Biofeedback
Volume 44, Issue 3, pp. 152–159
DOI: 10.5298/1081-5937-44.3.11

Research Article

Neurofeedback and Mindfulness in Peak Performance Training Among Athletes

Noel L. Ford, MA,[1,2] Sarah N. Wyckoff, PhD,[1] and Leslie H. Sherlin, PhD[1,2,3,4]

[1]SenseLabs, Mesa, AZ, and Atascadero, CA; [2]Department of Mind-Body Medicine, Southwest College of Naturopathic Medicine, Tempe, AZ; [3]Department of Psychology, Northern Arizona University, Flagstaff, AZ; [4]Department of Counseling, Ottawa University, Phoenix, AZ

Keywords: mindfulness, sport, performance, meditation, neurofeedback

Years of research have demonstrated that biofeedback, neurofeedback, and mindfulness, individually and in various combinations, have been employed to effectively improve sport performance. The present article discusses the literature supporting the combination of these techniques, the neurophysiologic measures that support the use of these techniques for performance enhancement, and practical methods for implementing a combination of biofeedback and mindfulness with athletes. Finally, a case study is presented to offer practical steps on implementing mindfulness and biofeedback for the purpose of performance enhancement.

In the fall 2015 issue of *Biofeedback*, Khazan (2015) offered a detailed approach for applying mindfulness and acceptance techniques during biofeedback to improve the lives of those seeking treatment for clinical conditions. Klich (2015) described how mindfulness-based biofeedback has been integrated into health care settings. The current article aims to address how mindfulness is combined with biofeedback to improve performance, particularly among athletes.

Mindfulness is a mental skill rooted in Eastern meditation practices that has been reapplied through various therapeutic techniques such as mindfulness-based cognitive therapy (Teasdale et al., 2000), acceptance and commitment therapy (Hayes, Luoma, Bond, Masuda, & Lillis, 2006), and mindfulness-based stress reduction (Kabat-Zinn, 2003, 2011). As is likely well understood at this point, mindfulness is about teaching individuals to "become more aware of thoughts and feelings and to change their relationship to them" (Bishop, 2002, p. 71). Combining mindfulness with biofeedback is a logical evolution in self-regulation therapies, given that they are natural complements to one another, as biofeedback would enhance mindfulness through becoming more aware of one's physiology (Wyner, 2015). Further, the proposed psychological mechanisms of action in mindfulness techniques include behavioral processes of operant conditioning employed in bio/neurofeedback interventions (Ivanovski & Malhi, 2007; Sherlin et al., 2011). Fortunately, most individuals are capable of the two required skills for mindfulness, attention and awareness (Brown & Ryan, 2003), which increases the number of individuals to whom it can be applied successfully.

Psychophysiology of Mindfulness

Psychophysiology offers an opportunity to quantify the mindful state and allow individuals to identify and volitionally create it. A large body of research has amassed in the investigation of psychophysiological markers of meditation. However, all meditative practices are not created equal. The methods used to elicit specific states differ across practices and, consequently, result in different psychophysiological signatures. Therefore, findings cannot be generalized to all techniques. Cahn and Polich (2006) discuss the classification of meditative styles along a continuum from mindfulness to concentrative practices, dependent on the attention regulation strategies employed. They assert that mindfulness techniques (e.g., Zen, Vipassana, Western mindfulness meditation) call for the allowance and nonjudgmental awareness of any thought, feeling, or sensation that arises during the maintenance of a specific attentional stance (i.e., open perceptivity), whereas concentrative techniques (e.g., Yogic, Buddhist Samantha, and transcendental meditations) call for the focused attention on specific mental or sensory activity (i.e., narrowing of attentional focus). They also make a distinction between state and trait effects of meditative practice, indicating that state effects refer to the altered sensory, cognitive, and self-referential awareness that occurs during meditation, whereas trait effects refer to long-term changes that occur within these domains and persist in the meditator with or without actively engaging in meditation. Recognition of these differences is essential for the evaluation of the literature, investigations of underlying mechanisms of action, and development of future research studies.

In a comprehensive review of the psychological mechanisms of mindfulness meditation, Ivanovski and Malhi (2007) assert that various techniques enhance an individual's ability to concentrate and inhibit distracting stimuli, reduce expectancy responses to unexpected stimuli, enhance visual perceptual sensitivity, and improve sustained attention and attention set shifting, with the magnitude of domain-specific changes associated with the level of meditative experience. For example, in an investigation of sustained attention performance among mindfulness-based and concentrative-based meditators compared with naive controls, meditators presented with superior attentional performance compared with controls, with long-term meditators demonstrating superior performance compared with short-term meditators and mindfulness meditators demonstrating superior performance compared with concentrative meditators (Valentine & Sweet, 1999).

These findings are further supported by concomitant neurophysiological measures, such as the presence and amplitude of specific waveforms or the amplitude and latency of event-related potentials (ERPs) within the electroencephalograph (EEG). An ERP occurs in response to a specific auditory or visual stimulus and is defined by its polarity (positive or negative), timing, and scalp distribution. For example, the N2 component is characterized by a negative voltage occurring 200 ms poststimulus, and the P3 (P300) component is characterized by a positive voltage occurring 300 ms poststimulus. Both the N2 and P3 components are hypothesized to index attentional processes such as object recognition and categorization, stimulus evaluation, categorization, context updating, and cognitive load (for review, see Woodman, 2010). Investigation of N2 and P3 components as "attentional correlates" of mindfulness meditation indicated that, compared with naive participants, novice and experienced practitioners produced larger amplitudes (i.e., greater attentional shift or response) of both components when asked to attend to an auditory tone task and smaller amplitudes when asked to ignore auditory distractor tones during a breath-counting task (Atchley et al., 2016). Similarly, individuals who completed an 8-week mindfulness intervention showed increased amplitudes in the late component of the contingent negative variation, a measure of concentration ability and allocation of attentional resources, when compared with a naive waitlist control group (Bostanov, Keune, Kotchoubey, & Hautzinger, 2012). These findings demonstrate that practicing mindfulness allows the individual to build attention control skills, both in directing attention and in avoiding distractors. For athletes, attention control is particularly valuable in honing the ability to quickly direct attention to where it is most needed at that moment, selecting only those stimuli that require attention and disregarding distractors.

Mindfulness meditation tasks have also been shown to produce state and trait changes in EEG, magnetic resonance imaging, and functional magnetic resonance imaging (fMRI) activity. Compared with control conditions, mindfulness meditation enhances Delta, Theta, Alpha, and Beta power in frontal and posterior sites and decreases Alpha frequency globally. Mindfulness meditation also is associated with left-hemisphere lateralization of anterior Alpha activation, Alpha alterations in coherence, and nonhabituating Alpha blocking. In addition, it elicits task-specific increases in Gamma activity. For a review of these findings, see Cahn and Polich (2006), Chiesa and Serretti (2010), Ivanovski and Malhi (2007), and Lomas, Ivtzab, and Fu (2015). These changes are all consistent with reported hypotheses around the use of neurofeedback for performance improvements (e.g., Vernon, 2005). The increases in slow-frequency activity are thought to indicate increases in processing efficiency reported among expert performers when compared with novices (e.g., Deeny, Hillman, Janelle, & Hatfield, 2003; Del Percio et al., 2009; Kim et al., 2008), whereas the Alpha lateralization has been demonstrated to enhance performance in archers (Landers et al., 1991). Finally, increases in fast frequencies, Beta and Gamma, suggest an increased ability for information processing as a result of meditation practice, a benefit to skill acquisition.

In fMRI research, mindfulness-based meditation has been shown to increase activation in the rostral anterior cingulate cortex and the dorsal medial prefrontal cortex in both hemispheres, whereas long-term practice of mindfulness meditation has been linked to thicker prefrontal cortex, anterior cingulate cortex, putamen, and right hippocampal cortical structures (Cahn & Polich, 2006; Chiesa & Serretti, 2010). These findings are indicative of enhanced abilities to regulate attention and attend to bodily sensations as well as faster conceptual processing (Chiesa & Serretti, 2010), all of which should promote performance through increased learning of skills, awareness of body, and better self-regulation.

Finally, differences in physiological parameters including slowed respiration (Ahani et al., 2014; Lehrer, Sasaki, & Saito, 1999) and increased respiratory-sinus arrhythmia or heart rate variability (HRV; Ditto, Eclache, & Goldman, 2006; Krygier et al., 2013; Lehrer et al., 1999) have been observed between control conditions and mindfulness-based meditation in novice and skilled practitioners. The physiological changes summarized here support the notion that mindfulness enhances athletes' ability to self-regulate, which in turn affects their ability to make good decisions and stay calm during high-pressure competitive situations.

Mindfulness and Biofeedback Among Various Populations

The literature describing the nature of mindfulness training and its many applications is vast (e.g., Baer, 2003; Kabat-Zinn, 2011). Mindfulness has been reported to improve a whole host of clinical problems, including but not limited to anxiety (Hoffman, Sawyer, Witt, & Oh, 2010; Goldin & Gross, 2010; Grossman, Niemann, Schmidt, & Walach, 2004), depression (Dimidjian & Linehan, 2006; Felder, Dimidjian, & Segal, 2012; Kangas, 2014), challenges resulting from developmental disabilities (Hwang & Kearney, 2013), and symptoms related to medical conditions (Brown & Ryan, 2003; Carlson, Speca, Patel, & Goodey, 2003; Grossman et al., 2004; Speca, Carlson, Goodey, & Angen, 2000). In addition, mindfulness research has demonstrated efficacy for improving stress management skills and mental well-being among healthy individuals (e.g., Chiesa & Serretti, 2009; Keng, Smoski, & Robins, 2011; Rosenzweig, Reibel, Greeson, Brainard, & Hojat, 2003).

The benefits of both biofeedback and mindfulness together have also been reported in various samples. In a small sample of patients with psychiatric diagnoses, HRV biofeedback combined with mindfulness successfully improved both HRV measures and mindfulness (Kleen & Reitsma, 2011). Unfortunately, the reported outcomes were not symptom based. Despite this limitation, the study demonstrated that the combination of HRV biofeedback and mindfulness is applicable in patient populations. Among nursing students, both biofeedback and mindfulness training independently reduced self-reported anxiety and perceived stress, despite the consistently demanding curriculum (Ratanasiripong, Park, Ratanasiripong, & Kathalae, 2015). In a pilot study among university students, biofeedback and mindfulness training were combined to effectively decrease perceived stress and symptoms of anxiety, depression, and academic distress while also effectively promoting perceived coping skills (Wyner, 2015).

Clearly, mindfulness and biofeedback are applicable to broader populations than those suffering physical or psychological ailments. Mindfulness has been effectively implemented in various athlete groups (e.g., Goodman, Kashdan, Mallard, & Schumann, 2014; Scott-Hamilton, Schutte, & Brown, 2016; Thompson, Kaufman, De Petrillo, Glass, & Arnkoff, 2011), as has biofeedback (e.g., Gruzelier, 2014; Thompson, Steffert, Ros, Leach, & Gruzelier, 2008; Vernon, 2005). In fact, since the 1990s, mindfulness has been part of the acceptance-based therapeutic approach applied with increasing frequency for peak performance training, particularly among athletes (Gardner & Moore, 2012).

Mindfulness was initially introduced to optimize performance because of the intuitive overlap of the mindful state and the present-focused state found among high-performing athletes (Gardner & Moore, 2004). Performance of any kind requires many things, but mental efficiency and attention regulation are core components. By enhancing executive functioning and cognitive processing (Prätzlich, Kossowsky, Gaab, & Krummenacher, 2016), mindfulness also likely boosts athletes' ability to learn and perform skills. Mindfulness has been reported to decrease perfectionism, thought disruption, and performance anxiety while also decreasing the likelihood of being overwhelmed with emotions (Kaufman, Glass, & Arnkoff, 2009).

In addition, some suggest that mindfulness may be a prerequisite to both peak performance and flow states (Gardner & Moore, 2006; Kee & Wang, 2008). Mindfulness teaches athletes to be present, focusing only on stimuli that immediately affect their performance and letting go of memories and/or emotions linked to prior aspects of a performance (Gardner & Moore, 2004). It permits the athlete to perceive mental activity with acceptance and therefore to move beyond each thought, rather than wasting mental effort on judging, suppressing, or changing thoughts. Often, trying not to think about a negative or irrelevant thought only creates more focus on it (Abramowitz, Tolin, & Street, 2001). Further, by letting go of thoughts, the athlete is able to attend to only the stimuli relevant to carrying out the skilled task rather than the anticipated outcome. Thus, mindfulness exercises offer an opportunity to train athletes to enhance and increase the frequency of experiencing flow (e.g., Kaufman, Glass, & Arnkoff, 2009).

As mindfulness provides an alternative to attempts to change perceptions and judgments of thought processes occurring throughout sport performance, biofeedback allows the physical sensations that accompany emotions and thoughts to be objectively observed and accepted. Given the importance of mental efficiency during skilled performance, improved attention regulation positively affects performance outcomes (Deeny et al., 2003; Del Percio et al., 2009; Kim et al., 2008; Milton, Hlustik, & Small, 2007). Neurofeedback specifically targets the underlying cortical activity that promotes improved performance (reviewed in

Sherlin & Larson Ford, 2016). Biofeedback provides athletes with an improved method for observing the self and for identifying the physiological responses associated with the autonomic nervous system. With training, athletes learn to shift from sympathetic to parasympathetic activity when appropriate, which promotes better performance and decreases the effects of performance anxiety. Biofeedback assists in decreasing thought rumination and mind wandering by offering physical bodily sensations to ground attention in the present moment. For example, a recent study suggested that focusing on the breath as opposed to a mental image was more effective in reducing mind wandering (Ju & Lien, 2016).

Combining Biofeedback and Mindfulness for Sport Performance

Surprisingly few studies demonstrate the combined efficacy of biofeedback and mindfulness. Given the well-known positive effects of biofeedback for enhancing sport performance (e.g., Gruzelier, 2014) and the benefits of mindfulness in sport (e.g., Gardner & Moore, 2012), there are likely gains to be made by combining the two modalities. Unfortunately, the literature is scarce on this front, even within the performance enhancement domain.

Fitting mindfulness and biofeedback training in with an already demanding sport training program can be challenging. This makes it even more important that the practitioner be personally experienced in mindfulness and therefore be able to proactively address the challenges of practicing mindfulness at its introduction (Campbell & Christopher, 2012; van Aalderen, Breukers, Reuzel, & Speckens, 2014). This will set the athlete up for success. Furthermore, because mindfulness-based therapy is an alternative to traditional cognitive behavioral therapy (CBT), approaching difficult cognitions and emotions with acceptance rather than an aim to change them, it is important that the practitioner be well trained in both psychological skills and mindfulness practices (Shapiro, Astin, Bishop, & Cordova, 2005).

For tips on how to implement mindfulness into a biofeedback practice or vice versa for the purpose of performance enhancement, consider the suggestions by Khazan (2015). However, keep in mind the clinical focus of that article and remember that biofeedback training with athletes is different from biofeedback with patients, as noted by Wilson and Peper (2011). Let's consider these differences here. The goals of training are different: optimizing performance for athletes versus rehabilitation or symptom amelioration for patients. The nature of the client himself or herself is likely to be different as well. Recognizing and capitalizing on athletes' increased motivation, persistence, competitive drive, and ability to learn and apply new knowledge quickly will allow practitioners to incorporate biofeedback combined with mindfulness with greater success.

Because athletes are generally healthy and highly motivated, the training time can be designed to be short and intense. Working with athletes also offers the chance to be very focused with both mindfulness and biofeedback applications. Unlike working with patients who are in need of improvements across many life domains, where demonstrating progress can be challenging, training athletes is targeted primarily at specific skilled tasks where improvements are more measureable. In addition, athletes are often much more accustomed to the process of coaching, including negative feedback, than typical patients are. This means athletes may be more willing to immediately adjust their behavior in accordance with recommendations. At the same time, athletes are also much more prone to overcorrecting. Clear instructions, including boundaries for implementation, should be offered to the client. Such boundaries include limiting at-home training time and scheduling down time.

Finally, technology provides another opportunity to incorporate mindfulness and biofeedback successfully within athlete populations. There are a multitude of mobile applications that promote mindfulness, in one form or another, which athletes may find valuable for their ease of use and portability. This could also allow the session time spent with the practitioner to be more focused on how to implement new understanding gained through practice beyond the office, for example, using visualization to help the athlete learn to recognize the ramp up in physiological arousal earlier in a competitive situation and then to respond with slow, diaphragmatic breathing to calm the sympathetic response of the autonomic nervous system and acceptance of anxious thoughts. However, each practitioner should carefully evaluate the utility of any mobile application suggested to the athlete, as there has been little empirical support for the efficacy of these mobile platforms (Plaza, Demarzo, Herrera-Mercadal, & García-Campayo, 2013).

Going forward, greater efforts must be made to demonstrate the efficacy of combining biofeedback with mindfulness. In addition, there should be greater diversity in the populations in which these modalities are implemented, and the outcomes with athletes should target sport-related variables to better indicate success for mindfulness and biofeedback improving performance.

Case Narrative: A Collegiate Division 1 Golfer

There are many ways a practitioner can engage with athletes. We offer a practical example of one way of combining neurofeedback and mindfulness for the purpose of performance enhancement.

The client, a 22-year-old female collegiate Division 1 golfer named Anna, was experiencing performance anxiety that was hindering her competitive play and keeping her from the school's travel team. Anna reported significant frustration and control issues over golf in competitive situations that were inhibiting her from performing well during qualifying or tournament play.

The Training Protocol

The training protocol was composed of mindfulness, CBT, and neurofeedback. This meant using mindfulness practices to bring awareness of the present moment to identify how the client responded to neurofeedback. Ultimately, the goal was to transfer the heightened awareness and coping strategies to the golf course. To achieve these goals, the client did an intense training protocol over the course of 3 weeks. This protocol is describes below.

The first step was evaluation, which included a quantitative electroencephalogram (QEEG) and sport psychology interview. The primary goals of the interview were to identify Anna's specific struggles with performance, her goals for training, and her current awareness of physiological sensations that contribute to performance issues. As part of the interview, a brief but detailed explanation was offered on how the interaction of the mind and body can facilitate or impede performance. This is an important step that must be undertaken to build understanding of neurophysiology at the client's level, which promotes motivation to alter thought processes and harness physiology.

HRV Training

Anna began HRV training in office and then continued throughout the 3-week training using a portable device (StressEraser, Helicor, Inc., New York, NY) several times per day, 5 to 10 minutes each use. She practiced guided and self-guided mindfulness exercises twice every day, in-office and at home, before bed. Neurofeedback sessions were conducted intensely for the first week and then titrated over 2 additional weeks.

Neurofeedback

In the first week, Anna started the day with a 30-minute neurofeedback session using an individualized protocol based on her QEEG. After a break, a second 30-minute neurofeedback session was conducted with a standard focus-enhancing protocol (i.e., decreasing slow-frequency activity and increasing faster frequencies over the frontal and motor cortex). This was followed by a 15- to 30-minute mindfulness-based CBT session, which included a guided exercise such as a body scan or simply observing and accepting thoughts. After lunch and a break, which sometimes included sleep, Anna participated in a third 30-minute neurofeedback session using a standardized training protocol for increased deep state relaxation (i.e., augmenting slow- and inhibiting fast-frequency activity in the parietal and occipital lobes). Before bed, the client was instructed to complete another 20 minutes of neurofeedback aimed at stress reduction and a 10-minute mindfulness exercise via iOS mobile applications, Versus and Headspace, respectively. The regimen was completed for 6 days in a row.

In the second week, the number of neurofeedback sessions was reduced to two per day, and in-office training occurred every other day, whereas mobile training was still recommended every day. In this case, Anna did not use a written log to track training sessions; however, that is a common and valuable practice to employ with athletes. Often, athletes are already experienced at keeping written logs to track performance, to identify patterns of performance and to be accountable to trainers. The neurofeedback protocols were alternated between the individualized protocol and one of the focus or relaxation protocols. In the third week, the neurofeedback sessions were reduced to one time per every other day, and the client chose the protocol based on daily preference.

Cognitive Acceptance and Reframing

Accepting and reframing the experience of anxiety was a major part of the training for this client. For example, Anna reported experiencing increasing anxiety, pressure, and muscle tightness as she addressed the golf ball on the tee box during tournament play. To accept that experience and reframe the meaning of the anxiety, Anna was directed to visualize that scenario and to allow her mind to become aware of the pressure and anxiety as well as how her body was reacting. Next, she was trained to detach the judgmental internal dialogue from the physical sensation of anxiety as she stood over the ball, specifically to accept that the experience of anxiety was related to her level of investment and desire to do well rather than anything external. Anna was instructed to use positive affirmations each time that she experienced the anxiety during the visualization exercise, such as, "When I experience anxiety and my body starts to react, that is not only OK but it is not related to golf and it's a result of my desire to do well."

Mindfulness

Anna practiced a guided mindfulness exercise, aimed specifically at experiencing anxiety while golfing. She visualized an entire round of golf and described in detail the anxiety as it ebbed and flowed throughout the round. This helped her to identify when the anxiety was at its worst and to practice acceptance. Once she identified anxiety, the client practiced "sitting" with the anxiety. Then Anna practiced positive affirmations and cognitive reframing about the meaning of the anxiety, changing it to an excitement about the opportunity to perform.

Generalization Beyond Sport

In the beginning of the training, Anna's verbal reports were very golf-centric, but as time progressed, she began to recognize how her anxiety was serving her and how it was affecting the rest of her life. Of particular significance, she uncovered the belief that if she allowed herself to have fun or enjoy life outside of golf, that meant she was not working hard enough to be the best golfer possible. In addition, Anna realized that having the belief that she could not perform well in tournaments because of her anxiety was actually serving as an excuse for a failure to perform well. Once she gained these and other insights, it was easier for her to detach the anxiety from golf and to accept that her performance is not always within her control. She began to see that if she focused on the process of preparation and competing and did everything possible to prepare and be present, she could accept the outcome of her golf performance. In addition, Anna came to see that failure did not equate to her being a bad person or serve as an indication that she did not work hard enough in preparation.

References

Abramowitz, J. S., Tolin, D. F., & Street, G. P. (2001). Paradoxical effects of thought suppression: A meta-analysis of controlled studies. *Clinical Psychology Review*, *21*, 683–703. doi:10.1016/S0272-7358(00)00057-X

Ahani, A., Wahbeh, H., Nezamfar, H., Miller, M., Erdogmus, D., & Oken, B. (2014). Quantitative change of EEG and respiration signals during mindfulness meditation. *Journal of Neuro-Engineering and Rehabilitation*, *11*, 87. doi:10.1186/1743-0003-11-87

Atchley, R., Klee, D., Memmott, T., Goodrich, E., Wahbeh, H., & Oken, B. (2016). Event-related potential correlates of mindfulness meditation competence. *Neuroscience*, *320*, 83–92. doi:10.1016/j.neuroscience.2016.01.051

Baer, R. A. (2003). Mindfulness training as a clinical intervention: A conceptual and empirical review. *Clinical Psychology Science and Practice*, *10*, 125–143. doi:10.1093/clipsy/bpg015

Bishop, S. (2002). What do we really know about mindfulness-based stress reduction? *Psychosomatic Medicine*, *64*, 71–84. doi:10.1097/00006842-200201000-00010

Brown, K. W., & Ryan, R. M. (2003). The benefits of being present: mindfulness and its role in psychological well-being. *Journal of Personality and Social Psychology*, *84*, 822. doi:10.1037/0022-3514.84.4.822

Bostanov, V., Keune, P. M., Kotchoubey, B., & Hautzinger, M. (2012). Event-related brain potentials reflected increased concentration ability after mindfulness-based cognitive therapy for depression: A randomized control trial. *Psychiatry Research*, *199*, 174–180. doi:10.1016/j.psychres.2012.05.031

Cahn, B. R., & Polich, J. (2006). Meditation states and traits: EEG, ERP, and neuroimaging studies. *Psychological Bulletin*, *132*, 180–211. doi:10.1037/0033-2909.132.2.180

Carlson, L. E., Speca, M., Patel, K. D., & Goodey, E. (2003). Mindfulness-based stress reduction in relation to quality of life, mood, symptoms of stress, and immune parameters in breast and prostate cancer outpatients. *Psychosomatic Medicine*, *65*, 571–581. doi:10.1097/01.psy.0000074003.35911.41

Campbell, J. C., & Christopher, J. C. (2012). Teaching mindfulness to create effective counselors. *Journal of Mental Health Counseling*, *34*, 213. doi:10.17744/mehc.34.3.j75658520157258l

Chiesa, A., & Serretti, A. (2009). Mindfulness-based stress reduction for stress management in healthy people: A review and meta-analysis. *Journal of Alternative and Complementary Medicine*, *15*, 593–600. doi:10.1089/acm.2008.0495

Chiesa, A., & Serretti, A. (2010). A systematic review of neurobiological and clinical features of mindfulness meditations. *Psychological Medicine*, *40*, 1239–1251. doi:10.1017/S0033291709991747

Deeny, S. P., Hillman, C. H., Janelle, C. M., & Hatfield, B. D. (2003). Cortico-cortical communication and superior performance in skilled marksmen: An EEG coherence analysis. *Journal of Sport & Exercise*, *25*,188–204.

Del Percio, C., Babiloni, C., Infarinato, F., Marzano, N., Iacoboni, M., Lizio, R., Aschieri, P., et al. (2009). Effects of tiredness on visuo-spatial attention processes in elite karate athletes and non-athletes. *Archives Italiennes De Biologie*, *147*, 1–10.

Dimidjian, S., & Linehan, M. M. (2003). Defining an agenda for future research on the clinical application of mindfulness practice. *Clinical Psychology: Science and Practice*, *10*, 166–171. doi:10.1093/clipsy.bpg019

Ditto, B., Eclache, M., & Goldman, N. (2006). Short-term autonomic and cardiovascular effects of mindfulness body scan meditation. *Annals of Behavioral Medicine*, *32*, 227–234. doi:10.1207/s15324796abm3203_9

Felder, J. N., Dimidjian, S., & Segal, Z. (2012). Collaboration in mindfulness-based cognitive therapy. *Journal of Clinical Psychology*, *68*, 179–186. doi:10.1002/jclp.21832

Gardner, F., & Moore, Z. (2006). *Clinical sport psychology*. Human Kinetics.

Gardner, F. L., & Moore, Z. E. (2004). A mindfulness-acceptance-commitment (MAC) based approach to athletic performance enhancement: theoretical considerations. *Behavior Therapy*, *35*, 707–723. doi:10.1016/S0005-7894(04)80016-9

Gardner, F. L., & Moore, Z. E. (2012). Mindfulness and acceptance models in sport psychology: A decade of basic and applied scientific advancements. *Canadian Psychology/Psychologie Canadienne*, *53*, 309. doi:10.1037/a0030220

Goldin, P. R., & Gross, J. J. (2010). Effects of mindfulness-based stress reduction (MBSR) on emotion regulation in social anxiety disorder. *Emotion*, *10*, 83. doi:10.1037/a0018441

Goodman, F. R., Kashdan, T. B., Mallard, T. T., & Schumann, M. (2014). A brief mindfulness and yoga intervention with an entire NCAA Division I athletic team: An initial investigation. *Psychology of Consciousness: Theory, Research, and Practice*, *1*, 339. doi:10.1037/cns0000022

Grossman, P., Niemann, L., Schmidt, S., & Walach, H. (2004). Mindfulness-based stress reduction and health benefits: A meta-analysis. *Journal of Psychosomatic Research*, 57, 35–43. doi:10.1016/S0022-3999(03)00573-7

Gruzelier, J. H. (2014). EEG-neurofeedback for optimising performance. I: A review of cognitive and affective outcome in healthy participants. *Neuroscience & Biobehavioral Reviews*, *44*, 124–141. doi:10.1016/j.neubiorev.2013.09.015

Hayes, S. C., Luoma, J. B., Bond, F. W., Masuda, A., & Lillis, J. (2006). Acceptance and commitment therapy: Model, processes and outcomes. *Behaviour Research and Therapy*, *44*, 1–25. doi:10.1016/j.brat.2005.06.006

Hofmann, S. G., Sawyer, A. T., Witt, A. A., & Oh, D. (2010). The effect of mindfulness-based therapy on anxiety and depression: A meta-analytic review. *Journal of Consulting Clinical Psychology*, *78*, 169–183. doi:10.1037/a0018555

Hwang, Y.-S., & Kearney, P. (2013). A systematic review of mindfulness intervention for individuals with developmental disabilities: Long-term practice and long lasting effects. *Research in Developmental Disabilities*, *34*, 314–326. doi:10.1016/j.ridd.2012.08.008.

Ivanovski, B., & Malhi, G. S. (2007). The psychological and neurophysiological concomitants of mindfulness forms of meditation. *Acta Neuropsychiatrica*, *19*, 76–91. doi:10.1111/j.1601-5215.2007.00175.x

Ju, Y. J., & Lien, Y. W. (2016). Better control with less effort: The advantage of using focused-breathing strategy over focused-distraction strategy on thought suppression. *Consciousness and Cognition*, *40*, 9–16. doi:10.1016/j.concog.2015.12.002

Kabat-Zinn, J. (2003). Mindfulness-based interventions in context: Past, present, and future. *Clinical Psychology: Science and Practice*, *10*, 144–156. doi:10.1093/clipsy.bpg016

Kabat-Zinn, J. (2011). Some reflections on the origins of MBSR, skillful means, and the trouble with maps. *Contemporary Buddhism*, *12*, 281–306. doi:10.1080/14639947.2011.564844

Kangas, M. (2014). The evolution of mindfulness-based cognitive therapy. *Australian Psychologist*, *49*, 280–282. doi:10.1111/ap.12072

Kaufman, K. A., Glass, C. R., & Arnkoff, D. B. (2009). Evaluation of mindful sport performance enhancement (MSPE): A new approach to promote flow in athletes. *Journal of Clinical Sport Psychology*, *25*, 334–356.

Kee, Y. H., & Wang, C. J. (2008). Relationships between mindfulness, flow dispositions and mental skills adoption: A cluster analytic approach. *Psychology of Sport and Exercise*, *9*, 393–411. doi:10.1016/j.psychsport.2007.07.001

Keng, S.-L., Smoski, M. J., & Robins, C. J. (2011). Effects of mindfulness on psychological health: A review of empirical studies. *Clinical Psychology Review*, *31*, 1041–1056. http://doi.org/10.1016/j.cpr.2011.04.006

Kim, J., Lee, H. M., Kim, W. J., Park, H. J., Kim, S. W., Moon, D. H., Woo, M., et al. (2008). Neural correlates of pre-performance routines in expert and novice archers. *Neuroscience Letters*, *445*, 236–241.

Khazan, I. (2015). Mindfulness- and acceptance-based biofeedback. *Biofeedback*, *43*, 104–110. doi:10.5298/1081-5937-43.3.08

Kleen, M., & Reitsma, B. (2011). Appliance of heart rate variability biofeedback in acceptance and commitment therapy: A pilot study. *Journal of Neurotherapy*, *15*, 170–181. doi:10.1080/10874208.2011.570695

Klich, U. (2015). The integration of mindfulness-based biofeedback and compassion in the healthcare setting. *Biofeedback*, *43*, 111–116. doi:10.5298/1081-5937-43.3.07

Krygier, J. R., Heathers, J. A., Shahrestani, S., Abbott, M., Gross, J. J., & Kemp, A. H. (2013). Mindfulness meditation, well-being, and heart-rate variability: A preliminary investigation into the impact of intensive Vipassana meditation. *International Journal of Psychophysiology*, *89*, 305–313. doi:10.1016/j.ijpsycho.2013.06.017

Landers, D. M., Petruzzello, S. J., Salazar, W., Crews, D. J., Kubitz, K. A., Gannon, T. L., & Han, M. (1991). The influence of electrocortical biofeedback on performance in pre-elite archers. *Medicine & Science in Sports & Exercise*, *23*, 123–129.

Lehrer, P., Sasaki, Y., & Saito, Y. (1999). Zazen and cardiac variability. *Psychosomatic Medicine*, *61*, 812–821. doi:10.1097/00006842-199911000-00014

Lomas, T., Ivtzan, I., & Fu, C. H. (2015). A systematic review of the neurophysiology of mindfulness on EEG oscillations. *Neuroscience and Biobehavioral Reviews*, *57*, 401–410. doi:10.1016/j.neubiorev.2015.09.018

Milton, J., Solodkin, A., Hlustik, P., & Small, S. L. (2007). The mind of expert motor performance is cool and focused. *NeuroImage*, *35*, 804–813. doi:10.1016/j.neuroimage.2007.01.003

Moore, Z. E., & Gardner, F. L. (2014). Mindfulness and performance. In Editor (Eds.), *The Wiley Blackwell handbook of mindfulness* (pp. 986–1003). City, ST: Publisher.

Plaza, I., Demarzo, M. M. P., Herrera-Mercadal, P., & García-Campayo, J. (2013). Mindfulness-based mobile applications: Literature review and analysis of current features. *JMIR mHealth and uHealth*, *1*(2), e24. doi:10.2196/mhealth.2733

Prätzlich, M., Kossowsky, J., Gaab, J., & Krummenacher, P. (2016). Impact of short-term meditation and expectation on executive brain functions. *Behavioural Brain Research*, *297*, 268–276.

Ratanasiripong, P., Park, J. F., Ratanasiripong, N., & Kathalae, D. (2015). Stress and anxiety management in nursing students: Biofeedback and mindfulness meditation. *Journal of Nursing Education*, *54*, 520–524. doi:10.3928/01484834-20150814-07

Rosenzweig, S., Reibel, D. K., Greeson, J. M., Brainard, G. C., & Hojat, M. (2003). Mindfulness-based stress reduction lowers psychological distress in medical students. *Teaching and Learning in Medicine*, *15*, 88–92. doi:10.1207/s15328015tlm1502_03

Scott-Hamilton, J., Schutte, N. S., & Brown, R. F. (2016). Effects of a mindfulness intervention on sports-anxiety, pessimism, and flow in competitive cyclists. *Applied Psychology: Health and Well-Being*, *8*, 85–103. doi:10.1111/aphw.12063

Shapiro, S. L., Astin, J. A., Bishop, S. R., & Cordova, M. (2005). Mindfulness-based stress reduction for health care professionals: results from a randomized trial. *International Journal of Stress Management*, *12*, 164. doi.org/10.1037/1072-5245.12.2.164

Sherlin, L., Arns, M., Lubar, J., Heinrich, H., Kerson, C., Strehl, U., & Sterman, M. B. (2011). Neurofeedback and basic learning theory: Implications for research and practice. *Journal of Neurotherapy*, *15*, 292–304. doi:10.1080/10874208.2011.623089

Sherlin, L. H., & Larson Ford, N. (2016). Biofeedback and neurofeedback in enhancing performance. In G. Tan, F. Shaffer, R. Lyle, & I. Teo (Eds.), *Evidence-based practice in biofeedback and neurofeedback* (3rd ed., pp. XX–XX). Wheat Ridge, CO: Association for Applied Psychophysiology and Biofeedback.

Speca, M., Carlson, L. E., Goodey, E., & Angen, M. (2000). A randomized, wait-list controlled clinical trial: the effect of a mindfulness meditation-based stress reduction program on mood and symptoms of stress in cancer outpatients. *Psychosomatic Medicine*, *62*, 613–622. doi:10.1097/00006842-200009000-00004

Thompson, R. W., Kaufman, K. A., De Petrillo, L. A., Glass, C. R., & Arnkoff, D. B. (2011). One year follow-up of mindful sport performance enhancement (MSPE) with archers, golfers, and runners. *Journal of Clinical Sport Psychology*, *5*, 99–116. doi:10.1017/cbo9781139871310.009

Teasdale, J. D., Segal, Z. V., Williams, J. M. G., Ridgeway, V. A., Soulsby, J. M., & Lau, M. A. (2000). Prevention of relapse/recurrence in major depression by mindfulness-based cognitive therapy. *Journal of Consulting and Clinical Psychology*, *68*, 615. doi:10.1016/b978-012369429-4/50034-3

Thompson, T., Steffert, T., Ros, T., Leach, J., & Gruzelier, J. (2008). EEG applications for sport and performance. *Methods*, *45*, 279–288. doi:10.1016/j.ymeth.2008.07.006

Valentine, E. R., & Sweet, P. L. G. (1999). Meditation and attention: A comparison of the effects of concentrative and mindfulness meditation on sustained attention. *Mental Health, Religion & Culture*, *2*, 59–70. doi:10.1080/13674679908406332

van Aalderen, J. R., Breukers, W. J., Reuzel, R. P. B., & Speckens, A. E. M. (2014). The role of the teacher in mindfulness-based approaches: A qualitative study. *Mindfulness*, *5*, 170–178. doi:10.1007/s12671-012-0162-x

Vernon, D. J. (2005). Can neurofeedback training enhance performance? An evaluation of the evidence with implications for future research. *Applied Psychophysiology and Biofeedback*, *30*, 347–364. doi:10.1007/s10484-005-8421-4

Wilson, V., & Peper, E. (2011). Athletes are different: Factors that differentiate biofeedback/neurofeedback for sport versus clinical practice. *Biofeedback*, *39*, 27–30. doi:10.5298/1081-5937-39.1.01

Woodman, G. F. (2010). A brief introduction to the use of event-related potentials in studies of perception and attention. *Attention, Perception, & Psychophysics*, *72*, 2031–2046. doi:10.3758/APP.72.8.2031

Wyner, D. R. (2015). Pilot study of a university counseling center stress management program employing mindfulness and compassion-based relaxation training with biofeedback. *Biofeedback*, *43*, 121–128. doi:10.5298/1081-5937-43.3.01

Noel L. Ford

Leslie H. Sherlin

Sarah N. Wycoff

Correspondence: Noel Larson Ford, MA, 2164 E. Broadway Rd, Tempe, AZ 85285, email: Noel.ford@senselabs.com.