The Compassionate Brain

KLIMECKI-LENZ, Olga Maria, SINGER, Tania

Reference

KLIMECKI-LENZ, Olga Maria, SINGER, Tania. The Compassionate Brain. In: J.R. Doty, M. Worline, E. Simon-Thomas, D. Cameron and S. Brown. *The Oxford Handbook of Compassion Science*. Oxford : Oxford University Press, 2017.

DOI : 10.1093/oxfordhb/9780190464684.013.9

Oxford Handbooks Online

The Compassionate Brain

Olga M. Klimecki and Tania Singer

The Oxford Handbook of Compassion Science
Edited by Emma M. Seppälä, Emiliana Simon-Thomas, Stephanie L. Brown, Monica C. Worline, C. Daryl Cameron, and James R. Doty

Print Publication Date: Sep 2017 Subject: Psychology, Social Psychology, Affective Science
Online Publication Date: Oct 2017 DOI: 10.1093/oxfordhb/9780190464684.013.9

Abstract and Keywords

This chapter focuses on the neuroscience of compassion and related social emotions such as empathy, empathic concern, or empathic distress. First, we review neuroscientific literature on empathy and relate empathy to similar social emotions. We then turn to neuroscientific research on caregiving and social connection before describing cross-sectional studies on the neural signatures of compassion. To investigate whether training of compassion can change neural functions, the neural "fingerprints" of compassion expertise were studied in both expert and inexperienced meditators. The latter included the comparison between functional plasticity induced by empathy for suffering as opposed to compassion training. These studies show that compassion training changes neural functions, and that the neural substrates related to empathy for suffering differ experientially as well as neuronally. This is in line with the observation of distinct behavioral patterns related to feelings of empathic distress and compassion, described towards the end of the chapter.

Keywords: Empathy, compassion, care, social connection, reward, neural substrates, empathy-for-suffering, prosocial behavior

Empathy and Related Concepts

In order to understand each other, humans can use their ability to *empathize* with others; that is, to share the emotions of others without mistaking them for their own emotions (de Vignemont & Singer, 2006). One can thus empathize with the happiness of someone else by feeling happy, or empathize with the sadness of someone else by feeling sad. In principle, an empathic response can elicit as much positive affect as it can elicit negative affect. This depends on the emotion of the other person we are entering in affective resonance with. However, in psychology and neurosciences, the vast majority of studies on empathy have so far focused on empathic responses to the suffering of others rather than on empathic joy or resonating with pleasant sensations experienced by another (but see Lamm, Silani, & Singer, 2015; Mobbs et al., 2009). More specifically, empathy for suffering has so far mainly been tested by measuring brain activations when someone is observing another person suffering emotional or physical pain (for meta-analyses, see Fan, Duncan, de Greck, & Northoff, 2011; Lamm, Decety, & Singer, 2011). The experimental setup typically involves the measurement of a participant's brain activity by means of functional magnetic resonance imaging (fMRI), while the participant is seeing pictures of painful situations such as someone cutting their hand accidentally with a knife or slamming their hand in a car door (Jackson, Meltzoff, & Decety, 2005). Alternatively, one can also use scenarios in which the scanned participant witnesses another person seated next to the MRI scanner getting painful stimulation, such as electric shocks (Singer, Seymour, O'Doherty, Kaube, Dolan, & Frith, 2004). Meta-analyses across different studies on empathy for pain from various laboratories and with different types of paradigms have shown that witnessing the pain of others is consistently associated with (p. 110) increased activations in a core network, the so-called empathy for pain network, consisting of the anterior insula (AI) and the medial/anterior cingulate cortex (Fan, Duncan, de Greck, & Northoff, 2011; Lamm, Decety, & Singer, 2011). Both of these regions are part of a neural network that has been proposed to process interoceptive awareness, emotional experiences in general (Craig, 2003), as well as emotional experiences related to pain perception in particular (Lamm & Singer, 2010; Peyron, Laurent, & Garcia-Larrea, 2000; Rainville, 2002; Singer, Critchley, & Preuschoff, 2009). Importantly, activation of this core network elicited when witnessing the suffering of others appears to be modulated by individual differences in trait empathy and trial-by-trial reports of experienced negative affect and empathy (Kanske, Bockler, Trautwein, & Singer, 2015; Klimecki, Leiberg, Lamm, & Singer, 2013; Lamm et al., 2011; Singer et al., 2004). This partial overlap between the brain regions processing the affective responses related to one's own painful experiences and those of others suggests that we understand other's emotions by activating neuronal networks coding for similar experiences within ourselves. In other words, the neural networks processing the emotions related to first-hand pain experiences and observed painful experiences of others are shared. More recent studies using multi-voxel pattern analyses suggest that some regions in AI code for modality-specific information related to feeling states such as pain, disgust, or even the experience of unfairness in self and others, while other subregions in AI code for more domain-general feelings of unpleasantness (Corradi-Dell'Acqua, Hofstetter, & Vuilleumier, 2011; Corradi-Dell'Acqua, Tusche, Vuilleumier, & Singer, 2016). As mentioned, empathy is not restricted to affective resonance with the suffering of others alone, and accordingly, such shared networks for first-hand and observed experiences have also been reported in other domains of empathy, such as empathy for smell and disgust (Jabbi, Bastiaansen, & Keysers, 2008; Wicker, Keysers, Plailly, Royet, Gallese, & Rizzolatti, 2003), empathizing with being touched in a neutral or pleasant manner (Keysers, Wicker, Gazzola, Anton, Fogassi, & Gallese, 2004; Lamm, Silani, & Singer, 2015), or for vicarious rewards (Mobbs et al., 2009).

In the context of empathic responses to the suffering of another person, two basic consequences have been distinguished in the literature (for more details, see Klimecki & Singer, 2013; and the chapter by Batson, Chapter 3 this volume): An empathic response can turn into what some researchers call *empathic distress* (e.g., Sagi & Hoffman, 1976), and other researchers call *personal distress* (Davis, 1983). Empathic or personal distress denotes the sharing of another person's suffering almost as if what was happening to the other person was also happening to oneself. It is a feeling accompanied by strong negative affect and the motivation to withdraw oneself from such situations in order to reduce aversive emotional experiences. Alternatively, one can also feel what is called *empathic concern* in some studies (e.g., Davis, 1983), and *compassion* in other studies (e.g., Gilbert, 2010; Lutz et al., 2008), with "compassion" being defined as a sensitivity to the suffering of another that is accompanied by the motivation to alleviate that suffering (Goetz, Keltner, & Simon-Thomas, 2010). In the next section, we will describe what is known to date about brain functions related to compassion and related concepts such as care and social connectedness, and then focus on brain plasticity underlying compassion training. Finally, we will examine in more detail the difference between empathy, empathic distress, and compassion and present recent results on their respective plasticity.

Neural Substrates of Care, Social Connection, and Reward and Their Link to Health

In order to place the implications of compassion research in context, it is useful to briefly review the neural underpinnings of caregiving and feelings of connection and reward. With regard to caregiving behavior, a recent review (Preston, 2013) summarized that, in rodents, offspring care relies on the activation of brain regions that include the amygdala, the ventral tegmental area, the nucleus accumbens, and the ventral pallidum. In humans, there is a homologous system, which also comprises the orbitofrontal cortex (OFC) and the subgenual anterior cingulate cortex. Preston (2013) also points out that the neural activations related to caregiving and altruism overlap to a large degree, which could indicate similar underlying neural mechanisms. These neural networks have also been related to feelings of social connection; that is, the perception of being cared for, valued, and loved by others (see Eisenberger & Cole, 2012, for review). It has, for instance, been shown that activations in OFC are increased when one sees pictures of a supportive romantic partner during physical pain experiences (Eisenberger et al., 2011) and when one is provided with supportive messages during social exclusion (Onoda et al., 2009).

(p. 111) Finally, the care and social connection system also overlaps with the neural networks implicated in reward; for instance, when receiving desired food, viewing attractive faces, or getting monetary rewards (e.g., O'Doherty, 2004; Schultz, 2000, for review). But note that although reward and affiliaton activate similar brain areas, these two systems probably implicate different underlying neurotransmitter systems, as affiliation and care have mostly been associated with neuropeptides such as oxytocin or opiads (Insel, Young, & Wang, 1997; McCall & Singer, 2012), whereas dopamine plays a crucial role in reward processing (Shultz, 2000, for review). Importantly, social support also seems to have beneficial implications for physical health. It has thus been proposed that the increase in brain areas related to care and reward is linked to a decrease in brain activations implicated in threat and stress, such as dorsal anterior cingulate cortex, anterior insula, and the periaqueductal gray, and that the active engagement in caregiving behaviors for loved ones reduces cardiovascular arousal and mortality rates (for review, see Eisenberger & Cole, 2012). As a recent review suggests, there is increasing evidence suggesting that the beneficial effects on health rely on hormones related to pregnancy and offspring care, such as progesterone and oxytocin (Brown & Brown, 2015).

Taken together, there seems to be a common neural network for caring, feelings of social connection, and altruism. Activation in this brain network also seems to have beneficial effects on health by down-regulating threat- and stress-related reactions. Investigating this neural network in more detail could give exciting insights into how care, affiliation, altruism, and health are linked.

Neural Substrates of Compassion

Although there are many more neuroimaging studies focusing on empathy than on compassion, compassion-related emotions have been increasingly studied in recent years. This research area started with cross-sectional studies on love and compassion and has been complemented by longitudinal studies on the effects of compassion training. As compassion and love are related positive social emotions, two cross-sectional fMRI studies on romantic and maternal love (Bartels & Zeki, 2000; and Bartels & Zeki, 2004, respectively) offered early insights on the neural representation related to these social emotions. The researchers measured brain activations associated with seeing pictures of romantic partners or pictures of one's own babies and found that both types of love activate the middle insula, the dorsal part of the anterior cingulate cortex, and the striatum (comprising the putamen, globus pallidus, and caudate nucleus). Activation in the insula is typically related to social emotions and interoception (Craig, 2003; Lamm & Singer, 2010; Singer et al., 2009), and, as already described, activations in the striatum have been linked to either care/affiliation or reward processes.

A direct test of the neural substrates of compassion was provided in two studies that investigated the effect of adopting a compassionate stance towards others. In one study, "unconditional love" towards pictures of individuals with intellectual disabilities was associated with increased activations of the middle insula, the dorsal anterior cingulate cortex, the globus pallidus, and the caudate nucleus (Beauregard, Courtemanche, Paquette, & St-Pierre, 2009). Similarly, instructing participants to adopt a compassionate attitude towards pictures of sad faces increased activations in the ventral striatum and the ventral tegmental area/substantia nigra (Kim et al., 2009). The involvement of the striatum in feelings of love and social support is also underlined by two additional studies: one study in which participants looked at a beloved person (Aron, Fisher, Mashek, Strong, Li, & Brown, 2005), and another study in which participants saw smiling faces (Vrticka, Andersson, Grandjean, Sander, & Vuilleumier, 2008). As these regions have been linked to affiliation and caring and have a high density of receptors for attachment-related neuropeptides such as oxytocin (Depue & Morrone-Strupinsky, 2005), these results suggest that feelings of compassion may involve experiences of care and closeness that are similar to those invoked during feelings of love.

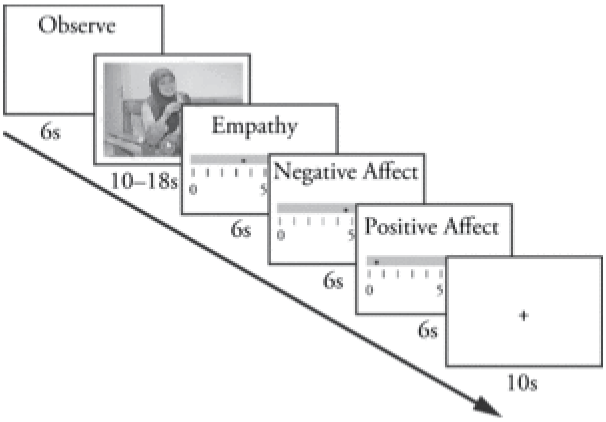
Neural Substrates of Compassion Training

Although the described cross-sectional neuroimaging studies offer exciting insights into the neural activations associated with positive social emotions such as love, loving-kindness, and compassion, one question remained: Can compassion training change neural activations—that is, can it induce functional plasticity in the brain? This question is interesting for several reasons. From the perspective of basic neuroscience, it is interesting to test whether there is evidence for functional and structural brain plasticity in the domain of social emotions. From an applied perspective, it would be important to see how the training of neural networks related to compassion is linked to well-being and prosocial behavior. With regard to the malleability of the human (p. 112) brain, neuroscientists have been concerned with this question for more than a century. In fact, as described by Pascual Leone and colleagues (2005), the famous neuroscientist and Nobel Prize laureate Ramon y Cajal (1904) postulated that the acquisition of new skills should be paralleled by changes in the brain. Over many decades, scientists studied changes in neural functions that were related to experiences in primates and patients (Pascual-Leone, Amedi, Fregni, & Merabet, 2005). Neuroimaging studies in healthy adults revealed that learning how to juggle induced structural changes in motor-related areas, whereas studying for an exam induced structural changes in memory-related areas (Draganski, Gaser, Busch, Schuierer, Bogdahn, & May, 2004; Draganski, Gaser, Kempermann, Kuhn, Winkler, Büchel, & May, 2006). These findings suggest that the acquisition of new skills is associated to structural brain plasticity in the domains of sensory-motor as well as memory functions. An open question was whether training emotions, such as compassion, can induce changes in the brain and whether functional (as opposed to structural) brain plasticity can be observed in adults.

There are several ways to approach such a question. One way is to study the neural signatures of expert meditators with thousands of hours of expertise in compassion-related meditation practices and compare them to the neural signatures of matched controls without any meditation expertise. Another way to approach the question of neural plasticity is to conduct longitudinal training studies with people who are new to compassion training and to examine how such socio-affective mental training affects brain functions. The first approach, of studying expert meditators cross-sectionally, was adopted by Lutz and colleagues (Lutz et al., 2008), for example. In their study, the researchers compared the neural responses of expert meditators listening to human vocalizations of distress while in a compassionate state to those of novice meditators. The results of this study revealed that, compared to novice meditators, expert meditators showed greater neural activity in the middle insula.

To complement these findings, we conducted a series of longitudinal compassion training studies with participants new to meditation. To confront participants with the suffering of others during an fMRI session, we developed and validated the Socio-affective Video Task (SoVT, Figure 9.1; for details, see Klimecki et al., 2013). The SoVT is based on excerpts from documentary film material depicting others' suffering (for instance, a women crying after an earthquake) as well as control videos depicting everyday life activities (such as people walking or talking). The film material was taken either from archives of raw material from Swiss television or from documentary films. To allow for repeated measurements with this stimulus material, the SoVT consists of three parallel sets of videos that are matched on a variety of criteria, such as empathy, valence and arousal. Each of these three video sets contains 12 videos that depict others' suffering and 12 videos that depict everyday-life situations. The SoVT enabled us to test participants up to three times without repeating the presentation of any one video. Using this task, we conducted a longitudinal study in which participants were either assigned to a compassion training group or to an active control group involving memory training (Bower, 1970). Both trainings lasted several days and were equivalent in structural aspects. More specifically, the content of each training was introduced to participants in an evening session after the first measurement. Then participants of both groups took part in a whole training day, which was followed by several one-hour evening sessions. In addition, participants were encouraged to practice the training method at home and to record the duration of their daily practice. The compassion training essentially followed the classical loving-kindness training in which participants cultivate feelings of benevolence and kindness towards a benefactor, themselves, a friend, a neutral person, a difficult person, and all beings. Participants visualize these persons one after the other and cultivate wishes such as "May you be happy" and "May you be healthy" towards the target person. As the compassion training mainly relied on silent visualizations exercised while sitting or walking, we chose the method of *loci training* (Bower, 1970) for the memory training due to its structural resemblance to the compassion training. The method of loci was used by the Greeks and Romans and consists of memorizing items by linking them to a sequence of locations. As this training was carried out in Zurich, Switzerland, participants first learned an imagined a route through Zurich with several locations, such as the airport and the opera. Subsequently, participants mentally linked the items to be remembered with each of these locations. If one was, for instance, to remember the words *milk* and *carrot*, one could imagine the airport building being flooded by milk, and a carrot singing on the stage of the opera.

(p. 113) To test for changes related to compassion training, we measured participants' brain activation as well as their feelings in response to the videos before and after the training. To capture both positive and negatively valenced affect as well as empathy, we asked participants to rate the degree to which they experienced empathy, positive affect, and negative affect while watching each of the videos (see Figure 9.1). Based on these three questions, we could assess the change in self-reported feelings related to compassion as opposed to memory training. Indeed, participants who underwent compassion training indicated an increase in positive feelings after the training for both videos depicting suffering others and videos depicting people in everyday-life situations, while no such change was present in the memory control group. Interestingly, in contrast to typical emotion-regulation strategies that aim at the reduction of negative affect, compassion training did not change the degree to which participants experienced negative affect. In other words, participants did not down-regulate their negative feelings as a result of the compassion training, but rather augmented their positive feelings. This finding extends previous research on the beneficial effect of loving-kindness training on everyday well-being (Fredrickson, Cohn, Coffey, Pek, & Finkel, 2008). Fredrickson and colleagues reported that after several weeks of loving-kindness training, participants reported increased well-being in daily life (Fredrickson et al., 2008). Our results extend this finding by showing that compassion training not only increases positive affect in response to everyday-life situations, but that it can also increase positive affect in response to witnessing the suffering of others. The maintenance of negative affect in response to suffering speaks to the notion that a compassionate person does not turn away from suffering, but actually relates to it in an engaged way.

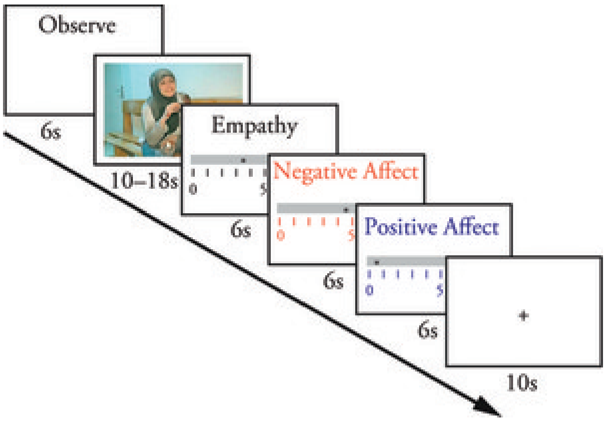


Click to view larger

Figure 9.1 Timeline of the Socio-affective Video Task (SoVT). Participants watched videos depicting others suffering or depicting people in everyday life activities. After each video, participants rated the degree to which they experienced empathy, positive affect, and negative affect. (See Color Insert)

O.M. Klimecki, S. Leiberg, C. Lamm, & T. Singer, Functional Neural Plasticity and Associated Changes in Positive Affect After Compassion Training, Cerebral Cortex, 2013, 23(7), 1552–1561, by permission of Oxford University Press

.



Click to view larger

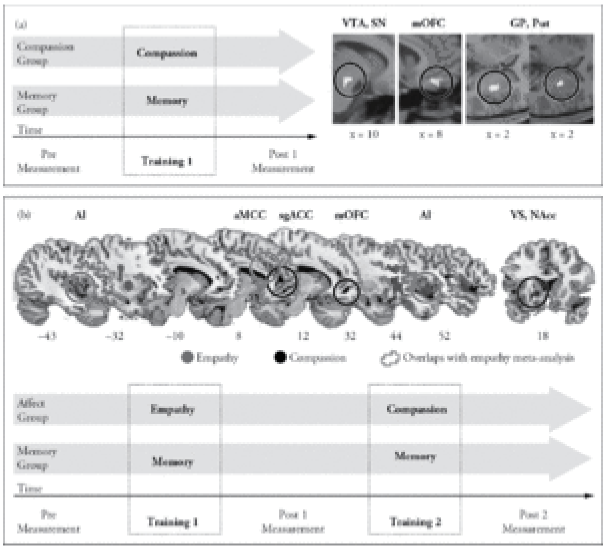
Figure 9.1 Timeline of the Socio-affective Video Task (SoVT). Participants watched videos depicting others suffering or depicting people in everyday life activities. After each video, participants rated the degree to which they experienced empathy, positive affect, and negative affect.

O.M. Klimecki, S. Leiberg, C. Lamm, & T. Singer, Functional Neural Plasticity and Associated Changes in Positive Affect After Compassion Training, Cerebral Cortex, 2013, 23(7), 1552–1561, by permission of Oxford University Press

.

On the neural level, compassion training, but not memory training, was associated with increased activation in the medial OFC, the putamen and the pallidum, and the ventral tegmental area/substantia nigra (Figure 9.2a). This study was the first demonstration of changes in neural function related to the training of emotions. These changes occurred after a relatively short training of roughly one week and were specific to brain regions consistently implicated in affiliation and caregiving (Preston, 2013), feelings of social connection (Eisenberger & Cole, 2012) as well as feelings of compassion and love (e.g., Bartels & Zeki, 2004; Beauregard et al., 2009; Kim et al., 2009). This pattern of activation was also observed in two of our previous studies without a control group and in an expert mediator immersing himself into compassionate states (Klimecki et al., 2013).

This pattern of results—a combination of sustained sharing of negative feelings with a concurrent increase of positive feelings associated with functional plasticity in networks related to affiliation and care—suggests that compassion differs from traditional emotion-regulation strategies, such as distraction, suppression, or cognitive reappraisal, as these other strategies mainly aim to reduce negative emotions. The difference between compassion and emotion-regulation strategies was tested by Engen and Singer (2015a), in a cross-sectional brain imaging study with long-term Buddhist meditation practitioners in which participants were again presented with the SoVT (Klimecki et al., 2013) while being asked either to engage in classical cognitive reappraisal strategies to regulate their emotions, or to engage in compassion meditation (Engen & Singer, 2015a). Comparing both conditions revealed that, whereas cognitive reappraisal engaged the classical fronto-parietal control network in the brain and was most efficient in reducing negative affect, compassion activated a similar brain network as the one in the already cited compassion training study including mOFC, striatum, and subgenual anterior cingulate cortex (ACC, Figure 9.3). In addition, compassion increased positive affect the most. These results confirmed that compassion can be seen as an alternative (p. 114) emotion-regulation strategy. In contrast to emotion-regulation, which often involves an active down-regulation of negative affect, compassion focuses on the active generation of positive affect and the underlying brain network related to care and affiliation (Engen & Singer, 2015a, 2015b).

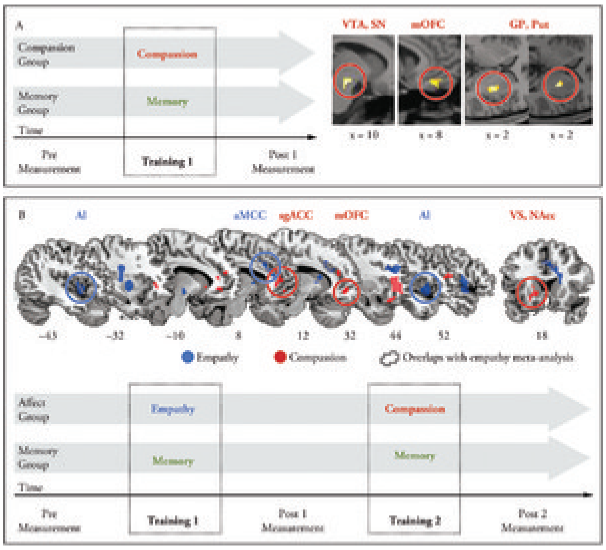


Click to view larger

Figure 9.2 Differential effects of empathy and compassion training on functional neural plasticity. (A) Compassion training augmented activations in the ventral tegmental area/substantia nigra (VTA, SN), the medial orbitofrontal cortex (mOFC), and the globus pallidus (GP) and putamen (Put). (B) Empathy training (in blue) lead to increased activations in anterior insula (AI) and anterior middle cingulate cortex (aMCC), while compassion training (in red) augmented activations in medial orbitofrontal cortex (mOFC), subgenual anterior cingulate cortex (sgACC) and the ventral striatum/nucleus accumbens (VS, NAcc). (See Color Insert)

Current Biology, 24(14), Singer, T. & Klimecki, O.M., Empathy and compassion, R875–R878., Copyright (2015), with permission from Elsevier

Reprinted from .



Click to view larger

Figure 9.2 Differential effects of empathy and compassion training on functional neural plasticity. (A) Compassion training augmented activations in the ventral tegmental area/substantia nigra (VTA, SN), the medial orbitofrontal cortex (mOFC), and the globus pallidus (GP) and putamen (Put). (B) Empathy training (in blue) lead to increased activations in anterior insula (AI) and anterior middle cingulate cortex (aMCC), while compassion training (in red) augmented activations in medial orbitofrontal cortex (mOFC), subgenual anterior cingulate cortex (sgACC) and the ventral striatum/nucleus accumbens (VS, NAcc).

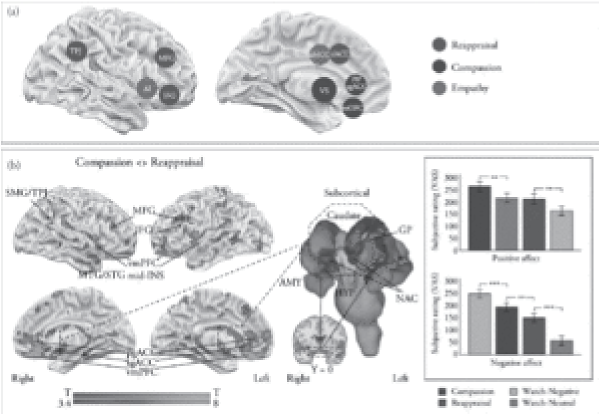
Current Biology, 24(14), Singer, T. & Klimecki, O.M., Empathy and compassion, R875–R878., Copyright (2015), with permission from Elsevier

Reprinted from .

In line with the assumption that activity in the neural network related to care and social connection can promote health and counteract feelings of threat (Eisenberger & Cole, 2012), our data suggest that compassion training can be seen as a novel tool to strengthen resilience and promote physical health through the activation of a positively valenced care system.

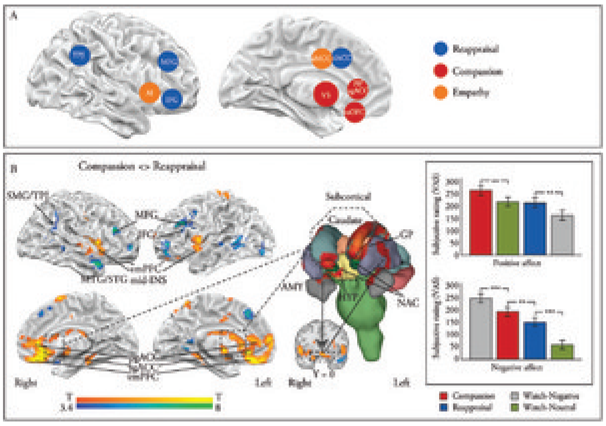
The Different Effects of Compassion vs. Empathy-for-Suffering Training

The review of neuroscience research on empathy and compassion described here suggests that, although both emotions are affective responses to the suffering of another being, each of these social emotions may have rather different subjective and neuronal fingerprints. To explicitly test this hypothesis, we conducted another longitudinal neuroimaging study, in which we aimed at differentiating between the neural and subjective signatures elicited through empathy-for-suffering training on one hand, and compassion training on the other, in the same individuals. Based on previous evidence (p. 115) showing that empathic responses to the suffering of others were related to brain activations in dorsal parts of the anterior insula and medial anterior cingulate cortex and associated with reported negative affect (Lamm et al., 2011), we hypothesized that empathy-for-suffering training would increase activations in this network associated with an increase in negative affect (Klimecki, Leiberg, Ricard, & Singer, 2014). Conversely, we expected compassion training to augment neural activations previously observed to be related to compassion and loving-kindness and to result in an increase in positive affect.



Click to view larger

Figure 9.3 Reappraisal, Compassion and Empathy involve different brain activations. (A) Brain regions implicated in reappraisal (blue), compassion (red) and empathy (orange). Empathy training (in blue) lead to increased activations in anterior insula (AI) and anterior middle cingulate cortex (aMCC), while compassion training (in red) augmented activations in medial orbitofrontal cortex (mOFC), subgenual anterior cingulate cortex (sgACC), globus pallidus (GP), putamen and the ventral striatum/nucleus accumbens (VS, NAcc). Reappraisal was related to activations in dorsal anterior cingulate cortex (dACC), inferior frontal gyrus (IFG), MFG, temporal parietal junction (TPJ) (B) The effects of compassion (yellow-orange) when used to regulate emotional reactions to negative stimuli, as compared to reappraisal (blue). Behavioral results show that while cognitive emotion regulation relies primarily on the down-regulation of negative affect, compassion appears to both decrease negative affect and increase positive affect suggesting that emotion regulation via compassion utilises different mechanisms than cognitive emotion regulation. Here, asterisks denote significance levels of t-tests with ** corresponding to $p < .01$, and *** corresponding to $p < .001$. Neurally, this difference is reflected in more engagement of midline and subcortical structures in compassion. Compassion, more than reappraisal, activates subcortical structures, including ventral striatum (VS with caudate and nucleaus accumbens, NAC) and amygdala. Critically, amygdala activation was higher in compassion than reappraisal, suggesting that active down-regulation of amygdala is not a key part of compassion. (See Color Insert)



Click to view larger

Figure 9.3 Reappraisal, Compassion and Empathy involve different brain activations. (A) Brain regions implicated in reappraisal (blue), compassion (red) and empathy (orange). Empathy training (in blue) lead to increased activations in anterior insula (AI) and anterior middle cingulate cortex (aMCC), while compassion training (in red) augmented activations in medial orbitofrontal cortex (mOFC), subgenual anterior cingulate cortex (sgACC), globus pallidus (GP), putamen and the ventral striatum/nucleus accumbens (VS, NAcc). Reappraisal was related to activations in dorsal anterior cingulate cortex (dACC), inferior frontal gyrus (IFG), MFG, temporal parietal junction (TPJ) (B) The effects of compassion (yellow-orange) when used to regulate emotional reactions to negative stimuli, as compared to reappraisal (blue). Behavioral results show that while cognitive emotion regulation relies primarily on the down-regulation of negative affect, compassion appears to both decrease negative affect and increase positive affect suggesting that emotion regulation via compassion utilises different mechanisms than cognitive emotion regulation. Here, asterisks denote significance levels of t-tests with ** corresponding to $p < .01$, and *** corresponding to $p < .001$. Neurally, this difference is reflected in more engagement of midline and subcortical structures in compassion. Compassion, more than reappraisal, activates subcortical structures, including ventral striatum (VS with caudate and nucleaus accumbens, NAC) and amygdala. Critically, amygdala activation was higher in compassion than reappraisal, suggesting that active down-regulation of amygdala is not a key part of compassion.

This study (Klimecki et al., 2014) consisted of two intervention groups: the emotion intervention group (empathy-for-suffering and compassion training) and an active memory control group which underwent the same type of mnemonic training as in our first compassion training study (Klimecki et al., 2013). Participants in the affective intervention group were first trained to empathically immerse themselves in the suffering of others and to feel the others' suffering as if it was their own. To test whether compassion training can counteract extensive sharing of suffering, participants were subsequently trained in compassion. Each of these trainings lasted a full day and was followed by a series of one-hour evening sessions and practice at home. After roughly one week dedicated to empathy-for-suffering training and the measurement of related effects, participants were (p. 116) trained in compassion for another week. The control group did two weeks of memory training. In the empathy-for-suffering training, participants imagined a series of other people and tried to feel their suffering as if it were their own. To this end, they used sentences like "I share your pain" or "I feel your suffering." In order to address this aspect in the subsequent compassion training, we explicitly included the cultivation of benevolence and kindness towards suffering others in the training sequence. The active control group underwent memory training with a structure that was equivalent to the emotion training.

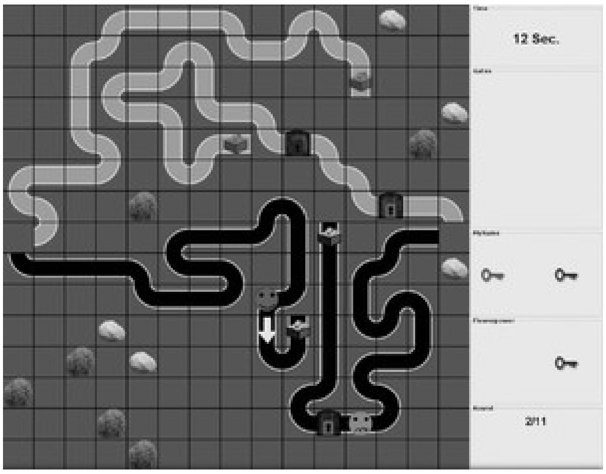
However, in the memory group, the focus was on training cognitive capacities. Both groups were tested with the SoVT and concurrent fMRI scans prior to the first training (pre-test), after the first training (empathy for suffering or memory), and after the second training (compassion or memory).

The results of this study revealed that empathy-for-suffering training indeed increased subjective reports of negative affect and experienced empathy for people in the videos. These changes were observed for situations in which participants witnessed others suffering, and for situations in which participants witnessed everyday-life events. In other words, the excessive sharing of suffering also biased participants into perceiving normal situations more negatively. Subsequent compassion training could counteract this effect. Compassion training thus returned the level of negative emotional experiences to baseline and increased positive affect—again, for everyday situations as well as for situations involving suffering. This result replicates our previous finding on the effects of compassion training and extends this finding by showing that these effects can also be obtained after an increase in empathy and negative affect. On the neural level, we observed for the first time functional neural plasticity in the heretofore-mentioned "empathy for pain network"; that is, the AI and the ACC—regions that have emerged as crucial for processing the affective component of pain (Corradi-Dell'Acqua et al., 2011; Corradi-Dell'Acqua et al., 2016; Kanske et al., 2015; Lamm et al., 2011). Furthermore, compassion training augmented neural activations in brain areas that we had previously observed in our other compassion studies (Klimecki et al., 2013), namely the medial OFC and the striatum (Figure 9.2b). Together with the behavioral findings, these results indicate that compassion is a powerful tool for strengthening positive other-related emotions and underlying neural activations, and that in addition, compassion training can counteract the potential detrimental effects of empathizing too much with the suffering of others, something that, if chronically experienced in daily life, can easily lead to exhaustion and burnout (for review, see Klimecki & Singer, 2012; Singer & Klimecki, 2014). These findings raise exciting possibilities for developing interventions that could help people improve their health and resilience through compassion training. In addition, it could be important to train people to differentiate between these two social emotions and to transform empathic reactions into compassionate responses when confronted with other people's stress and suffering. Based on these studies, Singer and colleagues have developed a nine-month-long compassion training program, the ReSource Project, in which participants are taught several types of mental training techniques in three consecutive three-month modules called Presence, Perspective, and Affect. Whereas the training modules Presence and Perspective focus on attentional-, interoceptive-, and meta-cognitive skills, the Affect module has a strong focus on teaching people how to distinguish empathy from compassion and how to strength care- and affiliation-related systems through regular practice of gratitude, loving-kindness, and compassion (for details about the ReSource project, see Singer, Kok, Bornemann, Bolz, & Bochow, 2014).

How Do Empathy and Compassion Relate to Prosocial Behavior?

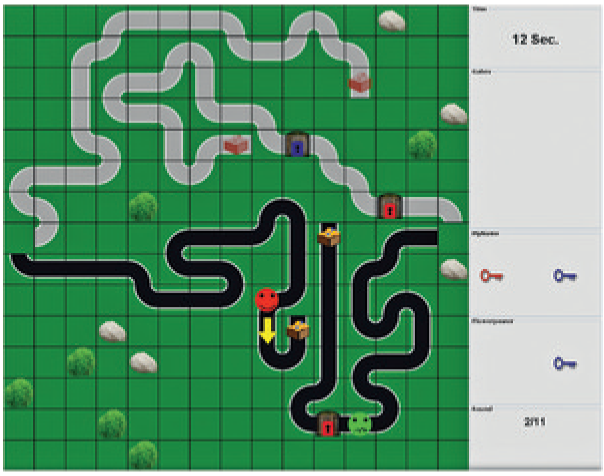
Having reviewed the neuroscientific and subjective fingerprints of social emotions such as empathy, empathic distress, and compassion and their trainability, we now turn to the question of how these social emotions and their training link to prosocial behavior. Note that, although this question has only been investigated in few training studies so far, the link between empathic distress and empathic concern (or compassion) with helping behavior in adults and children was already the focus of earlier empathy research in psychology (Eisenberg & Miller, 1987) and is also discussed in the chapter by Daniel Batson (Chapter 3 this volume).

To test whether helping behavior can be improved by compassion training, we conducted a longitudinal study in which we measured how several days of compassion training influence helping behavior (Leiberg, Klimecki, & Singer, 2011). Due to the scarcity of ecologically valid and well-controlled laboratory measures of helping behavior, we first developed the Zurich Prosocial Game (ZPG; see Figure 9.4). The ZPG is a computerized treasure hunt game in which two players (p. 117) simultaneously navigate through their respective path in a maze to reach their own treasure (which is worth real money). Gates that regularly fall on the paths along the way can block players. These gates can only be opened with the key of a corresponding color. As keys are scarce, there are often situations in which one player cannot advance without the help of the other player. These situations enable us to measure helping behavior. After validating the ZPG, we employed this task in a longitudinal study with two groups: one group of participants was trained in compassion over several days, while the other group served as an active control group and was trained in a cognitive method for memorizing items (Bower, 1970). Both groups played the game at baseline (prior to training) and following the training. The data revealed that, while there was no change in helping behavior in the active memory control group, the compassion training group increased their overall helping behavior. Interestingly, the more participants reported having practiced compassion, the more they engaged in altruistic helping behavior—operationalized as opening a door for another player in a situation in which this other player could not reciprocate the help.



Click to view larger

Figure 9.4 Screenshot of the Zurich Prosocial Game showing the two players hunting for their respective treasures. (See Color Insert)



Click to view larger

Figure 9.4 Screenshot of the Zurich Prosocial Game showing the two players hunting for their respective treasures.

In line with this finding, another study showed that after two weeks of compassion training, participants used more of their monetary resources to restore the monetary equilibrium between two other players after a norm violation in an economic game (Weng et al., 2013; see Weng, Schuyler and Davidson, Chapter 11 this volume). The positive impact of compassion training on helping behavior is further corroborated by the finding that compassion training was related to increased rates of helping behavior in a real-life situation where participants had the opportunity to offer their own seat to a person in crutches (Condon, Desbordes, Miller, & DeSteno, 2013). This effect, however, was not specific for compassion training, as it was also observed for participants undergoing mindfulness training (Condon et al., 2013; see Condon and DeSteno, Chapter 22 this volume). As these data show, compassion training is a powerful tool for improving helping behavior.

Finally, a recent study from our laboratory focusing on long-term experts in compassion meditation (McCall, Steinbeis, Ricard, & Singer, (p. 118) 2014) extended previous findings by showing that compassion expertise not only has an impact on levels of helping behavior, it also affects reactions to fairness violations and norm reinforcement. Thus, in contrast to controls, long-term compassion practitioners engaging in different types of monetary social exchange games derived from behavioral economics showed less anger when treated unfairly by others, and consequently showed less anger-based punishment. However, they showed a similar amount of norm reinforcement when witnessing the unfair treatment of others, but differed from matched controls in that they chose more often to reinstate equality by compensating victims as opposed to punishing the perpetrators (McCall et al., 2014). These results suggest that cultivating compassion could have more widespread effects on all kinds of social behaviors, including behavior crucial for norm reinforcement and justice in societies.

Finally, to test whether empathic distress and compassion can have opposing influences on social behavior following provocation, a recent study (Klimecki, Vuilleumier, & Sander, 2016) investigated how empathy-related traits predict behavioral reactions to provocation through unfair behavior. Due to the inherent difficulty of studying antisocial behavior in an ecologically valid yet highly controlled laboratory setting, we first developed and validated a new paradigm based on computerized economic and verbal interactions—the Inequality Game (Klimecki et al., 2016). In this game, participants are first presented with the behavior of a fair and an unfair other, and can only engage in cooperative or competitive behavior towards the other two players in the second part of the game. More specifically, participants played two phases of an economic interaction game with the possibility of sending messages to the other players. In the first phase of the game, participants were in a low-power position in which the fair other player chose cooperative economic distributions (high gains for himself and the participant) and nice messages (e.g., "You are very nice"), whereas the unfair other player chose competitive economic distributions (high gains for himself and low gains for the participant) and derogatory messages (e.g., "You are annoying"). Following this low-power phase, participants were in a high-power phase in which they could also make cooperative or competitive choices as well as select nice or derogatory feedback messages for the other players. Although participants on average punished the unfair other and rewarded the fair other, we observed considerable inter-individual differences in participants' behaviors. In fact, participants could be classified as prosocial (showing predominantly prosocial behavior to both others), sanctioning (punishing the unfair other and rewarding the fair other), and competitive (showing aggressive behavior towards both, the unfair and even the fair other). When we investigated how different empathy-related personality traits related to this behavior, we found that the higher participants scored on compassion and perspective-taking, the more they showed forgiveness behavior; i.e., cooperative and nice behavior toward the unfair other. Conversely, we observed that the more people reported feeling empathic distress in their lives, the more aggressively they behaved towards both, the unfair and even the fair other.

In summary, this study extends previous findings from behavioral psychology (see chapter by Batson, Chapter 3 this volume) by showing that compassion and empathic distress are related to helping behavior *and* aggressive behavior in opposing ways. Whereas compassion fosters helping behavior and forgiveness behavior, empathic distress is related to less helping behavior and more aggressive behavior.

Conclusion: Integration and Outlook

In this chapter, we started with a summary of the neuroscientific research on empathy. We then described the common neural substrates of care, social connection, and reward before turning to cross-sectional studies of love and compassion. These studies revealed that compassion is associated with an increase in positive feelings and with neural activations in a network associated with care and social connection, including the medial OFC and the ventral striatum. Importantly, the degree of compassionate experiences is not set in stone, but can be trained even in adults. Training compassion leads to an increase in positive affect associated with functional plasticity in brain networks related to care and compassion. Furthermore, we discussed evidence that compassion training can counteract potential negative effects of excessive empathy for suffering, characterized by an increase in negative affect and underlying activation in "empathy for pain" networks. This finding underlines the potentially beneficial role of compassion in strengthening resilience and acting as an efficient emotion-regulation strategy that works through the up-regulation of a system of care and affiliation rather than through the down-regulation of negative affect described in classical emotion-regulation strategies, (p. 119) such as cognitive reappraisal. Taken together, the findings that compassion training and expertise are associated with increased levels of helping, less aggression, and behaviors of restorative justice rather than anger or revenge-based punishment suggest exciting avenues for the development of interventions that allow for the targeted fostering of resilience, well-being, and prosocial behavior.

References

Aron, A., Fisher, H., Mashek, D. J., Strong, G., Li, H., & Brown, L. L. (2005). Reward, motivation, and emotion systems associated with early-stage intense romantic love. *Journal of Neurophysiology*, *94*(1), 327–337. doi: 10.1152/jn.00838.2004

Bartels, A., & Zeki, S. (2000). The neural basis of romantic love. *Neuroreport*, *11*(17), 3829–3834.

Bartels, A., & Zeki, S. (2004). The neural correlates of maternal and romantic love. *NeuroImage*, *21*(3), 1155–1166. doi: 10.1016/j.neuroimage.2003.11.003

Beauregard, M., Courtemanche, J., Paquette, V., & St-Pierre, E. L. (2009). The neural basis of unconditional love. *Psychiatry Research*, *172*(2), 93–98. doi: 10.1016/j.pscychresns.2008.11.003

Bower, G. H. (1970). Analysis of a mnemonic device. *American Scientist*, *58*(5), 496–510.

Brown, S. L., & Brown, R. M. (2015). Connecting prosocial behavior to improved physical health: Contributions from the neurobiology of parenting. *Neuroscience & Biobehavioral Reviews*, *55*, 1–17.

Condon, P., Desbordes, G., Miller, W. B., & DeSteno, D. (2013). Meditation increases compassionate responses to suffering. *Psychological Science*, *24*(10), 2125–2127. doi: 10.1177/0956797613485603

Corradi-Dell'Acqua, C., Hofstetter, C., & Vuilleumier, P. (2011). Felt and seen pain evoke the same local patterns of cortical activity in insular and cingulate cortex. *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience*, *31*(49), 17996–18006. doi:10.1523/JNEUROSCI.2686-11.2011

Corradi-Dell'Acqua, C., Tusche, A., Vuilleumier, P., & Singer, T. (2016). Cross-modal representations of first-hand and vicarious pain, disgust and fairness in insular and cingulate cortex. *Nature Communications, 7*.

Craig, A. D. (2003). Interoception: The sense of the physiological condition of the body. *Current Opinion in Neurobiology*, *13*(4), 500–505.

Davis, M. H. (1983). Measuring individual differences in empathy: Evidence for a multidimensional approach. *Journal of Personality and Social Psychology*, *44*(1), 113–126.

Depue, R. A., & Morrone-Strupinsky, J. V. (2005). A neurobehavioral model of affiliative bonding: implications for conceptualizing a human trait of affiliation. *Behavioral and Brain Sciences*, *28*, 313–350.

de Vignemont, F., & Singer, T. (2006). The empathic brain: How, when and why? *Trends in Cognitive Sciences*, *10*(10), 435–441. doi: 10.1016/j.tics.2006.08.008

Depue, R. A., & Morrone-Strupinsky, J. V. (2005). A neurobehavioral model of affiliative bonding: Implications for conceptualizing a human trait of affiliation. *Behavioral & Brain Sciences*, *28*(3), 313–350; discussion 350–395. doi: 10.1017/S0140525X05000063

Draganski, B., Gaser, C., Busch, V., Schuierer, G., Bogdahn, U., & May, A. (2004). Neuroplasticity: Changes in grey matter induced by training. *Nature*, *427*(6972), 311–312.

Draganski, B., Gaser, C., Kempermann, G., Kuhn, H. G., Winkler, J., Büchel, C., & May, A. (2006). Temporal and spatial dynamics of brain structure changes during extensive learning. *The Journal of Neuroscience*, *26*(23), 6314–6317. doi: 10.1523/jneurosci.4628-05.2006

Eisenberg, N., & Miller, P. A. (1987). The relation of empathy to prosocial and related behaviors. *Psychological Bulletin*, *101*(1), 91–119.

Eisenberger, N. I., & Cole, S. W. (2012). Social neuroscience and health: Neurophysiological mechanisms linking social ties with physical health. *Nature Neuroscience*, *15*(5), 669–674.

Eisenberger, N. I., Master, S. L., Inagaki, T. K., Taylor, S. E., Shirinyan, D., Lieberman, M. D., & Naliboff, B. D. (2011). Attachment figures activate a safety signal-related neural region and reduce pain experience. *Proceedings of the National Academy of Sciences*, *108*(28), 11721–11726.

Engen, H. G., & Singer, T. (2015a). Compassion-based emotion regulation up-regulates experienced positive affect and associated neural networks. *Social Cognitive and Affective Neuroscience*, *10*(9), 1291–1301.

Engen, H. G., & Singer, T. (2015b). Affect and motivation are critical in constructive meditation. *Trends in Cognitive Sciences*. doi:10.1016/j.tics.2015.11.004

Fan, Y., Duncan, N. W., de Greck, M., & Northoff, G. (2011). Is there a core neural network in empathy? An fMRI based quantitative meta-analysis. *Neuroscience & Biobehavioral Reviews*, *35*(3), 903–911. doi: 10.1016/j.neubiorev.2010.10.009

Fredrickson, B. L., Cohn, M. A., Coffey, K. A., Pek, J., & Finkel, S. M. (2008). Open hearts build lives: Positive emotions, induced through loving-kindness meditation, build consequential personal resources. *Journal of Personality and Social Psychology*, *95*(5), 1045–1062.

Gilbert, P. (2010). *Compassion Focused Therapy: Distinctive Features*. London: Routledge.

Goetz, J. L., Keltner, D., & Simon-Thomas, E. (2010). Compassion: An evolutionary analysis and empirical review. *Psychological Bulletin*, *136*(3), 351–374. doi: 10.1037/a0018807

Insel, T. R., Young, L., & Wang, Z. (1997). Central oxytocin and reproductive behaviours. *Reviews of Reproduction*, *2*(1), 28–37.

Jabbi, M., Bastiaansen, J., & Keysers, C. (2008). A common anterior insula representation of disgust observation, experience and imagination shows divergent functional connectivity pathways. *PLoS One, 3*(8), e2939.

Jackson, P. L., Meltzoff, A. N., & Decety, J. (2005). How do we perceive the pain of others? A window into the neural processes involved in empathy. *NeuroImage*, *24*(3), 771–779. doi: 10.1016/j.neuroimage.2004.09.006

Kanske, P., Bockler, A., Trautwein, F. M., & Singer, T. (2015). Dissecting the social brain: Introducing the EmpaToM to reveal distinct neural networks and brain-behavior relations for empathy and Theory of Mind. *NeuroImage*, *122*, 6–19. doi:10.1016/j.neuroimage.2015.07.082

Keysers, C., Wicker, B., Gazzola, V., Anton, J. L., Fogassi, L., & Gallese, V. (2004). A touching sight: SII/PV activation during the observation and experience of touch. *Neuron*, *42*(2), 335–346.

Kim, J. W., Kim, S. E., Kim, J. J., Jeong, B., Park, C. H., Son, A. R., … Ki, S. W. (2009). Compassionate attitude towards others' suffering activates the mesolimbic neural (p. 120) system. *Neuropsychologia*, *47*(10), 2073–2081. doi:10.1016/j.neuropsychologia.2009.03.017

Klimecki, O., & Singer, T. (2012). Empathic distress fatigue rather than compassion fatigue? Integrating findings from empathy research in psychology and social neuroscience. In B. Oakley, A. Knafo, G. Madhavan, & D. Sloan Wilson (Eds.), *Pathological Altruism* (pp. 368–383). New York: Oxford University Press.

Klimecki, O. M., Leiberg, S., Lamm, C., & Singer, T. (2013). Functional neural plasticity and associated changes in positive affect after compassion training. *Cerebral Cortex*, *23*(7), 1552–1561. doi:10.1093/cercor/bhs142

Klimecki, O., & Singer, T. (2013). Empathy from the perspective of social neuroscience. In J. Armony & P. Vuilleumier (Eds.), *Handbook of Human Affective Neuroscience* (pp. 533–549). New York: Cambridge University Press.

Klimecki, O. M., Leiberg, S., Ricard, M., & Singer, T. (2014). Differential pattern of functional brain plasticity after compassion and empathy training. *Social Cognitive and Affective Neuroscience*, *9*(6), 873–879. doi:10.1093/scan/nst060

Klimecki, O. M., Vuilleumier, P., & Sander, D. (2016). The impact of emotions and empathy-related traits on punishment behavior: Introduction and validation of the Inequality Game. *PLoS One, 11*, e0151028. doi:10.1371/journal.pone.0151028

Lamm, C., Decety, J., & Singer, T. (2011). Meta-analytic evidence for common and distinct neural networks associated with directly experienced pain and empathy for pain. *NeuroImage*, *54*(3), 2492–2502. doi: 10.1016/j.neuroimage.2010.10.014

Lamm, C., Silani, G., & Singer, T. (2015). Distinct neural networks underlying empathy for pleasant and unpleasant touch. *Cortex*, *70*, 79–89. doi:10.1016/j.cortex.2015.01.021

Lamm, C., & Singer, T. (2010). The role of anterior insular cortex in social emotions. *Brain Structure & Function, 214*(5–6), 579–591. doi:10.1007/s00429-010-0251-3

Leiberg, S., Klimecki, O., & Singer, T. (2011). Short-term compassion training increases prosocial behavior in a newly developed prosocial game. *PLoS One, 6*(3), e17798. doi: 10.1371/journal.pone.0017798

Lutz, A., Brefczynski-Lewis, J., Johnstone, T., & Davidson, R. J. (2008). Regulation of the neural circuitry of emotion by compassion meditation: Effects of meditative expertise. *PLoS One, 3*(3), e1897. doi:10.1371/journal.pone.0001897

McCall, C., & Singer, T. (2012). The animal and human neuroendocrinology of social cognition, motivation and behavior. *Nature Neuroscience*, *15*(5), 681–688. doi:10.1038/nn.3084

McCall, C., Steinbeis, N., Ricard, M., & Singer, T. (2014). Compassion meditators show less anger, less punishment, and more compensation of victims in response to fairness violations. *Frontiers in Behavioral Neuroscience*, *8*, 424. doi:10.3389/fnbeh.2014.00424

Mobbs, D., Yu, R., Meyer, M., Passamonti, L., Seymour, B., Calder, A. J., … Dalgleish, T. (2009). A key role for similarity in vicarious reward. *Science*, *324*(5929), 900. doi:10.1126/science.1170539

O'Doherty, J. P. (2004). Reward representations and reward-related learning in the human brain: Insights from neuroimaging. *Current Opinion in Neurobiology*, *14*(6), 769–776. doi:10.1016/j.conb.2004.10.016

Onoda, K., Okamoto, Y., Nakashima, K., Nittono, H., Ura, M., & Yamawaki, S. (2009). Decreased ventral anterior cingulate cortex activity is associated with reduced social pain during emotional support. *Social Neuroscience*, *4*(5), 443–454.

Pascual-Leone, A., Amedi, A., Fregni, F., & Merabet, L. B. (2005). The plastic human brain cortex. *Annual Review of Neuroscience*, *28*, 377–401.

Peyron, R., Laurent, B., & Garcia-Larrea, L. (2000). Functional imaging of brain responses to pain. A review and meta-analysis. *Neurophysiology Clinical*, *30*(5), 263–288. doi:S0987-7053(00)00227-6 [pii]

Preston, S. D. (2013). The origins of altruism in offspring care. *Psychological Bulletin*, *139*(6), 1305.

Rainville, P. (2002). Brain mechanisms of pain affect and pain modulation. *Current Opinion in Neurobiology*, *12*(2), 195–204.

Sagi, A., & Hoffman, M. L. (1976). Empathic distress in the newborn. *Developmental Psychology*, *12*(2), 175–176. doi:10.1037/0012-1649.12.2.175

Schultz, W. (2000). Multiple reward signals in the brain. *Nature Reviews Neuroscience*, *1*(3), 199–207. doi:10.1038/35044563

Singer, T., Critchley, H. D., & Preuschoff, K. (2009). A common role of insula in feelings, empathy and uncertainty. *Trends in Cognitive Sciences*, *13*(8), 334–340. doi:10.1016/j.tics.2009.05.001

Singer, T., & Klimecki, O. M. (2014). Empathy and compassion. *Current Biology, 24*(18), R875–R878. doi:10.1016/j.cub.2014.06.054

Singer, T., Kok, B. E., Bornemann, B., Bolz, M., & Bochow, C. B. (2014). *The ReSource Project. Background, Design, Samples, and Measurements* (1st ed.). Leipzig: Max Planck Institute for Human Cognitive and Brain Sciences.

Singer, T., Seymour, B., O'Doherty, J., Kaube, H., Dolan, R. J., & Frith, C. D. (2004). Empathy for pain involves the affective but not sensory components of pain. *Science*, *303*(5661), 1157–1162. doi:10.1126/science.1093535

Vrticka, P., Andersson, F., Grandjean, D., Sander, D., & Vuilleumier, P. (2008). Individual attachment style modulates human amygdala and striatum activation during social appraisal. *PLoS One, 3*(8), e2868. doi:10.1371/journal.pone.0002868

Weng, H. Y., Fox, A. S., Shackman, A. J., Stodola, D. E., Caldwell, J. Z. K., Olson, M. C., … Davidson, R. J. (2013). Compassion training alters altruism and neural responses to suffering. *Psychological Science*, *24*(7), 1171–1180. doi:10.1177/0956797612469537

Wicker, B., Keysers, C., Plailly, J., Royet, J. P., Gallese, V., & Rizzolatti, G. (2003). Both of us disgusted in My insula: The common neural basis of seeing and feeling disgust. *Neuron*, *40*(3), 655–664.

Olga M. Klimecki

Olga M. Klimecki, Swiss Center for Affective Sciences, Laboratory for the Study of Emotion Elicitation and Expression, Department of Psychology, University of Geneva, Geneva, Switzerland

Tania Singer

Tania Singer Department of Social Neuroscience Max Planck Institute for Human Cognitive and Brain Science Leipzig, Germany