Employing pain and mindfulness to understand consciousness: a symbiotic relationship
Joshua A Grant and Fadel Zeidan

Consciousness, defined here as the quality of awareness of self and the corresponding sensory environment, is considered to be one of the most enigmatic and contentious areas of scholarly dissection and investigation. The subjective experience of pain is constructed and modulated by a myriad of sensory, cognitive, and affective dimensions. Thus, the study of pain can provide many inroads to a concept like consciousness that the traditional sense modalities do not. Mindfulness defined here as non-reactive awareness of the present moment, can uniquely control and/or modulate particular substrates of conscious experience. Thus, in combination with brain imaging methodologies, we propose that the interactions between pain and mindfulness could serve as a more comprehensive platform to disentangle the biological and psychological substrates of conscious experience. The present review provides a brief synopsis on how combining the study of pain and mindfulness can inform the study of consciousness, delineates the multiple, unique brain mechanisms supporting mindfulness-based pain relief, and describes how mindfulness uniquely improves the affective dimension of pain, an important consideration for the treatment of chronic pain.

Pain is the breaking of the shell that encloses the understanding
Khalil Gibran

How, or why, does conscious experience arise? What brain processes or regions determine whether we will have a particular experience? Identifying the biological substrates that lead to and/or modify our conscious experience is regarded as one of the most enigmatic and contentious areas of scholarly dissection and investigation. To be clear, there are multiple issues to be resolved, some more tractable than others. In this paper, we barely scratch the surface on the topic(s) of the ‘not-so-easy’ easy problems of consciousness [1] that may be advanced through the study of pain and mindfulness [2].

For the sake of simplicity, we define consciousness as the quality of awareness of the experience corresponding to self and the respective sensory environment [3–6]. If we make the reasonable assumptions that consciousness does indeed exist and that it is, ‘roughly synonymous with having qualia’ there are still myriad puzzles to be solved [7]. These generally relate to the neurobiological correlates of consciousness and the neural processes which allow and influence our experiences, that is—to explain how the brain works. Neuroimaging and other objective methodologies have enabled neuroscientists to identify the behavioral and neural processes that support a wide array of sensory and cognitive constructs which at the very least, should relate to consciousness. For example, an ‘easy problem’ of consciousness would be explaining why it is that in one condition a peri-threshold stimulus is detected while in another condition it fails to reach conscious awareness [8]. The classical sensory and motor domains have all been used to explore consciousness and have taken us forward in our understanding of which brain areas underlie which aspects of experience. Viewing images inside of a functional magnetic resonance imaging (fMRI) scanner will produce significant activation in a number of visual cortical areas (i.e. occipital lobe) [9]. Auditory experiments have compared detected and non-detected sound stimuli revealing brain areas which are more active when a stimulus is consciously perceived [10]. A ‘finger tapping’ task will lead to significant activation of the primary motor cortex (i.e. parietal lobe) [11]. Yet, despite these once unfathomable feats, there is still much to learn about the brain regions and processes that sculpt our ever changing stream of consciousness.

Pain and consciousness
Unlike the classical sensory domains, the experience of pain is far from unimodal [12,13]. Nociception is the
physiological processing that facilitates noxious information, which at some point in the process becomes the conscious experience of pain (see Refs. [14,15]) for counter perspectives). Noiceptive processing is largely non-conscious and interacts with a cascade of psychosocial, cultural, and demographic factors to produce pain. The International Association for the Study of Pain (IASP) defines pain as “an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage” [16]. It is well established that the experience involves sensory, cognitive, and affective dimensions which, remarkably parallel the processes that comprise our conscious experience. Furthermore, pain is influenced by a host of factors ranging from cognitive processes such as attention to psychological constructs such as expectations [17–19], with the addition of clear genetic, social, and cultural influences [20–23]. Thus, with such a broad range of influences, the study of pain provides many inroads to a concept like consciousness that the traditional sense modalities do not.

**Mindfulness and consciousness**

Of course, for pain to inform us about consciousness we must be able to manipulate it and specifically in ways that are relevant to understanding consciousness. Converging lines of evidence demonstrate that a spectrum of self-regulatory techniques, including mindfulness-based meditation, can uniquely control and/or modulate particular substrates of conscious experience. To this extent, the combination of psychophysics, mindfulness and neuroimaging methodologies has provided unique insights into the capacity of an individual’s ability to self-regulate the salient and intrusive experience of pain and other sensory experiences. For these reasons, we suggest that studying the interactions between pain and mindfulness could serve as a more comprehensive model or platform to disentangle the manifestations of conscious experience.

While much could be said concerning the definition of mindfulness, for present purposes we consider mindfulness as a form of non-reactive awareness of one’s present-moment experience [24]. Mindfulness can be considered a meta-cognitive state that exists to varying degrees in everyone. It can also be trained and developed by mindfulness-based practices (for reviews-see Refs. [25–29]). Traditional Buddhist texts have long described the benefits of mindfulness-based practices to influence pain. The *Sallatha Sutta*, a Theravadin Buddhist scripture from the Pali Canon (translated as The Arrow) is particularly interesting. The verse explicitly states that there is a key difference in how trained and untrained individuals experience pain [30]. The Sutta likens the reaction to pain to being struck by an arrow and, in the case of untrained individuals, being struck immediately after by a second arrow. The two arrows are described as representing physical and mental pain. Physical pain seems to refer to the noxious sensation one initially feels while mental pain is described as the worry, distress and suffering that follows. The claim of Buddhist contemplatives is that mindfully-trained individuals, because they do not cling to sensory pleasure, also do not experience this follow-up, seemingly self-produced experience of pain. This traditional account is remarkably similar to modern views of pain in several ways.

**Mindfulness and pain**

Scientifically a pain response to a physical insult is known to involve two components. First pain is experienced very quickly and is typically sharp, propagating along myelinated A-delta fibers. Second pain arises somewhat slower, being carried by unmyelinated C-fibers [31,32]. While first pain performs protective functions such as withdrawal, second pain lasts longer, is often more dull, and likely plays many more diverse functions. It has been suggested, consistent with the traditional Buddhist sutta, that second pain is ‘affective’ in nature [33–37]. At an experiential level it is also well established that there are distinctions between pain intensity (sensory) and pain unpleasantness (affective) [38,39]. Low level neural regions including the thalamus, primary and secondary somatosensory cortices are more involved with processing the sensory dimension of pain, whereas the evaluative aspects of pain and pain affect is processed in the anterior insula, dorsal anterior cingulate, and prefrontal cortices [40]. The *Sallatha Sutta* was also surprisingly accurate in describing how mindfulness training uniquely attenuates affective pain (the second arrow) in contrast to sensory pain (the first arrow). In comparison to other pharmacological and behavioral pain therapies, mindfulness meditation has been repeatedly shown to be significantly more effective at attenuating the affective dimension of pain more than the intensity/sensory aspect of pain. Consistent with the notion that mindfulness is a quality or skill that can be trained, it appears that different mechanisms underlie the effects at different stages of proficiency. This is very important as it helps give texture to the largely intangible concept of consciousness.

The human experience is driven by reciprocal connectivity between so-called subject–object dichotomies [41–43]. Yet, one of the biggest hurdles in studying consciousness is pinning it down enough to make a meaningful comparison between two conditions. While there may be a constant underlying state that we experience as consciousness, which would only change when we’re something other than conscious, we can learn about that state by comparing how it’s content changes in people with varying skill sets—such as mindfulness. Thus, it is imperative that we specify the disparate mechanisms that appear to be involved across different meditative traditions (techniques) and proficiency. Brain imaging findings reveal that mindfulness meditation impacts the subjective experience of pain through multiple mechanisms including the modulation of cognitive-affective appraisals.
of noxious stimuli, as opposed to attenuating nociceptive information supra-spinally and/or at the level of the spinal cord [44–49]. However, some of said mechanisms are dependent on the level of mindfulness-based mental training.

Pain relieving mechanisms supporting novice and adept mindfulness practitioners

We propose that, at the early stages of training (less than eight weeks of training), mindfulness meditation alters the evaluation and meaning of pain by modulating self-appraisal processes. That is, novice meditators employ higher order brain regions [orbitofrontal cortex (OFC), subgenual anterior cingulate cortex (sgACC), right anterior insula] to down regulate ascending nociceptive input at the level of the thalamus. We suggest that this occurs through shifts in executive attention and the newly trained ability to assuage affective reactions to noxious stimuli [48,49]. Activation of the OFC may facilitate inhibitory connections of the GABAergically mediated thalamic reticular nuclei to further reduce the proliferation of nociceptive information throughout the cortex [evidenced by reductions in thalamic, periaqueductal gray matter (PAG), primary somatosensory activation (SI)]. Thus, in our view, brief mental training in mindfulness meditation engages cortico–thalamo–cortical interactions to reduce pain through mechanisms supporting the filtering of ascending nociceptive information [24,50] via unique reappraisal processes to essentially ‘close the gate’ on sensory (first) and affective (second) pain dimensions. We propose that novice mindfulness practitioners can effectively attend to qualitative aspects of noxious stimulus and attenuate accompanying affective appraisals by reorienting attention back to the meditative object (i.e. breath) in a non-reactive process.

In comparison, we propose that longer bouts of mindfulness meditation training (greater than eight weeks) can produce more stabilized, trait-like improvements on behavioral and neural pain responses [51–57]. Adept mindfulness practitioners report feeling less pain in response to a noxious stimulus when compared to age-matched controls even when not practicing mindfulness [58], demonstrating that long-term, plastic changes in how one experiences pain can be produced with longer bouts of training. Though, it remains to be firmly established that these results are causal and not the product of pre-existing differences. Contrary to beginner meditators, the neural mechanisms supporting long-term mindfulness practice are associated with significantly greater activation in somatosensory, insular and cingulate regions coupled with greater deactivation of appraisal-related brain regions (vmPFC) [44,46]. Thus, it seems that ascending nociceptive information is robustly perceived and processed, but importantly appraisals of said information are attenuated. The proposed decoupling between low level nociceptive processing and the corresponding meaning and/or contextualization of what the pain means to the self, in long-term meditation practitioners, provides evidence that the analgesic effects of meditation can be developed and enhanced through greater practice [46], a critical consideration for those seeking long-lasting narcotic-free pain relief [59]. In terms of consciousness, the mindfulness/pain literature teaches us more about how our ‘final’ experiences are shaped and importantly, suggests there may be an alternative to the suffering we seem to believe is inherent to physical pain. That is, advanced mindfulness training may result in feeling only the first (physical) arrow of pain.

Considerations for mindfulness, pain and consciousness

The potential implications of these findings for clinical pain are non-trivial. Evidence that the analgesic effects of meditation can be developed and enhanced through greater practice is critical for those seeking long-lasting, narcotic-free pain relief. Unlike the majority of pharmacological and behavioral approaches for pain, mindfulness hasn’t been shown to habituate or plateau in efficacy. Chronic pain conditions are accompanied with physiological dysfunction (i.e. nerve damage, herniated disc; inflammation) that renders the intensity of pain to be present, daily. This is important because it is now well established that a primary target for pain management therapies corresponds to the affective dimension of pain (i.e. pain interference; pain bothersome; pain unpleasantness) [60–67]. This makes sense as, it is likely the more mental or affective aspects of pain that color the patient’s quality of life. Thus, mindfulness-based therapies may be particularly effective for pain because they enhance one’s ability to self-regulate reactions to sensory experiences through acceptance-based strategies without the emphasis of changing one’s attitude toward said experience(s).

In a seminal study conducted by Price et al. [35], cancer patients rated their pain significantly higher on the affective dimension of pain when compared to the sensory aspect of pain. In contrast, labor pain was associated with significantly higher pain intensity when compared to pain unpleasantness ratings. It was postulated that the contextual evaluation of welcoming a new baby into the world when compared to facing one’s own death has profound implications for what might have otherwise been very similar experiences, in terms of pain. We have argued that mindfulness-based mental training resembles physical exercise [24,25]. That is, when an individual exercises a muscle group, said muscle group progressively strengthens as a function of training frequency. Thus, it seems as if one’s ability to be aware of awareness can be strengthened like a muscle. Mindfulness training can strengthen one’s ability to sustain attention in the present moment, non-reactively in a fashion where the state of mindfulness transitions to a mindfulness-based trait. These effects demonstrate that mindfulness holds promise in improving
components of the pain experience that significantly debilitate one’s quality of life and may lead to the comorbidities commonly exhibited in chronic pain patients. Mindfulness may uniquely impact how one relates to and/or may chance one’s relationship with their respective pain. This bridges us back to appreciating how the interaction between mindfulness and pain informs consciousness.

We postulate that mindfulness training reduces the significance and or motivational influences of pain on said organism. Some have proposed that mindfulness decouples pain-related sensory discrimination from self-related appraisals [24,25]. Others have stated that mindfulness integrates intrinsic and extrinsic processes that reduce the dualistic nature of my (intrinsic) pain (extrinsic). Recent evidence suggests that the precuneus/posterior cingulate cortex (PCC) is a mechanistic target for mindfulness-based therapies [68–72]. The precuneus/PCC has been characterized as a central node in the default mode network, a neural network associated with facilitating self-referential and the integration of intrinsic, self-narrative and extrinsic-perceptual processes [73–76]. The PCC is highly integrated across a host of cortical and subcortical regions that renders it well suited to varying levels of consciousness [77]. Higher PCC activation is believed to reflect higher levels of sensory and perceptual integration [78]. Mindfulness is postulated to dissolve subject–object dichotomies [79–81]. To this extent, adept meditators have exhibited significantly greater deactivation of the PCC when compared to age matched non-meditators [68,82,83]. We recently discovered that higher dispositional mindfulness, defined as the innate capacity to be aware of the present moment in a non-reactive manner, is associated with greater deactivation of the PCC and lower pain ratings [84]. Thus, the PCC may prove to be a significant mechanistic target for mindfulness-based pain relief as a function of training experience [85–87]. Through the scientific investigation of pain, we have learned that mindfulness impacts the moment-to-moment subjective experience by a) top–down attenuation of ascending low-level afferent processing at the level of the thalamus reducing the elaboration/significance of ascending sensory information, b) decoupling higher order appraisals from sensory discriminative processes, and c) reducing self-referential processes that enhance non-conceptual perceptual processes. These findings demonstrate that mindfulness modulates the subjective experience in distinct mechanistic fashion from other cognitive manipulations.

As the research in this field advances it may provide scientists with more testable hypotheses in terms of how the brain works. Said another way, it may help us tackle some of the easy problems of consciousness. For example, hypnosis is often used as an experimental tool as it allows the researchers to systematically vary aspects of experience that are not touchable by other means. Mindfulness could be used similarly. If advanced practitioners only experience first pain, or relatively little second pain, what influence does this have on x, y or z? It may provide a more comprehensive or ‘clean’ view on what first and second pain actually comprises, how separable they really are, and what brain areas contribute to each. We are a long way from understanding the intricacies of conscious experience but the coupling of mindfulness and pain promises to be an important tool along the way.

Conflict of interest statement
Nothing declared.

Acknowledgement
This work was supported by the National Center for Complementary and Integrative Health (R00-AT008238, R01AT009093).

References


Mindfulness, pain and consciousness

Grant and Zeidan 197


64. Jacob JA: As opioid prescribing guidelines tighten, mindfulness meditation holds promise for pain relief. JAMA 2016, 315:2385-2387.


