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Meditation-induced cognitive-control states regulate response-conflict adaptation: Evidence from trial-to-trial adjustments in the Simon task

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ABSTRACT

Here we consider the possibility that meditation has an immediate impact on information processing. Moreover, we were interested to see whether this impact affects attentional input control, as previous observations suggest, or the handling of response conflict. Healthy adults 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 a Simon task—which assesses conflict-resolution efficiency. 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) was considerably smaller after OMM than after FAM. Our findings suggest that engaging in meditation instantly creates a cognitive-control state that has a specific impact on conflict-driven control adaptations.

1. Introduction

Previous research has shown that meditation practice (ranging from days and weeks to several years) has substantial effects on how people process their physical and social environment, and how they regulate attention and emotion (see, Lippelt, Hommel, & Colzato, 2014, for a recent review). However, all meditation techniques are not the same: while some techniques demand practitioners to focus their attention on only one object or event at a time, other techniques allow, or even recommend accepting any internal or external experience or sensations that might enter awareness. Hence, different meditation techniques can be taken to bias the practitioner towards either tight or rather loose attentional control. This distinction is thought to be most evident with regard to *Focused Attention meditation* (*FAM*) and *Open Monitoring meditation* (*OMM*) (Lutz, Slagter, Dunne, & Davidson, 2008). FAM induces a narrow attentional focus due to the highly concentrative nature of the meditation, whereas OMM induces a broader attentional focus by allowing and welcoming any experiences that might arise during meditation.

In a seminal study, Tang and colleagues (2007) investigated whether a training technique based on meditational practices called integrative body-mind training (IBMT) could improve performance on an Attentional Network Task (ANT; Fan, McCandliss, Sommer, Raz, & Posner, 2002). The ANT is based on a flanker task and was developed to keep track of three

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different attentional sub skills: orientation, alerting, and conflict resolution. In the ANT task, participants discriminate a single target (e.g., letter or arrow) that is surrounded, or flanked, by distractors that indicate the same or opposite response (Eriksen & Eriksen, 1974). While IBMT had no effect on orienting and alerting scores, it did improve conflict resolution. As discussed by Eriksen and St James (1986), in the flanker task the "attentional spotlight" (i.e., the distribution of attention over space) is likely to be diffuse at stimulus onset, thus allowing interference from the flankers, but gradually narrows down to focus on the target. Along these lines, IBMT intervention might thus have effectively shrank the attentional spotlight to focus more strongly on the target and/or sped up the shrinking process. However, the nature of the flanker task makes it difficult to distinguish between such a rather input-related impact on information processing and effects that are more related to response-selection proper. In standard flanker tasks, incompatible flankers are known to create two kinds of selection problems (e.g., Kornblum, Hasbroucq, & Osman, 1990), one related to the fact that flankers represent alternative target stimuli that input-selection processes need to ignore, and another related to the fact that flankers are associated with an alternative but currently incorrect response—which creates response conflict. Accordingly, the findings of Tang et al. (2007) might indicate that meditation makes input selection more focused, or that it improves the handling of response conflict, or both.

The possibility that meditation affects processes other than genuinely attentional ones has been raised just recently. More specifically, we (Colzato, Oztürk, & Hommel, 2012; Colzato, Sellaro, Samara, Baas, & Hommel, 2015; Lippelt et al., 2014) have suggested that FAM and OMM established particular cognitive-control styles that makes response selection more strict/exclusive or more lenient/inclusive (cf., Lutz et al., 2008), respectively, and that this can happen instantaneously, that is, without much practice. In particular, 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. To test these predictions, we had people naïve to meditation engage in brief bouts of either FAM or OMM. We hypothesized that this would be sufficient to use particular (i.e., more serial or more parallel, respectively) cognitive-control states and affect performance on a subsequent response conflict task without any spatial-selection demands: the Simon task (Simon & Small, 1969). This task assesses the ability to deal with and resolve response conflict, that is, the ability to select a correct response in the face of other, competing responses (cf., Hommel, 2011). Participants are required to perform lateralized (left vs. right) responses on the basis of a non-spatial stimulus feature, often color. The position of the stimulus varies randomly in such a way that it can spatially correspond or not correspond with the position of the required response. The standard finding shows better performance if stimuli appear in response-congruent (C) than in response-incongruent (I) locations, demonstrating that action goals are indeed challenged, and yet people can overcome these challenges by overruling misleading stimulus-induced response tendencies (Hommel, 2011; Kornblum et al., 1990). If meditation can directly impact the efficiency of dealing with response conflict, the size of the Simon effect (I–C) should be affected by meditation type. As we assume that OMM induces a more lenient response-selection style, we would expect that the size of the Simon effect is larger after OMM.

Interestingly, the Simon effect is not entirely stable in size over time. More specifically, the effect of response congruency in the present trial (I–C) is less pronounced after an incongruent trial (iI–iC) than it is after a congruent trial (cI–cC; Gratton, Coles, & Donchin, 1992). This so-called "conflict-adaptation effect" (aka Gratton effect, the term that we prefer as being more theoretically neutral) has been taken to reflect the increase of cognitive control triggered by the experience of conflict (Botvinick, Braver, Barch, Carter, & Cohen, 2001). Accordingly, the Gratton effect can be taken to serve as a measure of control fluctuation and resulting adaptation and seems to rely on a regulatory feedback involving the anterior cingulate cortex (ACC) and the medial prefrontal cortex (PFC) (Botvinick, 2007; Botvinick, Cohen, & Carter, 2004; Botvinick, Nystrom, Fissell, Carter, & Cohen, 1999), the same brain areas found to be associated with enhanced cerebral blood flow with 5 days (30 min per day) IBMT (Tang, Tang, Lu, Feng, & Posner, 2015). Along the same lines, another study in which meditation-naïve participants were randomly assigned to either an 11 h IBMT course or a relaxation training, has reported that the IBMT group showed higher network efficiency and degree of connectivity of the ACC than a group that underwent relaxation training, (Xue, Tang, & Posner, 2011). Moreover, several other studies have also shown improvements in ACC functioning after meditation (Baerentsen, Hartvig, Stødkilde-Jørgensen, & Mammen, 2001; Lazar et al., 2000; Tang et al., 2009; Tang et al., 2010). In other words, both meditation and conflict management are driven by ACC and medial PFC. If so, it is possible that meditation does not, or not only impact the immediate handling of response conflict, as reflected in the Simon effect, but rather the trial-to-trial control adjustments that are reflected in the Gratton effect. If so, one would expect that such adjustments benefit from types of meditation that support focusing, which means that a more pronounced Gratton effect should be obtained after FAM.

The present study served to test these two hypotheses, together with a third hypothesis that meditation can impact the respective control processes instantaneously, that is, without extended practice or expertise. Accordingly, we presented participants with brief, single sessions of either OMM or FAM (Baas, Nevicka, & Ten Velden, 2014) and tested whether this would affect the size of the Simon effect (with smaller effects indicating tighter control) and the size of the Gratton effect (with larger effects indicating tighter control).