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Dispositional mindfulness is associated with reduced implicit learning

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ABSTRACT

Behavioral and neuroimaging evidence suggest that mindfulness exerts its salutary effects by disengaging habitual processes supported by subcortical regions and increasing effortful control processes supported by the frontal lobes. Here we investigated whether individual differences in dispositional mindfulness relate to performance on implicit sequence learning tasks in which optimal learning may in fact be impeded by the engagement of effortful control processes. We report results from two studies where participants completed a widely used questionnaire assessing mindfulness and one of two implicit sequence learning tasks. Learning was quantified using two commonly used measures of sequence learning. In both studies we detected a negative relationship between mindfulness and sequence learning, and the relationship was consistent across both learning measures. Our results, the first to show a negative relationship between mindfulness and implicit sequence learning, suggest that the beneficial effects of mindfulness do not extend to all cognitive functions.

1. Introduction

Mindfulness refers to the ability to stay attentive and receptive to events and experiences taking place in the present and thus disengage from habitual actions and thought tendencies. This construct has grown in popularity in recent years because it has been linked to a number of positive psychological and cognitive outcomes (Brown & Ryan, 2003). However, there may be tradeoffs to mindfulness, such that it benefits some domains of functioning but not others. The goal of the present study was to investigate the hypothesis that higher mindfulness is associated with *reduced* implicit learning, the type of learning that can take place without intent to learn or awareness of what has been learned (Reber, 1967).

Individual differences in the propensity, or disposition, for mindfulness, as assessed through self-report, are associated with enhanced psychological wellbeing. For example, people higher in mindfulness tend to have fewer symptoms of anxiety and depression (Brown & Ryan, 2003; Rasmussen & Pidgeon, 2011; Salmoirago-Blotcher, Crawford, Carmody, Rosenthal, & Ockene, 2011), lower levels of self-consciousness (Brown & Ryan, 2003; Evans, Baer, & Segerstrom, 2009), and lower levels of negative affect (Brown & Ryan, 2003). Dispositional mindfulness is also associated with better performance on a wide

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range of cognitive tasks that have implications for maintaining psychological health. For example, higher mindfulness is associated with better performance on sustained attention (Mrazek, Smallwood, & Schooler, 2012; Schmertz, Anderson, & Robins, 2009) and inhibitory control (Oberle, Schonert-Reichl, Lawlor, & Thomson, 2011) tasks, and with increased persistence on challenging tasks, reflecting an enhanced ability of more mindful people to regulate their emotions and attentional resources in the face of frustration (Evans et al., 2009). Studies measuring dispositional mindfulness therefore suggest that being mindful can benefit cognitive and mental health.

Mindfulness can also be cultivated through practice. Studies comparing the outcomes of mindfulness-based training groups to various matched control groups provide evidence for a causal link between mindfulness and improved psychological wellbeing and cognitive functioning. In healthy adults, mindfulness training increases performance on cognitive tasks assessing executive functions, including working memory (Jha, Stanley, Kiyonaga, Wong, & Gelfand, 2010; Mrazek, Franklin, Phillips, Baird, & Schooler, 2013), attention (Jha, Krompinger, & Baime, 2007) and inhibitory control (Allen et al., 2012). In the clinical realm, mindfulness-based therapies are effective at reducing symptoms and relapses of a wide range of psychiatric disorders, including depression and anxiety, chronic pain, addictions, and disordered eating (e.g., Barnhofer et al., 2009; Kabat-Zinn, 1982; Kristeller & Hallett, 1999; Rosenzweig et al., 2010; Shahar, Britton, Sbarra, Figueredo, & Bootzin, 2010; Tang, Tang, & Posner, 2013; Teasdale et al., 2000).

These effects of mindfulness training provide clues about its underlying neural bases. Many of the disorders shown to be ameliorated by mindfulness training have been linked with abnormal functioning and/or structure in brain regions supporting emotional control and processing, especially regions in the prefrontal cortex, including anterior cingulate and dorsolateral prefrontal cortices (Beauregard, Paquette, & Lévesque, 2006; Bishop, Duncan, Brett, & Lawrence, 2004; Luerding, Weigand, Bogdahn, & Schmidt-Wilcke, 2008; Phillips, Drevets, Rauch, & Lane, 2003; Uher et al., 2004).

The same prefrontal regions shown to have abnormalities in patient populations are consistent with those implicated in cognitive control and executive functioning in healthy populations (Cabeza & Nyberg, 2000; Miller & Cohen, 2001). Therefore, the mechanism by which mindfulness is hypothesized to exert its many salutary effects is by disengaging individuals from habitual response tendencies supported by subcortical neural systems (e.g., the striatum) and promoting engagement of executive control functions mediated by the frontal lobes (Holzel et al., 2013; Hölzel et al., 2011; Teper, Segal, & Inzlicht, 2013). Supporting this mechanistic hypothesis, higher mindfulness is associated with smaller caudate (a region in the striatum) and amygdala volumes (Taren, Creswell, & Gianaros, 2013), and with increases in both volume and functioning of prefrontal regions implicated in cognitive control (Grant, Courtemanche, Duerden, Duncan, & Rainville, 2010; Hölzel et al., 2007; Modinos, Ormel, & Aleman, 2010; Tang et al., 2010, 2013). For example, Tang et al. (2013) demonstrated that the resting state activity of several regions in the prefrontal cortex (i.e., brain activity during non-goal directed tasks) increased following mindfulness training. The changes in resting brain activity coincided with decreases in subjective craving and objective smoking behavior in a subset of participants who were smokers with no prior intent to quit. The authors interpreted the results as suggesting that mindfulness-induced changes in the underlying structure and function of frontal regions may have lasting, tonic influences on self-control capacity and, consequently, smoking behavior. Together, these findings raise the possibility that mindfulness may exert its salutary effects on human behavior by strengthening one of two competing neural systems, increasing the relative involvement of frontal control in cognitive functioning. For example, greater mindfulness may strengthen reliance on cognitive functions driven by frontal control processes, resulting in improved performance on cognitive functions relying on frontal brain regions but not those relying on subcortical structures.

If, as the evidence presented above supports, mindfulness is associated with greater engagement and altered structure of frontal control regions, then people higher in mindfulness might be *worse* at implicit cognitive processes in which reduced frontal involvement has been shown to benefit performance. Findings from a recent study by Whitmarsh, Uddén, Barendregt, and Petersson (2013) support this hypothesis; they found that individuals higher in dispositional mindfulness displayed poorer learning of artificial grammar, a cognitive task thought to depend on subcortical structures and to be impaired by explicit task instructions (Reber, 1976). The authors propose that greater mindfulness reduces habitual responding to unconsciously acquired preferences in the task, perhaps by promoting a non-reactive and non-judgmental disposition. The findings from this study demonstrate the potential relevance and importance of dispositional tendencies like mindfulness on implicit types of learning and retrieval.

In the present study, we examined how mindfulness relates to implicit sequence learning, hereafter referred to as *sequence learning*. This is the process by which people acquire complex regularities occurring in sequences of events without intending to learn them and without subsequent awareness of what has been learned. The ability to learn sequential relationships is important because it underlies essential functions of daily life; it contributes to our ability to perceive the world efficiently, to learn and use language, and even to engage in social interactions (Kuhl, 2004; Lieberman, 2000; Saffran, Newport, & Aslin, 1996).

Experimental studies of sequence learning, including those using neuroimaging, highlight the role of subcortical structures, especially the striatum, for this type of learning (Bennett, Madden, Vaidya, Howard, & Howard, 2011; Howard & Howard, 2013; Rauch et al., 1997; Rieckmann, Fischer, & Bäckman, 2010; Simon, Vaidya, Howard, & Howard, 2012; Simon et al., 2011). Crucially, there is also intriguing evidence that sequence learning is *impaired* by engagement of frontal control processes (Filoteo, Lauritzen, & Maddox, 2010; Foerde, Knowlton, & Poldrack, 2006; Howard & Howard, 2001; Nemeth, Janacsek, Polner, & Kovacs, 2012). For example, sequence learning improves following inhibitory theta burst stimulation (TBS) to the dorsolateral prefrontal cortex (Galea, Albert, Ditye, & Miall, 2009), and following hypnosis, a practice thought to temporarily disconnect frontal areas, such as the anterior cingulate, from other brain areas, such as the striatum