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Is meditation always relaxing? Investigating heart rate, heart rate variability, experienced effort and likeability during training of three types of meditation

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ABSTRACT

Meditation is often associated with a relaxed state of the body. However, meditation can also be regarded as a type of mental task and training, associated with mental effort and physiological arousal. The cardiovascular effects of meditation may vary depending on the type of meditation, degree of mental effort, and amount of training. In the current study we assessed heart rate (HR), high-frequency heart rate variability (HF-HRV) and subjective ratings of effort and likeability during three types of meditation varying in their cognitive and attentional requirements, namely breathing meditation, loving-kindness meditation and observing-thoughts meditation. In the context of the *ReSource* project, a one-year longitudinal mental training study, participants practiced each meditation exercise on a daily basis for 3 months. As expected HR and effort were higher during loving-kindness meditation and observing-thoughts meditation compared to breathing meditation. With training over time HR and likeability increased, while HF-HRV and the subjective experience of effort decreased. The increase in HR and decrease in HF-HRV over training was higher for loving-kindness meditation and observing-thoughts meditation compared to breathing meditation. In contrast to implicit beliefs that meditation is always relaxing and associated with low arousal, the current results show that core meditations aiming at improving compassion and meta-cognitive skills require effort and are associated with physiological arousal compared to breathing meditation. Overall these findings can be useful in making more specific suggestions about which type of meditation is most adaptive for a given context and population.

1. Introduction

It is widely assumed that meditation, irrespective of the type, is a way to relax by inducing a hypometabolic state of the body and a tranquil, but alert state of the mind (Benson et al., 1974; Jevning et al., 1992; Lazar et al., 2000). Recently, however, attention has been drawn to the fact that meditation might not generally lead to a relaxation response and that the effects of meditation on psychophysiological processes might depend on factors including meditation type and level of meditation experience (Britton et al., 2014). A better understanding about which types of meditation have relaxing or arousing effects will be crucial to make more precise suggestions about the applicability of meditation in different domains and populations. It is therefore important to empirically test whether different types of meditation have arousing or relaxing effects on psychological and physiological states and how these effects change with training expertise.

The current project focused on three meditation exercises including breathing-meditation, loving-kindness meditation and observing-thoughts meditation. These three meditation exercises can be regarded as the most widely practiced meditation exercises in Buddhist contemplative traditions (Wallace, 2006). The three core exercises differ with respect to the cognitive and affective processes involved, as well as with respect to the skills that they train. Breathing meditation requires the redirection and holding of attention to the object of breath and trains sustained attention and interoception (Malinowski, 2013). Loving-kindness meditation involves cognitive processes including redirection of attention to mental imagery and sentences, as well as remembering sentences, generating and maintaining mental imagery (Hofmann et al., 2011). Furthermore it involves affective processes such as generating and sustaining positive affect in order to train an increase in positive emotions, compassion and prosocial behavior. The observing-thoughts meditation requires cognitive processes such as redirection and holding attention to the object of thoughts, categorization of thoughts, development and maintaining meta-awareness in order to

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train detachment from mental events. Due to the greater amount and complexity of attentional, cognitive and affective processes involved in loving-kindness meditation and observing-thoughts meditation as compared to breathing meditation we assume that these exercises can be categorized as more demanding than breathing meditation and thus should be associated to higher levels of self-reported effort and physiological arousal when performed.

Meditation within Buddhist traditions can be regarded as a mental training technique that aims to train cognitive skills including sustained attention, working memory and other executive processes (Hölzel et al., 2011; Slagter et al., 2011; Wallace, 1999). It is suggested that meditation training is initially linked to mental effort, which should decrease with training expertise over time (Tang et al., 2012). Previous research has found that moderate practice of meditation improves measures of cognitive resources, including reduced mind wandering and increased attentional capacity (Lutz et al., 2009; Mrazek et al., 2013; Zeidan et al., 2010a). Perceived effort is also known to be related to feelings of enjoyment while one is profoundly focused on a task (Csikszentmihalyi, 2014). Evidence suggests that feelings of enjoyment are high if one's perceived ability to solve the task matches the capacities required to solve the task (Csikszentmihalyi and LeFevre, 1989). To our knowledge there are currently no studies that have directly assessed changes of perceived effort and enjoyment during meditation training over time. Based on studies showing that meditation can improve performance in cognitive tasks, we expect that effort during meditation will decrease over time while enjoyment will increase as participants become more experienced with the meditation training (Tang et al., 2012; Zanesco et al., 2013; Zeidan et al., 2010a).

Perceived mental effort is also often linked to physiological arousal (Hansen et al., 2003; Luft et al., 2009). Mental states that require high cognitive demands are known to influence the autonomic nervous system (ANS), divided into the parasympathetic nervous system (PNS) and sympathetic nervous system (SNS). Heart rate (HR) and heart rate variability (HRV) are often used as biomarkers of the ANS. HRV, in particular its high-frequency (HF-HRV) component (0.15 to 0.40 Hz), is a marker of the PNS activity (Camm et al., 1996; Reyes del Paso et al., 2013) and related to a variety of psychological factors including attention, working memory and emotion regulation (Thayer and Lane, 2009). We did not include the low-frequency (0.04 to 0.15 Hz) or veylow frequency components ($\leq$0.04) as additional outcome measures because their interpretation as indicators of autonomic activity remains unclear (Billman, 2011). Instead we used HR as a marker of SNS activity, because HR acceleration is known to be caused by SNS activity through the release of norepinephrine (Camm et al., 1996). Increased HR is associated with cognitive arousal and mental effort (Critchley et al., 2013). Previous studies provide evidence that increased PNS activity is linked to improved cognitive control during the performance of cognitive tasks (Hansen et al., 2003; Overbeek et al., 2014). Based on the expected decrease in perceived mental effort over time and based on the evidence that cardiac activity is related to mental effort we predicted that HR during meditation will decrease, while HF-HRV will increase over training.

So far the majority of studies on the influence of meditation on HR and HF-HRV have investigated the difference between meditation state and baseline conditions (for reviews see (Kok et al., 2013; Olex et al., 2013)). Regarding the effects of meditation compared to baseline measures of cardiovascular activity many studies on the effects of attention-focused types of meditation show an increase in parasympathetic activity as assessed by increases in HF-HRV or decreases in HR (Krygier et al., 2013; Libby et al., 2012; Takahashi et al., 2005; Wu and Lo, 2008; Zeidan et al., 2010b). In contrast, Lutz and colleagues showed that compassion meditation in experts led to an increase in HR compared to a baseline condition suggesting an activation of the SNS during compassion meditation (Lutz et al., 2009). In a previous cross-sectional study with experienced meditators, Peng et al. showed that HR was higher during types of meditation with controlled breathing compared to a relaxation meditation without controlled breathing (Peng et al., 2004). In a more recent cross-sectional study with expert meditators from different Buddhist traditions, changes in HF-HRV varied across types of meditation: An increase in HF-HRV was found during Theravada types of meditation that included a concentrative focus on bodily sensations. In contrast, a decrease in HF-HRV was found during Vajrayana types of meditation that included an active generation of mental imagery (Amihai and Kozhevnikov, 2014). These findings suggest that effects of meditation on cardiovascular activity might vary as a function of the type of meditation and the degree of meditation experience of the participants. Thus, it is important to conduct longitudinal studies in meditation naive participants. In contrast to previous cross-sectional studies, a longitudinal design would allow for the study how the practices of different types of meditation influence cardiovascular activity over time. To our knowledge, however, there have been no studies comparing the influence of different types of meditation on training-induced changes over time in cardiac responses during meditation state from naive participants. Therefore, based on evidence that different types of meditation influence PNS and SNS activity differently, and based on expected changes with increased training expertise, we hypothesized that different types of meditation change cardiac activity and perceived effort and enjoyment differently over time.

The current project, which is part of a nine-month longitudinal mental training study called the *ReSource* project (Singer et al., in preparation), compared subjective and physiological signatures during breathing meditation, loving-kindness meditation and observing-thoughts meditation and how these change through training. Each meditation exercise was trained within a three-month training module on a daily basis at home while participants listened to guided audio-files with instructions given by qualified meditation teachers. For further details see Section 2.1, 2.2 and Singer et al. (in preparation). Measures of the present study included HF-HRV as a marker of PNS activity and HR as a marker of SNS activity, as well as ratings of subjective experiences of effort and likeability during breathing meditation, loving-kindness meditation and observing-thoughts meditation. The measures were taken in week 3 and week 13 within each training module. The analysis of the current study is based on a within-subject design with the factor time (week 3 and week 13) and the factor type of exercise (breathing meditation, loving-kindness meditation and observing-thoughts meditation). Initially all participants learned the breathing meditation, because it trained skills, which were required to learn the loving-kindness meditation and observing-thoughts meditation. The order of exercises was counterbalanced for loving-kindness meditation and observing-thoughts meditation.

We had the following specific hypotheses:

(1) Based on the differences with regard to the amount and complexity of cognitive and affective processes involved during each type of meditation, we hypothesized that the loving-kindness meditation and observing-thoughts meditation are more effortful compared to breathing meditation. Therefore we expected HR and effort to be higher and HF-HRV and likeability to be lower for loving-kindness meditation and observing-thoughts meditation as compared to breathing meditation.

(2) In line with studies on changes in skill acquisition through mental training over time, we predicted that HR and effort will decrease from week 3 to week 13, whereas HF-HRV and experienced likeability will increase from week 3 to week 13.

(3) Based on the first hypothesis that different types of meditation influence cardiac responses differently, we expected changes in HR, HF-HRV, effort and likeability over time to be different across the three core exercises. Due to the more demanding processes involved during loving-kindness meditation and observing-thoughts meditation, we expected the decrease in HR and effort and increase in HF-HRV and enjoyment to be smaller compared to breathing meditation.