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A single bout of meditation biases cognitive control but not attentional focusing: Evidence from the global–local task

Lorenza S. Colzato*, Pauline van der Wel, Roberta Sellaro, Bernhard Hommel

Institute for Psychological Research, Leiden Institute for Brain and Cognition, Leiden University, Leiden, The Netherlands

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ABSTRACT

Recent studies show that a single bout of meditation can impact information processing. We were interested to see whether this impact extends to attentional focusing and the top-down control over irrelevant information. Healthy adults underwent brief single bouts 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 a global–local task. While the size of the global-precedence effect (reflecting attentional focusing) was unaffected by type of meditation, the congruency effect (indicating the failure to suppress task-irrelevant information) was considerably larger after OMM than after FAM. Our findings suggest that engaging in particular kinds of meditation creates particular cognitive-control states that bias the individual processing style toward either goal-persistence or cognitive flexibility.

1. Introduction

Previous literature demonstrated that long-term meditation practice has a beneficial effect on how people perceive their physical and social world and how they control and monitor their visual attention (see, Lippelt, Hommel, & Colzato, 2014, for a recent review). In their seminal work Lutz, Slagter, Dunne, and Davidson (2008) pointed out that two styles of meditation are commonly investigated: Focused attention meditation (FAM) and Open monitoring meditation (OMM). While FAM requires the voluntary focusing of attention on a chosen object, OMM calls for an overt, but unreactive, monitoring of the content of experience from moment to moment (Lutz et al., 2008). More recently Lippelt et al. (2014), suggested that the two most researched types of meditation practiced, FAM and OMM, are likely to exert different, to some degree even opposite effects on cognitive control. While the impact of meditation on human cognition is commonly assumed to require considerable practice over days, weeks, or even years, we have proposed, and provided preliminary evidence that engaging in meditation is sufficient to promote the establishment of particular cognitive-control styles even in individuals without any meditation practice (Colzato, Oztürk, & Hommel, 2012; Colzato, Sellaro, Samara, & Hommel, 2015; Colzato, Sellaro, Samara, Baas, & Hommel, 2015; Hommel, 2015; Lippelt et al., 2014). We assume that FAM increases top-down control and thus strengthens top-down support for relevant information and/or local competition between relevant and irrelevant information (Duncan, Humphreys, & Ward, 1997), while OMM weakens top-down control and thus reduces top-down support and/or local competition. In support of this assumption, Colzato, Sellaro, Samara, and Hommel (2015), Colzato, Sellaro, Samara,

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* Corresponding author at: Leiden University, Department of Psychology, Cognitive Psychology Unit, Wassenaarseweg 52, 2300 RB Leiden, The Netherlands.

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

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Baas, et al. (2015) showed that a brief single session of either FAM or OMM is sufficient to systematically bias the allocation of attention over time in both practitioners and non-meditators: As predicted by our account, the Attentional Blink (AB) was considerably reduced after OMM as compared with FAM. Given that the AB reflects top-down "over-control" (Gross et al., 2004), this observation fits with the idea that OMM weakens attentional top-down control (Colzato, Sellaro, Samara, Baas, et al. (2015)).

The finding that meditation can affect attentional control is consistent with previous demonstrations of meditation effects on sustained attention (Ainsworth, Eddershaw, Meron, Baldwin, & Garner, 2013; Baijal, Jha, Kiyonaga, Singh, & Srinivasan, 2011; Jha, Krompinger, & Baime, 2007; Tang et al., 2007; Zeidan, Johnson, Diamond, David, & Goolkasian, 2010; Elliott, Wallace, & Giesbrecht, 2014) and on the allocation of attention over time (Lutz et al., 2008; Slagter et al., 2007; van Leeuwen, Müller, & Melloni, 2009; van Vugt & Slagter, 2014), except that these previous studies were looking into the effects of short-term (5 days to one week) and long-term (years of practice) meditation training. Given that the observations of Colzato, Sellaro, Samara, and Hommel (2015), Colzato, Sellaro, Samara, Baas, et al. (2015) suggest that significant effects can be obtained even without any practice, we were interested to test whether such ultra-short-term effects can also be found in the control of attentional allocation over space. A well-established task to assess this issue is the global–local task developed by Navon (1977). This task indexes how fast people can process global vs. local characteristics of hierarchically constructed visual stimuli (e.g., larger shapes made of smaller shapes). Participants are typically presented with a global stimulus (e.g., large square) which is composed of smaller shapes, the local stimuli, and the relationship between global and local stimuli can be congruent (e.g., a large square made of small squares) or incongruent (a large square made of small rectangles). Typically, this task gives rise to the "global precedence" effect (i.e., performance is better when responding to global than to local features), which means that global features can be processed faster than local features. Global precedence is supposed to reflect a bias toward a large, comprehensive attentional focus, while attending to local features is considered to require more effort.

Surprisingly, long-term practice does not seem to affect the global precedence effect (Chan & Woollacott, 2007). However, there are reasons to assume that single bouts of OMM and FAM might have an effect on spatial focusing, even though they may operate through different mechanisms than longer-term practice. Evidence for a role of individual differences in attentional control in the global–local task comes from Dale and Arnell (2010, 2015), who found a negative correlation between global precedence and AB magnitude: people who showed a smaller global precedence effect (i.e., a relatively stronger disposition toward processing local information) showed a greater AB magnitude. These observations suggest that individuals can exert control over the allocation of attention when processing targets. Interestingly, single bouts of OMM and FAM might impact attention in a global–local task in two, not necessarily mutually exclusive ways.

For one, processing global information is commonly assumed to require a broader, more spatially distributed focus of attention, while processing local information is assumed to rely on a smaller, more tightly controlled focus (Navon, 1977). If OMM supports the processing of global features, which people attend to spontaneously anyway, performance should be particularly good when responding to global features, which should lead to a particularly pronounced difference between global processing and local processing (i.e. increased global precedence effect). If FAM, in turn, supports the processing of local features, this should reduce the difference between performance on global and on local features (i.e. decreased global precedence effect).

For another, the global–local task induces conflict by providing irrelevant information that suggests an alternative response. As we have mentioned, global–local tasks are often using congruent and incongruent stimuli, as this prevents a number of undesirable strategies (e.g., using only congruent stimuli would make information for the two levels redundant). It is interesting that congruency commonly matters in global–local tasks, as performance is better in congruent than in incongruent trials (Navon, 1977). This suggests that adopting a global or local task set does not prevent the processing of information related to the other task, which can be taken to indicate a task or goal conflict (Kiesel et al., 2010; see Fig. 1). If we thus assume that top-down control is strengthened by FAM and weakened by OMM (Lippelt et al., 2014), we would predict that congruency effects are smaller after FAM than after OMM.

The goal of the current study was to test these two sets of hypotheses, together with a third assumption that meditation can affect behavior even without extended practice or expertise. Therefore, we exposed participants without any (reported) meditation practice to brief, single bouts of either OMM or FAM (Baas, Nevicka, & Ten Velden, 2014) and assessed whether, first, this would affect the size of the global precedence effect (with larger effects indicating broader attentional spotlight) and, second, the size of the congruency effect (with smaller effects indicating reduced interference from the irrelevant task and target level). If the first hypothesis is correct, we would predict an interaction between the instructed target level (global vs. local) and the kind of meditation (FAM vs. OMM). Theoretically, such an interaction would indicate a relatively direct (i.e., expertise-unrelated) impact of meditation on the focus or distribution of visual attention. If the second hypothesis were correct, however, we would predict instead an interaction between congruency and the kind of meditation (FAM vs. OMM), with a smaller congruency effect after FAM than after OMM. Theoretically, such an interaction would indicate a relatively general impact of meditation on cognitive (meta)control, rather than a more specific impact on visual attention. Given that meditation has been found to improve mood (Chang et al., 2004) and that current mood-state is reckoned to affect cognitive-control processes (van Steenbergen, Band, & Hommel, 2010), we also assessed participants' subjective affective states, and we did so before and after the mediation, as well as at the end of the global–local task.

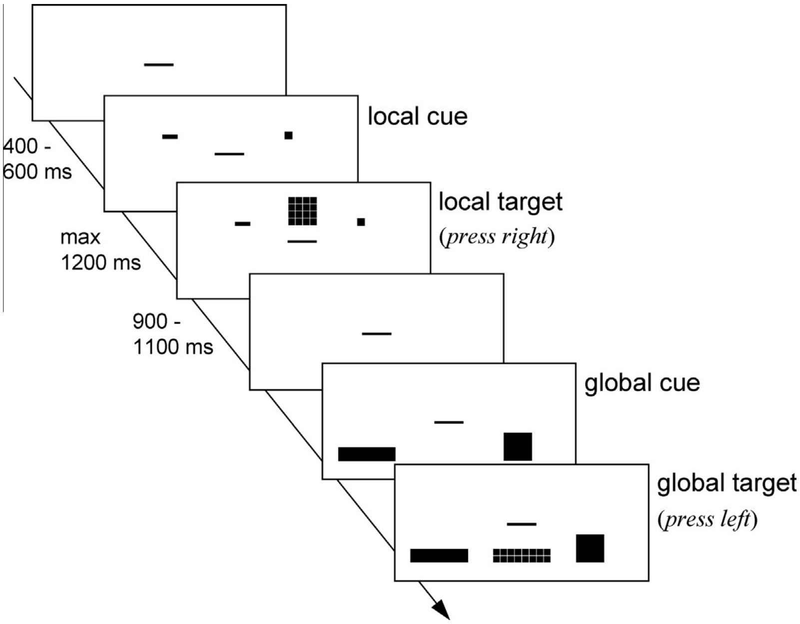

Fig. 1. Sequence of events of a congruent trial followed by an incongruent trial. The congruent trial presents a bigger shape composed of similar smaller shapes (e.g., a large square consisting of smaller squares), the incongruent trial presents a bigger shape composed of different smaller shapes (e.g., a large rectangle consisting of smaller squares).

2. Method

2.1. Participants

Twenty-two healthy adults (4 males; mean age = 20.41, SD = 2.6) from Leiden University participated in two experimental sessions separated by 1 week. Participants were selected individually using the Mini International Neuropsychiatric Interview (M.I.N.I.; Sheehan et al., 1998), 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). Half of the participants started with an OMM session while the other half with a FAM session. Written informed consent was obtained from all subjects; the protocol and the remuneration arrangements of 10 euro were approved by the local ethical committee (Leiden University, Institute for Psychological Research).

2.2. Global–local task

The experiment was controlled by a Windows-operated computer attached to a Philips 17″ monitor. Responses were made by pressing the "Z" or "?" of the QWERTY computer keyboard with the left and right index finger, respectively. The target stimuli were adopted from Colzato, van den Wildenberg, and Hommel (2008), Colzato et al. (2010) and Steenbergen, Sellaro, de Rover, Hommel, and Colzato (2015) and consisted of geometric figures. Larger (global) rectangles/squares consisted of smaller (local) rectangles or squares. Global stimuli (i.e., squares or rectangles; 93 × 93 pixels or 41 × 189 pixels respectively) were composed of many smaller "local" stimuli (i.e., squares or rectangles; 21 × 21 pixels or 8 × 46 pixels respectively). The space between the local elements of a stimulus was 3 pixels. A global square consisted of 16 small squares or 16 small rectangles; a global rectangle consisted of 16 small squares or 16 small rectangles. The "local" and "global" cues were the same size as the global and local stimuli and were presented at 189 pixels from the center of the computer screen.

Participants were presented with one of the four possible stimuli: a rectangle consisting of smaller rectangles or squares, or a square consisting of smaller rectangles or squares. A cue (a rectangle and square, congruous in location with the associated response button) appeared 400–600 ms before the stimulus (located at the center of the screen, between the two cues). The cue was either small or large, and indicated to which level (global/local) the participants should attend in the upcoming stimulus (see Fig. 1)—frequent switches between global and local attending were used to increase uncertainty, a measure aiming to maximize global–local effects. The rectangle or square was associated with a spatially assigned response button that was pressed with either the left ("z" from computer keyboard) or right ("/" from computer keyboard) index finger (which stimulus corresponded to which button was counterbalanced across participants). The four possible stimuli were presented with equal probabilities, so that 50% of the trials were congruent (a large square consisting of smaller squares or a large rectangle consisting of smaller rectangles) and the other 50% were incongruent (a large square consisting of smaller rectangles or a large rectangle consisting of smaller squares).

Cues and target stimuli were presented in red, and both remained on the screen until a response was given or 2500 ms had passed. The interval between response and presentation of the next cue was 900–1100 ms (see Fig. 1). In total, three blocks of trials were administered. The first two blocks consisted of 50 trials each, and were training blocks in which the dimension to be attended (global or local) was constant across all trials within that block. Training block order was counterbalanced between participants, meaning that half of the participants started with the "local block", the other half with the "global block". In the third experimental block of 160 trials, participants had to switch between attending to the global or local dimension every four trials. Participants performed on a total of 80 congruent trials (40 global and 40 local) and 80 incongruent trials (40 global and 40 local). Of the resulting 160 trials, 39 included a task/level switch (not considering the very first trial) and 120 a task/level repetition.

2.3. Procedure

Participants were invited individually to the laboratory. In both sessions, upon arrival, they were asked to rate their mood on a 9 × 9 Pleasure × Arousal grid (Russell, Weis, & Mendelsohn, 1989) with values ranging from −4 to 4. Thus, the scale provides a score that indicates the location of the participant's affective state within a two-dimensional space defined by hedonic tone and activation. 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 et al. (2014) investigating the differential effect of mediation techniques on creativity. 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 global–local task task. After the global–local task, participants rated their mood for the third time. After these measurements, the experimental session was ended. Half of the participants started randomly with the OMM session while the other half with the FAM session. After the second session, all participants were paid, debriefed and dismissed.

2.4. Data analysis

Mean RTs and proportions of errors were analyzed by means of ANOVAs using meditation (FAM vs. OMM), target level (global vs. local), the congruency between the stimuli on the two levels (congruent vs. incongruent), and task switch (i.e., same vs. different target level as in previous trial: task repetition vs. alternation) as within-subjects factor. Mood was analyzed by means of a repeated-measures analysis of variance (ANOVA) with meditation (FAM vs. OMM) and effect of time (first vs. second vs. third measurement) as within-subjects factor. A significance level of $p < .05$ was adopted for all statistical tests.

3. Results

3.1. Global–local task

The reaction time analysis showed five significant sources of variance (see Table 1). First, the effect of congruency, $F(1,21) = 34.31$, $p < .0001$, MSE = 743.96, $\eta_p^2 = 0.62$, reflecting interference of the irrelevant target level, as indicated by a faster RT on

Table 1
Mean reaction times (RT; in ms) and errors (in %) for each condition in the global–local task as a function of FAM and OMM session are displayed. Standard errors are shown in parentheses.

Session	FAM		OMM	
	Mean RT	Mean error	Mean RT	Mean error
Switch	405 (6.4)	7.2 (1.1)	420 (10.4)	7.6 (1.4)
Repetition	374 (5.3)	9.4 (1.1)	376 (5.9)	10.9 (1.1)
Switch cost	*31 ms*		*44 ms*	
Local Target	409 (5.5)	9.1 (1.1)	418 (8.9)	9.0 (1.4)
Global Target	370 (5.3)	7.5 (1.1)	379 (6.9)	9.5 (1.1)
Global precedence effect	*39 ms*		*39 ms*	
Incongruent	395 (5.2)	12.3 (1.3)	411 (8.7)	13.1 (1.5)
Congruent	385 (5.3)	4.3 (0.8)	386 (7.2)	5.4 (0.9)
Congruency effect	*13 ms*[*]		*25 ms*[*]	

[*] $p < .05$.

congruent as compared to incongruent trials (M = 386 ms, SD = 20.0 vs. M = 403 ms, SD = 21.1). Second, the effect of target level, $F(1,21) = 131.39$, $p < .0001$, MSE = 1036.15, $\eta^2_{\text{p}} = 0.86$, reflecting the well-known global precedence effect (Navon, 1977), that is, faster responses to globally than locally defined targets (M = 374 ms, SD = 19.5 vs. 414 ms, SD = 22.4). Third, the effect of switching, $F(1,21) = 57.48$, $p < .0001$, MSE = 2156.58, $\eta^2_{\text{p}} = 0.73$, which (unsurprisingly) revealed that repeating the task allowed for faster responding than switching between target levels (M = 375 ms, SD = 19.6 vs. M = 413 ms, SD = 25.2). The main effect of meditation was not significant, $F(1,21) = 0.73$, $p = .403$, $\eta^2{}_{\text{p}} = .034$, indicating that RTs were not significantly faster in the FAM (M = 390 ms, SD = 23.9) than in the OMM condition (M = 398 ms, SD = 36.0). More importantly for our purposes, congruency interacted with meditation, $F(1,21) = 6.72$, $p < .05$, MSE = 701.43, $\eta^2_{\text{p}} = 0.24$ (see Fig. 2): the size of the congruency effect was significantly larger after OMM than after FAM. In contrast, target level was not affected by meditation, $F < 1$, indicating that the global precedence effect was the same for FAM and OMM (see Table 1). Finally, there was an interaction of target level and congruency, $F(1,21) = 13.61$, $p < .001$, MSE = 801.45, $\eta^2_{\text{p}} = 0.39$, indicating that the congruency effect was larger in the local task (M = 372 ms, SD = 20.7 vs. M = 377, SD = 22.8, in the congruent and incongruent trials, respectively) compared to the global task (M = 400 ms, SD = 23.7 vs. M = 428, SD = 25.2, in the congruent and incongruent trials, respectively)—a common finding that is considered to reflect the greater dominance of the global task (Navon, 1977). We note that the three-way interaction of meditation, congruency, and target level approached significance ($p = .06$), due to a numerically more pronounced effect of meditation on congruency in the local task.

The analysis of the error rates revealed a main effect of congruency, $F(1,21) = 67.95$, $p < .0001$, MSE = 79.75, $\eta^2_{\text{p}} = 0.74$, reflecting interference from the irrelevant target level, as indicated by a smaller proportion of errors on congruent as compared to incongruent trials (M = 4.8%, SD = vs. 12.7%, SD = 6.0). As for RTs, target level interacted with congruency, $F(1,21) = 9.23$, $p < .01$, MSE = 36.42, $\eta^2_{\text{p}} = 0.30$, indicating that the congruency effect was larger in the local task (M = 4.5%, SD = 3.9 vs. M = 14.3, SD = 6.8, in the congruent and incongruent trials, respectively) than in the global task (M = 5.3%, SD = 4.1 vs. M = 11.2, SD = 6.7, in the congruent and incongruent trials, respectively). Finally, there was a three-way interaction involving task switching, congruency, and target level, $F(1,21) = 8.17$, $p < .01$, MSE = 69.98, $\eta^2_{\text{p}} = 0.28$. Tukey HSD post hoc tests showed that, if the task was repeated, the congruency effect was larger in the local task (M = 4.8%, SD = 3.8 vs. M = 18.1, SD = 8.3, in the congruent and incongruent trials, respectively) than in the global task (M = 6.9%, SD = 5.4 vs. M = 11.2, SD = 6.2, in the congruent and incongruent trials, respectively), $p < .01$, whereas if the task was alternated, the congruency effect in the local task (M = 4.1%, SD = 5.1 vs. M = 10.4, SD = 8.0, in the congruent and incongruent trials, respectively) was comparable to that in the global task (M = 3.7%, SD = 5.4 vs. M = 11.3, SD = 10.4, in the congruent and incongruent trials, respectively), $p = 0.96$.

3.2. Control analyses

In order to further elucidate which type of meditation can be held responsible for the differences in findings between OMM and FAM groups, we collected additional data for a control group in which participants (N = 22, mean age 20.5 years, SD = 2.3) did not engage in any meditation. They performed the identical global–local task but, following Colzato, Sellaro, Samara, Baas, et al. (2015), were asked to relax (e.g. reading magazines) in the time periods usually taken by the meditation. The congruency effect shown by the control group mirrored the effect observed in the OMM condition, $F < 1$, $p = .75$, whereas

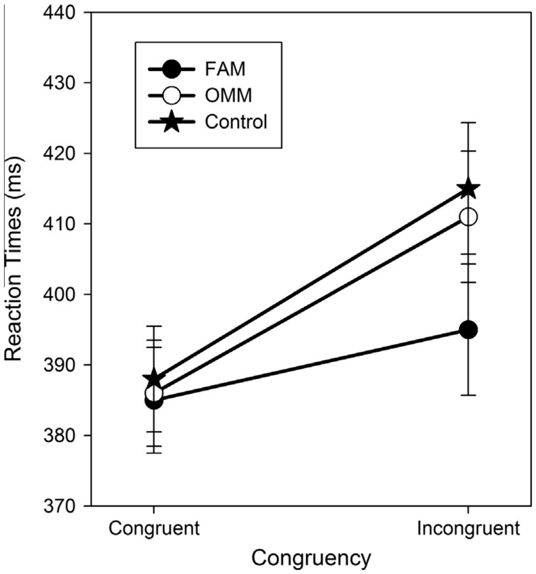

Fig. 2. Mean reaction times (ms) of congruency between the stimuli on the two target levels (congruent vs. incongruent) for FAM, OMM and Control group. Error bars represent standard errors.

it significantly differed from the effect observed in the FAM condition, $F(1,42) = 9.058$, $p < .005$, MSE = 687, $\eta_p^2 = 0.18$(see also Fig. 2). In contrast, the size of the global precedence effect shown by the control group was comparable to both OMM and FAM conditions, $F_s \leqslant 2.5$, $ps \geqslant .12$.

3.3. Mood

The ANOVA performed on participants' mean mood, $F(1,21) = 4.03$, $p < .05$, MSE = 0.75, $\eta_p^2 = 0.16$, and arousal rating, $F(1,21) = 25.94$, $p < .0001$, MSE = 1.69, $\eta_p^2 = 0.55$, revealed only a significant effect of time but no interaction between time and session [$F_s \leqslant 1$]. After both meditations (point 2 in time), mood increased [1.1 (SD = 0.19), 1.6 (SD = 0.25) and 1.1 (SD = 0.2)], while arousal decreased [0.5 (SD = 0.21), −0.9 (SD = 0.27) and 1.0 (SD = 0.24)].

4. Discussion

The findings are clear-cut. First, there was no indication that the global precedence effect would be affected by a single bout of meditation. This can be taken to replicate previous observations of no evidence that long-term meditation practice affects attentional focusing (Chan & Woollacott, 2007). Second, however, meditation did have a significant impact on the congruency effect. If we assume that FAM strengthens top-down support for relevant information and/or increases local competition between relevant and irrelevant information (Colzato, Sellaro, Samara, and Hommel, 2015; Lippelt et al., 2014), and if we consider that congruency reflects crosstalk from a currently irrelevant task or stimulus dimension (Kiesel et al., 2010), our observation indicates that undergoing FAM leads one to engage more in suppressing currently irrelevant information. In other words, FAM allows for more efficient cognitive (goal) persistence (Dreisbach & Goschke, 2004; Hommel, 2015) than OMM does, which in turn has been shown to promote cognitive flexibility (Colzato et al., 2012; Colzato, Sellaro, Samara, Baas, et al., 2015). This finding nicely fits with observations that congruency effects seem to rely on the lateral prefrontal cortex (Brass & von Cramon, 2004), whose functioning has been found to be affected through meditation (Farb et al., 2007). Fig. 3 captures the emerging idea that FAM tends to strengthen the impact of the task goal and/or the competition between alternative attentional foci (cf., Hommel, 2015).

Given that mood and arousal did not significantly change between the FAM and OMM groups after their respective meditation, we can rule out an account of our results in terms of mood and/or arousal changes. The fact that the ability to suppress the currently irrelevant task is more pronounced after FAM is in line with our previous finding of more effective handling of dynamic behavioral adjustments (i.e., trial-to-trial variability of the Simon effect: the Gratton effect; Colzato, Sellaro, Samara, and Hommel, 2015). The finding of greater control strength (i.e., impact of the goal) after FAM as compared to OMM may be of particular interest because it helps to explain and understand why impulse control disorders such as attention-deficit-/hyperactivity disorder and substance abuse are benefiting from meditation-based interventions (Cassone, 2015; Witkiewitz, Marlatt, & Walker, 2005). Even more importantly, our findings suggest that all meditation techniques are not equal, and that successful intervention presupposes the theoretically-guided selection of the best-suited technique.

Finally, our findings bring convergent evidence to the idea that meditation can affect behavior without expertise by means of a single bout of meditation (Baas et al., 2014; Colzato, Sellaro, Samara, and Hommel, 2015; Colzato, Sellaro, Samara, Baas, et al., 2015; Lippelt et al., 2014). While this is encouraging and suggests that substantial effects do not require much practice, it does of course not exclude that long-term practice may further strengthen or even introduce additional meditation benefits. In order to better optimize behavior, future studies should investigate how long-lasting meditation-induced biases of cognitive control are and which training schedules work best.

In sum, this study is the first to provide evidence that brief bouts of OMM and FAM meditation induce specific cognitive-control states that modulate the ability to suppress information from task-irrelevant levels of visual stimuli, rather than biasing potential selection toward particular representational levels.

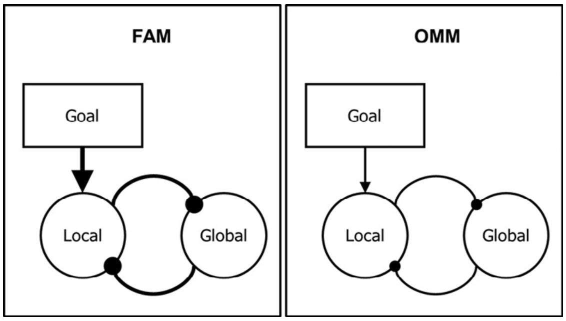

Fig. 3. Hypothetical impact of meditation-induced control states on the control of spatial attention. Focused-attention meditation (FAM) is assumed to increase the impact of the task goal on goal-relevant information and/or the competition between alternative aspects of a stimulus, such as local and global shape. Open-monitoring meditation (OMM) is assumed to weaken the impact of the goal and/or mutual competition.

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