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Research article

Combined motor point associative stimulation (MPAS) and transcranial direct current stimulation (tDCS) improves plateaued manual dexterity performance

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HIGHLIGHTS

- We asked if combining central and peripheral stimulation could improve hand dexterity without motor practice.
- Subjects were healthy young adults and had already reached plateau on a manual dexterity task.
- Combining anodal tDCS with MPAS significantly improved manual dexterity beyond the ceiling of performance.
- Central tDCS to complement peripheral MPAS may be a promising avenue of treatment for patients with impaired hand dexterity.

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ABSTRACT

Motor point associative stimulation (MPAS) in hand muscles is known to modify motor cortex excitability and improve learning rate, but not plateau of performance, in manual dexterity tasks. Central stimulation of motor cortex, such as transcranial direct current stimulation (tDCS), can have similar effects if accompanied by motor practice, which can be difficult and tiring for patients. Here we asked whether adding tDCS to MPAS could improve manual dexterity in healthy individuals who are already performing at their plateau, with no motor practice during stimulation. We hypothesized that MPAS could provide enough coordinated muscle activity to make motor practice unnecessary, and that this combination of stimulation techniques could yield improvements even in subjects at or near their peak. If so, this approach could have a substantial effect on patients with impaired dexterity, who are far from their peak. MPAS was applied for 30 min to two right hand muscles important for manual dexterity. tDCS was simultaneously applied over left sensorimotor cortex. The motor cortex input/output (I/O) curve was assessed with transcranial magnetic stimulation (TMS), and manual dexterity was assessed with the Purdue Pegboard Test. Compared to sham or cathodal tDCS combined with MPAS, anodal tDCS combined with MPAS significantly increased the plateau of manual dexterity. This result suggests that MPAS has the potential to substitute for motor practice in mediating a beneficial effect of tDCS on manual dexterity.

1. Introduction

Increasing the excitability of corticospinal projections has been found to improve recovery in stroke patients [1]. Efforts to increase corticospinal excitability have ranged from simple ballistic movement [2] and task-specific performance [3] to peripheral [4] and central [5,6] electrical stimulation. For example, paired associative stimulation (PAS), which consists of peripheral nerve stimulation (PNS) in association with motor cortex stimulation, is based on the Hebbian principle of spike timing-dependent plasticity [7]: if neurons are repeatedly depolarized in synchrony, the strength of synaptic connections among them increases.

A related technique involves synchronous peripheral stimulation of two muscles that cooperate for fine hand movement: Abductor Policis Brevis (APB) and First Dorsal Interosseous (FDI).

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Motor point associative stimulation (MPAS) increases the excitability of corticospinal projections to the stimulated muscles, similar to what has been observed in motor learning [8], and has been shown to increase the learning rate, though not the plateau, in a manual dexterity task in healthy subjects [9]. However, MPAS facilitation in upper limb dexterity is only obtained when used in combination with motor practice, e.g. training in a grooved pegboard test in healthy subjects [9] or physical therapy in stroke patients [4]. Because substantial upper limb motor training can be tiring and difficult for patients [10,11], and MPAS is a simple and low-cost technique that can be used in the clinic, an MPAS-based rehabilitation technique that did not require active movement would have considerable advantages.

Non-invasive central electrical stimulation, such as transcranial direct current stimulation (tDCS), results in tonic changes in cortical excitation and corticospinal connections when applied over sensorimotor cortex. tDCS involves two sponge electrodes, a cathode and an anode, which are placed on the head. When a small electric current is passed through the electrodes, the current flow modulates cortical excitability in the target area in a polarity-specific way. The anode causes an increase in excitability under the electrode while the cathode does the opposite [12]. The majority of work on tDCS has focused on primary motor cortex. Anodal tDCS over this region improves performance of a serial reaction time task in healthy subjects [13]. This technique also improves skilled motor function in chronic stroke patients [5]. In general, tDCS has demonstrated an effect on manual dexterity mostly when it is combined with a motor task practiced during stimulation [5,13,14]. Without motor practice, the cumulative effects of repeated sessions of tDCS can improve motor function in stroke patients [6], but multiple sessions of tDCS over days or weeks are required. tDCS is a simple and affordable technique that could be adapted for clinical use, but an approach that did not require physical practice would be the most useful.

There is some evidence that combining peripheral and central stimulation may yield stronger effects than either alone. Combining tDCS with PNS has been shown to cause lasting increases in motor cortex (M1) excitability [15,16] in healthy subjects. Furthermore, in stroke patients, in the presence of manual practice, PNS in combination with tDCS facilitated the beneficial effect of each intervention [17]. The effect of combining tDCS with MPAS has not been explored in healthy or clinical populations, but could have substantial advantages, as the synchronous muscle activations of MPAS may serve the function normally played by motor practice in tDCS interventions.

Here we ask whether adding tDCS over sensorimotor cortex enhances the effect of MPAS on manual dexterity in healthy adults. In this preliminary study we tested healthy subjects who were performing at or near their plateau of manual dexterity, reasoning that if combining tDCS and MPAS can further improve performance in this population, even by a small amount, then in clinical populations performing far from their peak, the effects of this technique could be substantial. We target sensorimotor cortex because MPAS affects both motor and somatosensory pathways. We therefore expected this tDCS positioning to maximally enhance relevant cortical plasticity. To identify any changes in motor cortex physiology related to these functional changes, we used transcranial magnetic stimulation (TMS) to assess the relationship between stimulus intensity and response amplitude (input/output or I/O curve). We addressed these questions in two experiments, first comparing the effects of adding sham, anodal, or cathodal tDCS to MPAS, and then examining the effects of tDCS alone.

2. Materials and methods

2.1. Subjects

Thirteen right-handed subjects (10 females) aged 18–40 years participated in Experiment 1. Twelve right-handed subjects (9 females) aged 18–40 years participated in Experiment 2. Ten subjects participated in both experiments. All subjects were naïve to the purpose of the study and gave written informed consent approved by Indiana University Institutional Review Board. Participants reported that they had no history of neurological or neuromuscular injury or disorder in the brain or upper limbs.

2.2. Experimental design

Each session consisted of behavioral and neurophysiological (TMS) measurements taken pre-and post-intervention (Fig. 1). Subjects were seated comfortably throughout the intervention, which entailed 30 min of sham or real MPAS in combination with 25 min

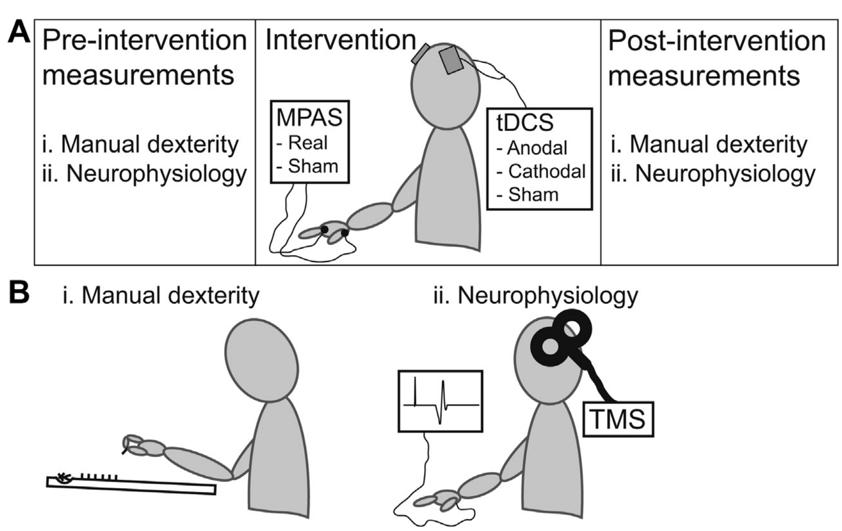

Fig. 1. A. Study design and interventions. Each session consisted of behavioral and neurophysiological measures before and after an intervention consisting of real MPAS (Experiment 1) or sham MPAS (Experiment 2) combined with cathodal (Experiment 1 only), anodal, or sham tDCS. B. Outcome measurements. i. Manual dexterity was measured with the Purdue Pegboard Test, with the time to transfer 20 pegs to the holes in the board representing manual dexterity. A thumb and index finger grip was used. ii. Neurophysiology measurement using TMS. The APB representation in motor cortex was stimulated with various TMS intensities. MEP amplitude at each intensity was recorded with EMG and used to construct an I/O curve, the slope of which represents cortical excitability.