Chapter 6

Neuroscience and Compassion

Introduction: Compassion and the Brain

There is a growing literature examining the relationship between compassion and various aspects of nervous system function, especially the brain. This is part of a broader trend in research seeking to establish the links, if any, between brain function and various emotional and psychological states including empathy (e.g., de Vignemont and Singer, 2006) and compassion (e.g., Weng et al., 2013). This chapter explores this expanding field and seeks to place emerging research findings about the neuroscience of compassion in their broader context.

The chapter starts by exploring neuroimaging studies of compassion and then examines the topic of empathy and the brain, noting evidence that observing another person's emotional state activates parts of the neuronal network that are also involved in processing that same state in oneself. This is followed by further discussion of evidence about the neuroscience of compassion and, especially, the effects of compassion training. In essence, evidence suggests that multiple areas within the brain are involved in compassion and compassion training, with some regions more strongly implicated than others. Finally, the chapter presents relevant conclusions and outlines potential directions for future work. The overall message is that neuroscientific findings to date underscore the importance of developing compassion as a skill and fundamental attribute for healthcare workers across all settings.

Neuroimaging Studies of Compassion

Functional magnetic resonance imaging (fMRI) studies are used to systematically examine the functional neural networks underlying human behaviour. Today, fMRI is an increasingly sophisticated technique for imaging brain function, albeit that it is not possible to infer a direct causal connection between, for example, a compassion-based task and any simultaneous or subsequent changes in neural activity. Even so, studies that seek to link neuroscience with emotional states such as empathy and compassion yield interesting results and hold further promise for the future (e.g., Hou et al., 2017).

Kim and colleagues performed a particularly valuable study of 'neurophysiological and behavioural markers of compassion':

> This study conducted an integrative, multi-method approach which first investigated two fundamental self-regulatory styles (self-criticism and self-reassurance) with fMRI, and second, measured participant's HRV [heart-rate variability], a marker of parasympathetic response, during compassion training, pre- and post- a two-week self-directed training period. (Kim et al., 2020; p. 5)

https://doi.org/10.1017/9781009390217.007 Published online by Cambridge University Press

These researchers reported significant links between compassion and neurophysiological markers:

> We identified neural networks associated with threat are reduced when practicing compassion, and heightened when being self-critical. In addition, cultivating compassion was associated with increased parasympathetic response as measured by an increase in HRV, versus the resting-state. Critically, cultivating compassion was able to shift a subset of clinically-at risk participants to one of increased parasympathetic response. Further, those who began the trial with lower resting HRV also engaged more in the intervention, possibly as they derived more benefits, both self-report and physiologically, from engagement in compassion. (Kim et al., 2020; p. 1)

These are fascinating, valuable findings, but, looking at the literature more broadly, methodological heterogeneity presents a real challenge across this field as a whole. Difficulties identifying which areas of the brain are involved in compassion include varying definitions of compassion across studies, different tasks used to generate compassion, and factoring in the impact of the noise generated by fMRI scanning. Also, because compassion includes feeling motivated to act, it is particularly difficult to generate a task that will measure this aspect of compassion on a fMRI scan. In addition, many people consider empathy and compassion to be synonyms of each other, so, unless researchers explicitly explain the difference, these can be confused (Lamm et al., 2019).

Notwithstanding these issues, an integrative approach to this topic, combining structural imaging and lesion studies with fMRI studies, for example, can enhance knowledge about brain structure and behaviour in relation to compassion. In 2018, Weng and colleagues published a study of 'visual attention to suffering after compassion training', which they found to be 'associated with decreased amygdala responses':

> Increases in visual preference for suffering due to compassion training were associated with decreases in the amygdala, a brain region involved in negative valence, arousal, and physiological responses typical of fear and anxiety states. This pattern was specifically in the compassion group, and was not found in the reappraisal group. In addition, compassion training-related increases in visual preference for suffering were also associated with decreases in regions sensitive to valence and empathic distress, spanning the anterior insula and orbitofrontal cortex. (Weng et al., 2018; p. 1)

This study concludes that, 'collectively, these findings suggest that compassion meditation may cultivate visual preference for suffering while attenuating neural responses in regions typically associated with aversive processing of negative stimuli, which may cultivate a more equanimous and nonreactive form of attention to stimuli of suffering' (Weng et al., 2018; p. 1).

The role of the insula was also highlighted by Novak and colleagues who published 'an integrative systematic review' of 'neural correlates of compassion' in 2022 (Novak et al., 2022). This paper included thirty-five studies 'examining the relationship between brain structure or function and compassion':

> Data from 2922 participants revealed 98 neural locations associated with compassion. We found that compassion tendency has been most frequently associated with neural activity in the left insula among fMRI studies. Results from the structural studies indicated frequent neuroanatomical associations between compassion tendency and grey matter volume in left and right insula and right caudate nucleus. (Novak et al., 2022; p. 54)

These researchers also commented on 'reasons for heterogeneity of neural findings' across the literature:

> We found a large divergence of neuroanatomical findings across both structural and fMRI studies. There might be several reasons for such a divergence: 1) the effect of social desirability, 2) empathizing with another person, instead of generating compassion, 3) random noise due to a small sample size, 4) differences in compassion inducing stimuli and 5) non-balanced proportion of females and males. (Novak et al., 2022; p. 54)

The issue of empathy merits particular consideration. The difference between empathy and compassion was explored in Chapter 3 of this book, which examined 'What Compassion Is Not'. Fundamentally, empathy means feeling *with* someone, while compassion means feeling *for* someone (Klimecki et al., 2013). In addition, compassion includes the motivation to act to alleviate suffering. So, given that empathy and compassion differ somewhat as concepts, do they also differ at the neuroscientific level?

Empathy and the Brain

Psychological models of empathy are based on the idea that observing and imagining another person in a particular emotional state activates a similar state in others. There is now fMRI evidence that observing another person's emotional state activates parts of the neuronal network that are also involved in processing that same state in oneself. Singer and colleagues studied brain activity while research subjects received a painful stimulus and while they perceived that a loved one was receiving a pain stimulus (Singer et al., 2004). In both circumstances, the bilateral anterior insula, rostral anterior cingulate cortex, brainstem, and cerebellum were activated.

Consistent with this, Fan and colleagues performed an fMRI-based meta-analysis of evidence regarding a possible 'core neural network in empathy' (Fan et al., 2011). This research group included forty studies in their analysis and concluded that the dorsal anterior cingulate cortex-anterior midcingulate cortex-supplementary motor area and bilateral insula can be regarded as constituting a core network in empathy.

So, empathy can be linked with certain patterns of activation in particular areas of the brain, but how do these findings relate to brain activity in compassion? Do the patterns differ? Do they overlap?

Klimecki and colleagues studied the differential pattern of functional brain plasticity after empathy training and compassion training (Klimecki et al., 2014). This group found that empathy training increases negative affect and increases brain activation in anterior insula and anterior midcingulate cortex – brain regions which are associated with empathy for pain. In contrast, training in compassion could reverse the increase in negative effect, boost self-reports of positive affect, and increase activation in a non-overlapping brain network involving the ventral striatum, pregenual anterior cingulate cortex, and medial orbitofrontal cortex. The authors concluded that training in compassion might reflect a new coping strategy to surmount empathic distress and strengthen resilience.

Overall, it is clear from this work, and from brain lesion studies (Hogeveen et al., 2016), that a network of brain regions is involved in various emotional abilities and states. The roles of different brain regions in myriad emotional states are likely to be complex and overlapping. For example, while the insula is linked with empathy (Fan et al., 2011; Klimecki et al., 2014), Novak and colleagues also outline 'the role of insula during compassion':

> Taken together, it is possible that while in functional studies the left insula activity can reflect (1) the integration processes of sensory input and (2) the awareness of participants of their experienced compassion towards other, processing of positive and/or negative emotions (3), in lesion studies insular damage did not allow participants to effectively integrate incoming sensory inputs, so the representation of compassion feeling in their awareness is likely to be impaired. (Novak et al., 2022; p. 55)

While empathy and compassion are related concepts, then, they also differ in certain respects (Klimecki et al., 2013), as already explored in Chapter 3 of this book ('What Compassion Is Not'). In parallel with this, it is also clear that training in empathy and compassion affect the brain somewhat differently (Klimecki et al., 2014). In other words, empathy and compassion are linked with each other to a certain degree, but also differ in particular ways, both experientially and at the level of neuroscience.

Growing Understanding of the Neuroscience of Compassion

The neuroscience of compassion continues to attract considerable research interest, especially over the past two decades. A significant proportion of this work looks at not only compassion and the brain, but also the effects of compassion training at a neuroscientific level. Overall, evidence to date shows that multiple areas within the brain are involved in compassion and compassion training, with some brain areas more strongly implicated than others.

In 2012, Desbordes and colleagues 'investigated how 8 weeks of training in meditation affects amygdala responses to emotional stimuli in subjects when in a non-meditative state' (Desbordes et al., 2012; p. 1). For this study:

> Healthy adults with no prior meditation experience took part in 8 weeks of either Mindful Attention Training (MAT), Cognitively-Based Compassion Training (CBCT; a program based on Tibetan Buddhist compassion meditation practices), or an active control intervention. Before and after the intervention, participants underwent an fMRI experiment during which they were presented images with positive, negative, and neutral emotional valences from the IAPS [International Affective Picture System] database while remaining in an ordinary, non-meditative state. Using a region-of-interest analysis, we found a longitudinal decrease in right amygdala activation in the Mindful Attention group in response to positive images, and in response to images of all valences overall. In the CBCT group, we found a trend increase in right amygdala response to negative images, which was significantly correlated with a decrease in depression score. (Desbordes et al., 2012; p. 1)

This work was 'consistent with the hypothesis that meditation training may induce learning that is not stimulus- or task-specific, but process-specific, and thereby may result in enduring changes in mental function' (Desbordes et al., 2012; p. 1).

In 2013, Weng and colleagues showed that greater altruistic behaviour following compassion training was associated with altered activation in brain areas involved in social cognition and emotion regulation, such as the inferior parietal cortex and dorsolateral prefrontal cortex (Weng et al., 2013). Nine years later, Lockwood and colleagues published an especially interesting fMRI study of 'neural representations for prosocial and self-benefiting effort', which helps inform this literature further:

> During fMRI, participants completed a decision-making task where they chose in each trial whether to 'work' and exert force (30%–70% of maximum grip strength) or 'rest' (no effort)

https://doi.org/10.1017/9781009390217.007 Published online by Cambridge University Press

> for rewards (2–10 credits). Crucially, on separate trials, they made these decisions either to benefit another person or themselves . . . Strikingly, we identified a unique neural signature of effort in the anterior cingulate gyrus (ACCg) for prosocial acts, both when choosing to help others and when exerting force to benefit them. This pattern was absent for self-benefiting behaviors. Moreover, stronger, specific representations of prosocial effort in the ACCg were linked to higher levels of empathy and higher subsequent exerted force to benefit others. In contrast, the ventral tegmental area and ventral insula represented value preferentially when choosing for oneself and not for prosocial acts. (Lockwood et al., 2022; p. 4172)

Overall, Novak and colleagues, in their 'integrative systematic review' of the 'neural correlates of compassion' found 'that the most frequent neural associations with compassion across all analysed studies can be found in the orbital part of the left inferior frontal gyrus, in the right cerebellum, the bilateral middle temporal gyrus, in the bilateral insula and the right caudate nucleus' (Novak et al., 2022; p. 46). This is consistent with other research evidence supporting the role of the cerebellum in social cognition (Hoche et al., 2016) and evidence that damage to the inferior frontal gyrus is associated with alexithymia, which is difficulty describing and identifying one's own emotions (Hobson et al., 2018).

Given the depth and range of these neuroscientific findings, and notwithstanding their methodological heterogeneity, what are the practical implications of this accumulating field of research? Does it provide guidance about what *to do* in practice? Or, at the very least, does it help move towards a neuro-biological explanation of the benefits of compassion?

What Are the Practical Implications of These Findings?

The ReSource Project is one of the largest scientific studies on the mental trainability of such qualities as compassion, mindfulness, perspective-taking, and pro-social behaviour.[1] Tania Singer initiated this multi-disciplinary, multi-method study in 2008, based on a grant from the European Research Council. Following a testing period from 2013 to 2016, the project continues to flourish (Singer et al., 2016). The key goal of the large-scale, nine-month training programme is the scientific evaluation of the effects of different kinds of mental practices on mental and physical health, brain plasticity, and pro-social behaviours. The skills taught include mindfulness and attention, social intelligence, compassion, empathy, emotion regulation, body awareness, coping with stress, cooperation, and altruism.

Key publications from this work include research on attention, compassion, and theory of mind (Trautwein et al., 2020), brain plasticity (Valk et al., 2017), experiences of contemplation and meditation (Kok and Singer, 2017; Przyrembel and Singer, 2018), regulation of heart rate variability and altruistic behaviour (Bornemann et al., 2016), and the impact of mental training on cortisol stress reactivity (Engert et al., 2017), body awareness (Bornemann and Singer, 2017), and pro-social behaviour (Böckler et al., 2018). This project provides enormously valuable insights into the nature and effects of mental training and helps to operationalise some of the emerging research findings about compassion, training, and the brain.

For example, Trautwein and colleagues examined 'differential benefits of mental training types for attention, compassion, and theory of mind':

[1] https://taniasinger.de/the-resource-project/ (accessed 27 June 2024).

https://doi.org/10.1017/9781009390217.007 Published online by Cambridge University Press

> Here we tested three consecutive three-month training modules aimed at cultivating either attention, socio-affective qualities (such as compassion), or socio-cognitive skills (such as theory of mind), in three training cohorts and a retest control cohort (*N*=332). While attentional performance improved most consistently after attention training, compassion increased most after socio-affective training and theory of mind partially improved after socio-cognitive training. These results show that specific mental training practices are needed to induce plasticity in different domains of mental functioning, providing a foundation for evidence-based development of more targeted interventions adapted to the needs of different education, labor, and health settings. (Trautwein et al., 2020; p. 1)

Consistent with these findings, Böckler and colleagues reported that 'distinct mental trainings differentially affect altruistically motivated, norm motivated, and self-reported prosocial behaviour':

> we investigated the malleability of prosociality by three distinct mental trainings cultivating attention, socio-affective, or socio-cognitive skills. We assessed numerous established measures of prosociality that capture three core facets: Altruistically motivated behaviours, norm motivated behaviours, and self-reported prosociality . . . linear mixed effects models reveal differential effects of mental trainings on the subcomponents of prosociality: Only training care and compassion effectively boosted altruistically motivated behaviour. No effects were revealed for norm-based behaviour. Self-reported prosociality increased with *all* training modules; this increase was, however, unrelated to changes in task-based measures of altruistic behaviour. (Böckler et al., 2018; p. 1)

Böckler and colleagues go on to note that 'these findings corroborate our motivation-based framework of prosociality, challenge economic views of fixed preferences by showing that socio-affective training boosts altruism, and inform policy makers and society about how to increase global cooperation' (Böckler et al., 2018; p. 1).

There is a recognised neuroscientific dimension to this work. In 2017, Valk and colleagues found structural changes in the brain following different kinds of mental training, with training of present-moment focused attention mostly associated with increases in cortical thickness in prefrontal regions, socio-affective training inducing plasticity in fronto-insular regions, and socio-cognitive training including change in inferior frontal and lateral temporal cortices (Valk et al., 2017). The brain, then, shows considerable plasticity in response to different types of mind training, consistent with outcomes from more experientially oriented studies of these techniques.

Conclusions: The Neuroscience of Compassion

Overall, research to date confirms not only a neuroscientific basis to compassion, but also a neuroscientific basis to compassion training. This is consistent with the broader literature about various forms of contemplative practice which also affect the brain (e.g., Lutz et al., 2008). This growing literature about the neuroscience of compassion is clearly exciting, but it still needs to be interpreted with caution, humility, and an awareness of its limitations. Future research could usefully seek to minimise methodological heterogeneity across this field and continue to focus on links between compassion training and benefits in practice, especially in healthcare, as well as the neuroscientific underpinnings of both compassion and compassion training. There is a particular need for further work on fears, blocks, and resistances to various aspects of compassion, along with any possible consequences, including potential negative effects (Kirby et al., 2019).

Despite these caveats, and research yet to be done, evidence about the neuroscience of compassion to date supports the idea that compassion can be deliberately cultivated through training, and that this affects the brain. There is evidence that activities such as compassion training and meditation can increase positive affect, boost resilience, facilitate altruistic behaviour, and possibly even assist with equanimity, and these effects are underpinned by growing neuroscientific evidence of impact on the physical brain (Klimecki et al., 2013; Klimecki et al., 2014; Weng et al., 2013; Weng et al., 2018). These valuable findings underscore the importance of developing compassion as a skill and fundamental attribute for healthcare workers across all settings.

References

Böckler A, Tusche A, Schmidt P, Singer T. Distinct mental trainings differentially affect altruistically motivated, norm motivated, and self-reported prosocial behaviour. *Sci Rep* 2018; **8**: 13560 (Link to license: https://creativecommons.org/licenses/by/4.0/ [accessed 27 June 2024]).

Bornemann B, Kok BE, Böckler A, Singer T. Helping from the heart: voluntary upregulation of heart rate variability predicts altruistic behavior. *Biol Psychol* 2016; **119**: 54–63.

Bornemann B, Singer T. Taking time to feel our body: steady increases in heartbeat perception accuracy and decreases in alexithymia over 9 months of contemplative mental training. *Psychophysiology* 2017; **54**: 469–82.

De Vignemont F, Singer T. The empathic brain: how, when and why? *Trends Cogn Sci* 2006; **10**: 435–41.

Desbordes G, Negi LT, Pace TWW, Wallace BA, Raison CL, Schwartz EL. Effects of mindful-attention and compassion meditation training on amygdala response to emotional stimuli in an ordinary, non-meditative state. *Front Hum Neurosci* 2012; **6**: 292 (Link to license: https://creativecommons.org/licenses/by/3.0/ [accessed 27 June 2024]).

Engert V, Kok BE, Papassotiriou I, Chrousos GP, Singer T. Specific reduction in cortisol stress reactivity after social but not attention-based mental training. *Sci Adv* 2017; **3**: e1700495.

Fan Y, Duncan NW, de Greck M, Northoff G. Is there a core neural network in empathy? An fMRI based quantitative meta-analysis. *Neurosci Biobehav Rev* 2011; **35**: 903–11.

Hobson H, Hogeveen J, Brewer R, et al. Language and alexithymia: evidence for the role of the inferior frontal gyrus in acquired alexithymia. *Neuropsychologia* 2018; **111**: 229–40.

Hoche F, Guell X, Sherman JC, Vangel MG, Schmahmann JD. Cerebellar contribution to social cognition. *Cerebellum* 2016; **15**: 732–43.

Hogeveen J, Salvi C, Grafman J. 'Emotional intelligence': lessons from lesions. *Trends Neurosci* 2016; **39**: 694–705.

Hou X, Allen TA, Wei D, et al. Trait compassion is associated with the neural substrate of empathy. *Cogn Affect Behav Neurosci* 2017; **17**: 1018–27.

Kim JJ, Parker SL, Doty JR, Cunnington R, Gilbert P, Kirby JN. Neurophysiological and behavioural markers of compassion. *Sci Rep* 2020; **10**: 6789 (Link to license: https://creativecommons.org/licenses/by/4.0/ [accessed 25 June 2024]).

Kirby JN, Day J, Sagar V. The '*Flow*' of compassion: a meta-analysis of the fears of compassion scales and psychological functioning. *Clin Psychol Rev* 2019; **70**: 26–39.

Klimecki OM, Leiberg S, Lamm C, Singer T. Functional neural plasticity and associated changes in positive affect after compassion training. *Cereb Cortex* 2013; **23**: 1552–61.

Klimecki OM, Leiberg S, Ricard M, Singer T. Differential pattern of functional brain plasticity after compassion and empathy training. *Soc Cogn Affect Neurosci* 2014; **9**: 873–9.

https://doi.org/10.1017/9781009390217.007 Published online by Cambridge University Press

Kok BE, Singer T. Effects of contemplative dyads on engagement and perceived social connectedness over 9 months of mental training: a randomized clinical trial. *JAMA Psychiatry* 2017; **74**: 126–34.

Lamm C, Rütgen M, Wagner IC. Imaging empathy and prosocial emotions. *Neurosci Lett* 2019; **693**: 49–53.

Lockwood PL, Wittmann MK, Nili H, et al. Distinct neural representations for prosocial and self-benefiting effort. *Curr Biol* 2022; **32**: 4172–85.e7 (Link to license: https://creativecommons.org/licenses/by/4.0/ [accessed 27 June 2024]).

Lutz A, Slagter HA, Dunne JD, Davidson RJ. Attention regulation and monitoring in meditation. *Trends Cogn Sci* 2008; **12**: 163–9.

Novak L, Malinakova K, Mikoska P, van Dijk JP, Tavel P. Neural correlates of compassion: an integrative systematic review. *Int J Psychophysiol* 2022; **172**: 46–59 (Link to license: https://creativecommons.org/licenses/by/4.0/ [accessed 26 June 2024]).

Przyrembel M, Singer T. Experiencing meditation: evidence for differential effects of three contemplative mental practices in micro-phenomenological interviews. *Conscious Cogn* 2018; **62**: 82–101.

Singer T, Seymour B, O'Doherty J, Kaube H, Dolan RJ, Frith CD. Empathy for pain involves the affective but not sensory components of pain. *Science* 2004; **303**: 1157–62.

Singer T, Kok BE, Bornemann B, Zurborg S, Bolz M, Bochow C. *The ReSource Project: Background, Design, Samples, and Measurements*. 2nd ed. Max Planck Institute for Human Cognitive and Brain Sciences, 2016.

Trautwein F-M, Kanske P, Böckler A, Singer T. Differential benefits of mental training types for attention, compassion, and theory of mind. *Cognition* 2020; **194**: 104039 (Link to license: https://creativecommons.org/licenses/by/4.0/ [accessed 27 June 2024]).

Valk SL, Bernhardt BC, Trautwein F-M, et al. Structural plasticity of the social brain: differential change after socio-affective and cognitive mental training. *Sci Adv* 2017; **3**: e1700489.

Weng HY, Fox AS, Shackman AJ, et al. Compassion training alters altruism and neural responses to suffering. *Psychol Sci* 2013; **24**: 1171–80.

Weng HY, Lapate RC, Stodola DE, Rogers GM, Davidson RJ. Visual attention to suffering after compassion training is associated with decreased amygdala responses. *Front Psychol* 2018; **9**: 771 (Link to license: https://creativecommons.org/licenses/by/4.0/ [accessed 26 June 2024]).