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Research Letter

Electrosensitives and perception of magnetic pulses

In our recently published paper by Landgrebe *et al.* (2008), earlier investigations (Frick *et al.* 2005) describing reduced ability in subjective electromagnetic hypersensitive patients (EHS) to discriminate real from sham transcranial magnetic pulses were confirmed. Transcranial magnetic stimulation (TMS) was performed with Magstim (Frick *et al.* 2005) and Medtronic (Landgrebe *et al.* 2008) equipment. However, the description of the sham condition was not clear-cut in either of the papers. For example, in Landgrebe *et al.* (2008), we stated that probands knew 'that each pulse had a 50% probability of representing a real magnetic stimulus or to be only an acoustic click without an accompanying magnetic pulse'. Regarding both papers, it should be clarified that both Magstim and Medtronic sham coils produce a magnetic field; however, this is very low compared to the verum coils. This has given rise to doubts concerning our statistical analysis, although the statistical tool (ANCOVA) does not require a null-exposure as the control condition to investigate differences in the perceptive ability. Nevertheless, we wish to present an alternative analysis of the pooled data of both studies, without distinguishing 'sham' and 'real' exposure conditions which includes magnetic field strength, administered at each stimulation, as a predictor into the statistical model.

We measured induced electric voltage directly on the surface at the centre of the coils using a dipole probe similar to Rossi *et al.* (2007) resulting in an indirect measure of the magnetic flux density. Thus, a dose–response relationship between emission and perception can be estimated and tested.

Subjects were tested using Medtronic ($n=194$) and Magstim ($n=84$) equipment. Each subject received four series of single transcranial magnetic pulses at the dorsolateral prefrontal cortex and after each pulse answered whether he/she had experienced any sensory perception. We pooled both datasets of 13 691 single perception experiments performed on 278 subjects (average age 48.1 years, S.D. = 12.0, 58.3% females, 42.4% EHS). The outcome variable (perceiving a sensation) is dichotomous and its log odds were modelled as a linear function of increasing exposure level and of individual learning throughout the experiment. Subjects' characteristics (age, sex, claimed hypersensitivity) were introduced into the model as level-2 variables within a hierarchical approach (see Raudenbush & Bryk, 2002, ch. 10) impacting both the intercept parameter and the slope for exposure. The individually randomized sequence of the experiment (starting with either sham or verum coil) was also modelled as a level-2 predictor variable. Estimation was performed using HLM5. Results are given for the population-average model with robust standard errors (Zeger *et al.* 1988).

Fig. 1 gives the electric voltage measured at the surface of the coils used. The Magstim equipment provides a larger difference between the sham and the verum condition than the Medtronic equipment. The truth table underlying Fig. 1 was used to transform the presets (% of maximum stimulation power) of the magnetic coils into emission parameters (voltage measured).

Variance components associated with both random intercept β_0 and random slope for β_2 had significant p values ($p<0.0001$). We therefore included the respective level-2 equations into the final statistical model. Differences of the equipment (Magstim *v.* Medtronic) could not be shown to have an impact either on the intercept parameter β_0 (t ratio = 1.74, $p=0.08$) or on the slope parameter β_2 (t ratio = 0.03, $p=0.078$). Table 1 summarizes the numerical results.

From Table 1 can be concluded that a sensory perception is a function of three significant determinants:

- First, an unspecific individual 'guessing tendency' β, which is dependent on subjects' gender (women guess more often), age (older subjects guess more often), sequence of the experiment (subjects starting with verum coils guess more often) and a remarkable effect for hypersensitivity: EHS [odds ratio (OR) 2.24] clearly feel more often exposed to a magnetic pulse of recognizable intensity than their controls.
- Second, during series 3 and 4 (approximately equivalent to the second half of an individual's experimental session), subjects showed a greater tendency to report a sensory perception. This tendency does not refer to the real exposure condition, but might be seen as an unspecific effect of higher alertness towards the experimental conditions, uniform for all participants (OR 1.27).
- Third, there is a dose–response relationship between exposure and perception. For each unit of voltage, the log odds of a positive sensory

Table 1. *Two-level logistic regression model on sensory perception of magnetic pulses*

Fixed effect	Level 2	Level 1	Coefficient	S.E.	t ratio	d.f.	p value	OR
Intercept (base rate)		β						
Intercept 2	γ		−3.643817	0.305992	−11.908	273	0.000	0.02615
Gender (female)	γ_{01}		0.290727	0.137000	2.122	273	0.034	1.33740
Age	γ_{02}		0.012508	0.005878	2.128	273	0.033	1.01259
Electrohypersensitive	γ_{03}		0.807914	0.137564	5.873	273	0.000	2.24322
Sequence (VSVS)	γ_{04}		0.516740	0.134617	3.839	273	0.000	1.67655
Repetition (learning)		β_1	0.242811	0.038150	6.365	13 680	0.000	1.27483
Exposure (μV)		β_2						
Intercept 3	γ_{20}		0.026130	0.002566	10.183	273	0.000	1.02647
Gender (female)	γ_{21}		−0.004084	0.001146	−3.564	273	0.001	0.99592
Age	γ_{22}		−0.000186	0.000047	−3.951	273	0.000	0.99981
Electrohypersensitive	γ_{23}		−0.003116	0.001147	−2.718	273	0.007	0.99689
Sequence (VSVS)	γ_{24}		−0.002798	0.001133	−2.470	273	0.014	0.99721

d.f., Degrees of freedom; OR, odds ratio; S.E., standard error; VSVS, sequence of verum–sham–verum–sham during perception experiment.

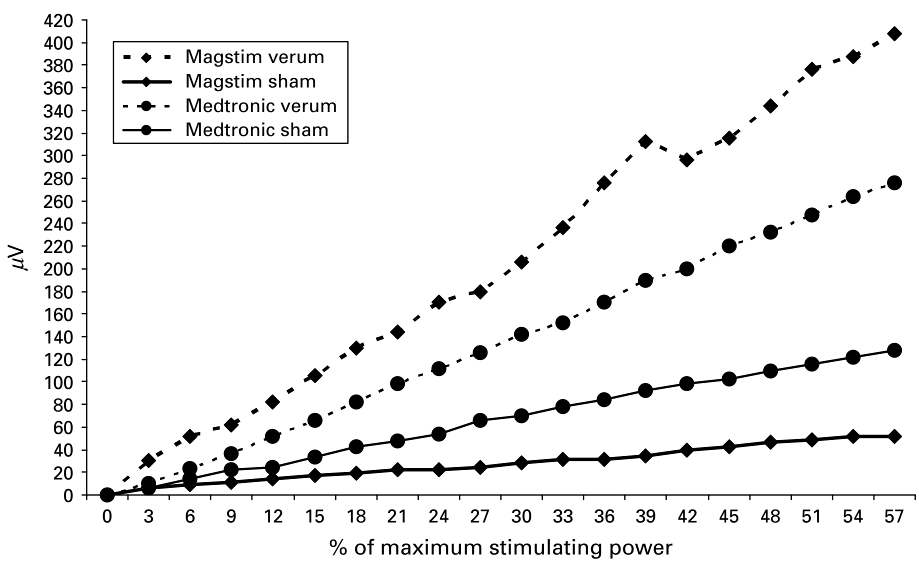

Fig. 1. Electric voltage at surface of coils used in Frick *et al*. (2005) and Landgrebe *et al*. (2008), as measured with a dipole electrode according to Rossi *et al*. (2007).

perception are increased by the coefficient γ_{20} of 0.0261 (OR 1.03). For women, this slope parameter is slightly smaller (γ_{21}, OR 0.9960). For each year of age the slope is also decreased (γ_{22}, OR 0.9998), and if the experiment started with a verum condition, the slope is also more gently inclined (γ_{24}, OR 0.9972). It is of note that EHS display a flatter slope parameter than their controls (γ_{23}, OR 0.9969). This means that EHS – all other factors being equal –have a slightly but significantly *diminished* ability to recognize a magnetic pulse signal with increasing exposure levels.

The re-analysis of our perception experiment data aimed to clarify if small magnetic fields remaining in sham coils may challenge our conclusion of diminished perceptive abilities in EHS. Including the physical properties of the verum and sham coils, we could establish a dose–response relationship for all probands, but with diminished slope for EHS. There are two effects associated with the status of self-declared electrohypersensitivity: a higher rate of false-positive alarms for sensory perception of magnetic pulses, and a diminished ability to recognize a magnetic pulse at increased real exposure levels.

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Declaration of Interest

None.

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