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# Alpha-band transcranial alternating current stimulation modulates precision, but not gain during whole-body spatial updating

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ABSTRACT

Spatial updating is essential to maintain an accurate representation of our visual environment when we move. A neural mechanism that contributes to this ability is called remapping: the transfer of visual information from neural populations that code a location before the motion to those that encode it after the motion. While there is ample evidence for neural remapping in conjunction with eye movements, only recent findings suggest a role of this mechanism for whole-body motion updating, based on the observation that alpha band (10 Hz) activity is selectively reorganized during remapping. This study tested whether alpha oscillations directly contribute to whole-body motion updating using transcranial alternating current stimulation (tACS). In a double blind sham controlled design, healthy volunteers received 10 Hz tACS at an intensity of 1 mA over either the left or right posterior hemisphere during a whole-body motion updating task. Updating performance was assessed psychometrically and indices of gain and precision were obtained. No tACS-related effects on updating gain were found, irrespective of whether the remapping was across or within the hemispheres. In contrast, updating precision was enhanced when a target representation had to be internally remapped to the stimulated hemisphere, but not in other remapping conditions. Our observations suggest that alpha band oscillations do not directly affect the transfer of target representations during remapping, but increase the fidelity of the updated representation by attenuating interference of afferent information.

## 1. Introduction

When navigating through the environment, we continuously keep track of objects in our immediate surroundings, internally updating their locations in conjunction with our moving body i.e. ‘spatial updating’ (for reviews see Klier and Angelaki, 2008; Medendorp, 2011). The neural correlates of this behavior have been studied extensively using saccadic updating paradigms. Based on monkey single-unit studies, one mechanism that has been identified is called remapping: the transfer of the representation of a stimulus location from neurons activated by the stimulus before the saccade to those that represent its location after the saccade (Colby et al., 1995; Sommer and Wurtz, 2008). Evidence for this mechanism has also been found in the human brain, based on brain oscillations (Van Der Werf et al., 2013), BOLD signals (Medendorp et al., 2003; Merriam et al., 2003) and TMS findings (Morris et al., 2007).

In contrast to saccades, the neural underpinnings of spatial updating across head and body motion have been studied much less. It is only recently that studies suggest that remapping can also account for updating across whole-body motion (Gutteling et al., 2015; Gutteling and Medendorp, 2016). Evidence is based on neural oscillations in the alpha band (8–12 Hz), whose power increases and decreases have been associated with the selective inhibition and engagement of neuronal populations, respectively (Jensen and Mazaheri, 2010).

In Gutteling et al. (2015), we showed that alpha band power across occipital-parietal areas switches hemispheres when a target location reverses sides relative to the body midline (which was aligned with gaze) during the motion. More specifically, an increase of power was observed in the hemisphere to which the target representation was remapped. These findings were interpreted as a protection mechanism in which alpha oscillations impede other inputs that could distort the quality of target representation (Gutteling and Medendorp, 2016). Furthermore, a correlation was observed between the change in power and the spatial extent of remapping, as if alpha oscillations facilitated transfer of the target representation from the one neuronal population to the other during remapping. However, it remains unclear whether alpha oscillations directly gate remapping, reduce interference effects, or only reflect a proxy outcome of the remapping process.

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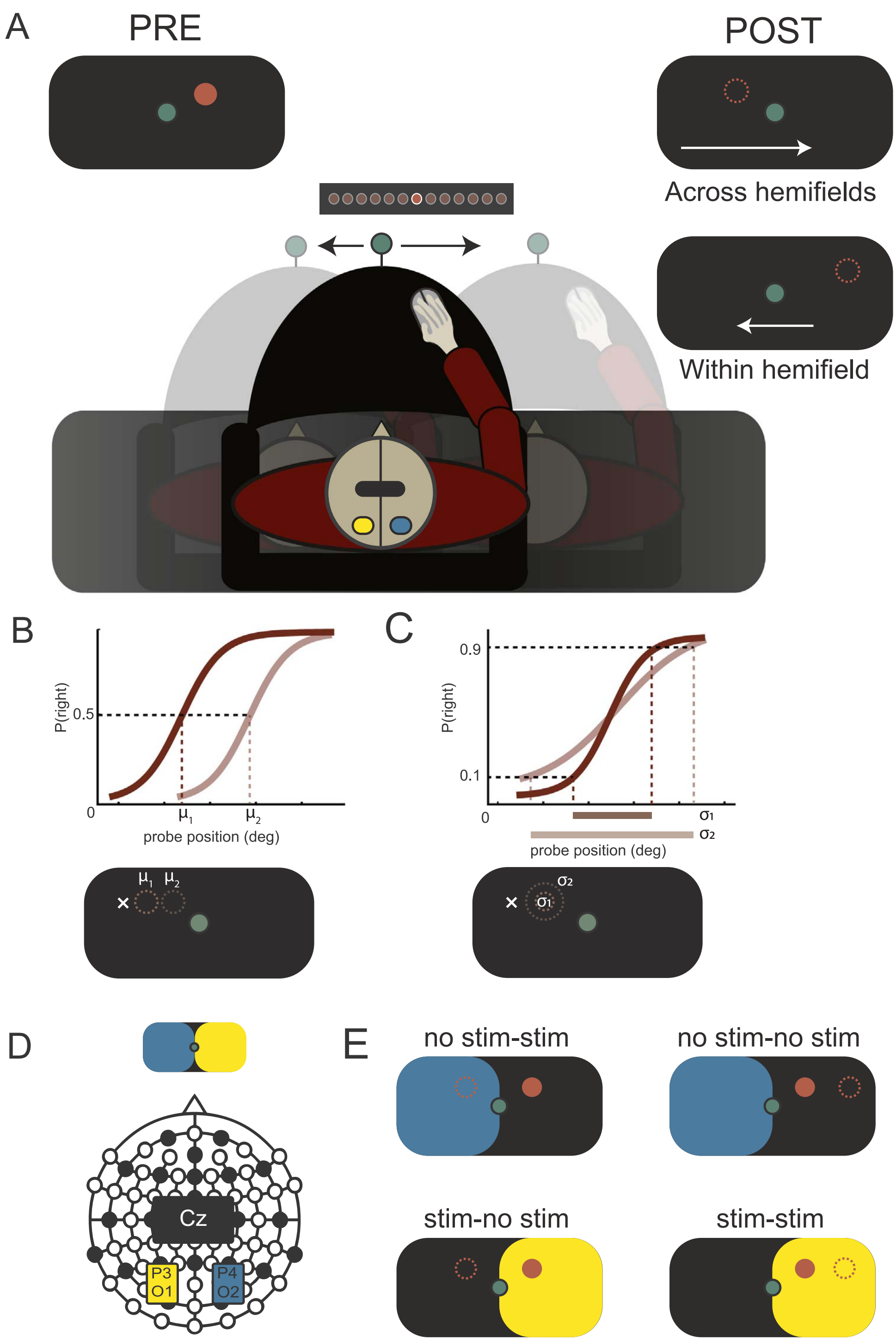


**Fig. 1.** Overview of the paradigm. A) Schematic top view of the experimental setup. Subjects were seated in the translation sled, in complete darkness, while a target (red circle) was presented using an LED array in front of the participant. Fixation was attached to the sled (green circle) and remained straight ahead of the subject. After target presentation, the sled moved either toward or away from the remembered target, resulting in an updated target either being remapped across hemifields, or within. Insets show the subjects' view before body motion (pre, left) and after (post, right). Dotted circles denote remembered (non-visible) targets. B) Derivation of the gain parameter and C) the variance from the psychometric curve. The gain is derived from the mean (50% point) of the curve and corrected for movement distance (see Section 2). In this paradigm, gain affects the remembered location of the spatial target. The variance is derived from the slope of the curve and affects the precision of the target location. D) Montage arrangement of the electrical stimulation. A small electrode was placed over either the left or right parieto-occipital areas, corresponding to EEG 10–20 electrode location P3/O1 and P4/O2 respectively. A larger electrode was placed over Cz. E) Overview of the experimental conditions from the subjects' view. Red filled targets represent visual (initial) targets, dotted circles represent remembered, remapped targets after the motion. Targets had to be remapped either to the other hemifield, or within the same hemifield. Conditions are named after the position of the initially presented target and remembered target relative to stimulation, e.g. in the no stim-stim condition the initial target appears in the hemifield contralateral to the non-stimulated hemisphere and the remembered target contralateral to the stimulated hemisphere. Colored hemifields denote the stimulated hemifield according to the montage in D. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Given that spatial updating is reflected in a specific spatiotemporal pattern of alpha band activity, we applied transcranial alternating current (tACS) at the alpha frequency (10 Hz) unilaterally over either left- or right occipital-parietal areas in a task that requires spatial updating during whole-body motion. We assessed the effect of stimulation psychometrically and derived two behavioral measures (see Fig. 1B): the updating gain, reflecting the *amount* of internal transfer of the remembered spatial location (i.e., the estimated spatial shift of a location), and updating precision, a measure for the *quality* of the remembered spatial location (i.e., the non-systematic variance in location). The gain and precision updating may reflect different mechanisms and be independently affected.

Previous studies have shown that a low current applied to the scalp, alternating at alpha frequency can entrain alpha band activity (Ruhnau et al., 2016; Zaehle et al., 2010), and cause behavioral effects in various cognitive domains (Brinkman et al., 2016; Cecere et al., 2015; Helfrich et al., 2014; Schutter and Wischnewski, 2016), although the exact mechanisms are in dispute (Herrmann et al., 2013; Kar and Krekelberg, 2014; Vossen et al., 2015).

Based on our recent observations (Gutteling and Medendorp, 2016), we hypothesize that alpha band is directly involved in the remapping, either as an interhemispheric transfer mechanisms and/ or an interference protection mechanism. Given this, alpha tACS will improve the updating gain for representations that are remapped across the