The influence of transcranial alternating current on the timing of decision making

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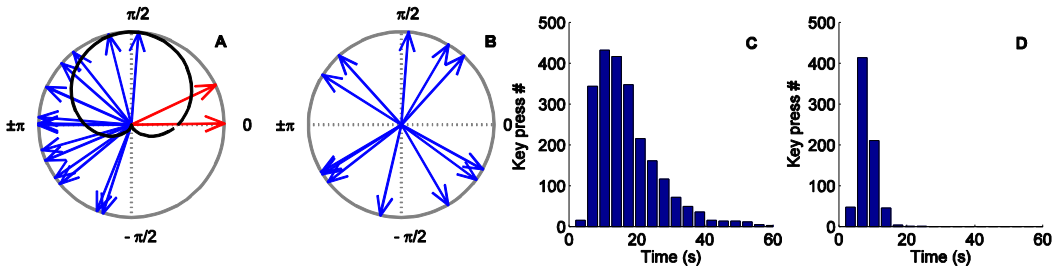
The influence of the phase of transcranial alternating current stimulation (tACS) has been previously shown to influence behavior by modifying the expression of tremor in patients with Parkinson's disease [1], additionally it has also been shown to influence perception of near threshold sounds [2]. Here, we provide preliminary evidence that tACS can also be used to influence the timing of decision making in a phase specific way.

Fourteen subjects performed a self-paced single finger key press task at a computer keyboard. Subjects were instructed to remain still except for finger movements, to make clear direct movements, and to avoid any type of rhythmic motion. Additionally, they were encouraged to not repeat movements within a predefined time of each other. While performing the task, subjects were exposed to tACS between 600uA and 925uA with a frequency of 0.5Hz, for a combined total of 700 minutes. Subjects also repeated the task in a sham condition, in which they were not provided with any stimulation for a combined total of 380 minutes. Electrodes were placed within saline soaked sponges, with the reference electrode (5cm x 7cm) positioned over Oz, and the source electrode (3cm x 3cm), placed over Fz. In the stimulation condition, current was ramped linearly over 10 seconds. Key press times with reference to stimulation onset in the stimulation condition, and with reference to an arbitrary time point for the sham condition were collected. Key presses that occurred less than 5 seconds after the previous button press were excluded, as were presses in the first and last 10 seconds of each session.

Key press times were converted to equivalent phases corresponding to the relative phase of stimulation. In the sham condition, it would be expected that the key press phases ($N = 1820$) do not differ significantly from a uniform distribution, and this is indeed the case as shown by a Rayleigh test ($p = 0.711$). However, in the stimulation condition, key press phases ($N = 2636$) display a significant non-uniformity ($p = 0.024$). Furthermore, upon exclusion of two subjects deemed to be performing the task incorrectly, in part due to their low variance waiting times and high key press rate (see figure D versus C), a strong statistical significance is reached in the stimulation condition ($p = 0.001$, $N = 2121$), while the sham condition remains non significant ($p = 0.623$, $N = 1299$). Individual subject means of key press phases relative to tACS during stimulation appear to cluster in the third and fourth quadrants as shown in figure A, while in the sham condition (figure B) there appears to be no clustering. The shift in the means with relation to the tACS peak during stimulation may be due to interactions between tACS and the neuronal activities of the subject specific decision making process.

The readiness potential, generated during self-paced movements, has often been viewed as a marker for movement preparation, however a recent study has suggested that the readiness potential may be viewed as a stochastic accumulator model [3], essentially acting to trigger an action. Here, we provide results consistent with this hypothesis, by applying tACS in order to modify the ongoing process by which the readiness potential is formed, and in turn modifying the decision making process without the conscious knowledge of the subject.



A) Stimulation mean key press phase for each subject, red: subjects with lowest waiting time (WT) and WT variance, black: relative amplitude of tACS, 1st and 2nd quadrants represent tACS in the positive half of its cycle, while 3rd and 4th quadrants represent tACS in the negative half of its cycle. **B)** Sham condition mean key press phase for each subject. **C)** Key press WT distribution for all subjects except those shown in red in A. **D)** The same as in C, but for subjects shown in red in A.

References

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