Relationships and the Neurobiology of Resilience

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Neuroimaging studies have identified specific brain areas and circuitries involved in resilient responses to stress. Key brain areas include the hippocampus, amygdala, hypothalamus, insula, anterior cingulate cortex and medial prefrontal cortex. After summarizing studies implicating these brain areas, evidence for their plasticity is reviewed. Existing studies suggest that close personal relationships influence resilience-related brain processes, and that mindfulness meditation holds particular promise as an intervention that both strengthens resilience-related brain processes and promotes resilient couple relationships.

As a couples therapist, my interest in neurobiology dates back to the early 90's when studies emerged suggesting that automatic brain processes play a much larger role in organizing our lives than most of us realize. These studies caught my interest because of the automatic nature of many of the behaviors, judgments and interpretations that often emerged during non-productive interactions between distressed partners. Brain studies eventually helped me realize that even ordinary habits of thinking and reacting to life are largely organized by automatized, non-consciously-executed internal mechanisms.

The internal mechanisms involved in regulating stress and resilience are no exception. For example, many people have conditioned internal processes that keep them operating in task mode a large percentage of their lives. When in this mode, people are constantly in their heads, striving, planning, and often fretting about one thing after another. They have trouble relaxing and shifting into brain states that rejuvenate and restore inner balance. Hence, they become depleted and less resilient. Such people often try to relax, but they just can't do it because their brains *automatically* gravitate toward task mode. I began wondering, "Can the automatic brain processes that keep people stressed be changed?" In order to place the results of my inquiry in context, a general understanding of the current evidence regarding brain processes involved in resilience may be helpful.

The Neurobiology of Resilience

While research on psychological and emotional factors that contribute to resilience has a long history (Curtis & Cicchetti, 2003), studies examining the neurobiology of resilience are fewer, appearing only more recently with the advent of brain imaging technologies (van der Werff, van den Berg, Pannekoek, Elzinga, & Van Der Wee, 2013). However, a growing number of neuroimaging studies conducted over the past fifteen years suggest that there are specific brain areas and circuitries involved in resilient response to stress. Key brain areas include the hippocampus, amygdala, hypothalamus, insula, anterior cingulate cortex (ACC) and medial prefrontal cortex (mPFC) (Dedovic, D'AGUIAR, & Pruessner, 2009). The majority of studies examining resilience processes in the brain have compared images of the brains of subjects who experienced traumatic events and subsequently developed symptoms of Post-Traumatic Stress Disorder (PTSD) with subjects who experienced traumatic events but did not develop PTSD symptoms. In these studies, traumatic events included experiences such as sexual abuse, severe injuries through accidents, and combat-related trauma. Subjects who did not develop PTSD symptoms in response to such events were considered more resilient. Key findings across studies can be summarized as follows: [1]

- *Larger hippocampus (HPC) volumes were found in more resilient subjects.*

Initial studies suggest the possibility that a smaller hippocampus may predispose trauma-exposed individuals to developing PTSD symptoms. The hippocampus is an important regulator of the hypothalamic-pituitary-adrenal axis, and a smaller hippocampus could diminish neuroendocrine regulation, resulting in a stronger emotional or hormonal stress response. Particularly notable is a twin study by Gilbertson et al (2002) in which brain scans were performed on four groups of subjects 1) trauma-exposed subjects who developed PTSD symptoms, 2) the non-exposed twin siblings of subjects in group 1, 3) trauma-exposed subjects who did not develop PTSD symptoms and 4) non-exposed twin siblings of subjects in group 3. Smaller hippocampal volumes were found in both PTSD subjects (group 1) and their non-traumatized twin siblings (group 2) when compared to trauma-exposed subjects who did not develop PTSD symptoms (group 3) and their non-exposed twin siblings (group 4). Further, severity of PTSD symptoms in group 1 subjects was negatively correlated with not only their own hippocampal volumes, but also the hippocampal volumes of their non-exposed twin siblings (group 2). This suggests that lower hippocampal volume may be a familial risk factor for developing PTSD in response to trauma.

- *More resilient subjects evidenced greater activation in the ventral medial prefrontal cortex (vmPFC) and rostral anterior cingulate cortex (rACC), and less activity in the amygdala (AMYG) and dorsal anterior cingulate cortex (dACC) when exposed to emotionally evocative stimuli.*

The amygdala is involved in generating the fear response by activating the Hypothalamic-Pituitary-Adrenal axis that releases hormones involved in the stress response. The ventral medial prefrontal cortex is known to play an important role in regulating the amygdala and suppressing negative emotion, and is associated with lower cortisol levels (Hänsel & von Känel, 2008). The rostral area of the anterior cingulate cortex is involved in emotional regulation while the dorsal ACC is more relevant for non-emotional cognitive tasks (Etkin & Wager, 2007). Overall findings from neuroimaging studies of resilience suggest that the brains of resilient

[1] The material in this section is gleaned from the comprehensive review of neuroimaging studies of resilience published by van der Werff et al. (2013).

people are better equipped to tamp down negative emotion. Such an interesting finding. Makes me curious about the environmental advantage these individuals have.

Plasticity in Resilience-Related Brain Areas

Are there conditions that facilitate or inhibit growth and activity in brain areas that enable resilience? Initial studies suggest that there are. In studies of rodents (Caldji, Diorio, & Meaney, 2003; Francis, Diorio, Liu, & Meaney, 1999; Liu, Diorio, Day, Francis, & Meaney, 2000; van Hasselt et al., 2012) and primates (Law et al., 2008; Parker & Maestripieri, 2011; Stevens, Leckman, Coplan, & Suomi, 2009), early stress has consistently been associated with impaired brain development. Specifically, chronic stress has been found to damage neurons and inhibit neurogenesis in the hippocampus and medial prefrontal cortex (McEwen, 2007). Stress has the opposite effect on the amygdala, causing dendritic growth accompanied by increased anxiety and aggression (Vyas, Mitra, Rao, & Chattarji, 2002).

Human studies yield results that are consistent with animal studies. In a study of women diagnosed with major depressive disorder (MDD), smaller hippocampal volumes were found in those who experienced chronic childhood maltreatment compared with those who had no history of maltreatment (Vythilingam et al., 2002). Early life stressors seem to modify normal hypothalamic-pituitary-adrenal axis activity, resulting in abnormal cortisol levels which, over extended periods of time, can damage various brain areas (Loman & Gunnar, 2010). A recent study compared the brains of 31 physically abused children with the brains of normally developing children. Compared with non-abused children, children who had been victims of physical abuse showed volume alterations in numerous areas throughout the brain (Hanson et al., 2010). Most notably, the abused children evidenced smaller orbitofrontal volumes. Further, the more severe the social stress reported by children and parents, the smaller the orbitofrontal volume was in the abused sample. Another study examined the brains of post-institutionalized children raised in impoverished orphanages in Eastern Europe and Asia (Tottenham et al., 2010). Children who were adopted from the orphanages at a later age were found to have significantly larger amygdalae than those who were adopted earlier on. Similar results were found in a sample of 10 year old children whose mothers had been severely depressed throughout their lives. Compared to children whose mothers were not depressed, children of chronically depressed mothers had significantly larger amygdala volumes (Lupien et al., 2011).

Supportive Relationships and the Neurobiology of Resilience

A number of studies in recent decades suggest that supportive relationships may contribute to resilience by reducing or protecting against the development of excessive allostatic load (T. E. Seeman, Singer, Ryff, Love, & Levy-Storms, 2002). Allostatic load refers to the wear and tear on the body that accumulates over time when an individual is exposed to chronic stress. Repeated exposure to real or perceived threats results in prolonged activation of the sympathetic–adrenal–medullary (SAM) and hypothalamic–pituitary–adrenal (HPA) axes, resulting in harmful levels of stress hormones which can damage the brain. This damage can lead to permanent dysregulation of the SAM and HPA axes, resulting in unregulated stress hormones (Juster, McEwen, & Lupien, 2010). Prolonged exposure to stress hormones can increase inflammation, raise blood pressure (and subsequently heart disease), damage muscle tissue, inhibit growth, and suppress the immune system (McEwen, 2000). Measurement of allostatic load includes combined indices of blood pressure and cardiovascular health, cholesterol, cortisol levels and epinephrine levels. In a study of subjects who were in their late 50's, T. E. Seeman et al. (2002) found that positive relationships were associated with lower allostatic load for both men and women. The same association was found in a sample of 765 subjects who were in their 70's, with the association being the stronger for men vs. women (T. E. Seeman et al., 2002). In a more recent study using data from the Social Environment and Biomarkers of Aging Study (SEBAS) in Taiwan, the presence of close friends and/or neighbors were found to be significantly related to lower allostatic load for both men and women aged 71 and older (T. Seeman et al., 2004). In younger subjects (aged 54-70), the presence vs. absence of a spouse was associated with lower allostatic load in men but not women (T. Seeman et al., 2004).

A key contributor to excessive allostatic load is thought to be an overproduction of the stress hormone cortisol. The positive associations between social support and physical health may be due in large part to the effect of positive relationships on cortisol levels (Heinrichs, Baumgartner, Kirschbaum, & Ehlert, 2003; Legros, Chiodera, & Geenen, 1988; Uvnas-Moberg & Petersson, 2005). The presence of close, supportive relationships have been associated with lower cortisol levels in adolescents (Byrd-Craven, Auer, Granger, & Massey, 2012), middle class mothers of 2-year old children (Adam & Gunnar, 2001), elderly widowed adults (Stafford, Gardner, Kumari, Kuh, & Ben-Shlomo, 2013), men and women aged 47-59 (Steptoe, Owen, Kunz-Ebrecht, & Brydon, 2004), healthy men (Heinrichs et al., 2003), college students (Lucas-Thompson, 2013; Maestripieri, M. Baran, Sapienza, & Zingales, 2010), 18-36 year olds from the UCLA community (Eisenberger, Taylor, Gable, Hilmert, & Lieberman, 2007), parents expecting their first child (Feinberg, Jones, Granger, & Bontempo, 2012), and relationship partners (Ditzen, Hoppmann, & Klumb, 2008; Kirschbaum, Klauer, Filipp, & Hellhammer, 1995; Meuwly et al., 2012; Papp, Pendry, Simon, & Adam, 2012; Rodriguez & Margolin, 2013). People who evidence attachment security have been found to have lower cortisol levels than those who evidence attachment anxiety (Brooks, Robles, & Schetter, 2011; Dewitte, De Houwer, Goubert, & Buysse, 2010; Diamond, Hicks, & Otter-Henderson, 2008; Gunnar, Brodersen, Nachmias, Buss, & Rigatuso, 1996; Jaremka et al., 2013; Kidd, Hamer, & Steptoe, 2013; Oskis, Loveday, Hucklebridge, Thorn, & Clow, 2011; Powers, Pietromonaco, Gunlicks, & Sayer, 2006; Quirin, Pruessner, & Kuhl, 2008) or attachment avoidance (Brooks et al., 2011; Pierrehumbert, Torrisi, Ansermet, Borghini, & Halfon, 2012; Powers et al., 2006). Associations between attachment security and cortisol levels have been observed as early as infancy (Bergman, Sarkar, Glover, & O'Connor, 2010) and toddlerhood (Gunnar et al., 1996).

Overall, studies on relationship quality and cortisol levels suggest that close supportive relationships play an important role in boosting resilience.

Strengthening Individual and Couple Resilience

There is a growing body of evidence documenting interventions that induce structural changes in brain areas that promote resilience (McEwen & Gianaros, 2011). Studies suggest that physical exercise (Erickson et al., 2011; Pereira et al., 2007) , cognitive therapy (Davidson & McEwen, 2012; de Lange et al., 2008), social service programs for older adults (M. C. Carlson et al., 2009) and mindfulness meditation (Hölzel, Lazar, et al., 2011) strengthen resilience processes in the brain.

Of particular relevance to the field of couple resilience is evidence regarding the benefits of mindfulness meditation. In addition to strengthening resilience-relevant brain areas, mindfulness training has been shown to enhance the functioning of couple relationships (Atkinson, 2013). Thus, mindfulness meditation may increase resilience via two avenues – one direct (through strengthening resilience-related brain areas) and the other indirect (through enhancing the quality of relationships). The remainder of this chapter is devoted to an examination of studies providing evidence for the impact of mindfulness training on individual and couple resilience.

Mindfulness Training and Resilience

Mindfulness involves a state of mind that is purposeful, non-reactive, non-judgmental, and attuned to the present moment, and has shown to be cultivated and strengthened through a process known as mindfulness training (Kabat-Zinn, 2013). The most well-researched form of mindfulness training is Mindfulness-Based Stress Reduction (MBSR), an 8-week program of systematic training in meditation as a self-regulatory approach to stress reduction and emotion management (Kabat-Zinn, 2013). However, many other mindfulness training courses exist across the country, including self-guided programs accompanied by audio-guided meditations (Salzberg, 2010; Williams & Penman, 2011). Three types of meditation are used most often in mindfulness training(Vago & Silbersweig, 2012). *Focused attention* meditation involves adopting the intention to keep one's focus of attention on a particular object such as the breath, a visualized image, or sensations in the body. When the mind wanders, the practitioner avoids self-judgment and simply brings attention back to the chosen object of focus. *Open monitoring* meditation involves monitoring the content of one's experience from moment-to-moment, attending fully to whatever is present (sensations, thoughts, feelings, etc.) in an accepting, non-judgmental way. The third type of meditation involves focusing one's attention in a way that cultivates empathy and compassion for self and others. Known as *compassion* or *loving-kindness meditation,* it focuses on challenging one's unexamined thoughts and emotions toward other people, and developing feelings of empathy and love for people, beginning with oneself and extending, eventually, to those with whom one has conflicts and/or dislikes.

Mindfulness meditation has been shown to reduce anxiety and depression (Hofmann, Sawyer, Witt, & Oh, 2010), and has also been shown to influence biomarkers related to resilience (Kok, Waugh, & Fredrickson, 2013) -- reducing blood pressure and cortisol levels (L. E. Carlson, Speca, Faris, & Patel, 2007; Matousek, Dobkin, & Pruessner, 2010), improving immune function (L. E. Carlson et al., 2007; Davidson et al., 2003), promoting resolution of psoriatic lesions in patients with psoriasis (Kabat-Zinn et al., 1998) and increasing telomerase activity

(Jacobs et al., 2011). People trained in mindfulness meditation show less reflexive emotional interference and physiological reactivity when completing tasks, decreased negative mood states, faster decrease in skin conductance response after aversive stimuli, less startle response in reaction to aversive stimuli, and less distractive and ruminative thoughts and behaviors. Mindfulness practices have been shown to increase parasympathetic tone and decrease sympathetic activity, resulting in decreased heart rates, blood pressure, cortisol levels, breathing rates, muscle tension, and lowered oxygen and carbon dioxide consumption (Hölzel, Lazar, et al., 2011).

Evidence from controlled studies suggests that mindfulness training achieves its resilience-related benefits through promoting growth and development in areas of the brain that are known to promote resilience (Dedovic et al., 2009; van der Werff et al., 2013). Across 17 different studies, meditators have been found to have increased volume, density and/or gyrification in resilience-relevant areas of the brain when compared to non-meditating controls (Atkinson, 2013). Dozens of additional studies have documented functional and connective changes within and between brain regions in response to mindfulness meditation (Cahn & Polich, 2006; Chiesa & Serretti, 2010; Hölzel, Lazar, et al., 2011; Rubia, 2009; Vago & Silbersweig, 2012). The medial prefrontal cortex and anterior cingulate cortex are among the most widely cited brain areas of gross morphological change during and in response to mindfulness meditation (Vago & Silbersweig, 2012). A number of studies have also found that mindfulness practice decreases amygdala activation (Brefczynski-Lewis, Lutz, Schaefer, Levinson, & Davidson, 2007; Creswell, Way, Eisenberger, & Lieberman, 2007; Desbordes et al., 2012; Goldin & Gross, 2010; Herwig, Kaffenberger, Jäncke, & Brühl, 2010; Hölzel et al., 2010). Further studies have found greater gray matter concentration in the hippocampus in meditators vs. non-meditators (Hölzel et al., 2008; Luders, Toga, Lepore, & Gaser, 2009). One study detected structural changes in the hippocampus within a period of 8 weeks in participants that underwent mindfulness-based stress reduction (Hölzel, Carmody, et al., 2011). fMRI studies show that meditation involves activation of the hippocampus and medial PFC (Lazar et al., 2000; Lou et al., 1999; Newberg et al., 2001), suggesting that the function of these brain regions is enhanced through regular meditation.

In addition to impacting brain areas that known to relevant to resilience, studies suggest that mindfulness meditation also strengthens couple relationships. Numerous studies have found associations between mindfulness and relationship quality/satisfaction (Kozlowski, 2013). Mindfulness has been positively correlated with marital satisfaction, empathic concern, and perspective taking (Wachs & Cordova, 2007), effective communication and adaptive response skills when faced with relational stress (Barnes, Brown, Krusemark, Campbell, & Rogge, 2007), and greater consideration of one's partner's point of view (Burpee & Langer, 2005). Barnes et al. (2007) found that mindfulness may help to inoculate partners against relational stress, and numerous studies suggest that mindfulness training may increase empathy (Beddoe & Murphy, 2004; Birnie, Speca, & Carlson, 2010; Block-Lerner, Adair, Plumb, Rhatigan, & Orsillo, 2007; Hutcherson, Seppala, & Gross, 2008; Krasner et al., 2009; Leiberg, Klimecki, & Singer, 2011). Mindfulness training has also been found to increase interpersonal cooperativeness (Haimerl & Valentine, 2001), decrease reactivity in relationships (Pruitt & McCollum, 2010), decrease interpersonal problems (Tloczynski & Tantriella, 1998), increase partners acceptance (Carson, Carson, Gil, & Baucom, 2004), and increase sexual satisfaction (Brotto, Basson, & Luria, 2008;

Brotto & Heiman, 2007; Brotto, Seal, & Rellini, 2012; Linda E Carlson, Speca, Patel, & Goodey, 2004; Goldmeier, 2013; Lazaridou & Kalogianni, 2013; McCarthy & Wald, 2013; McCreary & Alderson, 2013; Rosenbaum, 2013; Sommers, 2013).

In my own clinical practice (Atkinson, 2013), I have observed that mindfulness promotes a variety of processes that boost couple resilience:

Stress Reduction. Stress takes a significant toll on relationships. 54 % of Americans report fighting with people close to them due to stress and 26% report being alienated from a friend or family member because of stress (American Psychological Association, 2014). One of the most well-documented findings about mindfulness training is that it reduces of stress and anxiety. Mindfulness exercises interrupt the brain's tendency stay in the energy-depleting "task mode," and help it operate to in the rejuvenating and restorative "experiencing mode" a greater percentage of the time. As a result, partners who engage in regular mindfulness exercises are less stressed, agitated, irritable and "trigger-happy" with their partners.

Attentiveness. People in ailing relationships can often be heard saying things to their partners like, "You never listen to me!" Partners who have trouble being attentive when their mates are talking are often well-intended, but simply unable to prevent their minds from wandering or being sidetracked by reactions they have to what their partners are saying. Through continuously exercising the ability to notice when the mind has wandered or become sidetracked, then bringing attention back to the original focus, partners who practice mindfulness become more able to regulate attention, listen to their partners, and notice important details about their partners' lives.

Empathy. Neuroscientific studies suggest that empathy involves vicarious experiencing of another person's emotions. But you can't vicariously experience another person's emotion if you aren't in touch with your own. Greater sensitivity to one's own internal states is one of the most consistent benefits attained through mindfulness training. Mindfulness exercises strengthen the insula and anterior cingulate cortex -- areas that mediate interoception (attunement to internal sensations and feelings). As partners who engage in mindfulness training come to experience their own emotions vividly, they also become more able to tune into the emotions of their partners as well.

Response Flexibility. Mindfulness training increases the ability to notice the automatic "knee-jerk" tendencies of the brain, and this ability helps partners become more able to avoid reflexively following such tendencies. Partners become more able to avoid "buying into" their first impressions of their partners' motives, and they become more able to resist urges to interrupt their partners before they are finished speaking.

Mood Regulation. As partners progress in mindfulness training, they become more able to avoid unproductive rumination that perpetuates distress, and more able to engage parasympathetic processes that result in in physiological soothing. Consequently, they operate with less desperation and intensity when upsets occur in their relationships.

Through boosting each of the above processes, mindfulness training increases both individual and couple resilience. Given the accumulating evidence regarding this dual-impact action, mindfulness training may be the most potent resilience-building practice identified in the scientific literature.

Conclusion

The studies reviewed in this chapter suggest that there are specific brain processes involved in generating resilience which include the hypothalamus, medial prefrontal cortex, anterior cingulate cortex, the hippocampal-pituitary-adrenal axis and the amygdala. Damage or malfunctioning in these regions can produce dysregulation of stress hormones which contribute to excessive allostatic load over time, resulting in a variety of cardiovascular and immune system problems. Close, supportive relationship may reduce allostatic load in part by reducing cortisol levels. Among interventions that facilitate resilience processes in the brain, mindfulness meditation holds particular promise due to its dual avenues of influence. Studies suggest that mindfulness strengthens neural processes that promote resilience and indirectly facilitates resilience through strengthening relationships.

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