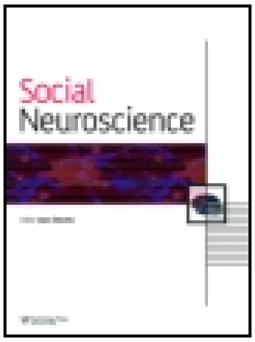

Social Neuroscience

ISSN: 1747-0919 (Print) 1747-0927 (Online) Journal homepage: http://www.tandfonline.com/loi/psns20

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To cite this article: Olga M. Klimecki (2015): The plasticity of social emotions, Social Neuroscience, DOI: 10.1080/17470919.2015.1087427

To link to this article: http://dx.doi.org/10.1080/17470919.2015.1087427

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SOCIAL NEUROSCIENCE, 2015
http://dx.doi.org/10.1080/17470919.2015.1087427

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The plasticity of social emotions

Olga M. Klimecki[1,2]

[1]Swiss Center for Affective Sciences, University of Geneva, Geneva, Switzerland
[2]Laboratory for the Study of Emotion Elicitation and Expression, Department of Psychology, University of Geneva, Geneva, Switzerland

Social emotions such as empathy or compassion greatly facilitate our interactions with others. Despite the importance of social emotions, scientific studies have only recently revealed functional neural plasticity associated with the training of such emotions. Using the framework of two antagonistic neural systems, the threat and social disconnection system on the one hand, and the reward and social connection system on the other, this article describes how training compassion and empathy can change the functioning of these systems in a targeted manner. Whereas excessive empathic sharing of suffering can increase negative feelings and activations in the insula and anterior cingulate cortex (corresponding to the threat and social disconnection system), compassion training can strengthen positive affect and neural activations in the medial orbitofrontal cortex and striatum (corresponding to the reward and social connection system). These neuroimaging findings are complemented by results from behavioral studies showing that compassion is linked to helping and forgiveness behavior, whereas empathic distress not only decreases helping behavior, but is even associated with increased aggressive behavior. Taken together, these data provide encouraging evidence for the plasticity of adaptive social emotions with wide-ranging implications for basic science and applied settings.

Keywords: Empathy; Compassion; Aggression; Helping behavior; fMRI.

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As humans, we frequently engage in social interactions, be it with family members and friends, or with colleagues and business partners. The central role that social bonds play for humans has been recognized by psychologists (Baumeister & Leary, 1995) and anthropologists alike (Dunbar, 2012). Along these lines, the evolution of the neocortex in humans has been linked to the evolution of social group size (Dunbar, 1998). But how is social information represented in the brain and what determines our social behavior? In this review, I integrate research from psychology and neuroscience to argue that there are two fundamental systems that shape our feelings, brain function, and social behavior: one system that is linked to feelings of distress and social disconnection as well as to aggressive behavior, and another system that is linked to feelings of reward, compassion, and social connection as well as to helping behavior. As these two antagonistic systems have also been linked to health in opposing ways (Eisenberger & Cole, 2012), an important question is whether health and cooperative behavior can be improved by training these systems in a targeted way. In recent studies, we have shown that it is indeed possible to change these systems in a highly specific manner. In fact, even short-term interventions of several days have induced functional neural plasticity in these opposing systems. While excessive experiences of distress led to increased brain activations in a network underlying negative affect and empathy for pain (insula and anterior middle cingulate cortex), compassion training increased positive emotions, helping behavior, and brain activations associated with positive affect, reward, and social connection (medial orbitofrontal cortex and striatum). These exciting results are

Correspondence should be addressed to: Olga Klimecki, Campus Biotech, CISA – University of Geneva, Chemin des Mines 9, Case postale 60, CH-1211 Genève 20. E-mail: olga.klimecki@unige.ch
No potential conflict of interest was reported by the author.

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discussed in terms of their implications for basic research and their contribution to the development of intervention techniques that aim to foster adaptive social emotions and cooperative behavior.

THE NEURAL REPRESENTATION OF EMOTIONS AND SOCIAL INCLUSION IS SHARED

Accumulating evidence in the field of social neuroscience suggests that the brain has, on the one hand, a shared representation for social connectedness and reward and, on the other, a shared representation for social disconnectedness and threat (Eisenberger & Cole, 2012). More specifically, social connection is represented by increased neural activations in regions that include the ventral medial prefrontal cortex and the ventral striatum. These networks are also reward sensitive. Several studies have shown that the value of stimuli, ranging from primary rewards such as food to more abstract rewards such as monetary gains, is represented in the orbitofrontal cortex and that reward predictions are encoded by the striatum (for review, see O'Doherty, 2004). In addition, striatal reward circuits also encode social rewards (for review, see Kishida & Montague, 2012). Conversely, the experience of social disconnection (e.g., in the form of social exclusion) has been related to activations in threat-sensitive brain regions that include the anterior insula (AI) and the anterior cingulate cortex (for review, see Eisenberger & Cole, 2012). These regions are also implicated in processing the affective component of painful and unpleasant events (e.g., Lamm, Decety, & Singer, 2011). In other words, there seems to be a shared neural system that processes pleasant events and social connectedness and another system that processes unpleasant events and social disconnectedness. This shared representation of social experiences and primary emotions was recently proposed as a potential mechanism through which the experience of social connectedness could be linked to physical health (Eisenberger & Cole, 2012). In light of these wide-ranging implications, the question arises as to how these two systems can be shaped in a targeted way. Despite the crucial role that social emotions play in our health, the neural plasticity related to social emotions was for a long time unresolved. This is partly due to the rather recent development of non-invasive brain imaging techniques, which started to be widely used in the 1990s. These techniques were first used to study basic perceptual processes and cognitive processes. The study of affective and social neurosciences started around the turn of the millennium, but neural plasticity associated with emotions has been studied only recently. To investigate the malleability of social emotions in adults, we conducted several studies on the training of empathy-related responses (for a recent review, see Singer & Klimecki, 2014). To understand these studies in context, it is worthwhile to first examine the definition of empathy and empathy-related emotions and to understand their link to social behavior.

EMPATHIC DISTRESS AND COMPASSION PREDICT OPPOSING SOCIAL BEHAVIOR

As outlined elsewhere in more detail (Klimecki & Singer, 2013), empathy occurs when the emotion of another person is shared and there is awareness that the other person is the source of the emotional experience. As empathy denotes feeling the same kind of emotion as the other, one can empathize with both pleasant and unpleasant emotions. One can thus feel happy when someone else is happy and feel sad when someone else is sad. When it comes to the suffering of others, an interesting distinction can be made between two different empathy-related responses, namely, empathic distress and compassion (for more details, see Klimecki & Singer, 2013). Although many terms exist for denoting these two concepts—in other works, empathic distress is also referred to as personal distress and compassion is also referred to as sympathy, empathy, and empathic concern—the terms *empathic distress* and *compassion* are used here to avoid confusion between the different concepts. In empathic distress, the suffering of others is shared to such a strong degree that the experience of negative emotions can become overwhelming and lead to withdrawal. People working in helping professions, such as doctors, nurses, or humanitarian aid workers, have a particularly elevated risk for experiencing empathic distress, which is in turn associated with increased burnout rates (for review, see Klimecki & Singer, 2012). Although empathizing with the suffering of others can lead to empathic distress, it can also be met with compassion. Compassion is defined as an emotion of concern toward a suffering person, accompanied by the motivation to help (Keltner & Goetz, 2007). Several decades ago, Batson, O'Quin, Fultz, Vanderplas, and Isen (1983) recognized the importance of the distinction between the two empathy-related constructs. In their experiments on helping behavior, participants were confronted with another person who was suffering from the administration of electric shocks. After providing self-reports on certain

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feelings in response to this situation, participants were given the opportunity to help the other by taking the electric shocks themselves. The researchers observed that in situations in which participants no longer had to witness the other's suffering, those participants who reported feeling more compassionate, warm, soft-hearted, etc., were more likely to offer to take the electric shocks themselves. On the other hand, persons who reported feeling distressed, upset, disturbed, etc., were more prone to withdraw from the situation rather than helping the other. These results show the differential effects that two empathy-related emotions can have on helping behavior: whereas the feeling of compassion encouraged helping behavior, the feeling of empathic distress promoted withdrawal behavior. Recently, we extended these findings by investigating how different empathy-related personality traits were related to interpersonal aggression (Klimecki, Vuilleumier, & Sander, 2015). Because of the difficulty of studying aggressive behavior in a highly controlled laboratory setting, we first developed and validated a novel computer-based paradigm called the Inequality Game. In this game, participants are first exposed to the behavior of a fair and unfair other and can subsequently engage in prosocial or antisocial behavior. The behavioral results of this experiment revealed that although participants on average punished the unfair other more than they did the fair other, there were considerable interindividual differences among participants. Whereas some participants behaved in a spiteful way, punishing even the fair other, other participants were not only nice to the fair other, but also showed forgiveness behavior toward the unfair other. These behavioral differences were predicted by participants' empathy-related traits, as measured several days prior to the experiment by means of an empathy questionnaire (Davis, 1983). The results of this experiment show that following a provocation, the degree to which participants were compassionate (e.g., "I often have tender, concerned feelings for people less fortunate than me") predicted forgiveness behavior, whereas empathic distress (e.g., "Being in a tense emotional situation scares me") predicted aggressive behavior, even against innocent others.

COMPASSION TRAINING

In light of the effects that different empathy-related traits can have on helping behavior and aggressive behavior, it is important to test the extent to which empathy-related capacities can be trained and how such training affects neural function, behavior, and emotional reactions. When it comes to training social emotions such as compassion, one method that has received considerable scientific attention (e.g., Fredrickson, Cohn, Coffey, Pek, & Finkel, 2008; Lutz, Brefczynski-Lewis, Johnstone, & Davidson, 2008) is called loving kindness meditation. We also chose this meditation-based method in its secular form for several of our longitudinal studies. In this meditative training, feelings of friendliness and benevolence are cultivated in silence toward a series of persons. One typically starts out by cultivating feelings of benevolence for a person that one feels close to and then extends these feelings to a series of other people, including oneself, difficult persons, and strangers. The ultimate aim of this training is to cultivate a feeling of benevolence and kindness toward all human beings. Previous research has shown that the regular cultivation of loving kindness over several weeks can increase self-reports of positive affect and well-being in everyday life (Fredrickson et al., 2008).

COMPASSION TRAINING INCREASES ALTRUISTIC HELPING BEHAVIOR

To study the extent to which compassion training can change helping behavior, we first developed and validated a novel computerized paradigm: the Zurich Prosocial Game (Leiberg, Klimecki, & Singer, 2011). This game allows for the repeated testing of helping behavior toward strangers in well-controlled laboratory conditions. In brief, the game consists of two players who simultaneously hunt for independent treasures in a maze (Figure 1). In the pursuit of the treasure, which corresponds to a monetary pay-off, the players are sometimes faced with obstacles. Helping behavior is measured by counting how many times and under which conditions the participant helps the other to overcome this obstacle. Using this game in a longitudinal intervention design, we observed that helping behavior increased in participants who underwent several days of compassion training. No such effect was observed for an active control group undergoing memory training. Interestingly, the increase in altruistic helping behavior in the compassion group was linearly related to the time that participants practiced compassion at home, suggesting that compassion practice increases altruistic behavior in particular. These results were recently extended by a study showing that participants who underwent meditation training in compassion or mindfulness—a form of awareness focused on the present moment—more often offered their seat to a person using crutches than did persons in a wait-list control group (Condon, Desbordes, Miller, & DeSteno, 2013).

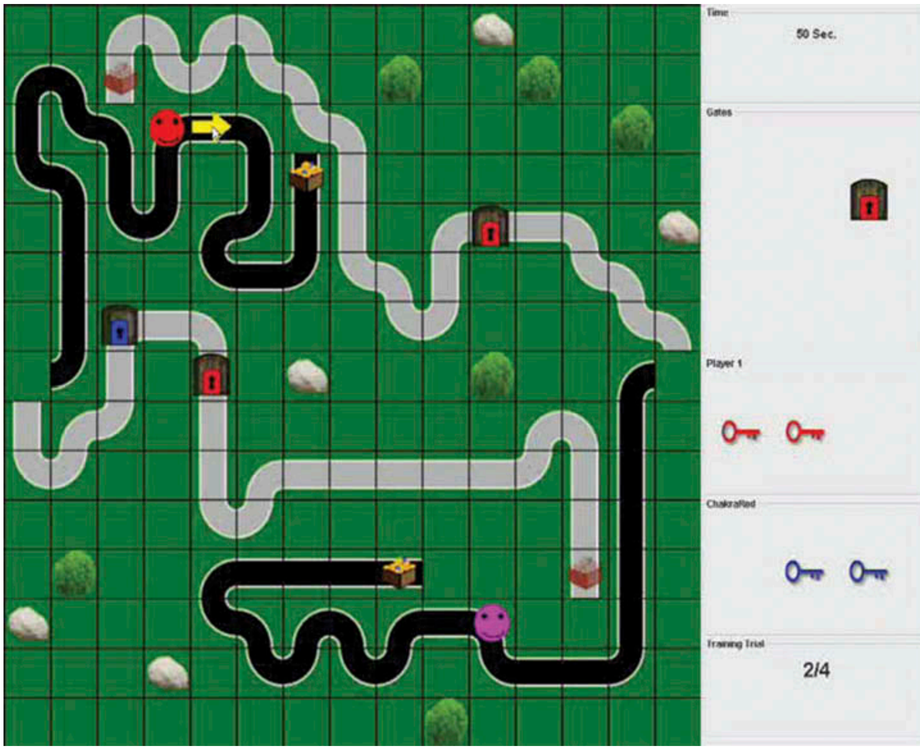

Figure 1. Example from the Zurich Prosocial Game. Two players hunt for a treasure and can be blocked by gates. These gates can be opened by keys with corresponding colors.

COMPASSION TRAINING INCREASES ADAPTIVE EMOTIONS AND RELATED NEURAL FUNCTIONS

In order to test functional neural plasticity involved in the training of compassion, we conducted a series of longitudinal functional magnetic resonance imaging studies in which meditation-naive participants were trained in compassion over several days (Klimecki, Leiberg, Lamm, & Singer, 2013). As outlined earlier, compassion might be a particularly adaptive response for persons working in helping professions, as they are repeatedly faced with suffering and have an elevated risk of burnout. To test whether compassion training can change emotional responses to suffering as well as associated brain activations, we conducted a study in which participants' brain activations were measured during the Socio-affective Video Task (Klimecki et al., 2013; Figure 2). In this task, which was specifically designed and validated for studies with repeated measurements, participants see documentary film clips depicting the suffering of others (e.g., a woman crying) and film clips depicting everyday scenes (e.g., someone talking). After each of these clips, participants report the extent to which they felt empathy, positive emotions, and negative emotions when seeing the film excerpt. During this task, participants' brain activations were measured. This was done prior to and after the compassion training. To control for repeated measurements and unspecific training effects, such as group activities, we compared these data to those of an active control group who underwent purely cognitive training of memory skills. The results of this analysis revealed that short-term compassion training of several days increased neural activations in brain areas typically associated with positive affect and social connectedness, namely, the medial orbitofrontal cortex and the striatum (Figure 3). These changes were consistently found across several compassion training studies (Klimecki et al., 2013). In addition to this increase of adaptive neural activation, compassion training also increased self-reported positive feelings both in response to everyday scenes and to the suffering of others. Interestingly, compassion training did not change negative emotions. Following the compassion training, participants thus still shared the negative emotions of the depicted persons to the same extent as before the training, but they experienced additional positive emotions. This pattern distinguishes compassion training from other emotion regulation strategies, such as reappraisal, where the goal primarily lies in

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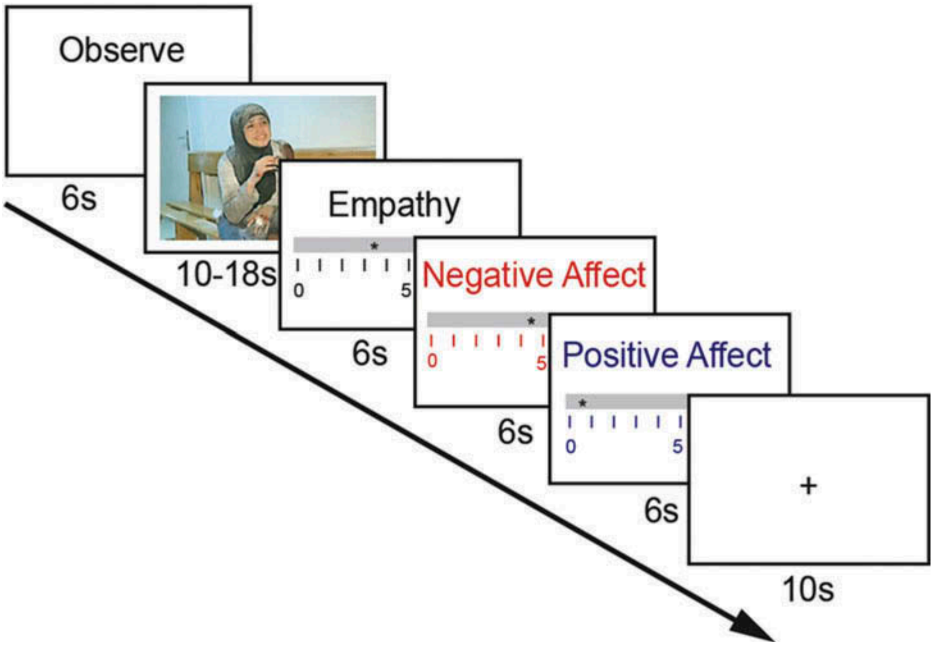

Figure 2. Timeline of the Socio-affective Video Task. After each video, participants rated their subjective experience of empathy, positive affect, and negative affect. With permission from Figure 1B of Klimecki et al. (2013).

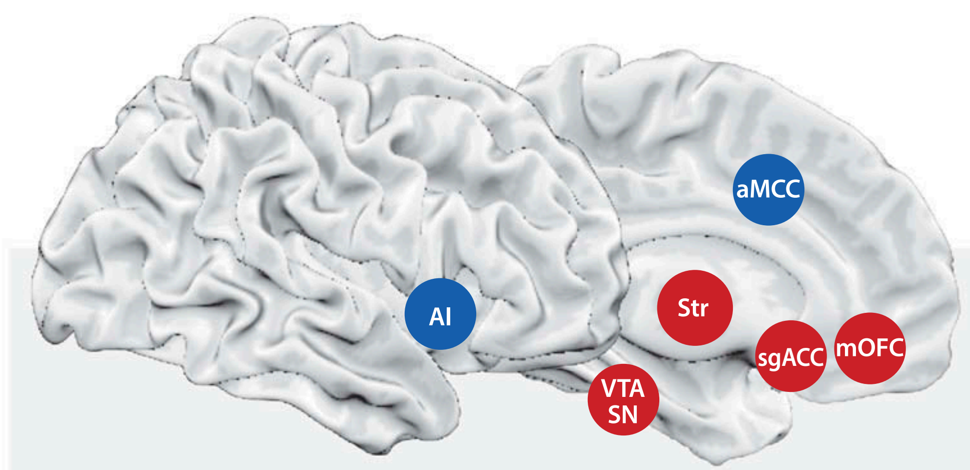

Figure 3. Differential plasticity in neural networks related to compassion (in red) and empathic distress (in blue). Whereas empathic distress is associated with activation increases in the anterior insula (AI) and the anterior middle cingulate cortex (aMCC), compassion training augments activations in the medial orbitofrontal cortex (mOFC), the subgenual anterior cingulate cortex (sgACC), the striatum, and the ventral tegmental area/substantia nigra (VTA/SN). Adapted and reprinted with permission from Figure 3A of Singer and Klimecki (2014).

the reduction of negative emotions. In fact, the capacity to share the negative feelings of others might be crucial for motivating helping behavior. Taken together, these results suggest that compassion training can strengthen positive social emotions and their neural representation. Importantly, these changes are not only manifest in response to everyday situations, but also in response to the distress of others. As recently suggested (Eisenberger & Cole, 2012), activation of this reward-related system may play a vital role in promoting physical health, as this system is linked in an antagonistic way to threat-related neural activity and stress-related physiological signatures. It may thus be that compassion training can counteract feelings of burnout and social disconnection through the strengthening of feelings of reward and social connectedness.

COMPASSION TRAINING AND EMPATHY TRAINING AFFECT ANTAGONISTIC NEURAL NETWORKS

To test the hypothesis that compassion training can help to overcome excessive negative emotions related to witnessing the suffering of others, we conducted another longitudinal training study (Klimecki, Leiberg, Ricard, & Singer, 2014). In this study, participants were first trained to empathize with the suffering of others as if it were their own suffering. Subsequently, participants were trained in compassion. Participants were tested three times: before the training, after the empathy training, and after the compassion training. In parallel, an active control group undergoing memory training was also measured at three time points: prior to the training, after the first training, and after the second training. The aim of this study design was to identify the neural and experiential changes associated with excessive sharing of suffering and to test whether subsequent compassion training could lead to more adaptive emotional and neural responses. In addition, this study design allowed for the direct comparison of different empathy-related responses within the same participants.

On the emotional level, participants' self-reports indicated that empathy training increased not only empathy, but also negative emotions. This increase was present when participants witnessed the suffering of others; in addition, participants reported feeling stronger negative emotions when exposed to everyday scenes. This finding underlines the potentially detrimental effects of sharing other's suffering too much by showing that not only does it increase negative emotions in response to suffering, but it also leads to a more gloomy view of everyday situations. On the neural level, we observed that in the experimental group, compared with the active control group, empathy training increased activations in the insula and the anterior middle cingulate cortex. This result provides first evidence for neural plasticity associated with feelings of empathic distress (Figure 3). Indeed, the described brain regions have previously been related to empathy for pain (for review, see Lamm et al., 2011), as well as to threat and social disconnection (for review, see Eisenberger & Cole, 2012). Interestingly, the subsequent compassion training could reverse these effects, both on the experiential and on the neural level. On the experiential level, compassion training led to the return of negative affect to baseline levels, while at the same time strengthening the experience of positive feelings, both in response to the suffering others and in response to people engaging in everyday activities. On the neural level, compassion training led to an activation increase in the medial orbitofrontal cortex and the striatum. This increase in positive emotions and brain activations related to reward and social connectedness is consistent with the above-described effects of compassion training. This longitudinal study extended the assumption of two antagonistic neural systems: one related to reward and social connection, the other related to threat and social disconnection, by showing differential neural plasticity of both systems within the same participants. In addition, the results indicate that compassion training can reverse the detrimental effects of excessive empathic distress and promote adaptive emotions by actively strengthening neural activity related to reward and social connection.

SUMMARY AND OUTLOOK

In this review, I have argued that two antagonistic systems shape our emotions and our social behavior and that these systems can be influenced through targeted training (Figure 4). On the one hand, there is a system related to feelings of threat and distress. On the behavioral level, these feelings are associated with reduced helping and increased aggression. On the neural level, feeling threatened or distressed is associated with activations in the anterior cingulate cortex and the AI and to physiological stress responses. On the other hand, there is a system related to positive social emotions such as compassion and social connectedness. On the behavioral level, compassion is associated with increased helping behavior and with reduced aggressive behavior. On the neural level, this system is associated with activations in the medial orbitofrontal cortex and the striatum, which have been proposed to reduce stress responses. In light of the wide-ranging effects that these two systems have on social behavior and health-related variables, it is interesting to observe that these two systems are malleable in adults. Whereas empathic distress is associated with negative emotions, and activation increases in the insula and the anterior cingulate cortex, compassion training has antagonistic effects: it strengthens positive emotions and increases activations in the medial orbitofrontal cortex and the striatum.

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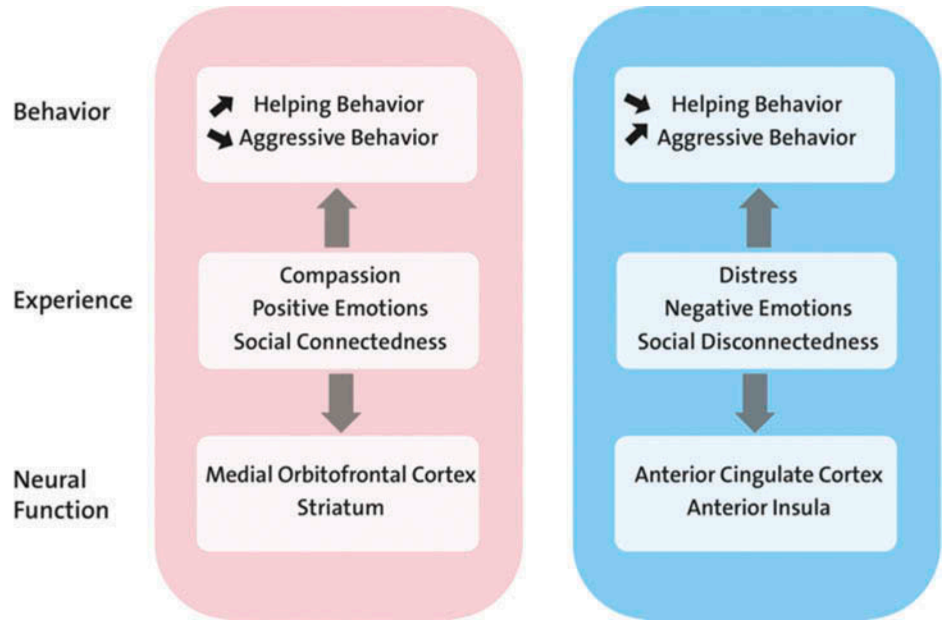

Figure 4. Schematic overview of the two antagonistic systems, spanning the level of behavior, experience, and neural function. Importantly, these systems can be shaped through training.

The results presented here on the plasticity of social emotions are exciting for several reasons. First, they underline the malleability of the emotional brain by showing that even short-term training of different emotional capacities in adults can lead to reliable and specific changes that are measurable on the neural level. Second, the results provide strong evidence for the existence of two dissociable systems related to empathic distress and compassion. This distinction spans the level of emotional experiences, neural plasticity, and social behavior. Finally, the plasticity of the two empathy-related systems is exciting, as these systems have been antagonistically linked to social behavior (Batson et al., 1983; Klimecki et al., 2015) and health (Eisenberger & Cole, 2012). Knowing how to train these systems in a targeted manner may have a tremendous impact not only on the development of training methods for people working in helping professions, but also for the general public. In addition, these same systems play a crucial role in decision-making (Ruff & Fehr, 2014). Future studies can investigate how decision-making can be influenced by training these systems in a targeted manner.

Although our understanding of the link between emotions, brain activations, and decision-making is still in its infancy, the results of the studies presented herein provide a theoretical framework that can guide future analyses. Although these studies have established the link between emotions and social behavior, between emotions and brain function, and between emotions and the perception of social connectedness, future studies are needed to determine the neural processes that link emotions and feelings of social connectedness to behavior and decision-making. A related and more specific question would be whether the maintenance of negative affect in response to another person's suffering plays a crucial role in guiding helping behavior and, if yes, what neural processes play a role in this link. It would also be worthwhile to complement such studies with experiments that examine the role that neurotransmitters such as oxytocin, which is important for bonding, play in social emotions and interpersonal behavior (see also the article by Gül Dölen).

Original manuscript received 1 June 2015
Revised manuscript accepted 21 August 2015
First published online 16 September 2015

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