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RESILIENCE TRAINING THAT CAN CHANGE THE BRAIN

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In this article, we provide a review of the latest research on behavioral and cognitive strategies that cultivate resilience and change the brain. We begin with a primer on the neuroscience of emotions and stress and how the brain regulates them. Then we focus on two major pathways to building a resilient brain: (a) behavioral pathways (learnable behaviors and habits) and (b) cognitive pathways (learnable cognitive/linguistic strategies). For the former, we review behaviors that can directly down-regulate fear and stress, including facing fears and controlling stressors. We also review behaviors that can boost physical health and therefore resilience; these strategies include sleeping, exercising, and dietary restriction. In addition, we review social behaviors that can boost resilience, such as connecting socially and expressing gratitude. For the latter, we review cognitive pathways to resilience. These include emotion-regulation strategies such as verbal expression of emotion, affect labeling, and cognitive reappraisal. We also discuss cognitive-training approaches, including cognitive-bias modification, mindfulness training, and cognitive therapy. Finally, we discuss issues related to coaching resilience, including the neural bases of expectation, growth mind-set, and self-affirmation, three factors that can influence learning and effectiveness of the various strategies discussed in the article, and we close with a summary of the current understanding of resilience and the human brain.

Keywords: resilience, well-being, emotion regulation, social affective neuroscience, stress

One of the challenges of consulting and coaching psychology is helping individuals, teams, and entire enterprises weather life and work stressors. These stressors can be one-time and acute, such as unexpected job transfer or job loss, or more chronic, such as bad bosses, broken peer relationships, and dysfunctional team members. Some people are more resilient than others in the face of such stressors, but many of the skills that make for resilience can be learned. Resilience has been defined in the literature in many different ways (Schetter & Dolbier, 2011). Here we define resilience broadly as successfully adapting to adversity. We review the latest research on behavioral and

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psychological strategies that cause sustained change in the nervous system (i.e., neuroplasticity) and boost resilience in adulthood.

Rather than offering an exhaustive summary of all potential techniques for boosting resilience, we focus only on strategies that have been shown to cause lasting psychological or physical health benefits and lead to some kind of sustained change in the nervous system (i.e., an effect in the nervous system that can be observed at least 24 hr after the intervention). Moreover, we focus on learnable strategies, rather than on more immutable dispositional, environmental, or genetic factors that also contribute to resilience. We do not cover topics such as optimism (Carver & Scheier, 2014), religiousness and spirituality (Cheadle & Dunkel Schetter, 2017) or forgiveness (Billingsley & Losin, 2017) because, although these factors have been associated with resilience, empirical evidence that they cause neuroplasticity is still sparse. As with previous reviews of resilience, we include the following as indicators or indices of resilience: measures of quality of life and subjective well-being, psychiatric and physical health, and mortality, often following various adverse experiences, including a life-altering medical diagnosis and trauma. More indirect measures of health are also included, such as cardiovascular measures, stress-hormone levels, and immune-system function, as well as measures of stress and pain tolerance.

We start by providing a brief primer on functional neuroanatomy and the neuroscience of emotions and stress and how the brain regulates them. We then review 15 different strategies that can boost resilience in the long term and lead to sustained change in the nervous system. This is followed by a discussion of issues related to coaching resilience, including the neural basis of three specific factors that can influence how successfully the 15 resilience-boosting strategies can be learned and implemented.

Neuroanatomy of Resilience

Overview of Brain Organization and Terminology

For readers not familiar with neuroscience, it is helpful to conceptualize the human brain as broadly supporting two sets of mental processes: one that produces instinctive and largely automatic responses and another that is deliberative and produces more controlled responses. This dual-system view of human behavior has a long history in psychology and has been variously referred to as *automatic versus controlled*, *System 1 versus System 2*, and *reflexive versus reflective* (Hofmann, Friese, & Strack, 2009; Lieberman, 2007). Automatic processes tend to be fast and spontaneous, arose earlier in evolution and arise earlier in development, and are largely sensory, such as cravings and emotions; controlled processes tend to be slow and effortful, arose later in evolution and arise later in development, and are often language-based and intentional, such as problem-solving and self-control (Adolphs, 2009; Lieberman, 2007). Brain regions that support automatic processes, also known as *the X-system* (for the "X" in the word *reflexive*), include subcortical structures such as the amygdala and striatum, among other regions. Brain regions that support controlled processes, also known as *the C-system* (for the "C" in the word *reflective*), include higher-level neocortical regions such as the prefrontal cortex (PFC), including the lateral prefrontal cortex (LPFC) and portions of the medial prefrontal cortex (MPFC; Lieberman, 2007).

Much of the discussion on resilience focuses on the interaction between the X-system and C-system. On the one hand, the C-system can exert control over the X-system, allowing inhibition of brain networks that support emotions, impulses, habits, and stress (Hofmann et al., 2009; Miller & Cohen, 2001). This top-down regulation of the X-system is the basic mechanism underlying self-regulatory processes such as impulse control and emotion regulation. On the other hand, the X-system can also affect the C-system, such that negative emotions and stress can disrupt normal functioning of the capacity-limited C-system, including the PFC (for review see Arnsten, 2009). This bottom-up influence of the X-system on the C-system can be adaptive, such as when an unusual encounter in the environment (e.g., a road closure on the drive to work) alerts the reflective brain to help resolve the situation (e.g., pay attention and figure out an alternative route to work). However, when the encounter is an acute and uncontrollable stressor, it can dramatically compromise prefrontal cognitive abilities such as working memory, and more prolonged stressors can lead to long-term damage to prefrontal neurons (Arnsten, 2009). Thus, in order to preserve neural resources critical for self-regulation, it is important to keep stress and anxiety at bay or under control before they become overwhelming.

With regards to terminology, readers should note that the PFC is a large and heterogeneous region with multiple and sometimes overlapping subregions and multiple different names for each subregion. For the sake of accessibility to a general audience, in this article we focus only on three prefrontal regions: the LPFC, MPFC, and anterior cingulate cortex (ACC). The LPFC is a key C-system region important for higher cognitive functions, such as working memory and overriding impulses. The MPFC allows for many important and seemingly diverse functions, including (a) encoding of reward and subjective value to inform decision-making (reward network), (b) interpreting affective information and modulating emotional response (affect regulation), and (c) thinking about oneself and others (default mode network; Acikalin, Gorgolewski, & Poldrack, 2017; Delgado et al., 2016). The rostral ACC is associated with distress and anticipation of pain, while the dorsal ACC is important for feedback-based learning and conflict monitoring, including emotional conflict (Eisenberger & Lieberman, 2004; Etkin, Egner, & Kalisch, 2011).

Fear and the Amygdala

Understanding how fears are learned and how they can be overcome, or extinguished, is critical for coping and resilience. Fortunately, one of the most studied and well-understood phenomena in psychology is that of learning and unlearning fear, specifically classical conditioning and extinction. Classical conditioning of fear in rodents has been viewed as a model for human anxiety for over a century (Eysenck, 1979; Milad, Rauch, Pitman, & Quirk, 2006). An animal can become afraid of a neutral event like an auditory tone if the neutral event is experienced along with an aversive event, such as a footshock, until a direct neuronal association is formed in the amygdala. Once the new connection is made between the tone neurons and the fear-response neurons, the tone neurons alone can eventually trigger a fear response (Pavlov & Anrep, 2003). To extinguish a learned fear in the laboratory, typically the tone is presented repeatedly, in the absence of the shock, so that the tone will be associated with safety. Similarly, in exposure treatment of anxiety disorders such as phobia and posttraumatic stress disorder (PTSD), the patient is exposed to the feared object or situation in a safe environment (e.g., standing on a rooftop with the therapist's assistance, to overcome a fear of heights), so that the feared object or situation can gradually come to be associated with safety (Craske, Treanor, Conway, Zbozinek, & Vervliet, 2014). Thus, one of the most effective ways to overcome a fear is by facing the fear itself, in a safe environment.

A brain region that is critical for extinction learning is a subdivision of the MPFC that sends robust projections to amygdala neurons that can inhibit the fear response (Milad et al., 2006). Studies in rodents have demonstrated that this MPFC region is necessary for long-term retention of extinction (Do-Monte, Manzano-Nieves, Quinones-Laracuente, Ramos-Medina, & Quirk, 2015). Neuroimaging studies implicate a homologous region in humans, namely ventral MPFC (Gottfried & Dolan, 2004; Milad et al., 2005; Phelps, Delgado, Nearing, & LeDoux, 2004), a region that is well suited to regulate emotional responses because it connects systems involved in episodic memory, self and social cognition, affective value, and emotion-related interoceptive and physiological responses (Roy, Shohamy, & Wager, 2012).

Undoubtedly, classical conditioning is not the only way humans learn and unlearn fear, because we can also learn through observation and verbal transmission of information. For example, learned fear of a colored patch can be extinguished via the MPFC without any exposure by verbally informing the participant that the patch will no longer be followed by shock (Phelps et al., 2004). Thus, one of the benefits of talking about our fear and anxiety, with a trusted person and in a safe environment, is that it encourages confrontation of the fear and thus its reduction over time.

Chronic Stress and the HPA Axis

As mentioned above, when we encounter a potential threat or stressor, the amygdala triggers a fight-or-flight autonomic response, a quick and temporary physiological response, such as increased heart rate and inhibition of the digestive system, that focuses resources on dealing with the threat. At the same time, via its connections to the hypothalamus, the amygdala also triggers a slower endocrine response in the pituitary and adrenal glands, culminating in the release of the stress hormone cortisol. This latter slower stress-response pathway is known as the *hypothalamic-pituitary-adrenal axis* (or *HPA axis*). By increasing blood glucose and suppressing the immune system, cortisol further aids the organism in focusing resources for surviving the threat (see Davis, 1992; Ulrich-Lai & Herman, 2009).

The autonomic fight-or-flight and the endocrine HPA systems evolved to help the organism respond to acute physical emergencies in the environment (such as being approached by a hungry bear). However, because humans have the ability to think about and imagine past and future threats, we have become adept at chronically activating these systems, in turn causing chronic wear-and-tear on the downstream visceral organs that these systems stimulate (e.g., the heart, digestive system, immune system) and exacerbating such medical conditions as heart disease and ulcers (Sapolsky, 1994). Prolonged elevation of stress or stress hormones can also wreak havoc on the brain, including abnormal cell growth in the amygdala, as well as neural damage in the hippocampus and prefrontal cortex. These neural changes are associated with anxiety and impairments in learning and memory. The good news is that removal of the stressor can reverse these neural and psychological impairments (Lupien, McEwen, Gunnar, & Heim, 2009).

Not all stressors can be completely removed, but the ravages of stress can be reduced by various cognitive and behavioral techniques, via connections between the HPA axis and prefrontal cortex, particularly the MPFC (Eisenberger & Cole, 2012). Just as the MPFC can regulate the fear response via direct projections to the amygdala, it can also regulate the stress response via direct projections to the hypothalamus (Diorio, Viau, & Meaney, 1993; Radley, Arias, & Sawchenko, 2006).

Behavioral Pathways to Building a Resilient Brain

As depicted in Figure 1, multiple different strategies can be used to change the brain and boost resilience. We have classified the various strategies into two broad categories, namely behavioral strategies (learnable behaviors and habits) and cognitive strategies (learnable cognitive/linguistic strategies). In this section we review behavioral (including lifestyle) strategies, grouped into three types: directly reducing fear and stress responses, boosting physical health, and seeking social connection and social support.

Reducing Fear and Stress Responses

Exposure and reconsolidation. As mentioned above, the basic way to overcome an irrational fear is exposure—gradually and repeatedly facing the feared situation in a safe environment until a new association is learned between it and safety. For instance, a fear of social interaction at work can be overcome by first imagining a stressful social interaction, then participating in a minimally stressful interaction (e.g., striking up a conversation with a coworker in the elevator), and eventually engaging in a stressful interaction (e.g., going out to lunch with a group of coworkers), thus learning that no grave harm can occur from these experiences. For a review of extinction and exposure therapy see Craske, Treanor, Conway, Zbozinek, and Vervliet (2014). Briefly, the prevailing view is that extinction training does not erase the original fear memory but rather forms a new amygdala-based memory associating the formerly feared situation with safety. This new memory is consolidated and stored in the MPFC, and it can inhibit the original fear response (Milad & Quirk, 2012). However, because the original fear memory is still present, the fear can return.

An emerging alternative intervention that can potentially weaken the fear memory itself, and hence reduce the return of fear, is reconsolidation interference. *Reconsolidation* refers to the phenomenon that when an existing memory is recalled, it is rendered labile and can therefore be rewritten, or reconsolidated, into long-term memory. One way to attenuate a labile fear memory is with extinction training during the reconsolidation time window (up to 4 hr following the reminder of the feared cue). In other words, a reminder of the feared situation prior to extinction learning can

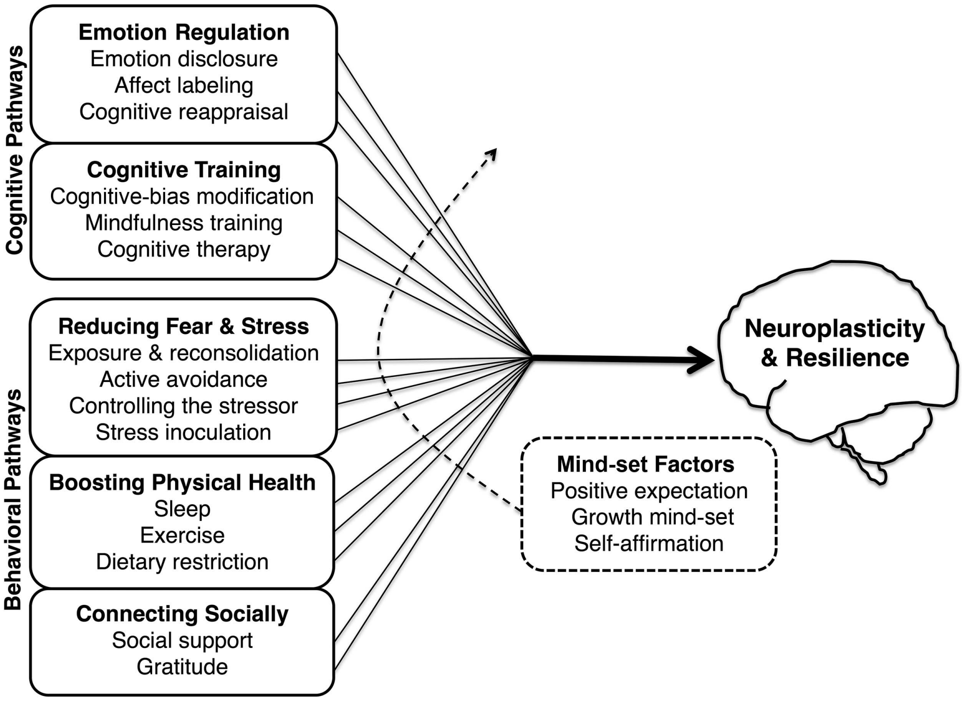

Figure 1. Schematic of the 15 strategies (solid boxes) that can boost resilience and lead to long-term change in the nervous system. Also shown are the three mind-set factors (dashed box) that can improve learning and implementation of these resilience-boosting strategies. Thin lines from the strategies converge onto a thick arrow to depict their additive effect on the nervous system and resilience.

help boost extinction learning (e.g., Schiller et al., 2010; Steinfurth et al., 2014) and weaken fear-circuit connectivity in the human amygdala (Agren et al., 2012). Although further studies are needed to translate this emerging technique into practice (for a full discussion of reconsolidation interference, see Beckers & Kindt, 2017), the implication is that to maximize treatment outcome, emotions should first be evoked during the treatment session and then coupled with safety. The broader implication of the literature on exposure and reconsolidation for consulting psychologists is that facing one's fears is an important component of overcoming the fears.

Active coping, self-efficacy, and control. Although exposure is a relatively passive method of reducing fear, fear can also be managed via more active coping, engaging in actions that can reduce physical or psychological harm. Indeed, the mere act of doing something, rather than remaining passive, can help dampen distress. For example, chronic-pain sufferers who use active-coping strategies, such as spending time with other people and doing household chores, report lower psychological distress (Snow-Turek, Norris, & Tan, 1996). In fact, active coping can rewire the brain to promote resilience in the long term. Research in rodents has demonstrated that active avoidance, such as taking the opportunity to walk away from a predictor of shock, actually disrupts fear-learning circuitry and directly changes connections that are made in the amygdala in a way that makes active coping easier the next time (reviewed in LeDoux & Gorman, 2001; LeDoux, Moscarello, Sears, & Campese, 2017). For example, rats that avoid a shock by physically walking out of a chamber in which they hear a predictor of shock subsequently show less fear of that chamber compared to rats who *passively* avoid the shock (i.e., by not entering the chamber in the first place). In other words, walking away from a threatening environment is better than not entering it at all. Active avoidance also recruits the MPFC to suppress amygdala-based fear responses both during learning and in subsequent tests, even in novel environments, suggesting that the learned active coping can generalize across different environments (Delgado, Jou, LeDoux, & Phelps, 2009; Moscarello & LeDoux, 2013).

Another method of active coping with long-term benefits is directly controlling the stressor when possible. In laboratory studies, rats that can terminate a shock by turning a wheel, compared with rats that experience the identical shock but without control, show plasticity in the MPFC, such that future shocks or other distressing stimuli, even if they are uncontrollable, come to activate the MPFC, leading to a reduction of stress responses and depressionlike behavior (e.g., Boeke, Moscarello, LeDoux, Phelps, & Hartley, 2017; Kerr, McLaren, Mathy, & Nitschke, 2012; Maier, 2015). Interestingly, even when the stressor is ongoing or otherwise not physically controllable, finding some feeling of mastery or adopting a fighting spirit may help buffer against the impact of the stressor. Self-efficacy, or the belief in one's ability to master life's challenges, is a protective factor against depression and facilitates recovery from a wide range of traumas, including natural disasters, terrorist attacks, military combat, and criminal assaults (Benight & Bandura, 2004). In fact, the mere perception of control, even in the absence of true control, may be helpful, such as in reducing the subjective perception of pain (Bowers, 1968; Mackie, Coda, & Hill, 1991) and reducing activation in the pain network, including the ACC and insula (Brascher, Becker, Hoeppli, & Schweinhardt, 2016; Salomons, Johnstone, Backonja, & Davidson, 2004; Wiech et al., 2006).

To summarize, engaging in active coping can strengthen the neural pathway for active coping and hence reduce future anxiety or negative affect. The key is for the coping to be active rather than passive. For example, an employee who holes up in his office to (passively) avoid his boss because of a recent harsh meeting and negative performance review would be helped by walking the hallways and chatting with liked colleagues and possibly even with his boss. This way, the employee takes a previously jarring experience that left him feeling immobilized and starts the process of rewriting it in his mind as manageable. However, it should be noted that excessive active avoidance can be maladaptive; for example, while frequent hand-washing during flu season is adaptive, when excessive hand-washing persists beyond flu season, it becomes a maladaptive compulsion (LeDoux et al., 2017).

Stress inoculation. Given that active coping can strengthen the neural pathway for active coping, exposure to manageable stress might be expected to have an effect of "steeling" (Rutter, 1981) or "toughening" (Dienstbier, 1989) the individual against future stressors. Indeed, people with a history of *some* traumatic experience have reported better psychological outcomes, such as lower distress and greater life satisfaction, compared with people with a history of *high* trauma or *no* trauma (Seery, Holman, & Silver, 2010), likely by making psychological and neurobiological changes that facilitate better management of subsequent stress (Dienstbier, 1989; Maier, 2015; Russo, Murrough, Han, Charney, & Nestler, 2012). For example, early exposure to manageable stress in squirrel monkeys increases white-matter volume in the MPFC (Katz et al., 2009) and modulates HPA response to subsequent stressors (Parker, Buckmaster, Schatzberg, & Lyons, 2004). Thus, exposure to manageable stressors may be a potential opportunity to proactively "toughen" or "inoculate" individuals against the ravages of future stressors. In stress-inoculation training (SIT), clients undergo stress-management skill training, including practice with applying their new skills when exposed to manageable stressors, for example through imagery, role-play, simulations, and graduated in-vivo exposure (Meichenbaum & Deffenbacher, 1988). A meta-analytic review of 37 studies implementing this technique to reduce anxiety and improve performance, such as test anxiety in students and performance anxiety in music performers, found that SIT was successful in reducing state anxiety, diminishing performance anxiety, and enhancing performance under stress (Saunders, Driskell, Johnston, & Salas, 1996). There is also merit to this proactive training approach with clients in high-risk or high-stress professions, such as fire fighters, police officers, military personnel, and surgeons (e.g., LaPorta et al., 2017; Lewis et al., 2015).

Take-Home on Reducing Fear and Stress Responses

Active coping, such as changing a stressful situation, actually strengthens the neural pathway involved in active coping. Exercising control strengthens the brain's ability to take control in the future. Thus, adaptive coping begets adaptive coping. Several implications follow:

- Passive avoidance of a feared (but harmless) situation is counterproductive. The passivity gets reinforced and the person continues to be anxious about and paralyzed by the situation. The employee who hides from her otherwise benign boss because of a recent demotion and pay cut will continue to feel helpless and undervalued if she keeps avoiding her boss.
- Active avoidance is better than passive avoidance, because active coping can reroute the fear pathway away from passive avoidance (freezing) and toward active coping (taking action), making it easier to be proactive again in the future. Instead of holing up in his office and staying immobilized, the employee could benefit from walking the halls and chatting with liked colleagues. If he encounters the boss and finds it unbearable, he can casually walk away and try again later. The key is to simply “do something,” to start resuming normal or pleasant activities, and to not allow fear to immobilize him.
- More effective is to ultimately face the feared situation and take action in an attempt to change it. The employee could benefit from reestablishing a positive connection with his boss, for example by approaching her in a positive setting and making friendly small talk. Or better yet, he can try to impress her with new and improved performance.
- If there is any opportunity to bring about positive change, it is especially important to grab it, because exercising control over harm changes the brain in a way that makes it easier to exert control in the future. By not giving up and by attempting different ways to improve his standing in the company or even seeking alternative jobs that pay more, the employee not only increases his chances of changing his current situation but may also strengthen his ability to actively cope with difficult situations in the future, even if those situations are different from the current one.
- By and large, it can be helpful to remain confident in one’s ability to bring about some change. The mere belief that one has control can help dampen the distress and thus make it easier to bring about change. Even if a promotion or pay increase does not seem likely in the near future, the employee could benefit from remaining optimistic and continuing to search for ways to change the situation. Optimism can dampen the distress and also make it more likely to find a solution (see section on positive expectation).

Boosting Physical Health

Factors that improve physical health also improve emotional well-being and resilience. Chief among these factors are sleep, exercise, and diet. We will not cover nutrition per se, however, as it is outside the scope of this article and has been reviewed elsewhere (Gomez-Pinilla, 2008).

Sleep. Sleep deprivation is a stressor, with negative consequences for physical and mental health. For example, chronic sleep deprivation increases blood pressure, cortisol, insulin, and proinflammatory cytokines (McEwen, 2006). Recent meta-analyses in human adults have indicated that lack of sleep is associated with increased markers of systemic inflammation (Irwin, Olmstead, & Carroll, 2016) and elevation in these biomarkers is associated with subsequent health problems, including development of depressive symptoms (Valkanova, Ebmeier, & Allan, 2013). Several different lines of work have suggested that sleep affects mood and well-being (reviewed in Rumble, White, & Benca, 2015; Vandekerckhove & Cluydts, 2010). For instance, making positive changes to one’s sleep habits that improve sleep quality is associated with greater subsequent physical and emotional well-being (N. K. Tang, Fiecas, Afolalu, & Wolke, 2017). Sleep, particularly REM sleep, may also help with recovery from stress and trauma (Goldstein & Walker, 2014). Slow-wave (“deep”) sleep, on the other hand, is important for transforming labile new memories into stable long-term ones (Marshall & Born, 2007; Payne, Chambers, & Kensinger, 2012) and may even strengthen immunological memories of previously encountered pathogens (Westermann, Lange, Textor, & Born, 2015).

The neurobiological pathways from sleep deprivation to psychological vulnerability likely involve serotonin, the HPA axis, and a PFC-amygdala circuit. In rodents, chronic sleep restriction results in depression-like physiological changes, namely decreased sensitivity of serotonin receptors and abnormal reactivity of the HPA axis (Novati et al., 2008). In humans, skipping sleep one night leads to changes in the amygdala-MPFC circuit the next day; specifically, the amygdala shows an exaggerated response to emotionally aversive images, and the connectivity between the amygdala and the MPFC is reduced, suggesting a compromised network for emotion regulation (Yoo, Gujar, Hu, Jolesz, & Walker, 2007). A similar pattern of heightened amygdala response and poor MPFC-amygdala connection is observed after four consecutive nights of only 4 hr of sleep a night (Motomura et al., 2013). In fact, the poorer the MPFC-amygdala connection, the greater the self-reported anxiety.

The recommended sleep duration for average healthy adults is 7 to 8 hr a night (Hirshkowitz et al., 2015; Irwin et al., 2016). Evidence-based recommendations to improve sleep (reviewed in Bloom et al., 2009; Sharma & Andrade, 2012) include time-honored "sleep hygiene" factors, such as reducing substance use (e.g., caffeine, alcohol, and nicotine), exercising during the day, and limiting daytime napping, as well as more recent recommendations such as limiting exposure to light-emitting devices before bed time (Chang, Aeschbach, Duffy, & Czeisler, 2015) and spending more time outdoors (Stothard et al., 2017).

Exercise. The benefits of physical exercise have been extensively studied and span the range of fighting a panoply of medical diseases, as well as improving mood, attenuating the stress response, and boosting cognitive function (Penedo & Dahn, 2005; Warburton, Nicol, & Bredin, 2006). Just as moderate early trauma and engagement with manageable stress can "toughen" a person, so too can physical exercise, as a form of "self-regulated toughening" (Dienstbier, 1989). A key player in the pathway from physical challenges like exercise to resilience is a protein called *brain-derived neurotrophic factor* (BDNF; Nagahara & Tuszynski, 2011). Released when the body is physically challenged, BDNF mediates neural plasticity, connectivity, survival, and production in multiple brain regions such as the hippocampus, which in turn play a critical role not only in learning but also in regulating stress (Nagahara & Tuszynski, 2011). All exercise may not be created equal in this regard, however, as only aerobic exercise was effective in enhancing neuron production in the hippocampus of adult rats compared with high-intensity or anaerobic training (Nokia et al., 2016; also see; Vivar, Peterson, & van Praag, 2016). The impact of exercise on BDNF may also extend to the ability to maintain social bonds, which in turn can be a critical resource for resilience (see the section below on connecting socially). Kim, Lim, Kim, Seo, and Kim (2015) showed that four weeks of treadmill exercise in rats reverses the typical stress-induced social interaction impairment, seemingly via BDNF-enhanced plasticity and serotonergic receptor activation in the hippocampus. Acute (Byun et al., 2014), as well as regular (Colcombe et al., 2004), aerobic exercise can also improve prefrontal blood flow and executive function in humans (for review, see Hillman, Erickson, & Kramer, 2008).

Dietary restriction. The medical and psychological benefits of physical exercise can also be triggered by another form of physical challenge, dietary restriction, specifically caloric restriction (reducing caloric intake while maintaining meal frequency) and fasting (skipping meals). By increasing BDNF production and hence reducing oxidative damage, inflammation, dysfunctional proteins, and elevated glucose and insulin, dietary restriction with adequate nutrient intake can improve mood and cognition, as well as slow down aging and associated diseases (Longo & Mattson, 2014). The physical and neurocognitive benefits of dietary restriction make sense from an evolutionary perspective, as natural selection has likely bestowed a survival advantage onto those individuals whose brains functioned optimally under duress (i.e., enabling a hungry ape to successfully escape a predator). Caloric restriction, typically implemented in the range of 20% to 40% reduction in daily intake, is the most studied and reliable dietary intervention shown to increase healthy life span (Lee & Longo, 2016). Notably, a multisite, longitudinal, randomized, and controlled trial (CALERIE 2) recently found that 2 years of 25% caloric restriction improved mood, sleep, and quality of life in nonobese adults, with no negative side effects (Martin et al., 2016). In another study, reducing caloric intake by 30% for 3 months improved memory in older adults (Witte, Fobker, Gellner, Knecht, & Flöel, 2009). Interestingly, dietary restriction may also facilitate unlearning of early traumatic experience, possibly through serotonin-dependent and amygdala-related neural plasticity (Riddle et al., 2013; Verma et al., 2016). Fasting (e.g., for 12 to 24 hr twice a week or every other day) is emerging as an equally effective alternative to caloric restriction, with potentially better compliance (Horne, Muhlestein, & Anderson, 2015). Although randomized and controlled fasting studies with robust designs are sparse, existing studies show improvements in weight and other health outcomes (Horne et al., 2015). Nonetheless, caution should be exercised when implementing dietary restriction, as the number of trials is limited, and fasting studies on vulnerable populations, such as older or underweight individuals, are lacking (Longo & Mattson, 2014).

Take-Home on Boosting Physical Health

Age-old wisdom and modern science agree that sleep, exercise, and diet hold the key to good health. Sleep deprivation is considered a stressor and can affect physical health, emotional well-being, and cognition. Physical exercise is also critical for reducing stress, improving mood and cognitive function, and warding off a host of medical diseases. As for diet, the latest research suggests that limiting food intake can have similar benefits as physical exercise, including improved mood, memory, learning, and sleep, as well as staving off various diseases. To summarize, some physical health strategies to boost resilience include:

- Getting sleep, about 7 to 8 hr a night for the average healthy adult.
- Getting physical exercise. Aerobic exercise in particular is important for hippocampal cell production and thus for learning and regulating stress.
- Reducing food intake, without compromising nutrient intake, and in consultation with a professional health provider.

Connecting Socially

Social connectedness and support. We have known for decades that social relationships can have a positive impact on mental and physical health (House, Landis, & Umberson, 1988), and recent large-scale epidemiological data from the Blue Zones project support this notion (Buettner, 2012). Having social connections and support have consistently been associated with lower risk of psychopathology, as well as lower morbidity and mortality in medical disease (Holt-Lunstad, Smith, & Layton, 2010; Thoits, 2011; Uchino, 2006). There are multiple ways in which positive social connectedness can benefit health, such as by reducing high-risk behaviors (e.g., smoking) and increasing treatment compliance; by fostering effective coping and emotion regulation; and by increasing feelings of belonging, companionship, self-esteem, and self-efficacy (see the section above on active coping, self-efficacy, and control and the section below on self-affirmation; Southwick, Vythilingam, & Charney, 2005; Thoits, 2011). Positive social relationships can also promote positive mood and well-being via social contagion (Fowler & Christakis, 2008). Even having a happy spouse predicts better health, beyond one's own happiness (Chopik & O'Brien, 2017).

Social connectedness has multiple immediate and long-term effects on the nervous system. Here we focus on the long-term effects. Much like lack of sleep, lack of social connectedness is a powerful stressor to social mammals such as humans. Chronic social isolation increases HPA activation, particularly when a social bond with a significant partner is disrupted (Cacioppo, Cacioppo, Capitanio, & Cole, 2015). Given the role of the amygdala and the MPFC in regulating the HPA axis, these brain regions are particularly affected by social connectedness and social support. Recall that chronic stress can lead to brain cell loss in the PFC and abnormal cell growth in the amygdala, changes associated with mood and cognitive impairment (Lupien et al., 2009). Thus, it has been posited that having positive social connections can bolster MPFC integrity with the opposite effect on the amygdala. In a sample of healthy adults, perceived social support was positively correlated with MPFC cortical thickness and negatively correlated with amygdala volume (Sherman, Cheng, Fingerman, & Schnyer, 2016). Although the causal role of social connection on brain structure is difficult to ascertain in humans, experimental animal studies have corroborated this pattern of results. Prolonged isolation in juvenile rats reduces dendritic complexity in the MPFC and increases it in the amygdala (Wang, Ho, Ko, Liao, & Lee, 2012). Even in adult rodents, prolonged isolation alters amygdala and MPFC integrity, and leads to anxietylike behavior (Lieberwirth, Liu, Jia, & Wang, 2012; Liu et al., 2012). Importantly, social reintegration can reverse many of these effects (Liu et al., 2012). Recent longitudinal studies of human adults have indicated that training social skills, such as compassion and perspective-taking, reduces cortisol response in a subsequent social-stress task (Engert, Kok, Papassotiriou, Chrousos, & Singer, 2017) and increases cortical thickness in social brain regions, including the LPFC and lateral temporal cortices (Valk et al., 2017).

Gratitude. Numerous studies have shown that expressing gratitude can boost psychological and physical well-being (Hill, Allemand, & Roberts, 2013; Seligman, Steen, Park, & Peterson, 2005). Expressing gratitude to another person (e.g., by writing a thankful letter) or even privately to oneself (e.g., by journaling about one's fortunes in a diary) can both be effective (Kaczmarek et al., 2015). For example, in a 2-week intervention study with a clinical sample of adults waiting to receive psychological treatment, daily journaling of things they were grateful for increased life-satisfaction and reduced anxiety, as did daily journaling of the kind acts they had committed (Kerr, O'Donovan, & Pepping, 2015). Gratitude's lasting effects on well-being may be related to its impact on the MPFC. Participants who engaged in a 1-hr exercise of writing a thankful letter showed increased gratitude-related generosity and increased activity in the MPFC 3 months later (Kini, Wong, McInnis, Gabana, & Brown, 2016). In other words, expressing gratitude can have lasting effects on a brain region that is important for emotion regulation and social reward.

Take-Home on Connecting Socially

Having positive social connections and social support have consistently been associated with better physical and psychological health.

- Positive social connections can increase health-promoting behaviors, improve mood, and reduce distress responses.
- Particularly important are close relationships that are meaningful, rather than having a large network of casual friends.
- Expressing gratitude for one's fortunes, even privately to oneself, can also boost psychological and physical well-being.
- In addition to these personal benefits, expressing gratitude to another person, for example for their good deeds, offers the additional benefit of promoting the formation and maintenance of a close relationship.

Cognitive Pathways to Building a Resilient Brain

Emotion Regulation

When confronting or manipulating a stressor is not possible or sufficient, a complementary approach to coping is to regulate the way one attends to or interprets the stressor. Many of these strategies are often collectively referred to as *emotion regulation* (Gross, 2015). Although the ideal emotion-regulation strategy depends on the individual person and situation (Gross, 2015), by and large strategies that involve explicit identification and expression of the emotional experience, such as expressive writing, tend to be more adaptive than avoidant strategies, such as denial, emotion suppression, or repressive coping (Gross, 2002; Mund & Mitte, 2012; Webb, Miles, & Sheeran, 2012). Avoidant strategies, however, are not always maladaptive. For example, active distraction can be beneficial at times, such as in the initial stages of regulating an overwhelming emotion to help reduce its intensity (Gross, 2015; Shafir, Thiruchselvam, Suri, Gross, & Sheppes, 2016) and in the immediate aftermath of witnessing or experiencing trauma, when distraction can disrupt the formation of memories and help reduce subsequent intrusive flashbacks (James et al., 2016). In the remainder of this section, we review the following strategies: (a) emotion disclosure, (b) affect labeling, and (c) cognitive reappraisal.

Emotion disclosure. Early psychologists like Freud (1933) asserted that talking about past adverse experiences could help "cure" many mental and physical ailments. Empirical studies have since demonstrated that verbally disclosing thoughts and feelings about personally meaningful experiences, such as writing about a traumatic experience for 20 min, can improve physical and psychological well-being in the long-term (Frattaroli, 2006; Hemenover, 2003; Pennebaker, 1997). These long-term benefits of emotion disclosure are consistent with findings that acceptance, rather than denial, predicts better outcome when faced with adversity (Carver et al., 1993; Manne et al., 2003; Silver, Holman, McIntosh, Poulin, & Gil-Rivas, 2002).

There are multiple mechanisms that may underlie the long-term benefits of emotional disclosure. Verbalizing one's emotions, either privately on paper or interpersonally to a confidant, can boost one's self concept and self-efficacy (see the section above on active coping, self-efficacy, and control and the section below on self-affirmation; Hemenover, 2003), improve understanding of the adverse experience (Pennebaker, 1997), and provide insight into regulation of those emotions (Maroney & Gross, 2014). Emotional expression and disclosure can also relieve the person of the burden and costs of keeping a secret (Slepian, Chun, & Mason, 2017) and of inhibiting (e.g., denying, suppressing) the emotion (Pennebaker, 1997). In support of this notion, anxious students who wrote about their feelings about an upcoming challenging task subsequently used fewer prefrontal resources (lower ACC-based error-related negativity) during the task, as if expressive writing helped them "offload" their worries from the PFC (Schroder, Moran, & Moser, 2017).

Another potential mechanism underlying the sustained benefits of disclosure may be one that resembles reconsolidation (see the section above on exposure and reconsolidation). It has been proposed that verbally reexperiencing past trauma allows the formerly implicit amygdala-based memory to be reencoded in explicit neocortex-based declarative memory, where it can be intentionally accessed and hence more easily regulated in the future (Brewin, 2001). Thus, whether with simple labeling or more extensive journaling or talking, the key idea is that words can help bring emotions out of the autopilot limbic system, where the default outcome is activation of autonomic, HPA, and fear circuits, and into the neocortex where control can more easily be exerted. Consistent with this model, writing a narrative of their marital separation improved newly separated adults' autonomic (cardiovascular) function several months later (Bourassa, Allen, Mehl, & Sbarra, 2017).

Nonetheless, reflecting on one's troubles is not always adaptive, such as when done to excess or when it turns to rumination, the repetitive self-focused attention to sad or angry feelings, making one feel worse (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). Several factors influence whether self-reflection turns into rumination. Positive mood, even if induced temporarily by an engaging distraction (e.g., going for a bike ride), makes it less likely for self-reflection to devolve into perseverations about problems and negative feelings (Nolen-Hoeksema et al., 2008). Self-distancing, for example by reinterpreting the negative experience as if it had happened to a friend, can also help reduce rumination (see Kross & Ayduk, 2011; Nolen-Hoeksema et al., 2008; Wisco & Nolen-Hoeksema, 2010).

Another challenge with emotion expression is in workplace situations that require employees to convey emotions that may be at odds with their true feelings, referred to as "emotional labor" (Hochschild, 1983). For example, employees in service professions are typically expected to always smile, and professionals such as doctors and judges are typically expected to exude confidence and impartiality in their decisions. Field studies have corroborated laboratory studies of emotion suppression by showing overall that chronically faking or suppressing emotions on the job is followed by poor psychological and physical outcomes, such as emotional exhaustion and insomnia, as well as poor job performance (Grandey, 2015). In these circumstances, expressive suppression should be used sparingly; instead, emotion disclosure (privately to oneself or to a confidant) and cognitive reappraisal (see below) would be more adaptive approaches (Maroney & Gross, 2014).

Affect labeling. Even the simple act of labeling an emotional experience can reduce emotional arousal, as measured by self-report, autonomic arousal, and amygdala activation (Hariri, Mattay, Tessitore, Fera, & Weinberger, 2003; Lieberman, Inagaki, Tabibnia, & Crockett, 2011). Simply putting feelings into words activates the LPFC, which in turn reduces activation in the amygdala (Lieberman et al., 2007; Torrisi, Lieberman, Bookheimer, & Altshuler, 2013). Because affective labels recruit the LPFC regions that can downregulate the amygdala, the mere act of affect labeling can dampen emotions even when the person does not believe affective labeling can effectively regulate emotions (Brooks et al., 2017; Lieberman et al., 2011). The practical implication is that merely saying "I feel anxious" or "I am sad" may dampen those very feelings.

Importantly, affect labeling can have lasting benefits, as it can reduce physiological (autonomic) reactivity to evocative images even a week after labeling (Tabibnia, Lieberman, & Craske, 2008) and enhance the outcome of exposure therapy, for example in individuals with fear of public speaking (Niles, Craske, Lieberman, & Hur, 2015). The neural mechanism underlying this lasting effect of words on feelings seems to be similar to the mechanism underlying fear extinction. In a preliminary study, increased activation in the LPFC and MPFC during labeling was associated with greater reductions in autonomic arousal a week later, with the MPFC mediating the effect of the LPFC on autonomic arousal (Tabibnia, Craske, & Lieberman, 2006). In other words, a pathway that is well known for extinguishing fear in animals may be recruited in humans by affect labeling.

To summarize the last two sections, emotion expression, particularly when using language, can be thought of as an effective initial step toward emotion regulation. Indeed, identifying the thoughts or situations that trigger upsetting emotions is regarded as a first step to change in most cognitive-based interventions, a step that reduces reflexive limbic responding and initiates more neocortical processing, facilitating control over the emotion. From there, deeper cognitive processing of the emotion helps determine adaptive coping.

Cognitive reappraisal. *Cognitive reappraisal* refers to reframing or reinterpreting an event in order to alter its emotional impact. For example, being stuck in traffic can be reappraised as an opportunity to listen to a podcast. In the laboratory, participants who use cognitive reappraisal during a negative experience report less negative emotion and show lower autonomic arousal; similarly, people who report frequently using reappraisal experience less negative emotion in negative situations and exhibit better psychological health (John & Gross, 2004). Cognitive reappraisal is involved in successful treatment of affective disorders, and it is associated with better psychological outcomes after stressful life events (Troy & Mauss, 2011). A recent meta-analysis of various emotion-regulation strategies identified cognitive reappraisal, particularly perspective-taking (e.g., self-distancing), as most effective (Webb et al., 2012).

Related to cognitive reappraisal is explanatory style (Ellis, 1962; Seligman et al., 1988), the way in which one tends to portray good and bad events in one's life. An individual with a negative or pessimistic explanatory style interprets bad events as permanent and pervasive (e.g., a failed job interview would be attributed to innate general incompetence, leading to expectation of failure in future interviews and in all aspects of life). Conversely, an individual with a positive or optimistic explanatory style interprets bad events as temporary and limited to a specific circumstance (e.g., a failed job interview would be interpreted as a bad fit between that specific job and the self). Cognitive therapies and interventions that incorporate positive-explanatory-style training have been very successful in treating or preventing depression (Reivich, Gillham, Chaplin, & Seligman, 2013).

The neural mechanism of reappraisal is very similar to that of affect labeling. According to a review of 48 neuroimaging studies, cognitive reappraisal recruits the LPFC and dampens response in the amygdala (Buhle et al., 2014). As with affect labeling, reappraisal may have lasting effects on emotional arousal; repeatedly reappraising an aversive image leads to diminished amygdala response to that image 7 days later (Denny, Inhoff, Zerubavel, Davachi, & Ochsner, 2015). In an fMRI study of both cognitive reappraisal and affect labeling, the LPFC-amygdala network overlapped between the two tasks (Burklund, Creswell, Irwin, & Lieberman, 2014). Thus, for clients who struggle with using reappraisal, particularly in the early stages of a distressing experience when emotions may be overwhelming, affective labeling may offer an alternative and potentially easier means to activating this emotion-regulation network. This stepwise approach of labeling before reappraising is consistent with the suggestion that acceptance prior to cognitive reappraisal can boost reappraisal success (Shallcross, Troy, & Mauss, 2015). In both acceptance and affective labeling, acknowledging and engaging with the negative emotion may help diffuse its initial potency, thus paving the way for more effective reappraisal.

Take-Home on Emotion Regulation

As with behavioral strategies of coping, cognitive strategies that involve confrontation (i.e., expression) of the emotion are generally more effective than strategies that involve avoidance (e.g., suppression). Emotional memories are primarily stored in subcortical limbic regions, from where they can nonconsciously trigger autonomic and hormonal responses that can be difficult to control and harmful if left unchecked. However, explicit confrontation of an emotion, such as talking about a past distressful experience, enables reexperiencing and therefore reencoding of that experience in the neocortex, facilitating conscious access to and therefore intentional cognitive regulation of those emotions in the future.

- Suppressing the expression of emotion is counterproductive. Even in jobs that require expression of an emotion that is at odds with one's true emotions, expressive suppression should be used sparingly. Instead, cognitive reappraisal and, usually, emotion disclosure to a confidant would be more adaptive ways of eventually bringing one's emotions in line with the expected emotions.
- Accepting, labeling, and verbally expressing an emotion can help reduce its potency and facilitate its cognitive regulation. The employee who is bothered by his feelings toward his boss would benefit from identifying and expressing (privately or to a confidant) his precise feelings, in order to gain insight and mastery. For example, is he upset because he thinks his boss does not value him? Is he ashamed? Is he afraid of future failure?
- Cognitive reappraisal can further help reduce distress. For example, can the employee interpret her boss's actions in an alternative way, such as an opportunity to grow? Another effective appraisal technique is self-distancing. For example, by imagining that a friend had gone through the same experience with the boss, the employee might come to view the experience from a more objective and less negative perspective.

Cognitive Training

Cognitive-bias modification. Individuals who are prone to depression or anxiety are more likely than others to attend to threatening or negative cues, interpret ambiguity in negative ways, and selectively remember negative events (Mathews & MacLeod, 2005). These negativity-biases in attention, interpretation, and memory can be modified with training, and the induced changes can reduce symptoms (Hertel & Mathews, 2011). This training is broadly referred to as *cognitive-bias modification* (CBM). For a description of the computerized tasks used in CBM, see Hallion and Ruscio (2011). Although inconsistencies in published findings persist, according to recent reviews, CBM for interpretation can reduce symptoms of depression (Koster & Hoorelbeke, 2015) and CBM for attention can reduce anxiety symptoms (Kuckertz & Amir, 2015). An fMRI study of attention-bias modification has shown that training alters the LPFC activation to emotional stimuli, which in turn shows functional connectivity with the visual association cortex related to attention (Browning, Holmes, Murphy, Goodwin, & Harmer, 2010). These results support the notion that CBM can "tune" prefrontal control over attention to emotional events in a way that is predicted to regulate anxiety. To summarize, although CBM may not quite be ready for prime time, it is worth keeping an eye on as a potential supplement to other interventions for anxiety and depression symptoms (Koster & Bernstein, 2015).

Mindfulness training. A much-studied strategy that may boost resilience in multiple ways is mindfulness (e.g., Holzel et al., 2011; Sayers, Creswell, & Taren, 2015), commonly described as a process of purposefully and nonjudgmentally paying attention to the present moment (Kabat-Zinn, 2003). Recent research suggests that mindfulness training may help buffer the stress response, thus leading to beneficial effects for stress-related health conditions such as depression, inflammation, and drug abuse (Creswell & Lindsay, 2014). Mindfulness has also been associated with improved executive function (particularly attention), positive affect and subjective well-being, and better social relationship quality (Brown, Ryan, & Creswell, 2007). As discussed above, each of these psychological, social, and biological changes alone contributes significantly to psychological and physical well-being and resilience. Other biological changes associated with mindfulness training include structural and functional changes in amygdala-PFC emotion-regulation circuitry (Guendelman, Medeiros, & Rampes, 2017; Y. Y. Tang, Holzel, & Posner, 2015), structural and functional changes in the LPFC and ACC associated with executive tasks (Holzel et al., 2011; Y. Y. Tang et al., 2015), as well as enhanced BDNF (Cahn, Goodman, Peterson, Maturi, & Mills, 2017) and telomere (Schutte & Malouff, 2014) function. However, mindfulness interventions are not always beneficial, such as in acute-health-treatment contexts (Reynolds, Bissett, Porter, & Consedine, 2017), and the research literature is not without criticism (Van Dam et al., 2017). For example, mindfulness is conceptualized and operationalized differently across studies, and the different operational definitions can lead to different behavioral and neural outcomes (e.g., Engert et al., 2017).

Cognitive therapy. The cognitive and behavioral coping strategies reviewed in this article can successfully be learned with proper intervention, even in clinically healthy adults (Denny & Ochsner, 2014; Kotsou, Nelis, Gregoire, & Mikolajczak, 2011). As an example of training changing psychological and physiological outcomes, here we discuss cognitive therapy, the most well-known and widely tested variant of cognitive–behavioral therapy, a type of intervention that is considered to be particularly efficacious for treating mood and anxiety disorders (Tolin, 2010). Cognitive therapy utilizes cognitive and behavioral strategies to change faulty cognitive tendencies, such as utilizing positive-explanatory-style exercises to reduce negativity bias (Clark & Beck, 2010). Meta-analyses have shown that cognitive therapy is as effective as antidepressant medication in treating depression and anxiety disorders and may even be more effective at reducing the risk of relapse after discontinuation (Clark & Beck, 2010; DeRubeis, Siegle, & Hollon, 2008; also see Johnsen & Friborg, 2015). Review studies have indicated that cognitive therapy for depression and anxiety generally reduces amygdala activation and enhances prefrontal function (Clark & Beck, 2010; DeRubeis et al., 2008). Cognitive–behavioral therapy can also increase gray-matter volume in the LPFC, an increase correlated with improvements in executive-control tasks (de Lange et al., 2008).

Take-Home on Cognitive Training

Different training programs have been developed to enhance cognitive skills that are important for resilience, including the ability to control attention (e.g., away from the negative) and improve cognitive control (e.g., cognitive reappraisal).

- Cognitive-bias modification (CBM) is a relatively novel intervention strategy that uses computer-based exercises to shift habitual and automatic thinking patterns toward a less negative direction. Although further research needs to be done, CBM may emerge as a convenient complement to more conventional interventions.
- Mindfulness training aims to improve one's ability to bring attention to the present moment, rather than the past or the future. By bringing awareness to one's present thoughts and emotions, mindfulness reduces the psychological burden of ruminating about past stressors or worrying about future stressors, and by strengthening attention control, mindfulness improves allocation of limited C-system resources that are important for emotion regulation and coping.
- Cognitive therapy employs various cognitive and behavioral strategies to change faulty cognitive tendencies (e.g., positive-explanatory-style exercises to reduce negativity bias). It is an extensively studied example of an intervention that can improve psychological and physiological outcomes related to resilience and change the brain, namely by dampening limbic arousal and buttressing the PFC.

Coaching Resilience

In this section, we review ways in which coaches and consulting psychologists can more effectively impart the various strategies reviewed above to their clients. First, we review the neural bases of three factors related to mind-set that can influence learning and behavior change, and we translate these into strategies that practitioners can use with their clients to improve their outcomes (see Figure 1). We then recommend an additive approach to coaching resilience and subsequently speculate about the value of teaching clients the neuroscience of resilience.

Three Brain-Friendly Strategies to Facilitate Learning and Behavior Change

Positive expectation. Expectation has a striking capacity to shape experience. Countless randomized controlled trials have demonstrated that inert or "placebo" pills can ameliorate various ailments, ostensibly because patients expect them to (Meissner, Kohls, & Colloca, 2011). Indeed, expectations of decreased pain powerfully reduce both self-reported pain and activation in the brain's pain network (Koyama, McHaffie, Laurienti, & Coghill, 2005). Recall that self-efficacy and even the mere perception of control (i.e., expectation that distress can be controlled) can also help dampen distress and experienced pain (see the section above on active coping, self-efficacy, and control). Expectation can also alter experienced pleasure; a sip of wine with an expensive label is rated as more pleasant and triggers greater reward-related activation in the MPFC than a sip of the same wine with a cheap label (Plassmann, O'Doherty, Shiv, & Rangel, 2008). Thus, positive expectation can facilitate a positive outcome. In other words, mere belief in a given intervention may itself lead to positive outcomes, whether the intervention is intended to reduce psychological suffering such as anxiety (Colloca, Lopiano, Lanotte, & Benedetti, 2004), or physical suffering such as chronic pain (Kam-Hansen et al., 2014; Kaptchuk et al., 2008; Vase, Riley, & Price, 2002) or asthma, (Kemeny et al., 2007; Luparello, Lyons, Bleecker, & McFadden, 1968), or even seemingly pure neurological diseases such as Parkinson's disease (De la Fuente-Fernández et al., 2001; Lidstone et al., 2010).

Growth mind-set. A specific instance of having positive expectations is having a growth mind-set about learning. In influential research related to learned helplessness (Abramson, Seligman, & Teasdale, 1978) and hardiness (Kobasa, 1979), Dweck and colleagues have shown that people who believe or are taught that abilities are malleable (growth mind-set) rather than immutable (fixed mind-set) tend to learn better and improve more (De Castella et al., 2013; Dweck, 2008). People's mind-sets influence whether and to what degree they exert effort in difficult situations, such as in solving a math problem (Dweck, 2008) or in empathizing with others (Schumann, Zaki, & Dweck, 2014). Because those with fixed mind-sets believe they cannot improve their weaknesses, they are vulnerable to helplessness, poorer emotion regulation and stress coping, and lower well-being (De Castella et al., 2013; Yeager & Dweck, 2012). In a study examining the role of beliefs in cognitive–behavioral therapy for social-anxiety disorder, having a growth mind-set predicted more benefit from treatment, even 12 months after treatment, even after controlling for baseline anxiety and other beliefs (De Castella et al., 2015). Thus, teaching clients to believe in their own ability to learn and change can improve intervention outcomes.

One way in which people with growth mind-sets learn better is through their reactions to failure. Fixed-minded individuals view mistakes as evidence of their own inability and therefore disengage, whereas growth-minded individuals view mistakes as opportunities to learn. In electroencephalography studies, compared with fixed-minded individuals growth-minded individuals show better error correction following feedback, greater neural markers of attention to feedback, and lower neural markers of emotional distress to errors (Mangels, Butterfield, Lamb, Good, & Dweck, 2006; Moser, Schroder, Heeter, Moran, & Lee, 2011). Inducing a growth mind-set leads to similar effects (Schroder, Moran, Donnellan, & Moser, 2014). Extending these findings, a resting-state fMRI study has associated increasing growth-mindedness with greater functional connectivity of the striatum with regions important for error-monitoring and error correction, such as the dorsal ACC and dorsolateral PFC (Myers, Wang, Black, Bugescu, & Hoeft, 2016). In other words, growth-mindedness is associated with an enhanced network that is critical for feedback-based learning.

Self-affirmation. In addition to negative expectation and a fixed mind-set, another mind-set factor that can hamper learning and behavior change is defensiveness, such as when self-integrity is threatened. Threats to self-integrity can arise in response to a variety of mundane and grave circumstances, including being subjected to an insult or stereotype, job loss, or a medical diagnosis (Cohen & Sherman, 2014). Thus, perceived criticism, such as a supervisor's request to improve job performance or a doctor's recommendation to exercise more, can be met with resistance. One way to reduce this defensiveness is through self-affirmation, an act that is a reminder of one's own adequacy and thus affirms self-integrity and buffers threat (Steele, 1988). For example, low-income individuals who were randomly assigned to describe a personal experience that made them feel successful or proud exhibited better executive control, higher fluid intelligence, and greater willingness to utilize benefits programs compared with their nonaffirmed peers (Hall, Zhao, & Shafir, 2014). Similarly, writing about personal core values, such as relationships with loved ones or religion, buffered minority students against being negatively stereotyped and improved academic performance, even years after intervention (e.g., Brady et al., 2016). Even Facebook use, a venue for reminding oneself of one's core values, can be self-affirming and increase acceptance of negative feedback (Toma & Hancock, 2013). In fMRI studies of self-affirmation and behavior change, affirmed participants showed greater activation in the MPFC and reward circuitry, and this neural response predicted subsequent changes in sedentary behavior (Cascio et al., 2016; Falk et al., 2015). These results suggest that self-affirmation may facilitate behavior change by changing the way the individual considers the self-relevance and value of the messages. (For more on behavior change, see Berkman, 2018).

Additive Model of Resilience Building

Just as risk factors generally have additive effects on stress vulnerability, so too protective factors, such as the resilience-building strategies reviewed in this article, can have an additive effect on stress resilience (Hobfoll, 2001; Southwick & Charney, 2012). In other words, having and strengthening multiple resilience-building skills will increase the likelihood of resilience. That is not to say that all the strategies reviewed here have been investigated with equal rigor or that all strategies have equal effect sizes. Further comparative and meta-analytic studies are needed to determine the relative impact of these strategies. Nonetheless, of the multitude of psychosocial resilience-building strategies reviewed here, leading scientists tend to highlight certain strategies, often with small to medium effects on resilience, as particularly important. These strategies include active coping, sleep, aerobic exercise, social support, cognitive reappraisal, mindfulness, and self-efficacy (Gilbert, Foulk, & Bono, 2017; Southwick & Charney, 2012; Webb et al., 2012).

Another benefit of amassing a large repertoire of coping skills is that it increases the likelihood of finding the skill set that best fits a given circumstance. Recall that the efficacy of a strategy depends in part on the context. As such, coping flexibility, or the ability to flexibly adopt different coping strategies across different situations, can have a moderate effect on coping success (Cheng, Lau, & Chan, 2014). For example, although reappraisal is generally an effective strategy for managing distress, it can be counterproductive when emotional intensity is very high, in which case distraction would be a better strategy (Shafir et al., 2016), or when the situation is controllable (Troy, Shallcross, & Mauss, 2013), in which case a more active strategy that controls the stressor would be preferred. Thus, by possessing both reappraisal and active-coping skills and by developing acumen on when to use each, a client increases chances of successfully coping across different situations.

Neuroscience Education

An implicit, and mostly untested, assumption of this article, and perhaps of this special issue, is that understanding the neural mechanism of a psychological process (e.g., fear) may help improve learning and successful deployment of strategies that modulate that process (e.g., active avoidance). Ample evidence supports the notion that neuroscience information makes explanations of a psychological phenomenon more appealing, albeit even when the information is completely irrelevant (Fernandez-Duque, Evans, Christian, & Hodges, 2015; Rhodes, Rodriguez, & Shah, 2014). And this allure of neuroscience explanations is not always illusory. At least in the context of chronic-pain management, there is compelling evidence from multiple randomized controlled trials that "therapeutic neuroscience education"—that is, educating patients about the neurophysiology of pain and how the brain can modulate the experience of pain—improves intervention outcome, such as reducing pain and disability (Louw, Zimney, Puentedura, & Diener, 2016). Thus, as with physical pain, so too emotional pain might be better managed with better understanding of the underlying mechanisms of the emotional pain and of the strategies that can help mitigate it. This idea aligns nicely with the theory of self-directed neuroplasticity (Schwartz, Stapp, & Beauregard, 2005), as well as with the placebo literature (see the section above on positive expectation), highlighting the impact of self-awareness and knowledge on biological responses and neural change.

Take-Home on Coaching Resilience

Although adaptive coping techniques can be learned, training is more successful when clients have confidence in their own ability to learn, believe in the efficacy of the intervention, and do not feel threatened. And coping is more successful when the client has a wide repertoire of coping strategies to draw from and the flexibility to apply the appropriate strategy in a given circumstance.

- Interventions aimed at teaching coping skills can be more effective when the client believes that new skills can be learned. Thus, prior to training, it could be helpful to remind clients of the plasticity of the human brain and of their inherent ability to learn new skills.
- Similarly, people are more receptive to feedback when their sense of self is not threatened. Exercising self-affirmation (e.g., by reminding clients of their core values or of a time when they felt accomplished) prior to intervention can help counteract potential feelings of threat that can occur during consultation or feedback sessions and thus facilitate behavior change. This is why the "feedback sandwich" (constructive criticism sandwiched between sincere compliments) can be an effective approach.
- More generally, interventions may be more effective if the client believes in the intervention.
- Understanding the underlying neuroscience of the intervention may help increase clients' trust in the intervention and help boost its outcome.

Conclusions

As summarized in Table 1, recent advances in neuroscience offer insights into strategies that can boost resilience and change the brain, particularly in the amygdala and MPFC. A number of behavioral strategies can directly combat distress, in the immediate and long term, by changing amygdala-based representations of fear and effecting plasticity in MPFC circuits that can help with future coping. These strategies include exposure and reconsolidation, active avoidance, exercising control, and stress inoculation. Behaviors that boost physical health and social connectedness can also change the brain and boost resilience. For example, proper sleep and aerobic exercise buffer stress, improve mood, and alter PFC function. Connecting socially and expressing gratitude can also enhance physical and psychological well-being and alter MPFC integrity and function. Psychological strategies like verbal expression of emotion, affect labeling, and cognitive reappraisal are also effective tools for regulating distress, as they facilitate processing of emotion more cerebrally, reducing more reflexive amygdala-based or autonomic emotional reactivity. Mindfulness training and cognitive therapy are well-tested interventions that can also boost resilience and change PFC-amygdala circuits important for emotion regulation.

The one pattern emerging from the reviewed literature is that overall engaging with or confronting a stressor and the associated emotions (whether behaviorally in vivo or cognitively via language) tends to be more adaptive than passive avoidance or suppression. Although some forms of avoidance, such as active avoidance and distraction, can be beneficial in some situations, avoidance generally does not resolve the underlying distress and may even lead to negative consequences. This idea is consistent with findings that active-coping strategies, such as seeking social support or reappraisal, are more adaptive than passive strategies, such as doing nothing or denial. Beneficial engagement with one's emotions or experience of the world can be accomplished in several different ways. Specifically, facing fears, labeling emotions, disclosing emotions, acceptance, and practicing mindfulness can all reduce fear and distress, and sometimes also promote well-being, in the long term. Similarly, engaging with and overcoming manageable stressors, including physical challenges such as aerobic exercise and dietary restriction, can also "toughen" the mind and boost resilience. Indeed, actively engaging

Table 1
Fifteen Potential Pathways to Resilience

Strategy	Effect(s) on resilience	Neural system(s) impacted	Representative references
		Behavioral strategies	
Reducing fear and stress			
Exposure and reconsolidation	Reduces fear	Amygdala, MPFC	Craske, Treanor, Conway, Zbozinek, and Vervliet (2014); Milad and Quirk (2012); Beckers and Kindt (2017); Schiller et al. (2010); Agren (2012); Steinfurth et al. (2014)
Active avoidance	Reduces fear and facilitates active coping in the future (even in novel contexts)	Amygdala, MPFC	LeDoux and Gorman (2001); Delgado, Jou, Ledoux, and Phelps (2009); Moscarello and LeDoux (2013); LeDoux, Moscarello, Sears, and Campese (2017)
Controlling the stressor	Reduces distress and facilitates coping with other (even uncontrollable) stressors in the future	MPFC	Maier (2015); Kerr, McLaren, Mathy, and Nitschke (2012); Boeke, Moscarello, LeDoux, Phelps, and Hartley (2017); Brascher et al. (2016)
Stress inoculation	Experience with moderate stressors toughens one against future stress	MPFC, HPA	Dienstbier (1989); Seery, Holman, and Silver (2010); Parker, Buckmaster, Schatzberg, and Lyons (2004); Katz et al. (2009); Maier (2015); Russo, Murrough, Han, Charney, and Nestler (2012)
Boosting physical health			
Sleeping	Supports homeostasis; supports consolidation of neuronal and immunological memory; can help improve mood	Serotonin, HPA, MPFC-amygdala connectivity, neocortex	McEwen (2006); Goldstein and Walker (2014); Rumble, White, and Benca (2015); Novati et al. (2008); Westermann, Lange, Textor, and Born (2015); Payne, Chambers, and Kensinger (2012); Tang, Fiecas, Afolalu, and Wolke (2017); Yoo, Gujar, Hu, Jolesz, and Walker (2007)
Exercising	Fights medical disease; improves mood, attenuates the stress response, and boosts cognitive function	BDNF, serotonin, hippocampus, LPFC	Penedo and Dahn (2005); Warburton, Nicol, and Bredin (2006); Hillman, Erickson, and Kramer (2008); Nagahara and Tuszynski (2011); Nokia et al. (2016); Byun et al. (2014)
Restricting food	Can slow down medical disease; can improve memory, mood, sleep, quality of life, and fear extinction	BDNF, serotonin, amygdala	Witte, Fobker, Gellner, Knecht, and Flöel (2009); Martin et al. (2016); Longo and Mattson (2014); Horne, Muhlestein, and Anderson (2015); Riddle et al. (2013); Verma et al. (2016)
Connecting socially			
Social connection and support	Associated with greater longevity, psychological well-being, and physical health	Amygdala, MPFC, HPA	Thoits (2011); Chopik and O'Brien (2017); Cacioppo, Cacioppo, Capitanio, and Cole (2015); Liu et al. (2012); Valk et al. (2017); Engert, Kok, Papassotiriou, Chrousos, and Singer (2017)

(*table continues*)

Table 1 (*continued*)

Strategy	Effect(s) on resilience	Neural system(s) impacted	Representative references
Gratitude	Reduces distress; enhances psychological and physical well-being	MPFC	Hill, Allemand, and Roberts (2013); Seligman, Steen, Park, and Peterson (2005); Kini, Wong, McInnis, Gabana, and Brown (2016); Kaczmarek et al. (2015)
		Cognitive strategies	
Emotion regulation			
Emotion disclosure	Improves physical and psychological well-being in the long term	Autonomic nervous system, ACC	Pennebaker (1997); Frattaroli (2006); Brewin (2001); Slepian, Chun, and Mason (2017); Schroder, Moran, and Moser (2017); Bourassa, Allen, Mehl, and Sbarra (2017); Maroney and Gross (2014)
Affect labeling	Reduces distress in short and long terms	Autonomic nervous system	Lieberman, Inagaki, Tabibnia, and Crockett (2011); Tabibnia, Lieberman, and Craske (2008); Torrisi, Lieberman, Bookheimer, and Altshuler (2013); Brooks et al. (2017)
Cognitive reappraisal	Reduces distress in short and long terms	Amygdala	Webb, Miles, and Sheeran (2012); Buhle et al. (2014); Burklund, Creswell, Irwin, and Lieberman (2014); Denny, Inhoff, Zerubavel, Davachi, and Ochsner (2015)
Cognitive training			
Cognitive-bias modification (CBM)	Aims to reduce negativity bias in attention, interpretation, or memory and thus improve symptoms of depression and anxiety	LPFC	Hertel and Mathews (2011); Koster and Hoorelbeke (2015); Kuckertz and Amir (2015); Browning, Holmes, Murphy, Goodwin, and Harmer (2010)
Mindfulness training	Buffers against stress; improves executive function, subjective well-being, and social-relationship quality	Amygdala, PFC	Sayers, Creswell, and Taren (2015); Creswell and Lindsay (2014); Holzel et al. (2011); Tang, Hölzel, and Posner (2015); Guendelman, Medeiros, and Rampes (2017)
Cognitive therapy	Effective treatment for depression and anxiety	Amygdala, PFC	Tolin (2010); Clark and Beck (2010); DeRubeis, Siegle, and Hollon (2008); de Lange et al. (2008)

Note. PFC = prefrontal cortex; MPFC = medial prefrontal cortex; LPFC = lateral prefrontal cortex; HPA = hypothalamic pituitary adrenal; BDNF = brain-derived neurotrophic factor; ACC = anterior cingulate cortex.

with a stressor or a challenge can boost long-term resilience by strengthening the neural pathway for active coping in the future and essentially immunizing or inoculating the person against future adversity.

Undoubtedly, the psychobiology of building resilience is far more complicated than what is presented here. There are a number of genetic and neurochemical factors that also contribute to resilience, such as neuropeptide-Y (e.g., Reichmann & Holzer, 2016), cortisol awakening response (e.g., Cahn et al., 2017; Meggs, Golby, Mallett, Gucciardi, & Polman, 2016), and DHEA (e.g., Walker, Pfingst, Carnevali, Sgoifo, & Nalivaiko, 2017). Equally important are developmental factors (Casey, Glatt, & Lee, 2015), as well as environmental and individual-difference factors (e.g., culture, sex, socioeconomic status, and age) that impact not only resilience (Schetter & Dolbier, 2011) but also brain structure and function (e.g., Farah, 2017). Even at the neuroanatomical level, the picture is more complicated than a single region such as the MPFC determining the regulation of fear and anxiety. Similarly, at the behavioral level, there is not always a linear relationship between a given strategy and well-being. Avoidance is one such strategy, as it is maladaptive in most cases but beneficial in others, albeit in moderation. Furthermore, some resilience-building strategies can boost the outcome of other strategies, such as physical exercise, which can reduce stress, promote executive function, and improve sleep, each of which can in turn improve self-regulation and mood. Thus, the ideal approach for fostering resilience likely involves multiple behavioral, social, physical-health, and cognitive strategies that work synergistically or additively with one another (Hobfoll, 2001; Southwick & Charney, 2012).

In conclusion, the adult human brain is plastic and can learn to become more resilient. Multiple different behavioral and psychological strategies can rewire the brain and cultivate resilience. Depending on the situation and person, employing a combination of these will likely work best to boost resilience. By and large, engaging with one's fears, stressors, and challenges (e.g., active coping, aerobic exercise, and mindfulness) are particularly effective strategies, as they can reduce distress and boost neural mechanisms for better coping in the future. Importantly, believing in the malleability of the human brain can itself improve learning and behavior change. Thus, perhaps it is the case that sharing with clients the evidence that the brain can change to become more resilient, as summarized in this paper, may itself help boost the their ability to learn and implement new coping skills.

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