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Charge Density, not Current Density, is a More Comprehensive Safety Measure of Transcranial Direct Current Stimulation

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Dear Editor

We do not agree with the conclusions of Jackson *et al.*¹ that the transcranial direct current stimulation (tDCS) threshold for causing brain lesion in a rat model is well below that previously reported by Liebetanz *et al.*² Jackson *et al.*¹ used current density at the electrode as the primary measure of tDCS dosage, effectively ignoring that the duration of stimulation was 6-times that used in Liebetanz *et al.*² However, duration is an important factor in electrical stimulation protocols. Charge density is a combined measure of current, electrode surface area and stimulation duration that is used in Liebetanz *et al.*² Comparison of various tDCS parameters across various studies is made in Table 1. Charge density, as well as charge density per unit brain volume, are also compared in Fig. 1 across 3 studies.^{1–3} To conclude, by expressing tDCS dosage levels with current density instead of charge density, we believe that Jackson *et al.*¹ have reached an incorrect conclusion regarding safety limits for animal brain. We mathematically demonstrate that when charge density is used to represent tDCS dosage, the safety limits established by Liebetanz *et al.*² were substantially exceeded in the Jackson *et al.*¹ study⁴.

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Figure 1. Jackson et al. 2017 actually shows higher safety threshold than previously reported by Liebetanz et al. 2009

(A) Charge density plot. (B) Charge delivery per unit volume of the brain (arbitrary, assuming 2000× human to rat brain volume ratio - the total charge delivered to the human brain per unit volume is much smaller when compared with the rat brain.) Note the logarithmic scale on the azimuth in both the plots (from Chhatbar et al.⁴).

Table 1Comparison of tDCS dose parameters (from Chhatbar *et al.*⁴)

Publication	Current (mA)	Pad Size (mm ²)	Duration (min)	Current Density (A/m ²)	Charge (C)	Charge Density (kC/m ²)
Jackson <i>et al.</i> 2017	0.50	25.00	60.00	20.00	1.80	72.00
Liebetanz <i>et al.</i> 2009	0.50	3.50	10.00	142.90	0.30	85.74
Liebetanz <i>et al.</i> 2009 lesion threshold	0.31	3.50	10.00	87.33	0.18	52.40
Typical human tDCS study	1.00	3500.00	20.00	0.29	1.20	0.34
Chhatbar <i>et al.</i> 2017	4.00	3500.00	30.00	1.14	7.20	2.06