p = .022$, $\eta_p^2 = 0.099$) was also found. Planned comparisons revealed that participants tended to be more accurate in the presence of direct as opposed to averted anger ($t(40) = 1.958$, $p = .057$, $d = 0.25$) and were more accurate for averted as opposed to direct fear ($t(40) = 2.701$, $p = .010$, $d = 0.50$); i.e. for threat + combinations (see Table 1).

Importantly, the ANOVA revealed that the task × emotion × gaze interaction of interest was marginally significant ($F(2,78) = 3.12$, $p = .049$, Greenhouse–Geisser corrected $p = .057$, $\eta_p^2 = 0.074$). This effect was mainly driven by a strong emotion × gaze interaction in the scene task ($F(2,78) = 5.12$, $p = .008$, Greenhouse–Geisser corrected $p = .012$, $\eta_p^2 = 0.116$): participants tended to be more accurate at discriminating scenes in the presence of direct anger as opposed to averted anger ($t(40) = 1.693$, $p = .098$, $d = 0.24$) and were significantly more accurate at discriminating scenes in the presence of a fearful face with an averted as opposed to a direct gaze ($t(40) = 2.851$, $p = .007$, $d = 0.53$), i.e. for Threat+ combinations, with no differences in accuracy between direct and averted neutral expressions ($t(40) = 0.548$, $p = .587$, $d = 0.09$) (see Fig. 2).

Finally, a significant task × emotion interaction ($F(2,78) = 6.082$, $p = .004$, $\eta_p^2 = 0.135$) was also observed,

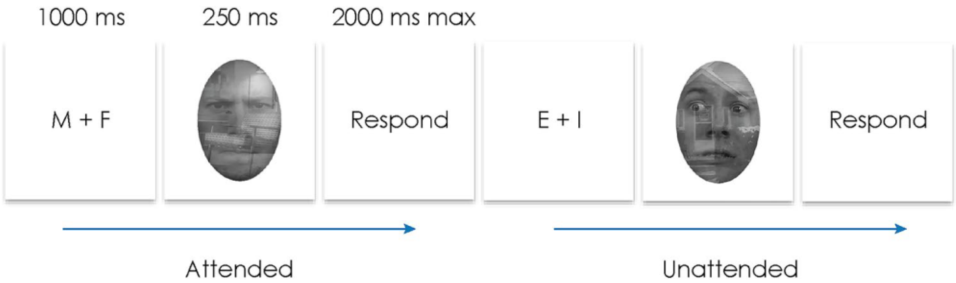

Fig. 1 Time course of the experiment over 2 trials. The instructions screen with M + F, (attended) or E + I, (unattended) and the central fixation cross, presented for 1 s was immediately followed by the stimuli presented centrally for 250 ms. Subjects had a maximum of 2 s to respond using the mouse upon the appearance of the "Respond" screen at which point the next trial began and a new instruction screen appeared. Note that stimuli were created using the Radboud Face Database, developed by the Behavioural Science Institute of the Radboud University, Nijmegen (Langner et al. 2010)

Table 1 Mean accuracy (% ± SEM) and mean reaction times (ms ± SEM) during Experiment 1, for each condition of interest and for the gender and scene tasks overall

Experiment 1	Accuracy (%)				Reaction times (ms)			
	Mean %	SEM	Min	Max	Mean	SEM	Min	Max
Gender task	81.65	1.07	65.00	96.30	564.80	22.98	321.00	898.00
Anger Av	77.59	1.633	53.85	100.00	560.90	21.99916	311.00	905.00
Anger Dir	79.12	1.773	55.56	100.00	582.36	28.25193	331.00	1074.00
Fear Av	82.45	1.493	66.67	100.00	576.75	25.35665	316.00	877.00
Fear Dir	81.51	1.418	61.11	94.44	547.51	22.14024	299.00	1019.00
Neutral Av	85.89	1.678	64.71	100.00	570.09	26.44820	281.00	1003.00
Neutral Dir	83.15	1.929	53.85	100.00	560.90	21.99916	311.00	905.00
Scene Task	71.86	1.55	54.63	90.74	675.49	27.77	362.00	1025.00
Anger Av	71.13	2.109	43.75	100.00	671.41	33.35334	334.00	1187.00
Anger Dir	74.65	2.310	44.44	100.00	655.31	27.69394	344.00	1029.00
Fear Av	75.82	2.112	41.18	100.00	666.07	28.80710	349.00	1110.00
Fear Dir	68.68	2.088	27.78	88.89	727.43	32.85484	358.00	1201.00
Neutral Av	69.74	2.302	33.33	94.44	670.92	29.44736	341.00	1104.00
Neutral Dir	71.09	2.160	38.89	94.44	661.75	27.73588	355.00	1005.00

Av averted gaze, *Dir* direct gaze

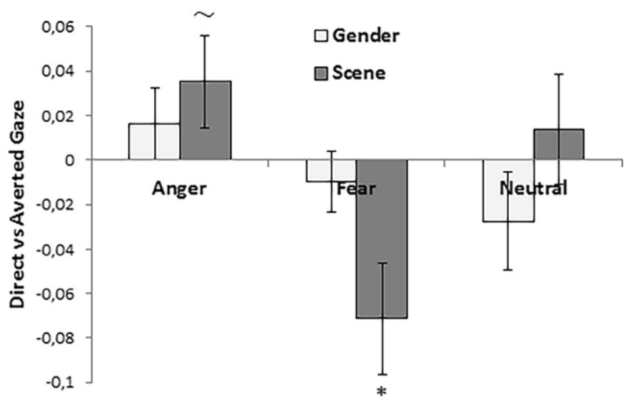

Fig. 2 Experiment 1: mean difference in accuracy (% ± SEM) between direct and averted gaze for angry, fearful, and neutral faces. A significant triple task × emotion × gaze interaction indicates that subjects were significantly more accurate in the discrimination of scenes in the presence of a fearful face with an averted as opposed to a direct gaze and tended to be more accurate in the presence of an angry face with a direct as opposed to an averted gaze. No significant or trend level differences in accuracy were found for neutral stimuli. (*$p<.05$, **$p<.01$, ***$p<.001$)

and separate ANOVAs indicated that this interaction was driven by a significant main effect of emotion for the gender task ($F(2,78)=8.139$, $p=.001$, $\eta_p^2=0.173$). Participants were more accurate in identifying the gender of a neutral, as opposed to an angry face ($t(40)=3.933$, $p<.001$, $d=0.65$), and tended to be more accurate for neutral as opposed to fearful faces ($t(40)=1.805$, $p=.079$, $d=0.29$). Participants were also more accurate in identifying the gender of fearful, as opposed to an angry face ($t(40)=2.183$, $p=.035$, $d=0.40$).

Reaction time analysis mirror the result pattern described for accuracy and is reported in the "Appendix" section and in Table 1.

Discussion

Experiment 1 addressed whether the influence of emotional salience of faces, given by specific combinations of gaze direction and emotional expression, on accuracy persists when they are not relevant to the ongoing task.

When faces were task-relevant (gender task), we observed reduced performance in the presence of fearful and angry as compared to neutral facial expressions, with no effect of gaze direction. This result replicates previous findings showing that threat-related, as compared to neutral displays, can disturb behavioural performance (see Carretié 2014 for a review), notably during a gender discrimination task (e.g. Neath and Itier 2015). Reduced performance possibly arises from the fact that gender discrimination tasks may be associated with negligible attentional costs (Reddy et al. 2004), thus leaving sufficient attentional resources available to process the emotional information conveyed by the facial expressions. We show here that this is the case even for object-based attention, i.e., when faces needed to be segregated from overlapping scenes.

Interestingly, a different pattern emerged when faces were task-irrelevant (scene task). Firstly, we observed an interaction between gaze and expression on accuracy when faces were unattended, suggesting that it is the salience of the emotional display as a whole, and not either the expression or the gaze direction alone (no effects of gaze for neutral), which influences performance. This is in contrast with results obtained when faces were attended, where the salience of the expression alone, and not of the emotion–gaze combination, influenced performance. Moreover, we observed better performance for highly salient combinations (Threat+, i.e., direct anger and averted fear) despite the resources required to discriminate task-relevant indoor and outdoor scenes. Although these results may seem to run counter to the notion of emotion disrupting task performance (Vuilleumier and Schwartz 2001; Eastwood et al. 2003; Fenske and Eastwood 2003; Hartikainen et al. 2000), one other study reported results consistent with ours: Phelps et al. (2006) found that participants were more accurate in identifying the orientation of Gabor patches preceded by a fearful as opposed to a neutral face. While facial cues and targets were presented at two different time points in that study, we observed here that the presence of task-irrelevant Threat+ combinations similarly enhanced early vision of scenes presented at the same time and spatially overlapping with faces.

The question remains as to why performance was best for Threat+ combinations and not simply for emotional versus neutral faces. We might speculate that this may be due to the difficulty of the scene task. We know that we integrate all available external cues, including gaze direction, when emotional expressions become difficult to identify (El Zein et al. 2015; N'Diaye et al. 2009; Graham and LaBar 2007). We argue that only direct anger and averted fear may be sufficiently salient to direct our attention towards the various salient features of the faces (Benuzzi et al. 2007; Adolphs et al. 2005), and may modulate arousal (Peck and Salzman 2014). Consistent with this hypothesis, the "GANE" model (Mather et al. 2016) proposes that arousal biases perception in favour of high-salience stimuli which, in this case, may have led to the preferential processing of overlapping scenes in the presence of highly salient combinations. Further studies using eye-tracking could better discern the precise nature of the attribution of attention with this type of stimuli.

Experiment 2

Results from Experiment 1 demonstrated that altering the salience of task-irrelevant emotional expressions by changing their gaze direction can influence performance, particularly when participants directed their attention to the scene (rather than to the face). In Experiment 2 we wanted to investigate the other side of this issue, namely whether changing the individual characteristics of the observer can influence the attribution of relevance of these expressions/gaze combinations to subsequently alter performance.

Rather than choosing trait differences in dominance and submissiveness, we decided to attempt to induce transient changes in dominance status using postures which, although controversial (see Smith and Apicella 2017), have been shown to induce reliable changes in feelings of power and other associated affective states across several sets of studies (Cuddy et al. 2018; Gronau et al. 2017; Cesario and Johnson 2017). We would like to suggest that some of the controversy surrounding these findings (e.g. Cesario and Johnson 2017; Garrison et al. 2016; Ranehill et al. 2015; Ronay et al. 2016; Smith and Apicella 2017) may arise from the fact that existing studies mainly investigated posture effects outside meaningful social contexts, thus underestimating the fundamentally social and communicative nature of these dominance displays. By manipulating the posture held prior to and at several intervals during the same behavioural experiment presented in Experiment 1, we aimed at prompting transient changes in dominance or submissiveness in the observer to examine differences in how the observer relates to fear and anger.

As an evolutionary ancient behaviour that exists across many animal species, postural expansiveness is usually regulated without awareness and spontaneously adapts to ongoing social interactions in humans (Tiedens et al. 2007). Social status can also be readily inferred from facial characteristics (Oosterhof and Todorov 2008) or "first-glimpse" scenarios (Mast and Hall 2004) as quickly as 40 ms or less (Rule et al. 2012). Moreover, personality trait dominance has been shown to be associated with the processing of cues of aggression and anger only when these cues were masked as opposed to unmasked (Hortensius et al. 2014; Terburg et al. 2012, 2011). We therefore predicted that the influence of individual and transient characteristics of dominance should be stronger when faces were unattended. Yet, we did not have specific predictions regarding the direction of this putative influence.

Methods and materials

Participants

All available studies using similar posture manipulations included between 18 and 38 subjects per posture condition (e.g., Cesario and McDonald 2013; Fischer et al. 2011; Huang et al. 2011). Aiming at including at least as many participants, we tested 45 healthy volunteers (22 males; mean age, 25 ± 3.5 years) in a within-subject design. Inclusion criteria and compliance ethic principles were the same as those described for Experiment 1.

Material

The stimuli and experimental design employed were the same as those described in Experiment 1, with the addition of a self-report questionnaire at the end of each session in which subjects were asked to rate how dominant, in control and powerful they felt on a scale from 1 to 5.

Pose procedure

We adopted a within-subject design with two consecutive sessions, each consisting of 216 trials separated in three blocks. Participants were randomly assigned to begin either with the expansive (n = 24) or constrictive (n = 21) pose condition, and adopted the other pose in the second session. To investigate the impact of postural expansiveness on visual attention to social displays, we had subjects adopt the posture (expansive/constrictive limbs in addition to an erect/slumped upper body with the head upright/lowered) for 3 min before every block of the task, which also lasted about 3 min (see Fig. 3). This experimental design builds on previous studies that applied whole body posture manipulations similar to ours, in which participants adopted postures for varying durations (20 s to 5 min) before they performed the tasks used as dependent measures (e.g. Bohns and Wiltermuth 2012; Carney et al. 2010; Cesario and McDonald 2013; Huang et al. 2011). These studies provide evidence that the effect of such postural manipulations lasts for at least a few minutes. Holding the body posture throughout the task is possible only when tasks allow for verbal responses, or when the chosen posture manipulation involves only the upper body.

In an attempt to dissociate the posture manipulation from the main behavioural task, participants were told that a secondary goal of the experiment was to observe the effects of different postures on heart rate. At this point of the experiment, two adhesive surface electrodes were placed between the radial and ulnar arteries of both wrists of the participant

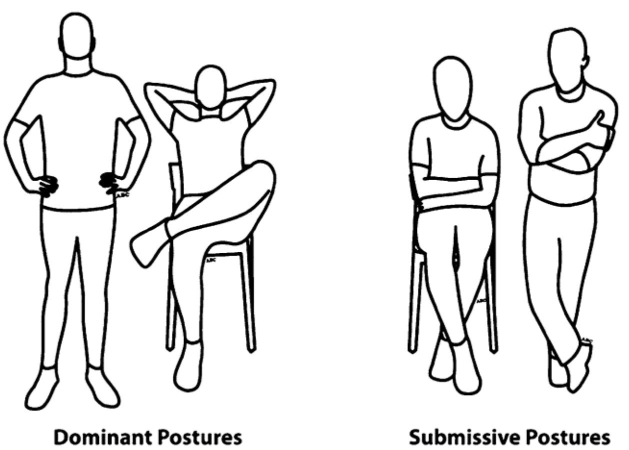

Fig. 3 Expansive and constrictive postures held in Experiment 2 (images created by Antoine Balouka-Chadwick). Note that these postures, when displayed in social contexts, have been shown to signal dominance and submissiveness (de Waal 2007)

and hooked up to the ADInstruments (ML870 P Powerlab 8/30) acquisition system. Yet, the acquisition system itself was switched off and no measures were recorded. Participants were then physically positioned into their assigned pose by an experimenter. To avoid any evocation of power, strength, dominance, or on the contrary, submissiveness, care was taken to avoid demonstrating the posture and using such adjectives as “open”, “closed”, “expansive” or “constrictive”.

Participants were instructed to maintain their position for 3 min before every block (72 trials) and informed they were being watched by the experimenter through a webcam to ensure they did so correctly. At the end of the 3-min period they were to proceed with the next block of the main experiment. In total, they thus adopted the same posture three times in each session. When session 1 was completed, subjects notified the experimenter who then instructed them to take their second posture, which they held for 3 min before beginning session 2 of the behavioural experiment.

After each session, subjects were prompted to complete the on-screen self-report questionnaire described above. Importantly, unlike studies like the one of Carney et al. (2010) wherein participants performed social judgment tasks, our participants were given no task whatsoever while holding the assigned postures.

Data analysis

The data were cleaned so that only correct responses with a reaction time superior to 200 ms were included in analyses. Reaction times inferior to 200 ms were excluded as they were considered to constitute anticipatory or erroneous key presses rather than actual reaction times. As in Experiment 1, including these faster RTs did not alter the results. To account for the within-subject design, we first ran a repeated-measures ANOVA with both sex of subject and order of pose (expansive–constrictive, constrictive–expansive) as between-subject factors and pose (expansive, constrictive), task (gender, scene), emotion (neutral, fear, anger) and gaze (direct, averted) as within-subjects factors. We then performed exploratory analyses of session 1 and 2 separately, by running two independent repeated measures ANOVAs for each session, with both posture and sex of subject as between-subject factors and task (gender, scene), emotion (neutral, fear, anger) and gaze (direct, averted) as within-subjects factors.

Results

After excluding one participant due to technical problems during the testing, we analysed data from 23 participants who adopted the expansive posture in session 1 and the constrictive posture in session 2, and 21 participants who adopted postures in the reverse order. Overall accuracy, collapsed across tasks and sessions, was well above chance at $M = 74.42 \pm 1\%$ (SEM), indicating that subjects understood instructions and could correctly perform the task.

A first repeated ANOVA with both order of pose (expansive–constrictive, constrictive–expansive) and sex of subject as between-subject factors and pose (expansive, constrictive), task (gender, scene), emotion (neutral, fear, anger) and gaze (direct, averted) as within-subjects factors revealed a tendency for a quintuple order of pose × pose × task × emotion × gaze interaction ($F(2,80) = 2.225$, $p = .115$, $\eta_p^2 = 0.053$), and a significant quadruple order of pose × task × emotion × gaze interaction ($F(2,80) = 3.648$, $p = .030$, $\eta_p^2 = 0.084$). These interactions suggest that the impact of pose may be different in Session 1 and Session 2. Since none of the past studies have used within-subject designs in which participants adopt expansive and constrictive postures in consecutive sessions, possible explanations for this order effect could be either related to potential long-term effects of the first posture (adopted three times in Session 1), or to learning effects that might have influenced task performance (suggested by better performance in Session 2 ($M = 75.68 \pm 1\%$) as compared to Session 1 ($M = 73.38 \pm 1\%$); $t(43) = 3.474$, $p = .001$). We therefore decided to perform exploratory analyses of Session 1 and 2 separately, by running two independent repeated measures ANOVAs for each session, with both posture and sex of subject as between-subject factors and task (gender, scene), emotion (neutral, fear, anger) and gaze (direct, averted) as within-subjects factors. These analyses imply that the pose effect will be assessed between subjects (Group 1 $n = 21$ and Group 2 $n = 23$ subjects), rather than within subjects with 44 participants. During Session 1, the task × emotion × gaze interaction for accuracy was modulated by pose. Our ANOVA revealed a significant quadruple pose × task × emotion × gaze interaction ($F(2,80) = 3.549$, $p = .033$, $\eta_p^2 = 0.081$). Separate ANOVAs for both the gender task and the scene task revealed that this effect was driven by the scene task, where we found a significant triple pose × emotion × gaze interaction ($F(2,80) = 4.646$, $p = .012$, $\eta_p^2 = 0.104$), which was not significant in the gender task ($F(2,80) = 0.007$, $p = .993$, $\eta_p^2 = 0.000$). The emotion × gaze interaction was found to be significant in both expansive participants ($F(2,42) = 3.922$, $p = .027$, $\eta_p^2 = 0.157$) and constrictive participants ($F(2,38) = 3.945$, $p = .028$, $\eta_p^2 = 0.172$). Planned comparisons of the interaction in the scene task revealed that participants having held an expansive posture discriminated between scenes significantly better in the presence of direct, as opposed to averted anger ($t(22) = 3.081$, $p = .005$, $d = 0.46$), although not for averted as opposed to direct fear ($t(22) = 0.233$, $p = .818$, $d = 0.05$), while participants having held a constrictive, submissive posture discriminated between scenes significantly better in the presence of averted, as opposed to direct fear ($t(20) = 2.518$, $p = .020$, $d = 0.64$), although not for direct as opposed to averted anger ($t(20) = 0.225$, $p = .824$, $d = 0.04$), (see Fig. 4). The difference between direct and averted neutral faces was neither significant for expansive posture ($t(22) = 1.668$, $p = .110$, $d = 0.49$), not for constrictive posture ($t(20) = 0.956$, $p = .350$, $d = 0.21$).

During Session 2, the task × emotion × gaze interaction for accuracy was not modulated by pose. The ANOVA revealed a significant task × emotion × gaze interaction ($F(2,80) = 3.868$, $p = .025$, $\eta_p^2 = 0.088$), but no significant quadruple pose × task × emotion × gaze interaction ($F(2,80) = 1.239$, $p = .295$, $\eta_p^2 = 0.030$). Separate ANOVAs for both the gender task and the scene task revealed that the task × emotion × gaze interaction was driven by the scene task, where we found a significant emotion × gaze interaction ($F(2,80) = 4.359$, $p = .016$, $\eta_p^2 = 0.098$), which was not

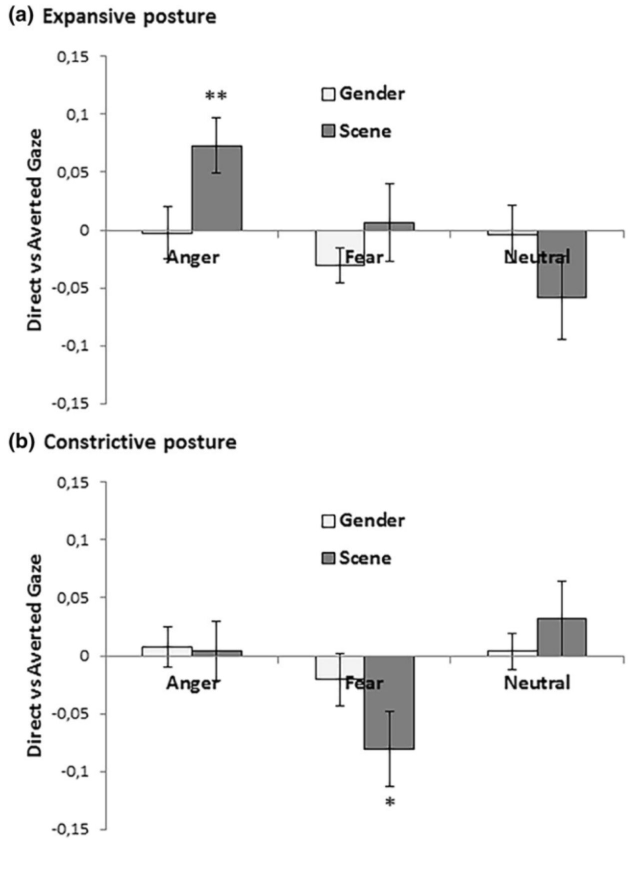

Fig. 4 Experiment 2—Session 1: mean difference in accuracy (% ± SEM) between direct and averted gaze for angry, fearful, and neutral faces split by expansive (dominant) and constrictive (submissive) poses. Participants having held an expansive posture discriminated between scenes significantly better in the presence of direct, as opposed to averted anger, while participants having held a constrictive posture discriminated between scenes significantly better in the presence of averted, as opposed to direct fear (*$p < .05$, **$p < .01$, ***$p < .001$)

significant in the gender task (F(2,80) = 0.556, p = .576, η_p^2 = 0.014). Planned comparisons of the interaction in the scene task revealed that participants discriminated between scenes significantly better in the presence of direct, as opposed to averted fear (t(43) = 2.053, p = .046, d = 0.25), and in the presence of averted, as opposed to direct neutral faces (t(43) = 2.053, p = .046, d = 0.23).

Reaction time analyses revealed faster responses in the gender than the scene task as in Experiment 1, but no significant interactions of pose × task × emotion × gaze or task × emotion × gaze in either session. Further details for the reaction time analyses are reported in the "Appendix" section. Tables 2 and 3 summarize descriptive statistics for Session 1 and 2, respectively, including both accuracy and reaction time measures.

Subjective evaluation of power

Self-reported feelings of dominance, power and control were averaged to one total score. ANOVAs with the total scores at the end of Session 1 or 2 as dependent variable revealed no significant impact of sex or type of pose taken (pose effect Session 1: F(1,42) = 0.86, p = .36, η_p^2 = 0.019, Session 2: F(1,41) = 0.17, p = .68, η_p^2 = 0.004).

Table 2 Mean accuracy (% ± SEM) during Experiment 2—Session 1, for each condition of interest and for the gender and scene tasks overall for the dominant and submissive postures

Experiment 2	Accuracy dominant (%)				Accuracy submissive (%)			
Session 1	Mean	SEM	Min	Max	Mean	SEM	Min	Max
Gender task	79.44	1.68	57.41	92.59	81.81	1.68	64.29	93.46
Anger Av	73.99	2.21	50.00	88.89	78.43	2.44	45.45	93.33
Anger Dir	73.79	2.59	42.86	94.44	79.05	2.36	57.14	94.44
Fear Av	83.35	2.41	55.56	94.44	83.02	2.20	64.71	100.00
Fear Dir	80.14	2.23	50.00	94.44	81.08	2.18	66.67	100.00
Neutral Av	82.51	2.37	55.56	100.00	84.51	2.12	66.67	100.00
Neutral Dir	82.13	2.48	50.00	100.00	85.02	1.99	66.67	100.00
Scene task	66.91	2.07	50.00	86.92	65.72	2.39	43.93	82.41
Anger Av	63.87	3.36	31.25	88.89	64.83	2.95	27.78	82.35
Anger Dir	71.26	2.42	44.44	94.44	65.42	3.21	38.89	83.33
Fear Av	65.09	3.27	38.89	88.89	71.38	2.76	44.44	94.44
Fear Dir	65.86	3.27	38.89	94.44	63.25	2.90	30.00	83.33
Neutral Av	70.59	2.53	50.00	88.89	63.17	3.18	38.89	83.33
Neutral Dir	64.68	3.04	44.44	88.89	66.28	3.50	33.33	94.44

Av averted gaze, *Dir* direct gaze

Table 3 Mean accuracy (% ± SEM) during Experiment 2—Session 2, for each condition of interest and for the gender and scene tasks overall for the dominant and submissive postures

Experiment 2	Accuracy dominant (%)				Accuracy submissive (%)			
Session 2	Mean	SEM	Min	Max	Mean	SEM	Min	Max
Gender task	79.59	1.59	65.74	90.74	83.06	1.37	71.43	91.75
Anger Av	77.45	2.36	50.00	94.44	81.58	2.58	47.06	100.00
Anger Dir	77.45	2.67	40.00	94.44	82.19	2.34	55.56	94.44
Fear Av	78.48	2.29	55.56	100.00	81.69	2.25	61.11	100.00
Fear Dir	76.55	2.63	47.06	100.00	80.84	2.53	50.00	100.00
Neutral Av	81.57	2.13	55.56	94.44	86.32	1.73	72.22	100.00
Neutral Dir	84.21	2.17	64.29	100.00	85.64	2.17	72.22	100.00
Scene task	68.53	2.28	44.44	87.04	72.30	2.02	51.85	86.11
Anger Av	66.44	3.61	27.78	94.44	74.13	3.01	33.33	94.44
Anger Dir	71.04	3.56	44.44	94.44	72.75	3.21	38.89	94.12
Fear Av	66.89	2.58	44.44	94.44	68.27	2.79	44.44	88.89
Fear Dir	69.40	2.71	38.89	83.33	74.26	2.09	53.33	88.89
Neutral Av	71.58	2.80	44.44	94.44	73.48	3.16	43.75	94.44
Neutral Dir	65.73	3.35	27.78	100.00	70.38	2.40	44.44	88.89

Av averted gaze, *Dir* direct gaze

Discussion

The results of Experiment 2 demonstrate that expansive or constrictive body postures dichotomized the impact of Threat+ combinations (direct anger and averted fear) on performance when faces were unattended. Participants having held an expansive posture performed best for anger with a direct gaze while participants having held a constrictive posture performed best for fear with an averted gaze. These effects occurred only in the scene (unattended face) and not in the gender (attended face) task, concurring with effects of trait dominance on the processing of masked as opposed to unmasked aggressive social signals (Hortensius et al. 2014; Terburg et al. 2012, 2011).

The split in performance between postures appears to be driven by a reduction in salience of one of the expressions/gaze combinations. Such a reduction in hitherto salient stimuli has already been demonstrated in attentional shifts towards ecologically relevant targets. Mohanty et al. (2008) found increased covert shifts of spatial attention toward previously neutral targets (tools) and away from previously salient targets (food) as subjects became satiated. This suggests a selective modulation in the motivational value of stimuli following changes in the goals of the observer that may be top-down driven to guide attention and result in enhanced visual encoding of stimuli appraised as most relevant while simultaneously decreasing the visual encoding of stimuli appraised as least relevant (Mohanty and Sussman 2013).

A transient attribution of power has previously been shown to influence social perception, by altering the direction of attention towards or away from dominant or submissive faces (Schultheiss and Hale 2007) or by leading to under-estimate or over-estimate body size (Yap et al. 2013). In light of this, we suggest that the opposing direction of the results following expansive and constrictive postures may be related to the attribution of power to the observer resulting in a modulation of the relevance of threatening social stimuli. Effectively, anger with a direct gaze signals imminent physical aggression and elicits attributions of dominance (Hess et al. 2007) while fear with an averted gaze is often associated with a submissive stance (Vigil 2009). We speculate that body postures, by modifying the agent's capacity to bear their social consequences (e.g. dominant postures and sensitivity to pain in Bohns and Wiltermuth 2012), may have selectively modulated the motivational value of these stimuli to preferentially enhance the visual encoding of the most relevant stimuli (Mohanty and Sussman 2013). Together, our results suggest that while emotional expression and gaze direction interacted to increase the salience of the stimuli, the postures held by our participants appeared to have altered the relevance of these salient stimuli. Nevertheless, we acknowledge that future studies are needed to formally test such a hypothesis.

General discussion

We have demonstrated that gaze direction can sufficiently increase the salience of threatening facial displays to influence performance in an ongoing task, even when these stimuli are task-irrelevant. The direction of our results concurs with previous findings of the influence of gaze on threatening stimuli presented explicitly to participants, that is to say increased salience of anger accompanied by a direct gaze and of fear accompanied by an averted gaze (e.g. El Zein et al. 2015). As mentioned in the discussion of Experiment 1, the improved performance for these highly salient gaze/expression combinations in the case of these task-irrelevant stimuli lead us to speculate that, when emotional expressions become difficult to identify, only sufficiently salient expressions direct our attention towards salient facial features (El Zein et al. 2015; N'Diaye et al. 2009; Graham and LaBar 2007; Benuzzi et al. 2007; Adolphs et al. 2005) that produce sufficient arousal (Mather et al. 2016; Peck and Salzman 2014) to result in the preferential processing of the overlapping scenes. Further, in Experiment 2, the improved performance found for task-irrelevant direct anger following expansive postures concurs with studies demonstrating an association between trait dominance and the processing of aggressive cues only when masked as opposed to unmasked (Hortensius et al. 2014; Terburg et al. 2012, 2011).

Further, our second experiment demonstrated that the attribution of relevance does not occur independently of the observer and highlighted the transient influence of body postures that are similarly meaningful across many species (e.g. (de Waal 2007; Hagelin 2002; Maslow 1943)). More specifically, we found the influence of Threat+ emotional/gaze combinations to be split by posture type such that, following an expansive (dominant) posture, participants performed best in the presence of direct anger and, following a constrictive (submissive) posture, participants performed best in the presence of averted fear. Thus, results from this experiment confirm that adopting expansive and constrictive postures alters the poser's subsequent behaviour in a way that is related to the status they embody (see Carney et al. 2015 for review), in agreement with the embodiment hypothesis (Barsalou 2008), and further demonstrate that postures can influence the perception of social information even when participants perceive no difference in feelings of power themselves.

Finally, we would like to address limitations of our studies, and suggest how future studies could address some of them. Experiment 2 was conceived as a within-subject study, although we only observed significant posture effects between groups in the first session. It is possible that learning effects (evidenced by higher performance in the second session) or potential long-term effects of the first posture (adopted three times in Session 1) could explain why no posture effects occurred in Session 2. While the learning issue is more difficult to tackle, future studies could prevent carry-over effects of posture by using within-subject designs with no posture in the first session. Further, these changes in perception occurred without explicit awareness of differences in feelings of dominance or power on the part of the participants. However, although these subjective measures were modeled after those used in Carney et al. (2010), their possible limitations include their explicit nature which may have dampened the effect of the postures themselves in Session 2, their brevity (only 4 questions) and the fact that they were employed only at the end of each session and not immediately after the postures were held.

Conclusion

Taken together, our two experiments demonstrate that eye gaze direction can sufficiently increase the salience of emotional expressions to persist even when task-irrelevant and that stimulus salience and observer characteristics jointly determine the relevance of threatening facial expressions and their interaction with attention.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

Appendix

Experiment 1: supplementary results

The data were cleaned so that only responses with a reaction time superior to 200 ms were included in analyses and for reaction time data analyses, only correct responses were included.

Analyses on reaction times

Reaction times collapsed across tasks reached 620.14 ± 24.97 ms (SEM). The repeated-measures ANOVA across tasks revealed a main effect of task (F(1,39) = 133.76, $p < .001$, $\eta_p^2 = 0.745$), indicating that participants were slower during the scene task (675.49 ms) as compared to gender task (564.80 ms). The ANOVA also showed a main effect of emotion (F(1,39) = 5.399, $p = .006$, $\eta_p^2 = 0.122$). Planned comparisons of this effect found that participants were significantly faster in the presence of fearful, as opposed to angry faces (t(40) = 2.942, $p = .005$, $d = 0.16$) and for fearful as opposed to neutral faces (t(40) = 2.616, $p = .012$, $d = 0.15$). Importantly, the interaction of interest between task, emotion and gaze was significant (F(2,78) = 6.371, $p = .003$, $\eta_p^2 = 0.140$), driven by a significant emotion × gaze interaction in the scene task (F(2,78) = 6.130, $p = .003$, $\eta_p^2 = 0.136$) in which participants were significantly faster at discriminating scenes in the presence of a fearful face with an averted, as opposed to a direct gaze (t(40) = 3.630, $p = .001$, $d = 0.31$). However, the difference in reaction times between direct and averted anger conditions was not significant (t(40) = 1.024, $p = .312$, $d = 0.08$) (see Table 1).

Experiment 2: supplementary results

Analyses on reaction times

The data were cleaned so that only responses with a reaction time superior to 200 ms were included in analyses and only correct responses were included. Reaction times collapsed across sessions reached 628.68 ± 24.77 ms (SEM).

To account for the within-subject design, we first ran a repeated-measures ANOVA with both order of pose and sex of subject (expansive–constrictive, constrictive–expansive) as between-subject factors, and pose (expansive, constrictive), task (gender, scene), emotion (neutral, fear, anger) and gaze (direct, averted) as within-subjects factors. Significant interactions between order of pose × sex × pose × emotion × gaze (F(2,80) = 3.874, $p = .025$, $\eta_p^2 = 0.088$), order of pose × pose × task (F(1,40) = 14.500, $p < .001$, $\eta_p^2 = 0.266$), order of pose × pose (F(1,40) = 31.643, $p < .001$, $\eta_p^2 = 0.442$)

suggested that the impact of pose may be different in Session 1 and Session 2, akin to accuracy results. We therefore analyzed Session 1 and 2 separately, by running two independent repeated measures ANOVAs for each session, with both posture and sex of subject as between-subject factors and task (gender, scene), emotion (neutral, fear, anger) and gaze (direct, averted) as within-subjects factors.

In session 1, neither the interaction between pose × task × emotion × gaze ($F(2,80) = 0.745$, $p = .478$, $\eta_p^2 = 0.018$) nor the one between task × emotion × gaze ($F(2,80) = 0.845$, $p = .433$, $\eta_p^2 = 0.021$) were significant (see Table 2). Similarly, in Session 2, neither the interaction between pose × task × emotion × gaze ($F(2,80) = 0.096$, $p = .909$, $\eta_p^2 = 0.002$) nor the one between task × emotion × gaze ($F(2,80) = 0.249$, $p = .707$, $\eta_p^2 = 0.009$) were significant (see Table 3).

In both sessions, the ANOVA did reveal a main effect of task (Session 1: $F(1,40) = 86.502$, $p < .001$, $\eta_p^2 = 0.684$; Session 2: $F(1,40) = 80.421$, $p < .001$, $\eta_p^2 = 0.668$), indicating that participants were significantly faster for the gender task (Session 1: 585.07 ± 24.09 ms (SEM); Session 2: 536.27 ± 21.94 ms (SEM)) as opposed to the Scene task (Session 1: 731.52 ± 31.16 ms (SEM); Session 2: 656.64 ± 28.01 ms (SEM)). In summary, reaction time analyses for Experiment 2 demonstrate no impact of pose.

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