Dear Sirs,

Cortical influences over low-order vestibular function such as the vestibular–ocular reflex (VOR) are widely accepted [1–3]. Hallpike and colleagues originally demonstrated that patients with temporal lobe lesions, exhibit a strong asymmetry (i.e. “directional preponderance”), in the vestibular nystagmus elicited during caloric stimulation” [3]. Recent work to establish the neural correlates of human vestibular cortical processing have implemented three main approaches. Functional imaging [4–6], clinical lesion studies [2, 7, 8] and brain stimulation data [9–11] have all implicated tempo-parietal areas, usually with right hemisphere dominance. However, it was not until the seminal paper by Dieterich et al. [4] that the concept of handedness-related vestibular hemispheric dominance took shape, showing that the right hemisphere is vestibular dominant in right-handed individuals and vice versa in left handers.

In this context, we read with interest the letter published on the 28th of October in this journal by Brandt and Dieterich, in which they state that vestibular dominance is concerned solely with “higher” but not “lower” order vestibular functions [12]. Here we firstly review our previously published data and secondly present new findings, which in contradiction to Brandt and Dietrich’s statement, demonstrates that handedness-related vestibular dominance is linked to “lower-order” functions such as the VOR.

Initially, we demonstrated for the first time behaviourally (previous studies were fMRI based) [4–6] a handedness-related cortical modulation of the VOR [13]. We rotated (i.e. velocity step 90°/s) subjects on a motorised Barany chair, whilst either viewing bi-stable visual perceptions (i.e. motion binocular rivalry) or performing a visuo-spatial working memory task, and found that the post-rotational VOR was asymmetrically suppressed. Notably, the directionality of the asymmetrical modulation was related to handedness. That is, in right handers we observed that the post-rotational VOR (i.e. stopping response) was suppressed following rightward rotations (left-beating vestibular nystagmus). Conversely, in left handers we observed that the post-rotational VOR was suppressed following leftwards rotation (right-beating nystagmus) [13] (Fig. 1a).

To probe the neural mechanisms underpinning such asymmetrical suppression, we modulated parietal cortex excitability using trans-cranial direct current stimulation (tDCS). We measured the VOR elicited via cold water (30 °C) caloric irrigations which induce a vestibular nystagmus that beats towards the non-stimulated ear, before and after tDCS in right-handed subjects. Facilitation of the right hemisphere (anodal stimulation) and concurrent inhibition of the left hemisphere (cathodal stimulation) resulted in a suppressed VOR during right ear cold irrigations (left-beating nystagmus) but normal responses during left ear cold irrigations (right-beating nystagmus). To identify the active electrode, we subsequently applied unipolar tDCS and found that cathodal stimulation of the left hemisphere resulted in a bilateral but asymmetrical suppression of the VOR. That is, right ear cold irrigations that previous fMRI studies have shown to be predominantly processed by the left hemisphere were suppressed to a greater degree than left ear cold irrigations which are predominantly processed by the right hemisphere (Fig. 1b) [5, 6, 11]. We previously proposed that the differential
effects (i.e. unilateral as opposed to bilateral suppression) observed upon the VOR in the two different tDCS montages was most likely attributable to the facilitation of the right hemisphere during bi-hemispheric stimulation [11]. Accordingly, we predicted that in left-handed subjects, inhibition of the right not the left hemisphere (Fig. 2a) should induce an asymmetrical modulation of the VOR. Herewith, we report that in six left-handed subjects we found this to be the case, specifically for those caloric irrigations that in left handers are predominantly right hemisphere based (right ear cold irrigations (30°C) [5, 6] (Fig. 2b, c). A 2 × 2 repeated-measures ANOVA revealed a significant main effect for side of caloric irrigation [F (1,5) = 39.85, p < 0.001], time (i.e. pre-post tDCS) [F (1,5) = 25.74, p < 0.004 and a significant interaction for side*time [F (1,5) = 37.29, p < 0.002]. Post hoc paired
tests (Bonferroni corrected) revealed significant differences for right but not left ear cold irrigations following right cathodal stimulation ($p < 0.001$, $t = 9.8$ and $p > 0.05$, respectively. A separate $2 \times 2$ repeated-measures ANOVA showed no main effect for either side or time following left cathodal stimulation ($p > 0.05$) (Fig. 2b, c).

To conclude, handedness-related vestibular dominance does concern both lower [11, 13, 14] and higher order vestibular function [7–10]. However, this does not detract from the hypothesis presented by Dieterich and Brandt, which focuses on the independent development in the child of hand dexterity and vestibular function [12]. Experimental and developmental studies in the future will have to examine whether data supports such a hypothesis. The task will be exciting but challenging given the widespread property of the human brain to lateralise large functional modules such as language, hand dexterity and spatial attentional/navigational functions that we now know also include vestibular cortical processing. Incidentally, a typographical error in the Brandt and Dieterich letter incorrectly states that language is lateralised to the right hemisphere!

Conflict of interest The authors report that they have no conflict of interest.

Ethical standard Ethical approval for this study was granted from our local Research Ethics Committee.

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