

**Behavioral Assessment of Mindfulness: Defining Features, Organizing Framework, and
Review of Emerging Methods**

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Abstract

The development and implementation of psychometrically sound behavioral measures of mindfulness is important to advancing the science of mindfulness. To help organize, conceptualize, and guide the development of behavioral measures of mindfulness, we propose defining features, and a four-domain framework, of the behavioral assessment of mindfulness. The framework domains include measurement of (I) *objects* of mindful awareness, (II) *time-course* of mindful awareness, (III) *sensitivity* of mindful awareness, and (IV) *attitudes* towards present moment experience. We describe mindfulness processes in each domain, and review extant behavioral method(s) and specific behavioral measure(s) of mindfulness processes per domain. Four of the 12 reviewed measures demonstrate acceptable reliabilities and preliminary evidence of construct validity as measures of mindfulness processes.

Highlights

- Rigorous behavioral measures of mindfulness are critical to mindfulness science
- We propose key defining features of behavioral measures of mindfulness
- We propose four domains of behavioral assessment of mindfulness
- We describe mindfulness processes, behavioral methods and measures per domain
- Four behavioral mindfulness measures demonstrate acceptable psychometric properties

Keywords: behavioral measurement; first-person methods; interoceptive sensitivity; mindful attention; mindful attitudes; mindful awareness; mindfulness assessment

Introduction

In recent years there has been a rapid growth of interest in and study of mindfulness [1]. To facilitate this science, measurement methods of mindfulness have been developed and implemented widely, most commonly self-report scales of mindfulness [1-3]. However, reliance on self-report scales to measure mindfulness is limited in a number of fundamental and well-established ways (see [1, 4-6] for reviews). Consequently, responding to calls for advancing mindfulness measurement and thereby the science of mindfulness [1-3, 7], a number of research groups have developed and tested novel behavioral measures of mindfulness.

To-date, behavioral measures of mindfulness have emerged, organically so to speak, through creative efforts of various research groups. There are, however, no established defining features of behavioral measures of mindfulness to help guide such work. Likewise, there is no organizing framework or proposed set of principles to conceptually or methodologically organize this work to-date, nor to systematically guide the ongoing development of novel measurement methods. Accordingly, in this paper we propose defining features of behavioral measures of mindfulness, lay out a novel organizing framework for such measures, and review extant behavioral methods and measures of mindfulness.

Behavioral Assessment of Mindfulness: Defining Features

We argue that behavioral measures of mindfulness are characterized by two essential and defining features. First, *behavioral measures of mindfulness are designed to measure attention of, awareness of, or an attitude(s) towards, present moment experience(s)*. Second, *experimental stimuli in behavioral measures of mindfulness are present moment experiential objects of mindful awareness common to mindfulness training* (e.g., breath, interoception, mental events; c.f., numbers, words, or arrows on a computer screen). Such defining features may help to conceptualize and specify behavioral assessment of mindfulness, and may guide

the development of novel behavioral measures of mindfulness. Such features may also help to distinguish behavioral measures of mindfulness from long-standing cognitive tasks, such as those measuring external attention (typically visual attention) or executive functions (e.g., working memory), that have to-date been the primary behavioral measures of outcomes, or putative cognitive proxies, of mindfulness [8-10].

Behavioral Assessment of Mindfulness: Organizing Framework

We propose a framework consisting of four domains that may further help to organize, conceptualize, and guide the development of extant and emerging behavioral measures of mindfulness. Each domain entails one or more behavioral method(s) and measure(s) designed to assess a group of inter-related mindfulness processes (see Table 1). The domains include measurement of (I) *objects of mindful awareness*, (II) *time-course of mindful awareness*, (III) *sensitivity of mindful awareness*, as well as (IV) *attitudes towards present moment experience* (see Figure 1). Below, we describe the mindfulness process(es), behavioral method(s), and measure(s) included in each domain.

Table 1. *The four domains of behavioral assessment of mindfulness framework.*

Domains	Examples of Mindfulness Processes	Behavioral Methods	Examples of Behavioral Measures
I. Objects of Mindful Awareness	<ul style="list-style-type: none"> • Mindful awareness of a meditation anchor 	1. Real time ES of awareness of a specific present moment experiential object (e.g., meditation anchor, mind wandering) during mindfulness practice	Meditation Breath Attention Scores Task [15]
	<ul style="list-style-type: none"> • Mindful awareness of body 	2. Manualized qualitative coding of open-ended real-time ES reflecting the objects of mindful awareness during mindfulness practice	Mindful Awareness Task –
	<ul style="list-style-type: none"> • Mindful awareness of hedonic tone • Mindful awareness of mind 		Objects of mindful awareness scores
II. Time-Course of Mindful Awareness	<ul style="list-style-type: none"> • Sustained mindful awareness 	1. Performing a task that requires sustained mindful awareness of an easily detectable present moment experience (i.e., experience with high detection rates) for which correct and incorrect responses can be objectively verified	Breath Counting Task [26]

	<ul style="list-style-type: none"> • Sustained mindful awareness • Latency of disengagement from mindlessness 	2. Analysis of the timing and order of real time self-caught ES of mindful awareness during mindfulness practice to detect mindful and mindless time periods	Mindful Awareness Task – Time-course of mindful awareness scores
III. Sensitivity of Mindful Awareness	<ul style="list-style-type: none"> • Interoceptive sensitivity • Accurate detection of biased attention 	1. The first and third person correspondence method - Comparison of subjective (i.e., first-person) reports of a present moment experience with objective (i.e., third-person; e.g., physiological, behavioral) markers, or experimental manipulations, of that experience	Heartbeat Detection Tasks [37]
IV. Attitudes Towards Present Moment Experience	<ul style="list-style-type: none"> • Non-judging • Acceptance • Curiosity • Disidentification from experience 	1. An experimental elicitation of a present moment experience (e.g., using videos and audio), concurrent with an implicit attitude measurement of associations with, or attitudes towards, the elicited experience	Single Experience and Self- Implicit Association Test [57]

Note. ES = Experience Sampling

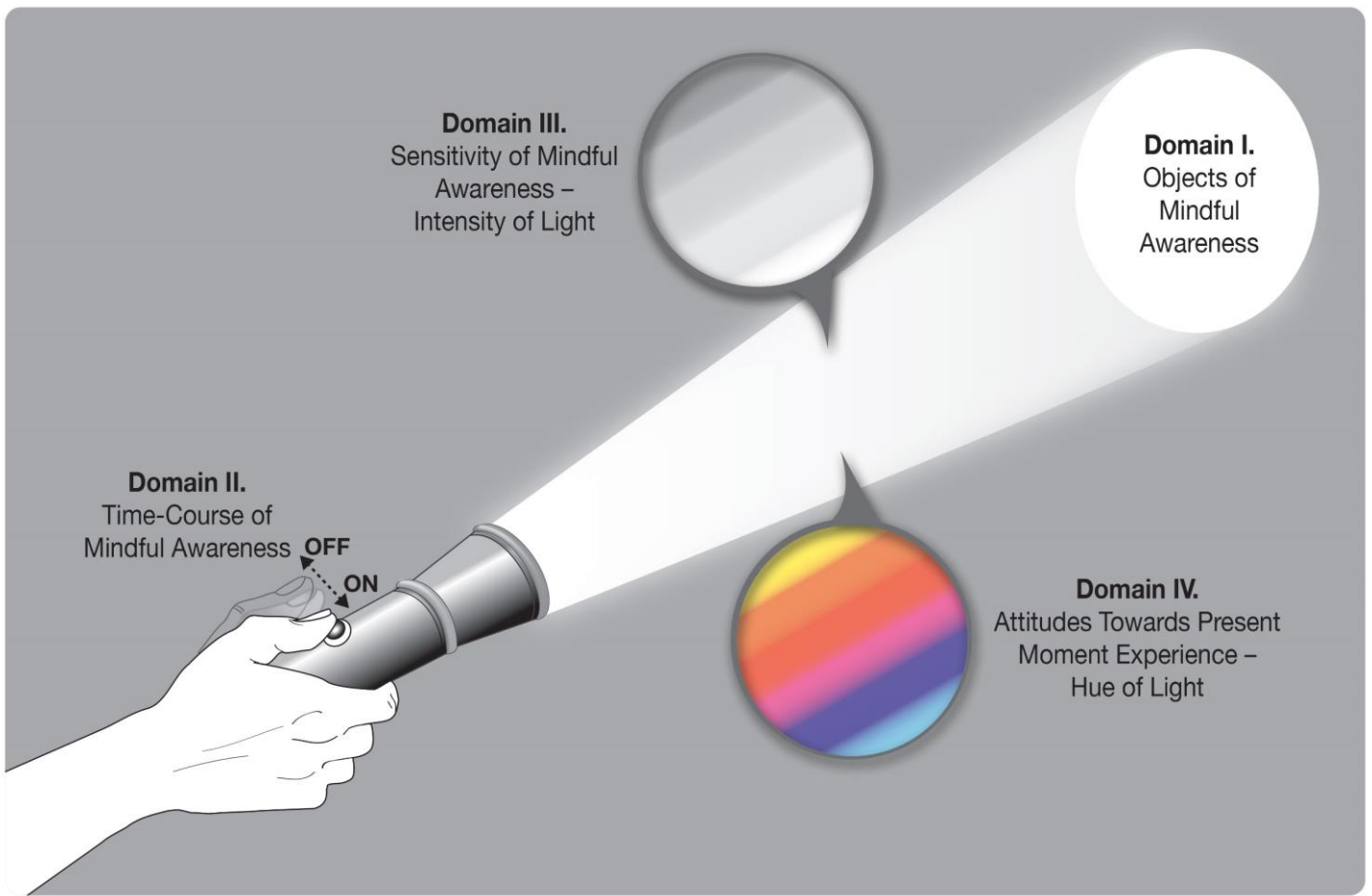


Figure 1. The four domains of behavioral assessment of mindfulness - flashlight metaphor.

The flashlight and its beam of light, illuminating present moment experience, represent mindful awareness. The *direction* in which the flashlight is pointed, causing it to illuminate specific types of present moment experiences, represents the *objects of mindful awareness* (Domain I). Turning the light *on and off* over time represents the *time-course of mindful awareness* (Domain II). The *intensity* of the light, enabling the detection of subtle changes in present moment experience, represents *sensitivity of mindful awareness* (Domain III). The *hue* of the light, coloring the perception of present moment experience with specific attitudinal qualities, represents *attitudes towards present moment experience* (Domain IV).

Domain I. Measuring Objects of Mindful Awareness

Mindfulness involves awareness of various present moment experiences or objects. Indeed, canonical Buddhist texts delineate four foundations of mindfulness, three of which refer to experiential objects of mindful awareness – body, hedonic tone, and mind [11, 12]. Likewise, the objects of mindful awareness are also central to many forms of mindfulness meditation. For example, focused Attention (FA) meditation involves focusing mindful awareness on a meditation anchor, an object such as the breath to which the practitioner directs and sustains mindful awareness, as well as mindful awareness of mind wandering [13]. Many forms of Open Monitoring (OM) meditation involve mindful awareness of various objects in consciousness such as thoughts, emotions, and sensations [14].

To date, two behavioral methods utilizing real time Experience Sampling (ES) have been developed and used to measure the frequency of mindful awareness of experiential objects (see Table 1). The first method entails real time ES of awareness of a specific present moment experiential object (e.g., meditation anchor, mind wandering) during mindfulness practice. The *Meditation Breath Attention Scores Task*, *Experimenter-Prompted Mindfulness Task*, *Self-Prompted Mindfulness Task*, and the *Mindful-Breathing Exercise* apply this method to measure mindful awareness of the breath during a 10-20-minute FA mindfulness of the breath meditation [15-17]. The first two tasks use random or quasi-random ES probes (i.e., probe-caught ES) to which participants indicate whether their awareness is focused on the breath. In the *Self-Prompted Mindfulness Task* participants spontaneously indicate whenever they notice that their awareness wandered from their breath (i.e., self-caught ES). The *Mindful-Breathing Exercise* combines both methodologies in a single task (i.e., probe-caught and self-caught ES).

The *Meditation Breath Attention Scores Task* displays moderate levels of internal consistency (inter-item correlation coefficients from .31 to .47), and relatively low test-retest

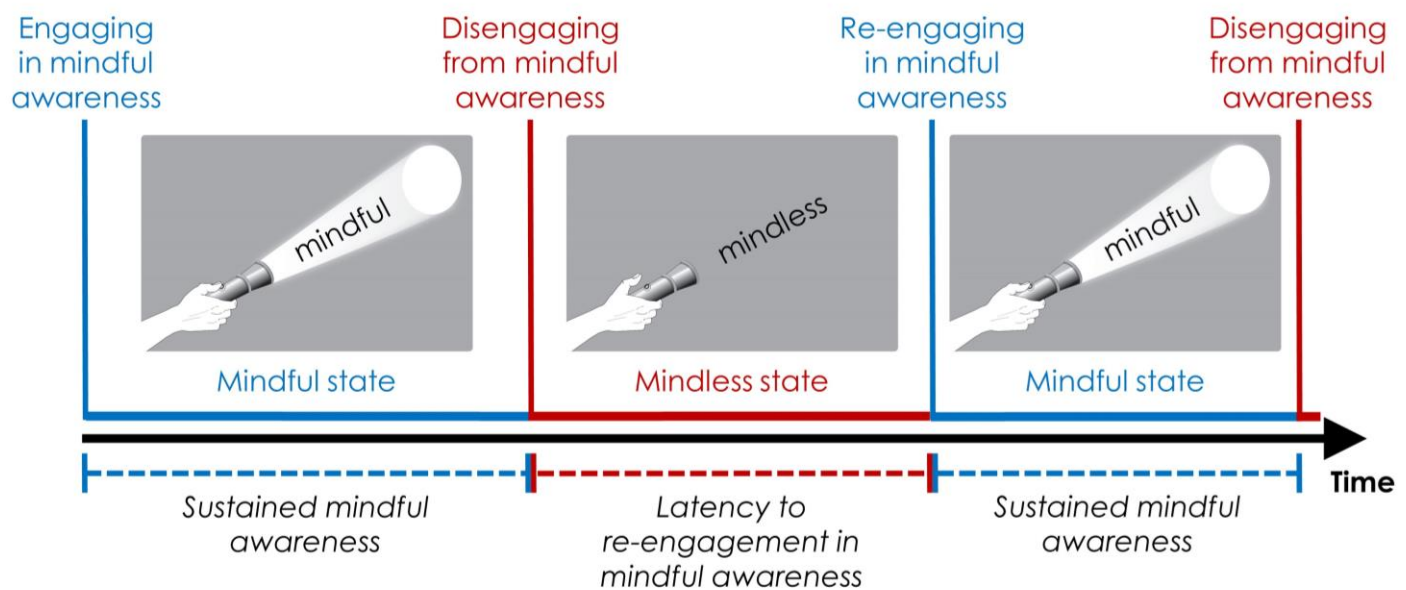
reliability (mean $r = .50$) [18, 19]. In contrast, the Mindful-Breathing Exercise displays higher and acceptable levels of test-retest reliability ($r = .70$ to $.83$) [16, 20]. Although to the best of our knowledge there are no published internal consistency data for the Mindful-Breathing Exercise, it is possible that the larger number of 22 ES probes in this task (cf. 5-10 ES probes in Meditation Breath Attention Scores Task) contributes to a more reliable estimate of mindful awareness of the breath. Findings also support the construct validity of the Meditation Breath Attention Scores Task as a measure of mindful awareness of the breath in the context of FA meditation (e.g., associations with retrospective ES of awareness of the breath) [18, 19, 21]. Findings likewise support the validity of all of four tasks as indicators of self-reported non-distraction and acting with awareness (associations with mindfulness scales measuring these processes) [15-19, 21].

The second behavioral method used to measure the objects of mindful awareness applies manualized qualitative coding of open-ended real-time ES reflecting the objects of mindful awareness during mindfulness practice. We recently developed the *Mindful Awareness Task*, a behavioral and phenomenological task that applies this method to measure mindful awareness of body, hedonic tone, and mind (i.e., three canonical Buddhist foundations of mindfulness), as well as a time-course analysis method to measure the time-course of mindful awareness (the latter method is described in “Domain II. Measuring the Time-Course of Mindful Awareness” below). In the Mindful Awareness Task, participants perform a 20-minutes mindfulness meditation (combined OM with FA) in which they are instructed (a) to monitor a wide range of prominent present moment experiences (e.g., sensations, emotions, thoughts), and (b) to direct their awareness to their breath when they do not notice any experience. To measure performance during the meditation, participants are instructed (a) to verbally state a label describing each experience they notice (e.g., “warm”, “calm”, “tension”, or “thinking”), and (b) to press a button when they notice their inhalation

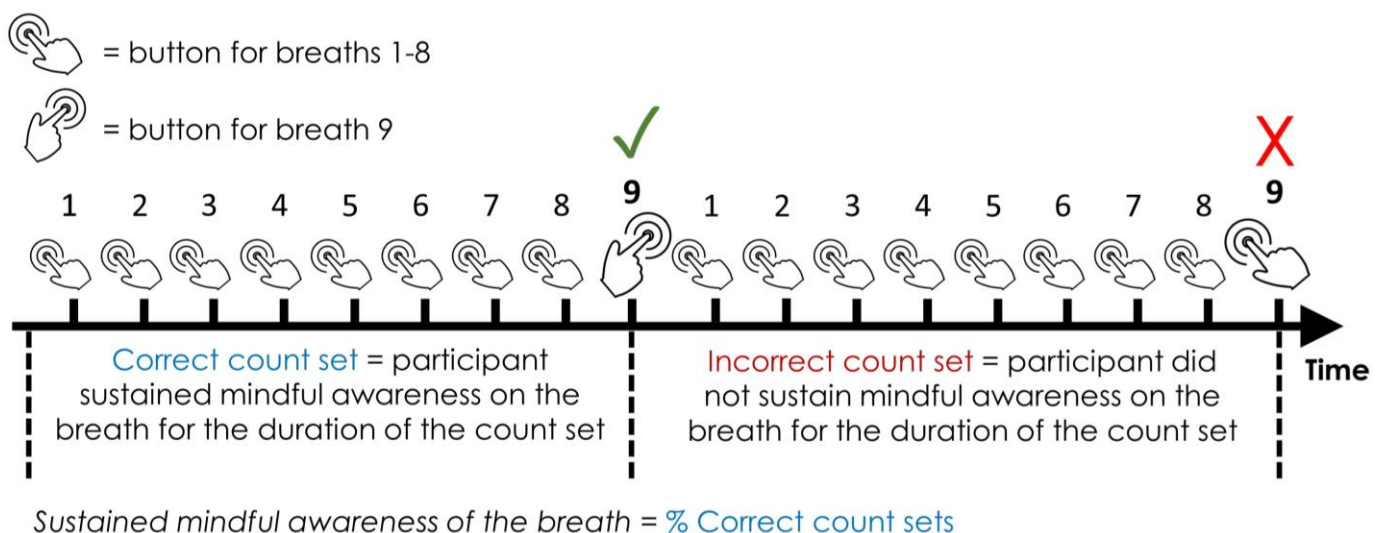
or exhalation (see Figure 2C). Mindful awareness of body, pleasant and unpleasant hedonic tone, and mind are scored using manualized qualitative coding of the content of participant's verbal labels (e.g., "warm" is coded as body, "calm" is coded as pleasant hedonic tone, "tension" is coded as unpleasant hedonic tone, and "thinking" is coded as mind). The number of labels referring to body, pleasant and unpleasant hedonic tone, and mind are summed to produce four individual difference scores reflecting mindful awareness of these experiential objects.

The Mindful Awareness Task objects of mindful awareness scores display excellent inter-rater reliability (mean $\kappa = .90$), good internal consistency (split-half reliabilities mean $r_{\text{Spearman-Brown corrected}} = .82$), construct validity (predicted convergent and discriminant associations with indices of mindful awareness of body, pleasant and unpleasant hedonic tone, and mind), known-groups validity (i.e., distinguishing mindfulness meditators from non-meditators), and incremental validity (i.e., predicting key criterion variables beyond self-report measures of mindfulness; Y Hadash *et al.*, presentation in International Symposium for Contemplative Research, Phoenix AZ, November 2018).

A. Time-Course of Mindful Awareness: Mindfulness Processes Expressed in Time



B. Breath Counting Task



C. Mindful Awareness Task

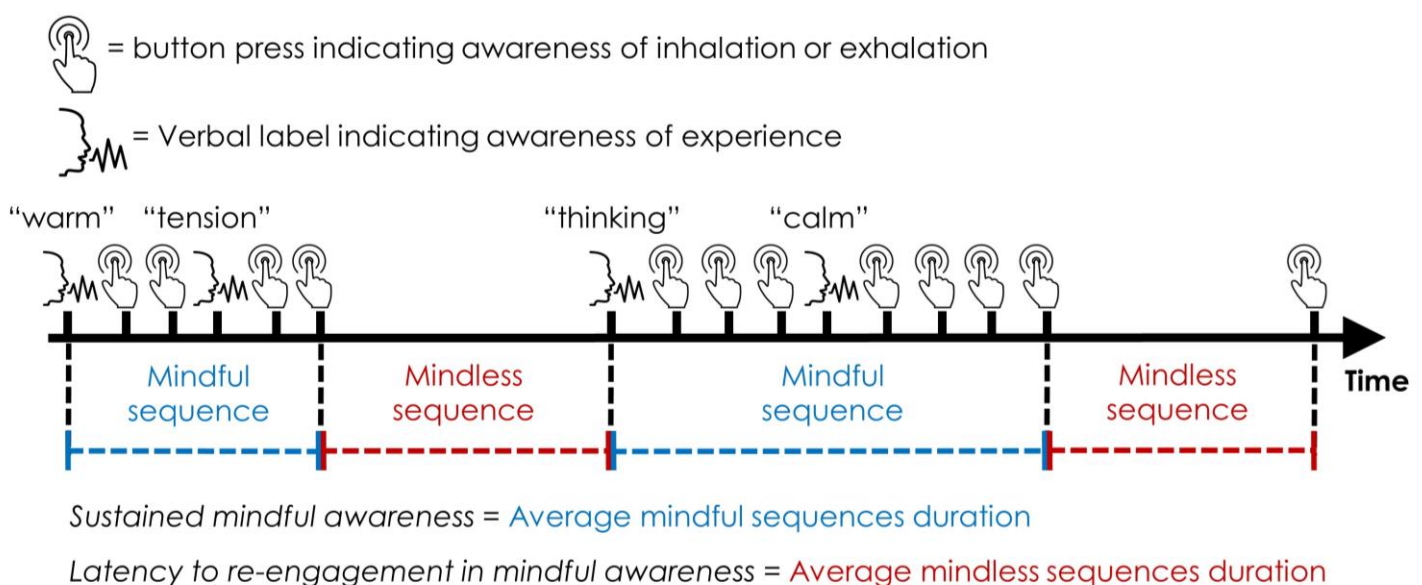


Figure 2. Conceptualization and measurement of the time-course of mindful awareness. (A)

Temporal dynamics of mindful and mindless states, and mindfulness processes reflected in the duration of these states – sustained mindful awareness and latency to re-engagement in mindful awareness. (B) Breath Counting Task data, correct and incorrect count sets, and computation of a score indicating sustained mindful awareness of the breath. (C) Mindful Awareness Task data, mindful and mindless sequences, and computation of a sustained mindful awareness score and a latency to re-engagement in mindful awareness score.

Domain II. Measuring the Time-Course of Mindful Awareness

As a process that unfolds from moment-to-moment in time, mindfulness practice entails sustaining mindful awareness on present moment experience and reengaging in mindful awareness once mindless states occur (i.e., states with no awareness of present moment experience) [11, 12]. We refer to the expression of mindful awareness in time as the time-course of mindful awareness. Indeed, Buddhist scholars and mindfulness researchers have previously referred to at least two important mindfulness processes expressed in time. The first is *sustained mindful awareness* – the capacity to engage in continuous awareness of present moment experience (see Figure 2A) [11, 22-25]. The second is *latency to re-engagement in mindful awareness* – the time it takes to re-engage in mindful awareness following the onset of mindless states (i.e., states with no awareness of present moment experience; see Figure 2A) [12, 13, 22, 24].

To-date, two behavioral methods have been developed and used to measure these processes (see Table 1). The first method involves performing a task that requires sustained mindful awareness of an easily detectable present moment experience (i.e., experience with high detection rates) for which correct and incorrect responses can be objectively verified. This method has been implemented in the *Breath Counting Task* which measures sustained

mindful awareness during FA mindfulness of the breath meditation [26]. In this task participants are instructed to count their breaths from 1 to 9 repeatedly, pressing one button on breaths 1–8, and a second button on breath 9 (see Figure 2B) [26]. The tasks' score is the percentage of correct count sets – sequences of 9 button presses with correct button presses. To have correct count sets, participants need to sustain mindful awareness on their breath and to retain the task set (i.e., remember to count breathes; see Figure 2B). The Breath Counting Task displays acceptable internal consistency (split-half reliability $r = .57$ before spearman-brown correction), moderate test-retest reliability (i.e., ICC = .60), as well as construct validity (e.g., associations with real time ES of meta-awareness), known-groups validity (e.g., distinguishing meditators from novices), and incremental validity (e.g., predicting meta-awareness beyond self-report measures of mindfulness) [26, 27]. Study of the task in mindfulness-based interventions and lab contexts has raised important methodological questions that may require exploration of different task iterations to maximize its utility and sensitivity to mindfulness practice (MJ Hirshberg *et al.*, presentation in International Symposium for Contemplative Research, Phoenix AZ, November 2018).

The second behavioral method used to measure the time-course of mindful awareness entails analysis of the timing and order of real time self-caught ES of mindful awareness during mindfulness practice to detect mindful and mindless time periods. The Mindful Awareness Task applies this method to measure mindfulness processes expressed in time, as well as qualitative coding methods to measure the objects of mindful-awareness (see “Domain I. Measuring the Objects of Mindful Awareness” above). As noted above, in this task participants perform a 20-minutes mindfulness meditation (combined OM with FA) in which they are instructed to (a) monitor a wide range of prominent present moment experiences (e.g., sensations, emotions, thoughts), and (b) to direct their awareness to their breath when they do not notice any experience. To measure performance during the

meditation, participants are instructed (a) to verbally state a label describing each experience they notice, and (b) to press a button when they notice their inhalation or exhalation (see Figure 2C).

To quantify the time-course of mindful awareness, the precise timing and order of all reports of mindful awareness (i.e., labels and button presses) are analyzed to divide and classify the 20-minutes meditation into *mindful sequences* and *mindless sequences*. Time periods in which participants continuously indicate mindful awareness via verbal labels and button presses are classified as mindful sequences (see Figure 2C). A *sustained mindful awareness score* is computed by averaging the duration of all mindful sequences in the 20-minute meditation. Second, time periods in which participants do not provide any indication of mindful awareness – no button presses indicating awareness of the breath and no verbal labels reflecting awareness of other present moment experiences – are classified as mindless sequences (see Figure 2C). Because participants re-engage in mindful awareness (indicated by a verbal label or a button press) at the end of each mindless sequence, we compute a *latency to re-engagement in mindful awareness score* by averaging the duration of all mindless sequences in the 20-minute meditation (see Figure 2C).

The Mindful Awareness Task sustained mindful awareness and latency to re-engagement in mindful awareness scores display good internal consistency (split-half reliabilities mean $r_{\text{Spearman-Brown corrected}} = .83$), construct validity (e.g., associations with retrospective ES measuring sustained mindful awareness and latency to re-engagement in mindful awareness, and a visual sustained attention task score), known-groups validity (i.e., distinguishing mindfulness meditators from non-meditators), and incremental validity (i.e., predicting key criterion variables beyond self-report measures of mindfulness; Y Hadash *et al.*, presentation in International Symposium for Contemplative Research, Phoenix AZ, November 2018).

Domain III. Measuring Sensitivity of Mindful Awareness

Various Buddhist canonical texts and contemporary Buddhist and secular mindfulness traditions emphasize the importance of developing mindful awareness of subtle experiences in the body and mind, such as subtle sensations throughout the body [28-32]. Accordingly, accurate detection of subtle changes in interoceptive and mental experience is an important mindfulness process. In line with recent conceptualizations of *interoceptive sensitivity* as accuracy in detection of internal bodily sensations [33-35], we labeled this mindfulness process(es) sensitivity of mindful awareness.

To-date, this process has been measured using a behavioral method we refer to as the *first and third person correspondence method* (based on seminal ideas from Varela and Shear [36]). This method entails comparison of subjective (i.e., first-person) reports of a present moment experience with objective (i.e., third-person; e.g., physiological, behavioral) markers, or experimental manipulations, of that experience (see Figure 3 and Table 1) [34, 35, 37]. Importantly, this method requires that detected present moment experience can be measured or manipulated using a valid objective/third-person observable indicator [37]. It also requires that detected present moment experience be sufficiently subtle and thus difficult to detect, so that detection rates of the experience are not susceptible to a ceiling effect (i.e., a minimal amount of participants receive the maximal detection rate value) [38, 39].

Behavioral interoceptive sensitivity/accuracy tasks [34, 35, 37] have been used in mindfulness studies as individual difference measures of mindfulness-induced sensitivity to interoceptive experience. The most commonly used tasks are *Heartbeat Detection Tasks* that quantify accurate detection of heart beats by contrasting first-person reports of introspectively sensed heartbeats with electrocardiogram heartbeat data. Two commonly used variants of Heartbeat Detection Tasks are *Heartbeat Discrimination Tasks* in which participants judge whether an external stimulus is simultaneous with their heartbeats [37, 40], and the *Schandry*

Heartbeat Tracking Task in which participants count their own heartbeats during specified time periods [41]. Importantly, Heartbeat Detection Tasks have been shown to display good internal consistency [33, 40], test-retest reliability [38, 42], and construct validity in measuring accurate heartbeat detection [40, 43]. However, extant findings provide limited support of the construct validity and known-groups validity of these tasks as measures of mindfulness processes. One study found increased heartbeat detection task scores following a 6-9 months mindfulness-based intervention [38]. However, a second study found no increase in heartbeat detection task scores following shorter mindfulness-based interventions [44], and three studies report no differences in Heartbeat Detection Tasks scores between long-term meditators and non-meditators [30, 45, 46].

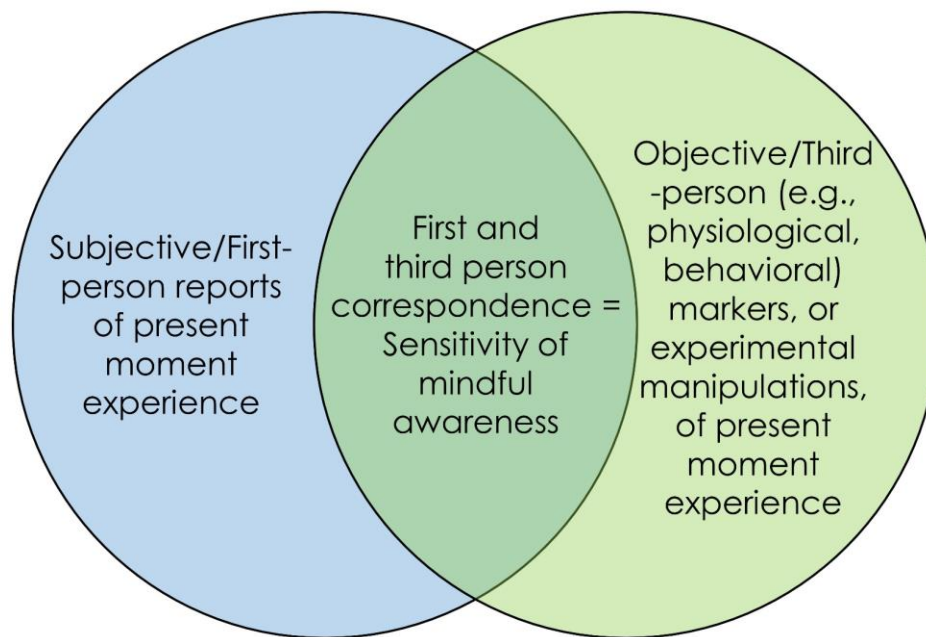


Figure 3. The first and third person correspondence method. The overlap between the circles represents sensitivity of mindful awareness, operationalized as correspondence between first and third person methods.

Other measures utilizing the first and third person correspondence method have been used to assess detection of other forms of interoceptive experience. Preliminary findings provided modest support of the construct validity of a measure of tactile sensitivity, the *Somatic Signal Detection Task*, as a measure of a mindfulness process (i.e., increased tactile sensitivity following a body scan mindfulness practice) [47]. However, measures of respiratory interoceptive accuracy, *Respiratory Load Detection, Discrimination, and Tracking Tasks*, demonstrated no known-groups validity as measures of mindfulness processes (i.e., no difference between long-term meditators and non-meditators) [39].

Recently, the *Probe-Caught Meta-Awareness of Bias Task* utilized the first and third person correspondence method to measure accurate momentary detection or meta-awareness of biased/dysregulated attention [48]. Uniquely, this task uses a signal detection methodology to quantify accurate detection or meta-awareness of biased attention through correspondence between subjective reports of biased attention (i.e., probe-caught ES) and objective data (i.e., objective performance data). Findings provides preliminary support of the construct validity of the Probe-Caught Meta-Awareness of Bias Task as a measure of sensitivity/accuracy of meta-awareness of biased/dysregulated attention (e.g., biased attention with meta-awareness predicted greater attentional control on the immediately proceeding trial relative to biased attention without meta-awareness) [48]. However, to-date its construct validity or known-groups validity as a measure of a mindfulness process has not been tested.

In sum, while sensitivity/accuracy behavioral tasks display construct validity in measuring accurate detection of subtle changes in interoceptive and mental experience, evidence supporting their construct validity or known-groups validity as measures of mindfulness processes are sparse. Importantly, many of the aforementioned studies documenting non-significant differences between meditators or mindfulness intervention completers and controls were underpowered (10-20 participants in each group) [30, 39, 44,

46]; and some of these studies [38, 44] used the Schandry Heartbeat Tracking Task [41] which may be confounded by beliefs about heart rate (see [49, 50]). Future studies with bigger samples and measurements not confounded by beliefs are needed to examine whether sensitivity/accuracy tasks may be valid measures of mindfulness processes.

Domain IV. Measuring Attitudes Towards Present Moment Experience

Mindfulness practice is characterized by a particular relationship with, or attitudes towards, present moment experience, such as non-judging, acceptance, curiosity, and disidentification from experience [22, 24, 32, 51-53]. Collectively, these attitudes towards present moment experience are often referred to as attitudinal qualities of mindfulness, and are considered foundational to the practice and cultivation of mindfulness [24, 32, 53].

To-date, only one behavioral method has been used to measure attitudes towards present moment experience (see Table 1). It entails an experimental elicitation of a present moment experience (e.g., using videos and audio), concurrent with an implicit attitude measurement of associations with, or attitudes towards, the elicited experience [54]. To do so, associations with, or attitudes towards, the elicited experience are measured by means of implicit attitude measures such as the Implicit Association Test [55] – a well-established method to measure associations between semantic categories [56].

This method is implemented in the Single Experience and Self-Implicit Association Test paradigm [57]. To-date, one variant of this paradigm has been developed to assess individual differences in non-judging of fear and disidentification from fear [54, 57]. Fear is elicited via short frightening videos played immediately before Implicit Association Test blocks, and then maintained via background audio played during the blocks. The Implicit Association Test blocks measure the direction (positive or negative) and strength of the cognitive association between self and the experience of fear. Negative associations between self and fear represent negative judgments of fear, positive associations between self and fear

represent identification with fear, and no associations between self and fear represent non-judging and disidentification from fear. The Fear Single Experience and Self-Implicit Association Test displays acceptable levels of internal consistency (split-third reliability mean $r_{\text{Spearman-Brown corrected}} = .74$) and construct validity as a measure of non-judging and disidentification from fear (e.g., sensitive to effects of experimental manipulations of identification with experience and disidentification from experience; associations with indexes of mindfulness, non-judging of experience, and disidentification from experience) [57]. Importantly, although attitudes towards present moment experience are foundational to mindfulness, no other behavioral methods or measures of these processes have been published to-date. No doubt, this represents a particularly underdeveloped domain of behavioral assessment of mindfulness.

Conclusions

We proposed two defining features of behavioral measures of mindfulness as well as a framework to help organize, conceptualize, and guide the development of extant and emerging behavioral measures of mindfulness (see Table 1). Of the 12 reviewed measures, four demonstrate acceptable reliabilities and preliminary evidence of construct validity as measures of mindfulness processes: Mindful-Breathing Exercise [16], Mindful Awareness Task, Breath Counting Task [26], and the Single Experience and Self-Implicit Association Test [57]. Of these, the Mindful Awareness Task and Breath Counting Task also display preliminary evidence of known-groups validity (i.e., distinguishing meditators from novices), and incremental validity (i.e., predicting key criterion variables beyond self-report measures of mindfulness). Other measures, such as Heartbeat Detection Tasks, obtained limited support for their construct validity and known-groups validity as measures of mindfulness processes, and require further testing in future studies. We hope this review and framework will help guide implementation of behavioral measures of mindfulness processes in future studies,

inform further empirical validation and testing of existing measures, as well as encourage and guide the development of novel behavioral methods and measures of mindfulness processes.

Acknowledgements

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