



## Delineating the contributions of sustained attention and working memory to individual differences in mindfulness

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### ABSTRACT

Mindfulness can be deconstructed into two constituent components: present-moment awareness and acceptance. Attention and working memory are theorized to contribute to individual differences in trait mindfulness, although the precise relationship among these constructs remains unclear. The purpose of the present study was to evaluate the association of neurocognitive indices of attention and working memory with a bidimensional trait measure of mindfulness. Fifty-five psychiatrically and neurologically healthy adults completed the Conners Continuous Performance Test, Penn Letter *N*-back Test, and Philadelphia Mindfulness Scale. Results indicated that present-moment awareness was associated with a response speed variability measure of sustained attention, whereas acceptance was more strongly linked to working memory efficiency, even after accounting for general intellectual ability. These findings suggest that sustained attention and working memory capacities may differentially subservise individual differences in present-moment awareness and acceptance, thereby illuminating our understanding of the cognitive mechanisms which may underlie trait mindfulness.

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### 1. Introduction

Mindfulness represents a complex construct which is thought to be composed of two primary trait dimensions: present-moment awareness and acceptance (Cardaciotto, Herbert, Forman, Moitra, & Farrow, 2008). The role of cognition in supporting these two constituents of trait mindfulness has been elaborated upon in theoretical models of this construct. *Awareness* is theorized to be carried out through the self-regulation of attention – “observing and attending to the changing field of thoughts, feelings, and sensations from moment to moment” (Bishop et al., 2004, p. 232). The awareness of present-moment experiences is thus thought to require sustained attention so as to maintain focus toward ongoing events over extended periods of time. *Acceptance* reflects an orientation to experience characterized by a non-judgmental attitude toward internal and external events such that an individual is experientially open to the present moment (Bishop et al., 2004). This dimension of mindfulness is thought to be a relational process whereby individuals are open and receptive to experience, a process which when fostered can lead to a higher level of cognitive complexity. Indeed, continued practice with acceptance can lead to improved differentiation, for example, among thoughts, emo-

tions and physical sensations (Brown & Ryan, 2003). Aside from theoretical models of mindfulness, it remains unclear how specific cognitive functions might serve to support individual differences in mindfulness-based awareness and acceptance.

A small number of studies have examined the contributions of sustained attentional abilities to trait aspects of mindfulness. Schmertz, Anderson, and Robins (2009) evaluated the relationship between several self-report measures of mindfulness and performance indices on a well-validated test of sustained visual attention, the Conners Continuous Performance Test-II (CPT-II; Conners, 2000). This task requires individuals to press a button to target stimuli (i.e., any letter except for *X*) and withhold their responses to a non-target stimulus (i.e., the letter *X*). The results of correlational analyses indicated that lower levels of trait awareness were associated with more frequent omission errors (i.e., failures to respond to target stimuli), suggesting that less awareness of present-moment experiences may predispose one to brief lapses in sustained visual attention. In contrast, variability of response times to target stimuli over the course of task performance was unrelated to trait mindfulness measures. Using a similar visual attention task, Josefsson and Broberg (2011) found that the total score on a multidimensional trait measure of mindfulness was associated with an aggregate index of errors on this task (including omissions, commissions and repeated responses to target stimuli). A study by Mrazek, Smallwood, and Schooler (in press) also showed that higher levels accuracy on a test of sustained visual attention could be linked to greater mindfulness-based awareness. Additionally, this

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investigation found that lower levels of awareness were associated with more erratic reaction times to target stimuli, which stands in contrast to the findings of the study by Schmertz et al. (2009) which found no such relationship. To further understand the relationship between sustained attention and trait mindfulness, Rosenberg, Noonan, DeGutis, and Esterman (2011) developed a novel continuous performance measure that was designed to induce greater response time variability to target stimuli by visually alternating background scenes while participants completed a primary visual attention task. Consistent with the findings of Mrazek et al. (in press), lower of mindfulness-based awareness was associated with greater reaction time variability, although this relationship was limited to conditions under which background visual distractions were introduced. With regard to error-related indices, there were too few errors on this task to meaningfully evaluate their associations with self-reported mindfulness.

Taken together, the results of a small number of studies indicate that higher levels of trait mindfulness may be associated with more accurate detection of visual stimuli on sustained attention tasks. This research, therefore, suggests that there may be a relationship between behavioral measures of attention and self-reports of mindfulness. Additionally, there are emerging data which indicate that a separate index of sustained attention, reaction time variability, may also be associated with trait measures of mindfulness, particularly with respect to the awareness component of this construct. These preliminary findings, however, are based on studies that are limited in a number of ways. First, the mindfulness measures employed in these studies typically did not differentiate between the primary dimensions of present-moment awareness and acceptance. The results reviewed above suggest that the relationship observed between sustained attention and mindfulness is likely most pertinent to the awareness component of this trait, although the research to date is ambiguous in this respect. Second, previous studies did not consistently discriminate between accuracy-based measures of sustained visual attention (i.e., omission errors) versus those based on reaction time variability to target stimuli, both of which have shown some association with mindfulness measures. Third, although theoretical formulations of present-moment awareness emphasize the self-regulation of attention as a critical component of mindfulness, research in this area has tended to disregard the potential contributions of working memory to trait mindfulness. *Working memory* represents a system for temporary storage and updating of information as it becomes available (Baddeley, 1992). Although there is little research to guide our hypotheses in this respect, one might suppose that greater working memory capacity may be associated with higher trait mindfulness, as working memory is presumably associated with “remembering” to be mindful.

The purpose of the present study, therefore, was to examine the relationship of trait mindfulness and its two constituent dimensions (i.e., awareness and acceptance) with indices of sustained attention (i.e., omission errors and reaction time variability) and working memory. Based on previous research (Rosenberg et al., 2011; Schmertz et al., 2009), we hypothesized that the awareness component of a bidimensional trait measure of mindfulness would be related to sustained attentional abilities, although it remains unclear the extent to which accuracy – versus reaction time variability – based indices might be implicated in this relationship. Furthermore, preliminary evidence from a mindfulness training program indicates that the awareness component of mindfulness may be associated with individual differences in working memory capacity (Chambers, Lo, & Allen, 2008). Therefore, we expected that working memory would be associated with trait mindfulness. An aspect of trait mindfulness which has not been studied from a cognitive perspective is that of acceptance; therefore, analyses related to this component of mindfulness are exploratory and may shed

light on the cognitive abilities which support this trait dimension. Clarifying the contributions of sustained attention and working memory to trait mindfulness will increase and broaden our understanding of the cognitive mechanisms which may underlie individual differences in this construct, and inform research to isolate the effects of mindfulness-based interventions on cognitive functioning in both clinical and non-clinical populations.

## 2. Materials and methods

### 2.1. Participant characteristics

All individuals included in this study were between 18 and 55 years of age, English-speaking, and able and willing to provide written informed consent to participate. Exclusion criteria included a history of serious physical illness or neurologic disorder (e.g., moderate or severe brain injury, seizure disorder), major psychiatric illness (e.g., schizophrenia, bipolar disorder), any serious visual or hearing impairments, or significant manual limitations that would affect performance on the laboratory tasks.

Fifty-five adults met the inclusion and exclusion criteria for this study. Their mean age was 19.9 years ( $SD = 3.8$ ) and 66% were female. At the time of assessments, participants had completed approximately 13.0 ( $SD = 1.4$ ) years of education. Overall intellectual level was estimated within the average range ( $M = 106.0$ ,  $SD = 7.3$ ) based on the Wechsler Test of Adult Reading (Wechsler, 2001). According to Canadian census categories, the ethnic composition of the sample was as follows: White (11%), Black (9%), Latin American (4%), Chinese (24%), West Asian (4%), Filipino (4%), Korean (4%), Arab (2%), South Asian (29%), and Other (11%). Nearly all participants (96%) were right-handed.

### 2.2. Procedure

This study received approval from the Social Sciences, Humanities and Education Research Ethics Board at the University of Toronto. Participants were students enrolled in introductory psychology courses at the University of Toronto Scarborough. All individuals gave written informed consent to participate in this research. Participants were compensated up to a maximum of three full course credits (or one full credit per hour) for introductory psychology or \$30 at a rate of \$10 per hour of participation.

Prior to beginning any of the laboratory procedures, participants completed a urine drug screen to test for the presence of illicit substances (amphetamines, cocaine, methamphetamines, opiates, and marijuana/THC) as these drugs may impact performance on the cognitive tests. All participants were free of illicit substances at the time of assessments. Testing took place within a quiet laboratory and all assessments were administered under the supervision of a licensed clinical psychologist (ACR).

### 2.3. Measures

#### 2.3.1. Philadelphia Mindfulness Scale (PHLMS; Cardaciotto et al., 2008)

The PHLMS is a bidimensional trait measure of mindfulness that was intentionally constructed to independently measure the two primary dimensions of mindfulness: present-moment awareness and acceptance. Participants are asked to rate 20 statements using a 5-point Likert-type scale (1 = *never*, 2 = *rarely*, 3 = *sometimes*, 4 = *often*, and 5 = *very often*) based on how frequently these experiences occurred over the previous week. Awareness items on the PHLMS capture the extent to which the respondent monitors ongoing internal and external experiences. For example, an item from this scale reads “I notice changes inside my body, like my heart beating faster or my muscles getting tense”. Acceptance items

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