The role of experience-based perceptual learning in the face inversion effect

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\section*{ABSTRACT}

Perceptual learning of the type we consider here is a consequence of experience with a class of stimuli. It amounts to an enhanced ability to discriminate between stimuli. We argue that it contributes to the ability to distinguish between faces and recognize individuals, and in particular contributes to the face inversion effect (better recognition performance for upright vs inverted faces). Previously, we have shown that experience with a prototype defined category of checkerboards leads to perceptual learning, that this produces an inversion effect, and that this effect can be disrupted by Anodal tDCS to Fp3 during pre-exposure. If we can demonstrate that the same tDCS manipulation also disrupts the inversion effect for faces, then this will strengthen the claim that perceptual learning contributes to that effect. The important question, then, is whether this tDCS procedure would significantly reduce the inversion effect for faces; stimuli that we have lifelong expertise with and for which perceptual learning has already occurred. Consequently, in the experiment reported here we investigated the effects of anodal tDCS at Fp3 during an old/new recognition task for upright and inverted faces. Our results show that stimulation significantly reduced the face inversion effect compared to controls. The effect was one of reducing recognition performance for upright faces. This result is the first to show that tDCS affects perceptual learning that has already occurred, disrupting individuals’ ability to recognize upright faces. It provides further support for our account of perceptual learning and its role as a key factor in face recognition.

1. Introduction

Perceptual learning refers to an enhanced ability to distinguish between similar stimuli as a consequence of experience with them or stimuli like them, and plays a key role in learning to identify stimuli as such. It amounts to an enhanced ability to discriminate between stimuli. We argue that it contributes to the ability to distinguish between faces and recognize individuals, and in particular contributes to the face inversion effect (better recognition performance for upright vs inverted faces). Previously, we have shown that experience with a prototype defined category of checkerboards leads to perceptual learning, that this produces an inversion effect, and that this effect can be disrupted by Anodal tDCS to Fp3 during pre-exposure. If we can demonstrate that the same tDCS manipulation also disrupts the inversion effect for faces, then this will strengthen the claim that perceptual learning contributes to that effect. The important question, then, is whether this tDCS procedure would significantly reduce the inversion effect for faces; stimuli that we have lifelong expertise with and for which perceptual learning has already occurred. Consequently, in the experiment reported here we investigated the effects of anodal tDCS at Fp3 during an old/new recognition task for upright and inverted faces. Our results show that stimulation significantly reduced the face inversion effect compared to controls. The effect was one of reducing recognition performance for upright faces. This result is the first to show that tDCS affects perceptual learning that has already occurred, disrupting individuals’ ability to recognize upright faces. It provides further support for our account of perceptual learning and its role as a key factor in face recognition.

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in a recent study, Civile, Verbruggen, et al. (2016) demonstrated that tDCS over Fp3 significantly affected perceptual learning and reduced the inversion effect that can otherwise be obtained with checkerboards (see Fig. 1). The authors adopted the same old/new recognition task as in Civile, Zhao, et al. (2014)’s study which uses a categorization task to pre-expose participants to the stimuli i.e. checkerboards. Hence, the authors employed the same tDCS montage previously used in other categorization experiments (e.g. Ambrus et al., 2011) delivering tDCS stimulation at 1.5 mA to the Fp3 site when participants were performing the categorization task. Civile, Verbruggen, et al. (2016) showed that the control condition (sham tDCS stimulation over Fp3) delivered during the pre-exposure phase, i.e. the checkerboard categorization task, see right panel of Fig. 1) replicated the usual inversion effect (see Civile, Zhao, et al., 2014 for multiple demonstrations of this effect) for checkerboards drawn from the Familiar category (difference between solid circle and open square), but, as expected, not for checkerboard exemplars drawn from a Novel category that had not been pre-exposed. Critically, anodal tDCS to the same brain region changed this pattern (left panel of Fig. 1), as there was now no significant inversion effect for stimuli drawn from the Familiar or Novel categories, and upright exemplars drawn from a familiar category were less well recognized than those drawn from the novel category (difference between solid circles), an indication that perceptual learning may even have been reversed. This remarkable and informative result suggested that perceptual learning in humans could be turned ‘on’ and ‘off’.

Civile, Verbruggen, et al.’s (2016) study is the first evidence that anodal tDCS administered during the pre-exposure phase can affect perceptual learning later on when participants are asked to memorize and recognize exemplars of checkerboards drawn from the checkerboard categories seen in during the pre-exposure phase (categorization task). The next important question to address is whether or not the same tDCS procedure would also affect perceptual learning that has already taken place. Given the lifelong expertise we have for faces, and given the already established analogy between the inversion effect obtained with checkerboards (Civile, Zhao, et al., 2014; Civile, Verbruggen, et al., 2016; McLaren, 1997; McLaren & Civile, 2011) and that usually obtained with faces (for a review see Maurer et al., 2002), in the current study we extended the tDCS paradigm used in Civile, Verbruggen, et al. (2016) to the inversion effect for faces. We hypothesized that we would obtain a strong inversion effect for familiar faces in the sham tDCS group, but a significantly reduced inversion effect for familiar faces in the anodal tDCS group because, by analogy with Civile, Verbruggen, et al.’s (2016) familiar upright checkerboards, we expected anodal tDCS over Fp3 to disrupt recognition performance for familiar upright faces.

Such a result would advance our understanding of both the mechanisms controlling perceptual learning and the face inversion effect in a number of ways. We would have found an experimental procedure (anodal tDCS at Fp3 brain site) able to selectively affect perceptual learning and its expression, and this would help in discriminating between competing theories of this phenomenon. Furthermore, we would have additional evidence that perceptual learning is a contributor (at least in part) to the face inversion effect. Finally, this would be the first demonstration in the literature of how relatively brief tDCS stimulation could reduce our ability to recognize upright familiar faces.

2. Method

We adopted the tDCS montage used in Civile, Verbruggen, et al. (2016). Each subject was randomly assigned to either sham or anodal tDCS conditions. In the sham condition, the tDCS stimulation was only delivered for 30 s, to evoke the sensation of being stimulated, without causing neurophysiological changes that may influence performance. In the anodal tDCS condition, the stimulation was delivered for 10 min commencing just before the subjects began the study phase and lasting for the entire duration of an old/new recognition computer task that used images of faces. In both sample groups, the sham and tDCS stimulation started when the computer task began. In the first part of the computer task, the study phase, subjects were asked to memorize a set of upright and inverted faces presented one at a time. Following this, subjects were given a recognition task where they pressed one key if they thought they had seen the face before, and another key if they thought they had not seen the face before. All the faces seen in the study phase were presented again intermixed with an equal number of new faces of each type (i.e. upright faces, and inverted faces). This old/new recognition task is a standard method of assessing face processing and the inversion effect (Civile, McLaren, & McLaren, 2014, 2016; Diamond & Carey, 1986; Yin, 1969). Our main measure was accuracy scores during recognition converted into signal-detection d-prime “d′”. We also examined reaction time responses to check for any speed-accuracy trade-off that could affect our interpretation of the results.

2.1. Subjects

Forty-eight students (39 women; mean age = 18.9, age
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