Consciousness and Cognition 37 (2015) 57–62

Contents lists available at ScienceDirect

Consciousness and Cognition

journal homepage: www.elsevier.com/locate/concog

Meditation-induced states predict attentional control over time

Lorenza S. Colzato [a,*], Roberta Sellaro [a], Iliana Samara [a], Matthijs Baas [b], Bernhard Hommel [a]

[a] Leiden University, Cognitive Psychology Unit & Leiden Institute for Brain and Cognition, Leiden, The Netherlands
[b] University of Amsterdam, Faculty of Social and Behavioural Sciences, Programme group Work and Organizational Psychology, Amsterdam, The Netherlands

ARTICLE INFO

Article history:
Received 23 April 2015
Revised 28 July 2015
Accepted 9 August 2015
Available online 28 August 2015

Keywords:
Focused attention meditation (FAM)
Open monitoring meditation (OMM)
Attentional Blink
Meditation state
Attention

ABSTRACT

Meditation is becoming an increasingly popular topic for scientific research and various effects of extensive meditation practice (ranging from weeks to several years) on cognitive processes have been demonstrated. Here we show that extensive practice may not be necessary to achieve those effects. Healthy adult non-meditators underwent a brief single session of either *focused attention meditation* (*FAM*), which is assumed to increase top-down control, or *open monitoring meditation* (*OMM*), which is assumed to weaken top-down control, before performing an Attentional Blink (AB) task – which assesses the efficiency of allocating attention over time. The size of the AB was considerably smaller after OMM than after FAM, which suggests that engaging in meditation immediately creates a cognitive-control state that has a specific impact on how people allocate their attention over time.

1. Introduction

Even though many people still view meditation as a technique primarily intended for relaxation and wellbeing, numerous studies have shown that meditation alters various affective and cognitive processes. Indeed, meditation has substantial effects on how people perceive and process their physical and social environment and how they regulate attention and emotion (for reviews, see Lippelt, Hommel, & Colzato, 2014; Lutz, Slagter, Dunne, & Davidson, 2008). Moreover, by reducing anxiety, meditation may enhance efficient functioning of the goal-directed attentional system and reduce the extent to which processing is influenced by the stimulus-driven attentional system (Eysenck, Derakshan, Santos, & Calvo, 2007). However, all meditation techniques are not equal – neither in terms of their goals nor in terms of their effects. Lutz et al. (2008) and more recently Lippelt et al. (2014) have distinguished between two general meditation practices: Focused attention meditation (FAM) and Open monitoring meditation (OMM), which are likely to exert differential effects on attentional control.

During FAM, practitioners are required to focus attention on a chosen object or event, such as a candle flame or breathing. To sustain this focus, the practitioner has to constantly monitor the concentration on the chosen event to avoid mind wandering (Tops, Boksem, Quirin, IJzerman, & Koole, 2014). During OMM, instead the focus of the meditation becomes the monitoring of awareness itself (Lutz et al., 2008; Vago & Silbersweig, 2012), and there is no internal or external object or event that the meditator has to focus on. These different aims of the two techniques have been found to be associated with different effects on cognitive, affective, and neural processing. For instance, OM meditators have been found to outperform FAM practitioners in a sustained attention task when the target stimulus was unexpected (Valentine & Sweet, 1999). This might indicate that the OMM practitioners had a wider attentional scope, even though the two practitioners groups did not differ in

* Corresponding author at: Institute for Psychological Research, Leiden University, Cognitive Psychology Unit, Wassenaarseweg 52, 2333 AK Leiden, The Netherlands.

E-mail address: colzato@fsw.leidenuniv.nl (L.S. Colzato).

http://dx.doi.org/10.1016/j.concog.2015.08.006
1053-8100/

performance when the stimulus was expected. Electrophysiological evidence for meditation-induced improvements in attention comes from a recent study in which Vipassana (i.e., OMM-style) meditators performed an auditory oddball task before and after meditation (in one session) and random thinking (in another session) (Delgado-Pastor, Perakakis, Subramanya, Telles, & Vila, 2013). Meditators showed greater P3b amplitudes to target tones after meditation than either before meditation or after the no-meditation session, an effect that is thought to reflect enhanced attentional engagement during the task.

These and other differential effects of the two meditation types on information processing have motivated the hypothesis that they engage different cognitive-control styles (Lippelt et al., 2014): While FAM induces a single-channel processing mode that strengthens top-down support for relevant information and/or increases local competition between relevant and irrelevant information (Duncan, Humphreys, & Ward, 1997), OMM induces a more parallel processing mode in which top-down support and/or local competition are reduced. Consistent with this idea, while the size of the Simon effect (reflecting the efficiency of handling response conflict) was unaffected by type of meditation, the amount of dynamic behavioral adjustments (i.e., trial-to-trial variability of the Simon effect: the Gratton effect) were shown to be considerably smaller after OMM than after FAM (Colzato, Sellaro, Samara, & Hommel, 2015). In the present study, we will test the control style hypothesis in the context of visual attention.

So far, the literature has focused on long-term effects of meditation. In a seminal study, Slagter et al. (2007) investigated the effects of 3 months of intensive Vipassana (i.e., OMM-style) meditation training on the allocation of attention over time as indexed by the "attentional-blink (AB)" – when two target stimuli (T1 and T2) embedded in a rapid stream of events are presented in close temporal proximity, the second target stimulus is often not noticed. This effect is thought to result from competition between the two target stimuli for limited attentional resources (Raymond, Shapiro, & Arnell, 1992). After the training, participants showed a smaller AB, suggesting that they were more efficient in allocating their attentional resources to the processing of T1 and T2. The reduced AB was accompanied by a smaller T1-elicited P3b, the above-mentioned brain-potential thought to index attentional resource allocation. van Leeuwen, Müller, and Melloni (2009) found age-(and/or practice-)related effects of long-term meditation. In line with these results, only the older and very experienced meditators (on average 10,704 h of experience) showed a smaller AB during OMM than during FAM (van Vugt & Slagter, 2014). However, as the two kinds of meditations were performed in the same experimental session, the lack of an effect in less experienced meditators may be due to carry over effects or the failure to distinguish between FAM- and OMM-related activities.

While these observations provide evidence that meditation can affect attentional control, one can ask whether this impact really requires so much practice. In fact, if it is really the case that particular kinds of meditation engage specific cognitive-control styles (Lippelt et al., 2014), it should be possible to demonstrate that meditation immediately induces control states that immediately impact behavior. Let us consider how control states may be systematically modulated by FAM and OMM, respectively. As elaborated elsewhere (Hommel, 2012), biologically plausible models of decision-making (for a review, see Bogacz, 2007) share two basic ingredients: mutual inhibition between representations of alternatives, such as A and B in the Fig. 1, and top-down support for goal-compatible alternatives (e.g., Duncan et al., 1997; see A in our example). Following the reasoning of Colzato, Ozturk, and Hommel (2012; Colzato et al., 2015), control policies can be expected to modulate the strength of the top-down bias (control route 1) and/or local competition (control route 2; see Hommel, 2012). If so, the strong emphasis on focusing and the exclusion of irrelevant thoughts in FAM would be expected to induce an increase of top-down bias and/or local competition, while the emphasis on openness and lack of exclusion in OMM would be expected to induce a decrease of bias and competition. In other words, FAM should establish a rather "serial", "exclusive" control mode that would lead individuals to select one target at the time, while OMM should establish a rather "parallel",

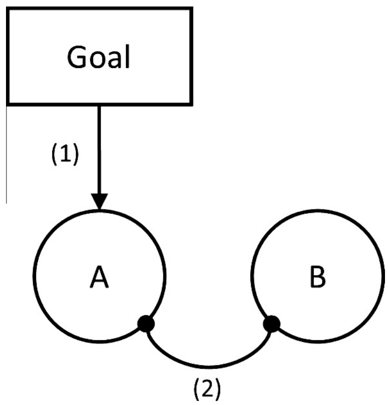

Fig. 1. Possible mechanisms involved in decision making. The goal-relevant alternative A is supported by the goal representation (1) but competes with choice alternative B through mutual inhibition (2). Thus, in addition to the competition, bias is provided by the goal. In the case of the AB, OMM might induce weak top-down control and/or reduced local competition and establish a rather "parallel" control mode that supports the selection of multiple targets, which should lead to a smaller AB; FAM would have the opposite effect.

"inclusive" control mode that should allow selecting multiple targets at once. Assuming that cognitive-control states are relatively inert (Allport, Styles, & Hsieh, 1994; Meiran, Hommel, Bibi, & Lev, 2002) and tend to outlive the task context they were established for, we assumed that engaging in meditation would still have a measurable impact on a subsequent AB task. If it would, having just engaged in FAM should produce a particularly pronounced AB while having engaged in OMM should have the opposite effect. We thus had people naïve to meditation engage in brief bouts of either FAM or OMM and expected the AB to be larger after FAM than after OMM.

2. Method

2.1. Participants

Forty healthy adults (mean age = 20.2) from Leiden University participated in the experiment. The sample size was calculated on the basis of previous studies investigating the effect of meditation on attentional allocation in practitioners (Slagter et al., 2007; van Leeuwen et al., 2009). Participants were selected individually via a phone interview using the Mini International Neuropsychiatric Interview (M.I.N.I.; Sheehan et al., 1998). The M.I.N.I. is a well-established brief diagnostic tool in clinical and stress research that screens for several psychiatric disorders and drug use (Colzato, Kool, & Hommel, 2008; Colzato, Ruiz, van den Wildenberg, & Hommel, 2011; Sheehan et al., 1998). Participants (2 male, 38 female) were randomly and equally distributed in two experimental groups. Twenty participants were exposed to an *open monitoring meditation* (OMM) session and 20 to a *focused attention meditation* (FAM) session. Written informed consent was obtained from all subjects; the protocol and the remuneration arrangements of 5 euro were approved by the local ethical committee (Leiden University, Institute for Psychological Research).

2.2. Rapid serial visual presentation (RSVP) task

In the RSVP task adopted from Colzato, Sellaro, Rossi Paccani, and Hommel (2014), participants had to identify and report two digits (T1 and T2) presented in a rapid stream of letter distractors. All stimuli were presented in a resolution of 800 by 600 pixels in 16 bit color on a 17" CRT refreshing at 100 Hz. Participants were seated at a viewing distance of about 50 cm. The fixation mark ("+"), as well as all RSVP items were presented centrally in black on a gray background (RGB 128, 128, 128). Each item was set in 16 point Times New Roman font. RSVP items included letters and digits. Letters were drawn randomly without replacement from the alphabet. Digits were drawn randomly from the set 2–9. After reading the instructions, which included a slow demonstration of the RSVP, and indicating to have fully understood the task, participants were required to undergo 24 trials of training. If more than 50% of the responses were incorrect during the training, the training part was automatically repeated. A fixation 'plus' sign, which was shown for 2000 ms, marked the beginning of each trial. After a blank interval of 250 ms, the RSVP commenced, consisting of 20 items that were displayed 70 ms each and an inter-stimulus interval of 30 ms. The occurrence of T1 in the stimulus stream was varied randomly between positions 7, 8 and 9 to reduce the predictability of first target onset. T2 was presented directly after T1 (lag 1), or after another 2, 4, or 7 distracters (lag 3, 5, and 8 respectively). Both targets were to be reported (order of report was not considered) after the RSVP – the question being "which two targets did you see?"– by pressing the corresponding digit keys. A full experimental session lasted 15 min and contained one block of 144 trials (3 locations of T1 $\times$ 4 lags $\times$ 12 repetitions).

2.3. Procedure

Participants were invited individually to the laboratory. Upon arrival, they were asked to rate their mood on a 9 $\times$ 9 Pleasure $\times$ Arousal grid (Russell, Weis, & Mendelsohn, 1989) with values ranging from -4 to 4. Hereafter, participants put on their headphones and listened to a 17-min OMM or FAM fragment that was based on transcripts of meditation manipulations by Colzato et al. (2012). The audio fragments were developed, validated, and successfully applied in a previous study by Baas, Nevicka, and Ten Velden (2014) investigating the differential effect of mediation techniques on creativity. The scripts used to induce FAM and OMM are archived in the Open Science Framework (OSF) and available through https://osf.io/udbc8/. In the OMM condition, a male voice guided participants in a step-by-step manner to pay attention to the present moment and to simply notice their feelings, thoughts, and bodily sensations entering into their awareness from moment-to-moment without conceptual elaboration or emotional reactivity. In the FAM condition, the same male voice guided participants in a step-by-step manner to focus and sustain their attention on their own breathing, monitor the quality of attention, and bring their attention back to their breathing whenever their mind had wandered. Next, participants rated again their mood and were presented with the RSVP task. After the RSVP task, participants rated their mood for the third time. After these measurements, the experimental session was ended and all participants were paid and dismissed.

2.4. Data analysis

Independent samples *t*-tests were performed to test age differences between the groups. T1 and T2 accuracy data were submitted to separate ANOVAs with lag (1, 3, 5, and 8) as a within-participants factor and Group (FAM vs. OMM) as a between-participant factor. T2 accuracy was based only on those trials in which T1 was correctly reported (T2|T1). Mood was analyzed by means of a repeated-measures analysis of variance (ANOVA) with group (FAM vs. OMM) as a between-subjects factor and effect of time (first vs. second vs. third measurement) as a within-subjects factor. A significance level of $p < .05$ was adopted for all statistical tests.

3. Results

Age did not significantly differ between groups (19.5 vs. 20.7 in the FAM and OMM group, respectively), $t(38) = -1.06$, $p = .30$. As expected, an ANOVA of conditional T2 accuracy (T2|T1) revealed a two-way interaction between group and lag, $F(3,114) = 3.07$, $p = .03$, MSE = 0.012, $\eta_p^2 = 0.08$, indicating that the AB (the lag effect) was smaller after OMM than after FAM (see Fig. 2). Moreover, an ANOVA on T1 accuracy (see Fig. 2), $F(3,114) = 4.97$, $p = .003$, MSE = 0.016, $\eta_p^1 = 0.12$, showed that the degree to which T2 impaired T1 processing at the shortest lag was much reduced for the OMM group. Both observations suggest that OMM induced a more parallel processing mode that allowed for a more efficient distribution of attentional resources over T1 and T2. ANOVAs revealed that pleasure [1.2 (SD = 1.5) vs. 1.7 (SD = 1.6) vs. 0.4 (SD = 1.6) and 1.1 (SD = 1.5) vs. 1.8 (SD = 1.6) vs. 0.7 (SD = 1.6) in the FAM and OMM group, respectively] and arousal [0.9 (SD = 1.5) vs. −0.2 (SD = 1.9) vs. 0.1 (SD = 2.0) and 0.2 (SD = 1.3) vs. −1.2 (SD = 1.4) vs. 0.0 (SD = 1.7) in the FAM and OMM group] did not significantly change between groups, $F(2,76) < 1$, $p = .66$, MSE = 1.213, $\eta_p^2 = 0.01$ and $F(2,76) = 1.008$, $p = .37$, MSE = 2.142, $\eta_p^2 = 0.03$, respectively. This suggests that we can rule out an account of our results in terms of mood and arousal.

3.1. Control analyses

In order to further elucidate which meditation can be held responsible for the differences in findings between OMM and FAM group, we collected additional data of a control group in which participants ($N = 20$, 1 male, mean age 20.0 years) did not engage in a meditation. They performed the identical RSVP task but were asked to relax (e.g. reading magazines) in the time periods usually taken by the meditation. The performance on conditional T2 accuracy (T2|T1) of the control group fell in-between the effects of the OMM and FAM group, $F(6,171) = 2.61$, $p < .05$, MSE = 0.010, $\eta_p^2 = 0.08$ (see also Fig. 2). Post-hoc multiple comparisons tests (Newman–Keuls) revealed that the FAM group showed a greater AB than the OMM group ($p = .007$) and the control group ($p = .02$), which showed comparable AB ($p = .96$). In contrast, the performance on T1 accuracy (see Fig. 2), $F(6,171) = 4.42$, $p < .01$, MSE = 0.013, $\eta_p^2 = 0.13$, showed that for the control group the degree to which T2 impaired T1 processing at the shortest lag was similar to the FAM group ($p = .69$) but in both cases stronger than in the OMM group (ps $\leqslant .007$).

4. Discussion

The present study is the first to demonstrate that OMM and FAM induce temporary cognitive states that have a systematic impact on the way people allocate their attention over time, as assessed by the AB task. We suggest that OMM induces a more parallel processing style by weakening top-down support for relevant information and/or reducing local competition between relevant and irrelevant information (Colzato et al., 2015; Lippelt et al., 2014), while FAM has the opposite effect.

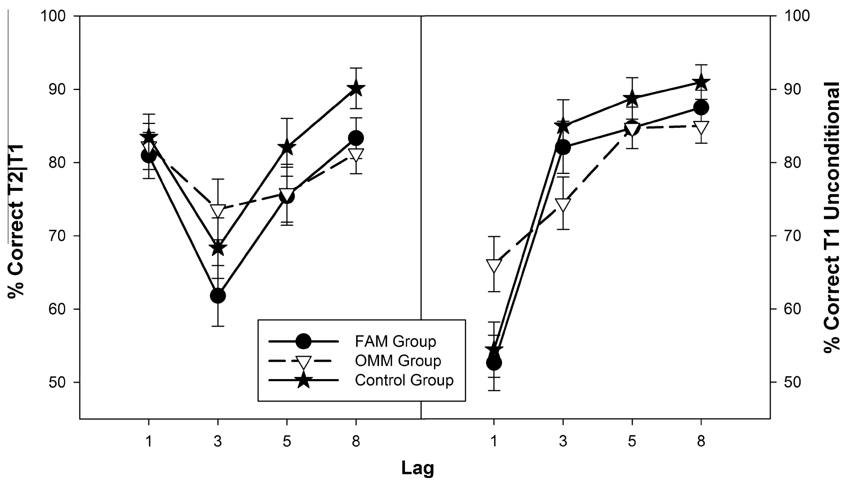

Fig. 2. T1 (unconditional) performance (left panel) and T2 performance given T1 correct (T2|T1) (right panel), shown separately for each lag and for T2|T1 for OMM, FAM and control group.

This would be expected to lead to a broader distribution of attention over time after OMM and, thus, a smaller AB – just as our findings demonstrate.

Our observations are in line with previous reports showing that long-term OMM practice in practitioners was associated with smaller ABs (Lutz et al., 2008; Slagter et al., 2007; van Leeuwen et al., 2009; van Vugt & Slagter, 2014), but suggest that extended practice is not necessary to demonstrate such effects. Future studies will be needed to assess how long the short-term effects of meditation last. Moreover, it might be interesting to replicate our findings with electrophysiological or electromagnetic methods. Previous studies of that sort have provided evidence that individual differences in attentional resource allocation are systematically reflected in particular markers, like the P3 and the corresponding M3 (Shapiro, Schmitz, Martens, Hommel, & Schnitzler, 2006). It would be interesting to see whether OMM leads to a reduction in these markers, and perhaps a smaller T1-elicited P3b reflecting a reduction in T1 capture (Wickens, Kramer, Vanasse, & Donchin, 1983).

From a methodological perspective, our observations suggest that it might be useful for meditation-training studies to test for possible effects more frequently. In particular, interventions with longer durations and multiple blocks or days of training should include tests right after each unit, in addition to the assessment of longer-term aftereffects. It might also be interesting to analyze performance in a more comprehensive fashion. For instance, one of the obvious questions our findings is raising is what being a well-experienced practitioner may be good for. While the performance we have considered in the present study does not show important differences, we find it unlikely that practicing many years has no effect whatsoever. One possibility is that practitioners may be more skilled to analyze the current situation and to implement the most suitable control state – a skill that our method to induce control states exogenously rendered irrelevant. It is also possible that practitioners are more efficient to switch between different control states – a skill that our between-subjects design was not sensitive to.

In sum, our findings suggest that FAM and OMM have a different, systematic impact on cognitive processing and the allocation of attentional resources over time in particular. Engaging in meditation immediately changes cognitive control states and the way they guide local attentional processing. As such, our findings shed an interesting new light on the potential of meditation for optimizing cognitive control in general and attentional performance in particular by biasing cognitive processing toward either more serial or more parallel processing.

Acknowledgments

This work was supported by research Grant from the Netherlands Organization for Scientific Research (NWO) awarded to Lorenza S. Colzato (Vidi Grant: #452-12-001).

References

Allport, D. A., Styles, E. A., & Hsieh, S. (1994). Shifting intentional set: Exploring the dynamic control of tasks. In C. Umilta & M. Moscovitch (Eds.), *Attention and performance XV* (pp. 421–452). Cambridge, MA: MIT Press.
Baas, M., Nevicka, B., & Ten Velden, F. S. (2014). Specific mindfulness skills differentially predict creative performance. *Personality and Social Psychology Bulletin, 40*, 1092–1106.
Bogacz, R. (2007). Optimal decision-making theories: linking neurobiology with behaviour. *Trends in Cognitive Sciences, 11*, 118–125.
Colzato, L. S., Kool, W., & Hommel, B. (2008). Stress modulation of visuomotor binding. *Neuropsychologia, 46*, 1542–1548.
Colzato, L. S., Ozturk, A., & Hommel, B. (2012). Meditate to create: The impact of focused-attention and open-monitoring training on convergent and divergent thinking. *Frontiers in Psychology, 3*, 116.
Colzato, L. S., Ruiz, M. J., van den Wildenberg, W. P., & Hommel, B. (2011). Khat use is associated with impaired working memory and cognitive flexibility. *PLoS ONE, 6*, e20602.
Colzato, L. S., Sellaro, R., Rossi Paccani, C., & Hommel, B. (2014). Attentional control in the attentional blink is modulated by odor. *Attention, Perception, & Psychophysics, 76*, 1510–1515.
Colzato, L. S., Sellaro, R., Samara, I., & Hommel, B. (2015). Meditation-induced cognitive-control states regulate response-conflict adaptation: Evidence from trial-to-trial adjustments in the Simon task. *Consciousness and Cognition, 35*, 110–114.
Delgado-Pastor, L. C., Perakakis, P., Subramanya, P., Telles, S., & Vila, J. (2013). Mindfulness (Vipassana) meditation: Effects on P3b event-related potential and heart rate variability. *International Journal of Psychophysiology, 90*, 207–214.
Duncan, J., Humphreys, G., & Ward, R. (1997). Competitive brain activity in visual attention. *Current Opinion in Neurobiology, 7*, 255–261.
Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: Attentional control theory. *Emotion, 7*, 336–353.
Hommel, B. (2012). Convergent and divergent operations in cognitive search. In P. M. Todd, T. T. Hills, & T. W. Robbins (Eds.), *Cognitive search: Evolution, algorithms, and the brain* (pp. 221–235). Cambridge, MA: MIT Press.
Lippelt, D. P., Hommel, B., & Colzato, L. S. (2014). Focused attention, open monitoring and loving kindness meditation: Effects on attention, conflict monitoring, and creativity – A review. *Frontiers in Psychology, 5*, 1083.
Lutz, A., Slagter, H. A., Dunne, J. D., & Davidson, R. J. (2008). Attention regulation and monitoring in meditation. *Trends in Cognitive Sciences, 12*, 163–169.
Meiran, N., Hommel, B., Bibi, U., & Lev, I. (2002). Consciousness and control in task switching. *Consciousness and Cognition, 11*, 10–33.
Raymond, J. E., Shapiro, K. L., & Arnell, K. M. (1992). Temporary suppression of visual processing in an RSVP task: An Attentional Blink? *Journal of Experimental Psychology: Human Perception and Performance, 18*, 849–860.
Russell, J. A., Weis, A., & Mendelsohn, G. A. (1989). Affect grid: A single-item scale of pleasure and arousal. *Journal of Personality and Social Psychology, 57*, 493–502.
Shapiro, K., Schmitz, F., Martens, S., Hommel, B., & Schnitzler, A. (2006). Resource sharing in the Attentional Blink. *Neuroreport, 17*, 163–166.
Sheehan, D. V., Lecrubier, Y., Sheehan, K. H., Amorim, P., Janavs, J., Weiller, E., ... Dunbar, G. C. (1998). The Mini-International Neuropsychiatric Interview (M.I.N.I.): The development and validation of a structured diagnostic psychiatric interview for DSM-IV and ICD-10. *Journal of Clinical Psychiatry, 59*, 22–23.
Slagter, H. A., Lutz, A., Greischar, L. L., Francis, A. D., Nieuwenhuis, S., Davis, J., et al (2007). Mental training affects distribution of limited brain resources. *PLoS Biology, 5*, e138.
Tops, M., Boksem, M. A., Quirin, M., IJzerman, H., & Koole, S. L. (2014). Internally-directed cognition and mindfulness: An integrative perspective derived from reactive versus predictive control systems theory. *Frontiers in Psychology, 5*, 429.

Vago, D. R., & Silbersweig, D. A. (2012). Self-awareness, self-regulation, and self-transcendence (S-ART): A framework for understanding the neurobiological mechanisms of mindfulness. *Frontiers in Human Neuroscience, 6*, 296.
Valentine, E. R., & Sweet, P. L. (1999). Meditation and attention: A comparison of the effects of concentrative and mindfulness meditation on sustained attention. *Mental Health, Religion and Culture, 2*, 59–70.
van Leeuwen, S., Müller, N. G., & Melloni, L. (2009). Age effects on Attentional Blink performance in meditation. *Consciousness and Cognition, 18*, 593–599.
van Vugt, M. K., & Slagter, H. A. (2014). Control over experience? Magnitude of the Attentional Blink depends on meditative state. *Consciousness and Cognition, 23*, 32–39.
Wickens, C., Kramer, A., Vanasse, L., & Donchin, E. (1983). Performance of concurrent tasks: A psychophysiological analysis of the reciprocity of information-processing resources. *Science, 221*, 1080–1082.