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The mindful eye: Smooth pursuit and saccadic eye movements in meditators and non-meditators

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ABSTRACT

Background: This study examined the effects of cultivated (i.e. developed through training) and dispositional (trait) mindfulness on smooth pursuit (SPEM) and antisaccade (AS) tasks known to engage the fronto-parietal network implicated in attentional and motion detection processes, and the fronto-striatal network implicated in cognitive control, respectively.
Methods: Sixty healthy men (19–59 years), of whom 30 were experienced mindfulness practitioners and 30 meditation-naïve, underwent infrared oculographic assessment of SPEM and AS performance. Trait mindfulness was assessed using the self-report Five Facet Mindfulness Questionnaire (FFMQ).
Results: Meditators, relative to meditation-naïve individuals, made significantly fewer catch-up and anticipatory saccades during the SPEM task, and had significantly lower intra-individual variability in gain and spatial error during the AS task. No SPEM or AS measure correlated significantly with FFMQ scores in meditation-naïve individuals.
Conclusions: Cultivated, but not dispositional, mindfulness is associated with improved attention and sensorimotor control as indexed by SPEM and AS tasks.

1. Introduction

Smooth pursuit and saccadic eye movements are two types of eye movements that both human and non-human primates voluntarily employ to allow the image of an object fall and maintain near to or on the fovea. The function of smooth pursuit eye movements (SPEM) is to keep a retinal image within the area of the fovea during the movement of an object. The initiation as well as the maintenance of accurate SPEM requires attentional control (Hutton & Tegally, 2005). The primary measure of pursuit accuracy is the velocity gain which corresponds to the ratio of smooth pursuit velocity over target or object velocity (100% if SPEM velocity matches the target velocity) (Lencer & Trillenberg, 2008). Other indicators of SPEM efficiency are the frequency of compensatory catch-up and intrusive anticipatory saccades made during the smooth pursuit task.

Saccades refer to the fast eye movements made to the sudden appearance of a visual target. Prosaccades require the participant to make a saccade to a single-target stimulus as soon as it appears. The antisaccade (AS) paradigm, on the other

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hand, requires the participant to inhibit a reflex-like saccade towards the target, and instead initiate a saccade in the direction opposite to the target (Hutton & Ettinger, 2006). It examines the conflict between a pre-potent stimulus that produces a strong urge to make a saccade to the target, and the overriding goal to look in the opposite direction. Correct AS performance requires accurate perception, ability to transform location information to a mirror image representation, and suppression of a saccade towards the AS stimulus. Performance is assessed as the error rate, spatial accuracy and latency of (anti)saccades (Hutton & Ettinger, 2006). Given their high test-retest reliability (Ettinger et al., 2003) and the ease of administration, SPEM and AS paradigms have been used to assess cognitive functions in a wide variety of contexts (Hutton & Ettinger, 2006; Lencer & Trillenberg, 2008). However, no published study, to our knowledge, has yet utilised these paradigms to understand the neural and cognitive influence of mindfulness as a trait ('dispositional' mindfulness) (Brown & Ryan, 2003), or mindfulness developed through training ('cultivated' mindfulness) (Ivanovski & Malhi, 2007).

Mindfulness, a translation of the Pali term *sati*, is operationalized in modern psychology as a quality of awareness that arises from paying attention to the experience on a moment-by-moment basis without judging, elaborating upon, or fixating on this experience in any way (Kabat-Zinn, 1990). Its practice typically begins with the mindfulness of bodily sensations to the awareness of feelings and thoughts, progressing to a present-centred awareness without an explicit focus, in most Buddhist traditions as well as formal intervention-style practices such as Mindfulness-Based Stress Reduction (MBSR; Kabat-Zinn, 1990) and Mindfulness-Based Cognitive Therapy (MBCT; Segal, Williams, & Teasdale, 2002). Dispositional mindfulness refers to the naturally occurring tendency to display this non-judgmental present awareness in everyday life and varies amongst individuals (Brown & Ryan, 2003).

There is growing evidence for a positive effect of cultivated mindfulness on a range of cognitive functions (reviews, Chiesa, Calati, & Serretti, 2011; Gallant, 2016). Mindfulness practice enhances stability of attention by reducing cortical noise (Lutz et al., 2009) and appears to increase information processing capacity (Slagter et al., 2007) with the cognitive system more rapidly available to process new targets (Slagter, Lutz, Greischar, Nieuwenhuis, & Davidson, 2008). It is reported to positively influence orienting attention (van den Hurk, Giommi, Gielen, Speckens, & Barendregt, 2010), dual attention (Jensen, Vangkilde, Frokjaer, & Hasselbalch, 2012) and performance on a range of tasks requiring attention and/or cognitive flexibility (Hodgins & Adair, 2010; Jha, Krompinger, & Baime, 2007; Jha, Stanley, Kiyonaga, Wong, & Gelfand, 2010; Kumari, Hamid, Brand, & Antonova, 2015; Moore, Gruber, Derose, & Malinowski, 2012; Semple, 2010; Tang et al., 2007; van den Hurk, Janssen, Giommi, Barendregt, & Gielen, 2010). According to a recent review (Gallant, 2016), mindfulness-led improvements in executive functioning, within Miyake et al.'s model (2000), are more consistently found on specific measures of inhibition (Allen et al., 2012; Heeren, Van Broeck, & Philippot, 2009; Moore & Malinowski, 2009; Sahdra et al., 2011; Teper & Inzlicht, 2013), relative to updating (Jha et al., 2010; Mrazek, Franklin, Tarchin, Baird, & Schooler, 2013) and shifting components (Anderson, Lau, Segal, & Bishop, 2007; Chambers, Lo, & Allen, 2008; Heeren et al., 2009; Moynihan et al., 2013).

There are, however, only few data at present examining the association between trait mindfulness, as measured in the general non-meditating population using self-report questionnaires (Brown & Ryan, 2003), and cognitive function, with some studies (Stillman, Feldman, Wambachm, Howard, & Howard, 2014; Stillman et al., 2016; Whitmarsh, Uddén, Barendregt, & Petersson, 2013) indicating a negative relationship between trait mindfulness and implicit learning, i.e. learning without conscious awareness.

The aim of the present study was to examine the influence of mindfulness both as a trait and developed through training on visuo-spatial attentional and voluntary inhibition processes indexed by the SPEM and AS paradigms, respectively. Based on previous report of positive effects of mindfulness practice on a range of attention, working memory and inhibition tasks (reviews, Chiesa et al., 2011; Gallant, 2016), we hypothesised that meditators, compared with meditation-naïve individuals, will show more accurate gain and lower frequency of catch-up and anticipatory saccades on the SPEM task, and a lower error rate, higher spatial accuracy and reduced within-subject variability in spatial accuracy (i.e. more consistent performance) on the AS task. Furthermore, we hypothesised tentatively (in absence of direct previous data) that in meditation-naïve individuals, trait mindfulness, as assessed by the Five Factor Mindfulness Questionnaire (FFMQ; Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006), will correlate with better SPEM and AS performance, particularly on measures that significantly differentiate meditators and non-meditators.

2. Methods

2.1. Participants and design

The study involved two groups. Group 1 consisted of 30 experienced mindfulness practitioners (meditators) and Group 2 of 30 meditation-naïve individuals (all males; age range 19–59 years). All participants were assessed on a single occasion.

Meditators were recruited from local and national Buddhist centres via poster advertisement and presentations of the study and its aims at meetings of centre members. They were required to have at least 2 years of consistent meditation practice (minimum 45 min per day at least 6 days a week). Meditation-naive men were recruited from a healthy volunteer database or by circular emails sent to staff and students of King's College London, UK. They were required to have no experience of mindfulness-related practices, including meditation, yoga, tai-chi, qigong or martial arts.

Additional inclusion criteria for all participants were: (i) right-handedness (Oldfield, 1971), (ii) current IQ > 80 as assessed with the two-test version of Wechsler Abbreviated Scale of Intelligence (Wechsler, 1999), (iii) aged 18–60 years, (iv) normal