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ASSESSING MINDFULNESS & ACCEPTANCE PROCESSES IN CLIENTS

Illuminating the Theory & Practice of Change

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CHAPTER 8

What Does Mindfulness Training Strengthen? Working Memory Capacity as a Functional Marker of Training Success

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Over 1,500 years ago, the Indian Buddhist sage Master Asanga offered a useful description of mindfulness: “nonforgetfulness of the mind, having the function of nondistractedness” (Wallace, 2005, p. 157). In this definition, seen repeatedly in other ancient texts, holding in mind and remembering the object of the mind were considered to be central features of *smṛiti*, the Sanskrit term for mindfulness. (In Pali, the language of the earliest Buddhist scriptures, it is known as *sati*). These ancient definitions emphasize the process of holding awareness from the *prior* moment into the present moment. They differ from current conceptualizations of mindfulness, which emphasize the ongoing process of attending to present-moment experience in a particular way, with no mention of holding onto any aspect of the prior moment (Kabat-Zinn, 1994). This distinction is subtle and may seem meaningless, since there is an apparent attentional interdependence between the prior moment and the present moment. Yet “holding” emphasizes the influence of a memory-related trace originating in the recent past as the entryway into our present-moment

experience, while “attending to” emphasizes the contents of present-moment experience over the putative influence of recent memory.

An understanding of mindfulness offered by expert practitioners’ first-person accounts detailed within ancient texts suggests that memory-related features of mindfulness are important (for review, see Wallace, 2005, pp. 58-60). It is striking that the historical framing of mindfulness, as the mental mode of remembering to attend to information most relevant to present-moment experience while remaining undistracted, is akin to the cognitive neuroscience construct of working memory. In this chapter, we provide an overview of theory and research on working memory and suggest that working memory capacity may be a useful functional marker of mindfulness. Further, we argue that advancing our understanding of the mechanisms of action by which mindfulness training produces salutary effects requires a richer account of its relationship to working memory.

WORKING MEMORY CAPACITY

Working memory capacity (WMC) is the capacity to selectively maintain and manipulate goal-relevant information without becoming distracted by irrelevant information over short intervals. As such, working memory capacity comprises attentional processes to select information and appropriate behavioral responses, and memory-related processes to maintain information in an active, easily accessible form. This capacity allows task-relevant information to be readily available in the service of current goals.

Working memory is used during many everyday activities, from holding in mind a list of beverage requests from guests while hosting a dinner party to remembering which clerk behind the bank counter is helping us with a complex multistep transaction. A variety of information can be maintained in working memory. Information can be verbal (beverage names), visual (facial features of bank clerks), spatial, conceptual, or phonetic. Importantly, errors in working memory performance are most likely when we encounter distraction and interference; for example, when a dinner guest bursts into celebratory song (verbal interference) or when all of the bank clerks are wearing similar uniforms and have short brown hair (visual interference). Working memory is beneficial when short-term but not long-term storage of information is most useful. In the real world, party guests are more likely to have a good time if they receive the beverages they requested this evening, as opposed to what they asked for at the last party.

LABORATORY EVALUATION OF WORKING MEMORY CAPACITY AND ATTENTION

Laboratory tasks for assessing working memory attempt to capture the critical components of storing information over very short intervals while resisting distraction. One widely used and well-validated task is the operation span task (Ospan). In this task, participants have to memorize unrelated words or, in some variants, letter sequences and also verify simple mathematical statements, such as “Is $10/2 - 2 = 1$?” (Kane & Engle, 2002; Unsworth, Heitz, Schrock, & Engle, 2005). Words to be memorized alternate with equations to be verified, and after viewing a series of words and equations, the participants must report all of the words in the correct serial order. As the number of word-equation pairs increases, participants become progressively unable to report the words. The number of words that are consecutively reported without error is used to calculate an individual’s operation span score. Performance measures on tasks indexing WMC, such as the Ospan, are highly correlated with performance on tasks measuring attentional processes. These include tasks of attentional orienting (Unsworth, Schrock, & Engle, 2004) and conflict monitoring (Redick & Engle, 2006).

As with working memory, attentional orienting and conflict monitoring systems are used frequently in everyday life. Orienting involves voluntarily directing attention to the most task-relevant subset of information and restricting information from all other less relevant inputs. In a clothing store, for example, we use our orienting system to selectively restrict our gaze toward the dressing room on the far left as we wait for our friend to exit so we can hurry to a movie that is about to start. We use our conflict monitoring system to prioritize between competing behaviors while overcoming habitual or automatic behavior. An example of successful conflict monitoring is when we walk past our own car in the mall parking lot and head toward our friend’s car so that she can drive us to the movie theater. While habit might lead us straight to our car, our conflict monitoring system allows us to overcome this habitual behavior to guide us toward the appropriate destination for the task at hand. As is apparent from these examples, working memory, orienting, and conflict monitoring are all operating during most real-life scenarios. Even while orienting and conflict monitoring processes are guiding our present-moment behavior (gazing at the dressing room door or walking toward our friend’s car),

it is our working memory system that keeps active our plan to go to the matinee in our friend's car. Working memory also holds a representation of which one among the many dressing rooms is occupied by our friend. Thus, working memory is critical for guiding attentional processes in the service of current goals.

THE ROLE OF WORKING MEMORY IN DEALING WITH COGNITIVE AND AFFECTIVE CHALLENGES

Tasks in which mental content is emotionally neutral, such as maintaining a list of our guests' beverage requests during a dinner party, are characterized as having "cold" cognitive demands. Complex analytical reasoning problems found on tests such as the LSAT and IQ tests are highly demanding of cold cognitive control. It is well established that higher WMC is tied to improved performance on cold cognitive tasks. For instance, performance on WMC tasks corresponds with general fluid intelligence scores and academic achievement (see Kane & Engle, 2002, for review). WMC also correlates with increased success on laboratory tests of orienting and conflict monitoring when stimuli are digits, numbers, letters, and symbols (Unsworth et al., 2004).

WMC is also sensitive to individual differences in the ability to manage mental content that is emotionally valenced, or "hot." Individuals with lower WMC suffer from more emotionally intrusive thoughts, have less success in suppressing positive and negative emotions, and have difficulty with emotion reappraisal tasks (Brewin & Smart, 2005; Schmeichel, Volokhov, & Demaree, 2008). Thus, WMC correlates with an individual's success at willfully guiding behavior while overcoming cognitive and affective (cold or hot) challenges, distractions, and conditioned response tendencies. At a dinner party, a host with high WMC is more likely to successfully fulfill drink requests, whether distractions come in the form of friends loudly singing Jimmy Buffett lyrics with various beverage names or an angry outburst from a guest who felt overlooked.

While individuals differ in their baseline level of WMC, and thus in their degree of success at cold and hot control, individuals at all levels of WMC suffer from degradation in their WMC after engaging in highly demanding tasks (Schmeichel, 2007). Importantly, reduced WMC is

observed regardless of whether the task requires cold cognitive processing, such as performing a conflict monitoring task, or hot emotional processing, such as suppressing the experience of anxiety (Johns, Inzlicht, & Schmader, 2008) or inhibiting emotional expressions while watching an emotionally evocative video (Schmeichel, 2007). These lines of research reveal that WMC is a generalizable capacity, in that it can be used for both cognitive control and emotion regulation. They also reveal that WMC can be depleted, thus limiting the capacity to overcome cognitive or affective challenges.

Interestingly, although WMC fatigues after it is used intensively in demanding tasks, it can also be improved and strengthened through training. Many studies have demonstrated that working memory processes are bolstered with computer-based training methods that engage attention and working memory processes with affectively neutral stimuli (e.g., Olesen, Westerberg, & Klingberg, 2004; Persson & Reuter-Lorenz, 2008). The degree of improvement in working memory corresponds to practice duration (Jaeggi, Buschkuhl, Jonides, & Perrig, 2008) akin to a dose-response effect, wherein the more one practices the tasks, the more improvement in WMC is observed. Also, several recent studies of computer-based cognitive control training techniques report that in addition to improving attention and working memory, these training methods reduce affective symptoms in patients with anxiety (Siegle, Ghinassi, & Thase, 2007) and depression (Papageorgiou & Wells, 2000). In other words, these results suggest that it is possible to target improvements in cold cognitive operations and see benefits in affective symptoms. This directional effect mirrors the finding that individuals with higher WMC, as indexed on cold cognitive control tasks like the Ospan, are more successful at emotion reappraisal tasks than individuals with lower WMC (Schmeichel et al., 2008).

EFFECTS OF MINDFULNESS TRAINING ON ATTENTION TASKS

Very little is known about the impact of mindfulness training on WMC (Chambers, Lo, & Allen, 2008). Nonetheless, attention and working memory processes, when indexed in the context of tasks with affectively neutral content (such as symbols, neutral faces, digits, and letters), appear to be highly interdependent and interrelated (e.g., Jha, 2002). Several recent studies (discussed below) provide evidence that mindfulness training improves performance on attention tasks, leading to our prediction that this type of training is

likely to improve WMC as well. Research studies examining the impact of mindfulness training on attention tasks have been conducted among both experienced long-term meditation practitioners and novices.

Attentional Improvements in Experienced Mindfulness Practitioners

Functional brain imaging has identified a set of neural structures that are activated during tasks that require the use of attention. These attention network regions include the dorsolateral prefrontal cortex, the superior parietal cortex, and the intraparietal sulcus. Using functional magnetic resonance imaging (fMRI) during performance of an attention task, Brefczynski-Lewis, Lutz, Schaefer, Levinson, and Davidson (2007) reported that systematic alterations in activity within these and other attention network regions varied as a function of the duration of long-term mindfulness practice. Neural and behavioral evidence also suggests that experienced mindfulness practitioners can further bolster attentional functioning by engaging in intensive periods of practice, such as during meditation retreats when participants engage in ten to twelve hours of contemplative practice daily. For example, participation in a three-month retreat by long-term practitioners resulted in performance improvements during the attentional blink task (Slagter et al., 2007). The attentional blink is an effect seen when participants are asked to notice two target stimuli (such as letters) presented in quick succession within a stream of rapidly presented stimuli of another type (such as numbers). The second target stimulus often is not reported; this is thought to be due to competition between the two targets for limited attentional resources. In the study by Slagter and colleagues, retreat participants but not control participants demonstrated a reduced attentional blink effect, suggesting that they had either learned to allocate their attentional resources more efficiently by the end of the retreat, or that those resources had increased.

Another aspect of attention that increases in efficiency with mindfulness practice is attentional alerting, which is the ability to achieve and sustain a vigilant or alert state of preparedness. One study has demonstrated increases in attentional alerting after a one-month retreat (Jha, Krompinger, & Baime, 2007), and other researchers have documented increases in sustained attention after a ten-day retreat (Chambers et al., 2008). Recently, Cahn and Polich (2009) investigated whether the degree of improvement

in neural signatures of attention would track with self-reported time spent engaging in daily mindfulness practices among long-term practitioners. They found that attention-related brain wave signatures were largest in participants reporting more time engaging in mindfulness exercises each day. Thus, studies from long-term mindfulness practitioners provide strong support that mindfulness training improves attentional operations.

Attentional Improvements in Novice Mindfulness Practitioners

Attention may be improved with mindfulness training among novices as well. A recent study (Jha et al., 2007) examined how meditation training influences functioning of specific attentional subsystems. Since specific subsystems of attention are related to working memory (Jha, 2002), positive support that mindfulness training improves these aspects of attention would further support the hypothesis that mindfulness training improves WMC. In the study by Jha and colleagues (2007), novice participants receiving mindfulness training in the form of participation in an eight-week mindfulness training course akin to mindfulness-based stress reduction (MBSR; Kabat-Zinn, 1990) courses performed the Attention Network Test (ANT) before and after training.

The ANT has been devised to identify three functionally and neuroanatomically distinct cognitive networks—alerting, orienting, and conflict monitoring—during a single task (Fan, McCandliss, Sommer, Raz, & Posner, 2002). As described previously, alerting consists of achieving and sustaining a vigilant or alert state of preparedness, while orienting restricts processing to the subset of inputs relevant to current task goals, and conflict monitoring prioritizes among competing tasks and resolves conflict between goals and performance. The ANT combines methodology from two basic laboratory paradigms that have been used to investigate attentional subsystems: the attentional spatial cuing paradigm and the flanker paradigm (see Fan et al., 2002, for an overview).

Attentional spatial cuing paradigms provide a means to behaviorally index attentional alerting and orienting. In this paradigm, participants sit at a computer and perform a visual computer task similar to a simple video game. They are instructed to detect a target that is presented following either informative or neutral spatial cues. Informative cues provide spatial information regarding the target location with high probability. Neutral

cues signal the imminent appearance of a target but provide no spatial information regarding its location. Neutral cues confer an attentional advantage when compared to no-cue trials. This advantage in performance is thought to be due to alerting. The neutral warning cue signifies that a target is forthcoming and thereby summons greater attentional resources to become available for their forthcoming deployment. Response times are slowest in identifying targets preceded by no cues, faster following neutral cues, and fastest following spatial cues. Comparisons of response times between no-cue and neutral trials assess alerting, and comparisons between neutral and informative cues assess orienting.

Flanker paradigms allow researchers to index conflict monitoring behavior by selectively manipulating the presence or absence of response competition while keeping other task demands constant. In this simple visual computer task, participants are instructed to identify a target by a two-alternative forced choice method; for example, determining if an arrow (<) is facing left or right. The target is surrounded by task-irrelevant "flankers" that are either of the same response category as the target (<<<) or of another response category (><>). Responses in trials in which the flanking stimuli indicate a different response than the central stimulus (incongruent condition) are significantly slower than those in trials in which all stimuli indicate the same response (congruent condition). Slower response times are attributed to the need for greater conflict resolution and monitoring during incongruent relative to congruent trials.

The ANT task incorporates both spatial cuing and flanker paradigms to manipulate both attentional cuing (informative, neutral, and no cues) and the type of target (congruent or incongruent flanker). The response time differences between pairs of conditions are used to assess the functioning of these three networks on this single task. Alerting is indexed by subtracting performance measures on neutral cue trials from no cue trials. Orienting is indexed by subtracting performance measures on spatial cue trials from neutral cue trials. Conflict monitoring is indexed by subtracting performance measures on congruent target from incongruent target trials.

In the 2007 study using the ANT (Jha et al., 2007), participants' training emphasized concentrative practices in which they were guided to selectively attend to some stimuli (their breath) while ignoring all other stimuli. The hypothesis was that mindfulness training emphasizing concentrative practice would be associated with greater efficiency in the functioning of voluntary attentional selection. Indeed, mindfulness training participants improved in their orienting performance relative to control participants.

In addition, other recent studies have found that conflict monitoring is improved in novices after a few days to several weeks of mindfulness training (Chan & Woollacott, 2007; Tang et al., 2007; Wenk-Sormaz, 2005). Since both orienting and conflict monitoring are forms of voluntary attentional selection, these results collectively suggest that mindfulness training in novices may indeed alter the functioning of voluntary input-level (orienting) and response-level (conflict-monitoring) selection processes.

EFFECTS OF MINDFULNESS TRAINING ON EMOTIONAL EXPERIENCE

The above studies review the benefits of mindfulness training on attentional functions in tasks using emotionally neutral stimuli. There is also considerable evidence that mindfulness training may alter information processing for emotional stimuli, may reduce affective symptoms, and may improve affective experience among patients with affective disorders, including generalized anxiety disorder and depression (Evans et al., 2008; Segal, Williams, & Teasdale, 2002; Williams, Russell, & Russell, 2008). Similar results have been found in healthy participants. For example, Jain and colleagues (2007) reported reductions in perceived stress and rumination after participation in a four-week MBSR program versus a relaxation training course. Consistent with this result, Broderick (2005) found that under induced negative mood, brief mindfulness instructions were more beneficial for reducing negative mood than a distraction strategy. Ortner, Kilner, and Zelazo (2007) similarly demonstrated the benefits of mindfulness training in dealing with negative affect. They reported that performance on a perceptual discrimination task requiring participants to remain undistracted after viewing negative disturbing images was improved after seven weeks of mindfulness training. Many other studies (e.g., Anderson, Lau, Segal, & Bishop, 2007; Davidson et al., 2003) also support the conclusion that participation in mindfulness training, whether over days (Broderick, 2005; Chambers et al., 2008), weeks (e.g., Anderson et al., 2007), or decades (e.g., Ortner et al., 2007), positively alters emotional experience by reducing negative mood and improving positive mood and well-being.

Carmody and Baer (2008) extended these findings by exploring the link between practice duration and mindfulness-related changes in emotional experience (see also Shapiro, Oman, Thoreson, Plante, & Flinders, 2008). They correlated the time that individuals spent engaging in formal

mindfulness practices during an eight-week clinical MBSR course with changes in medical symptoms and mood following training. Importantly, they found a significant correspondence between practice time and self-reported improvements in well-being and other symptom measures.

WORKING MEMORY CAPACITY AS A MEDIATOR OF THE EMOTIONAL BENEFITS OF MINDFULNESS TRAINING

Clearly, the benefits of mindfulness training for emotional experience are well established. Yet it is unclear why mindfulness training improves emotional experience. One possibility is that the effects of mindfulness training are similar to computer-based cognitive control training (Siegle et al., 2007), in that mindfulness training produces primary improvements in cold cognitive control, which leads to improvements in emotional experience. According to this hypothesis, cold cognitive control mediates the effects of mindfulness training on emotion. Another possibility is that the effects of mindfulness training on emotional experience are a direct result of training and are not mediated by improvements in cold control processes. A third possibility is that mindfulness training has both direct and indirect effects on emotion regulation processes.

We recently explicitly investigated the interrelationships between mindfulness practice duration on cold and hot processes (Jha, Stanley, Kiyonaga, Wong, & Gelfand, in press; Stanley, Kiyonaga, Schaldach, & Jha, under review). We examined the influence of mindfulness training on WMC during the high-stress, resource-depleting period of predeployment military training in a group of Marine reservists. We recruited two predeployment military cohorts and provided mindfulness training to one group ($N = 31$) but not the other ($N = 17$). Four months prior to their deployment to Iraq, the mindfulness training group attended an eight-week course called Mindfulness-based Mind Fitness Training (MMFT), which is modeled after MBSR but modified for military contexts (Stanley et al., under review). This group also agreed to candidly log the amount of time they spent engaging in formal mindfulness exercises. Performance on the Ospan task was used to index WMC, and the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988) was used to index positive and negative affect at two time points, corresponding to the beginning (time 1) and end

(time 2) of the mindfulness training course. We had three main questions: Do the intense demands of the predeployment period deplete WMC and degrade affective experience over time? Can mindfulness training bolster WMC and affective experiences during the predeployment period? And to the extent that there is a relationship between mindfulness training and affective experience, is it mediated by WMC?

While Ospan performance remained stable in a civilian control group ($N = 12$), it degraded over time in the military control group. Within the mindfulness training cohort, those who reported low practice time had performance degradation, while those who reported high practice time had improvements in performance over time. In addition, the predeployment interval impacted affective experience. Increases in negative affect and decreases in positive affect at time 2 versus time 1 were more pronounced in the mindfulness training participants who reported low vs. high practice time. In contrast, only minimal fluctuations in affective experience were observed in the group reporting high practice time. To determine if these affective changes were directly related to practice time as opposed to practice-related availability of WMC, we conducted a mediation analysis in the mindfulness training cohort. There was a direct relationship between positive affect and practice time. Yet the relationship between negative affect and practice time was indirect, and mediated by WMC. These preliminary findings suggest that negative and positive affect may be regulated through different mechanisms in the context of mindfulness training. That is, individuals who have engaged in sufficient mindfulness practice to bolster their WMC may use this capacity to control their negative affect, but not to boost their positive affect.

CONCLUSIONS

In sum, a review of the literature on WMC suggests many compelling links with mindfulness training. First, processes sensitive to WMC are also sensitive to mindfulness training, including attentional orienting (Unsworth et al., 2004; Jha et al., 2007), conflict monitoring (Redick & Engle, 2006; Chan & Woollacott, 2007), and the attentional blink (Colzato, Spape, Pannebakker, & Hommel, 2007; Slagter et al., 2007). Second, both WMC (Schmeichel, 2007) and mindfulness training (Carmody & Baer, 2008) correspond to the ability to bolster both cold cognitive performance on these attention tasks and hot emotion regulation processes. Finally, our recent

results suggest that mindfulness training alters WMC and that improvements in WMC due to mindfulness training are related to changes in negative affect. Thus, as suggested by Asanga, nonforgetfulness and nondistraction, operationalized in the present-day construct of working memory capacity, may indeed be important components of mindfulness. Future studies investigating the clinical efficacy of mindfulness training should consider using WMC tasks, such as the Ospan, as proximal markers of training success, which may mediate other functional changes.

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