

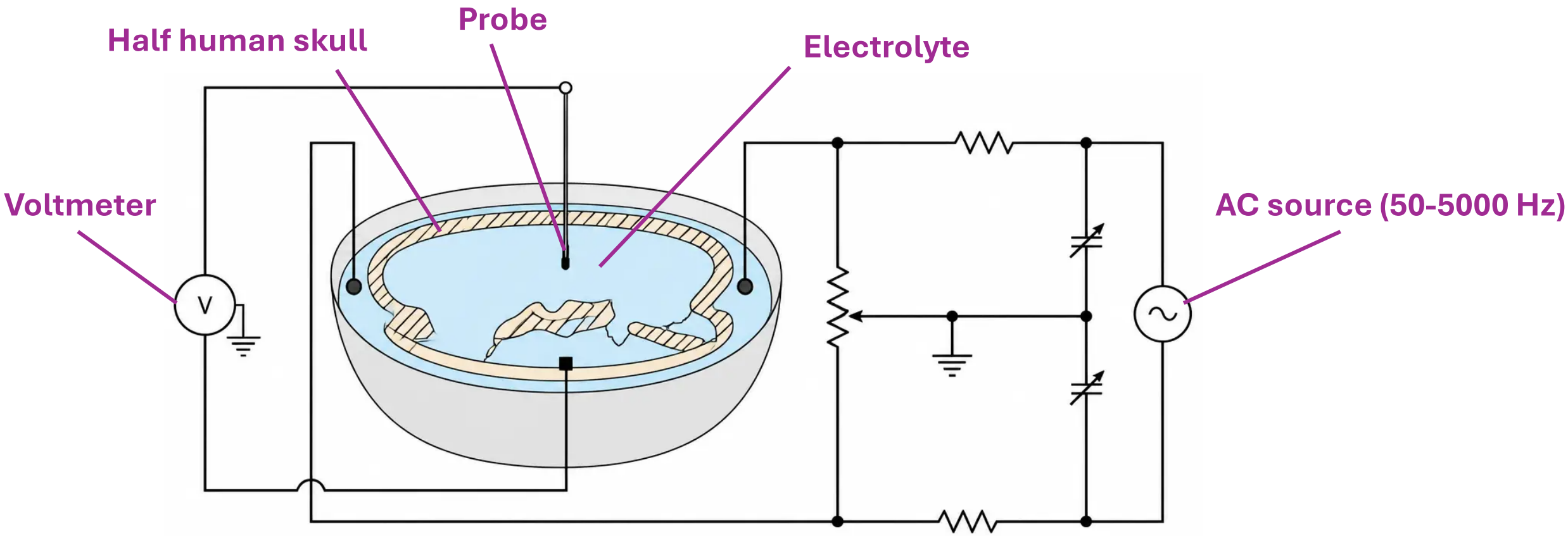


Defaults have no citations - *The skull conductivity example*

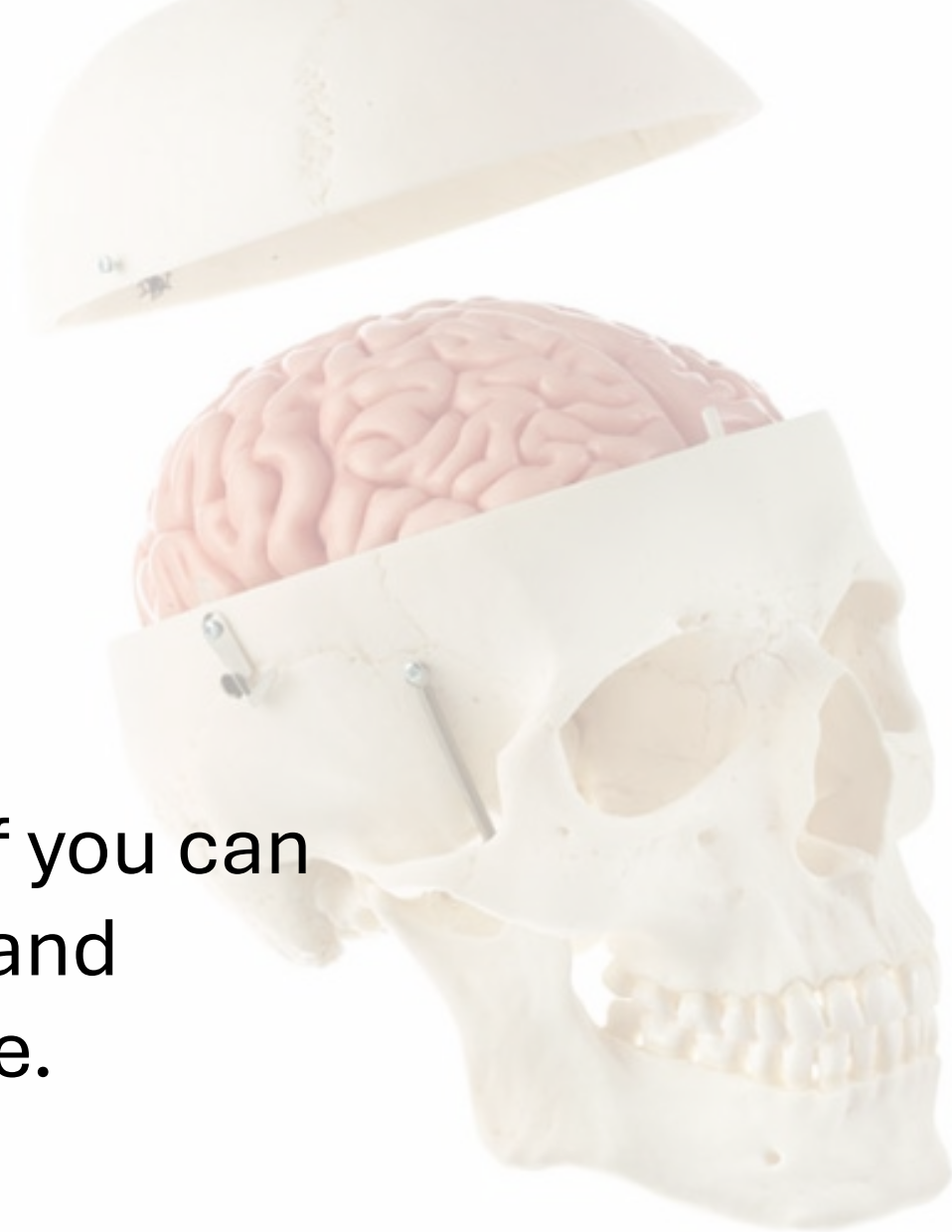
Timoleon Fourfaro, BHAVI/Guardians 2026

One skull, one number, 1968

1. A real human skull, in a head-shaped tank of electrolyte.
2. The same fluid fills the skull's pores and surrounds it.
3. A probe measured the potential.



Redrawn after Rush & Driscoll (1968)



A number can be **reproducible** only if you can say **what** it is, **how** it was measured, and whether **independent methods** agree.

What is conductivity?

Conductivity σ

How easily a material lets current flow

Unit: siemens per metre (S/m)

opposites

Resistivity ρ = 1 / σ

How strongly a material resists current

Unit: ohm metres (Ω·m)

Rush & Driscoll, 1968:

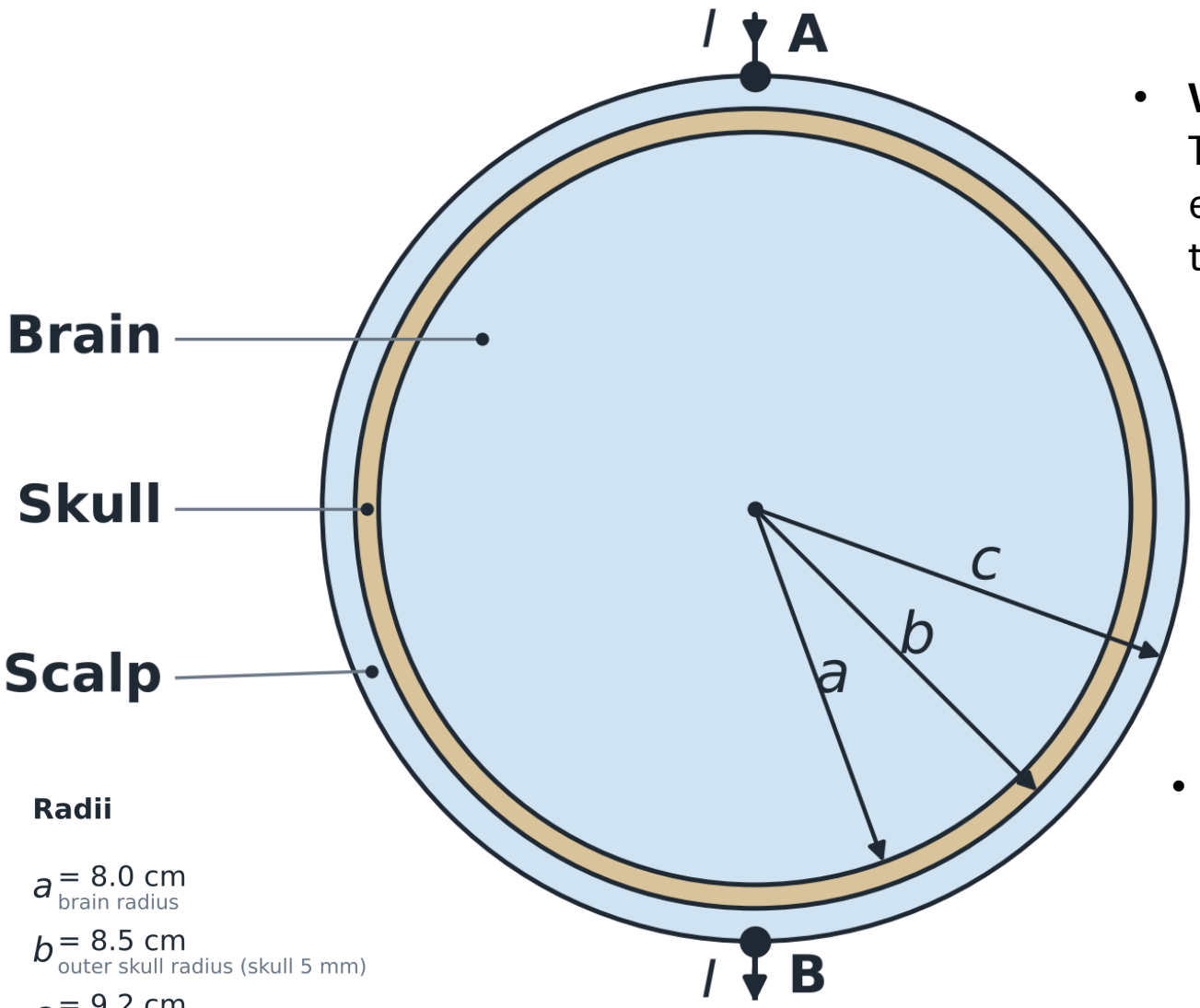
The number 80 compares the skull with the soft tissue around it:

ρ brain / scalp = 1 unit

ρ skull / brain = 80

“an optimum effective isotropic resistivity for the skull tested”

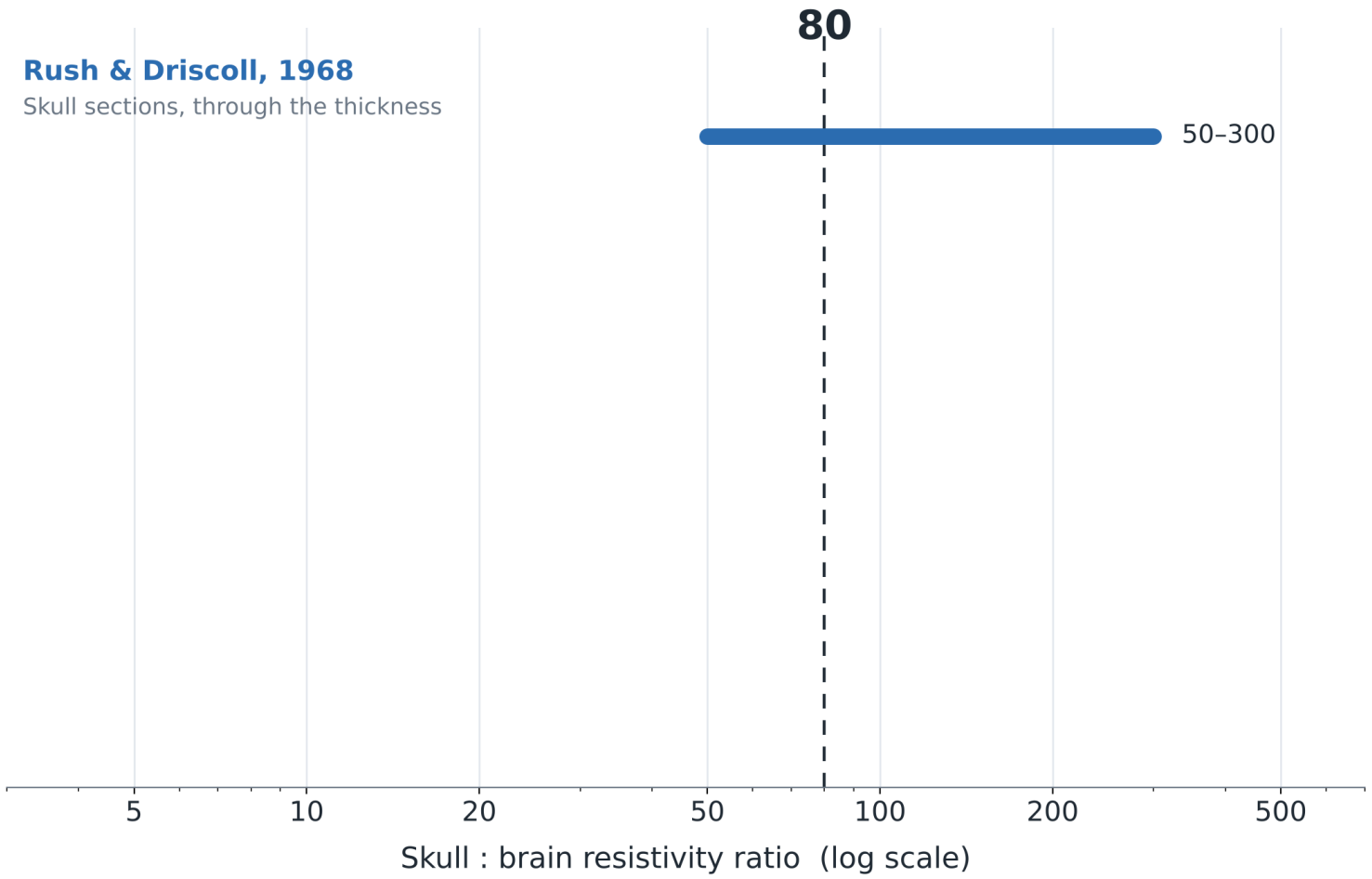
The model: three nested conductors, and one number tuned to match the tank



- **What it is**
  The head as three nested spheres (brain, skull, scalp), each a uniform conductor. The skull resists current 80 times more than the other two.
  - **What goes in**
    Two scalp electrodes pass a known current: in at A, out at B.
  - **How it's calculated**
    Current spreads through each layer according to Laplace's equation.
- **What comes out**
  How much current reaches the brain, and where it goes.

Redrawn after Rush & Driscoll (1968)

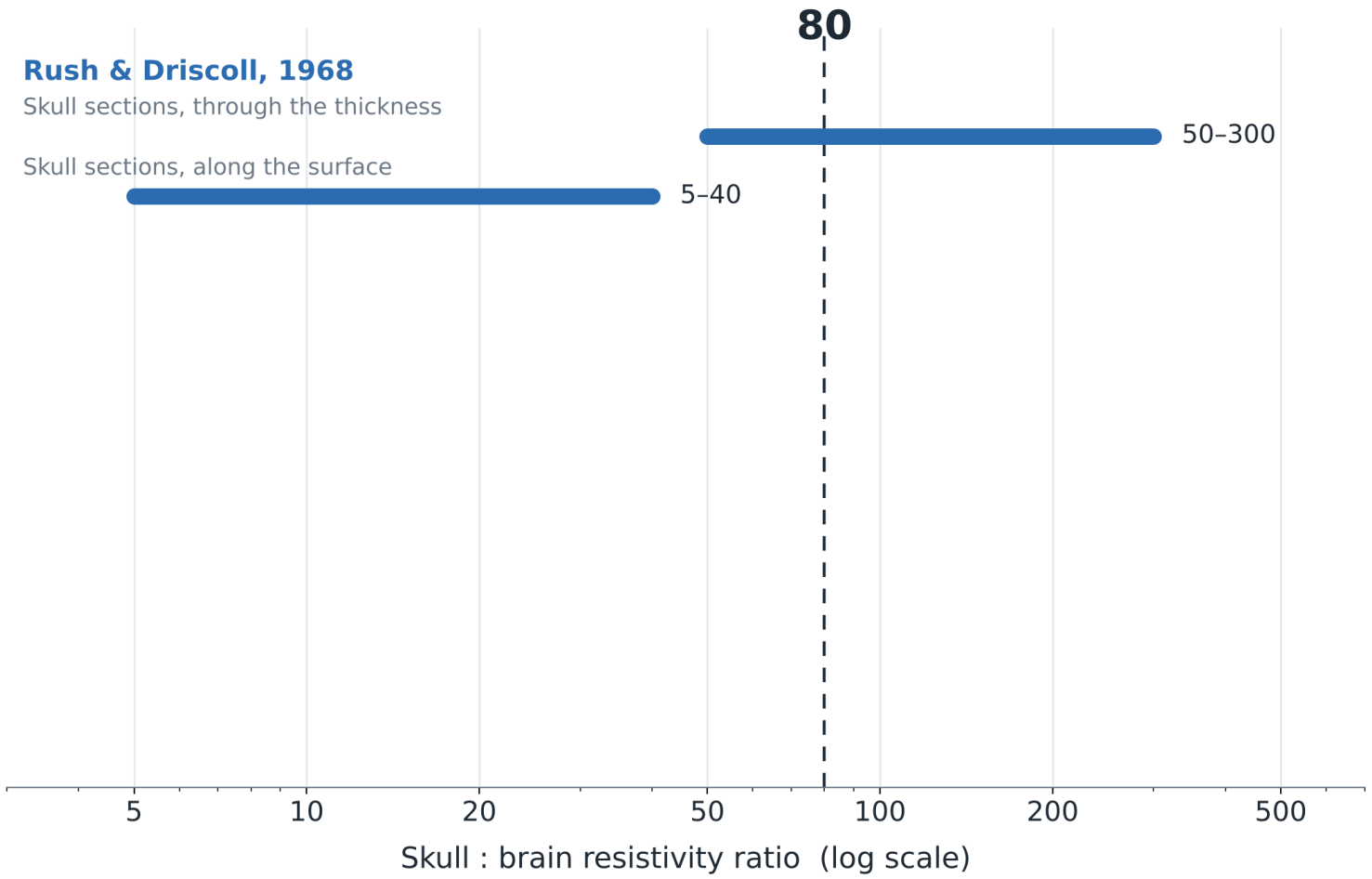
The paper reported a range, then used one number



> The dry skull is effectively an insulator (10^{13} ohm-cm.) and takes on a resistivity directly proportional to that of any fluid with which it is permeated. The ratio of transverse skull resistivity to that of permeating fluid was found in a previous study[1] to be quite variable over different sections of skull, ranging from 50 to 300.

Rush & Blanchard (1966)

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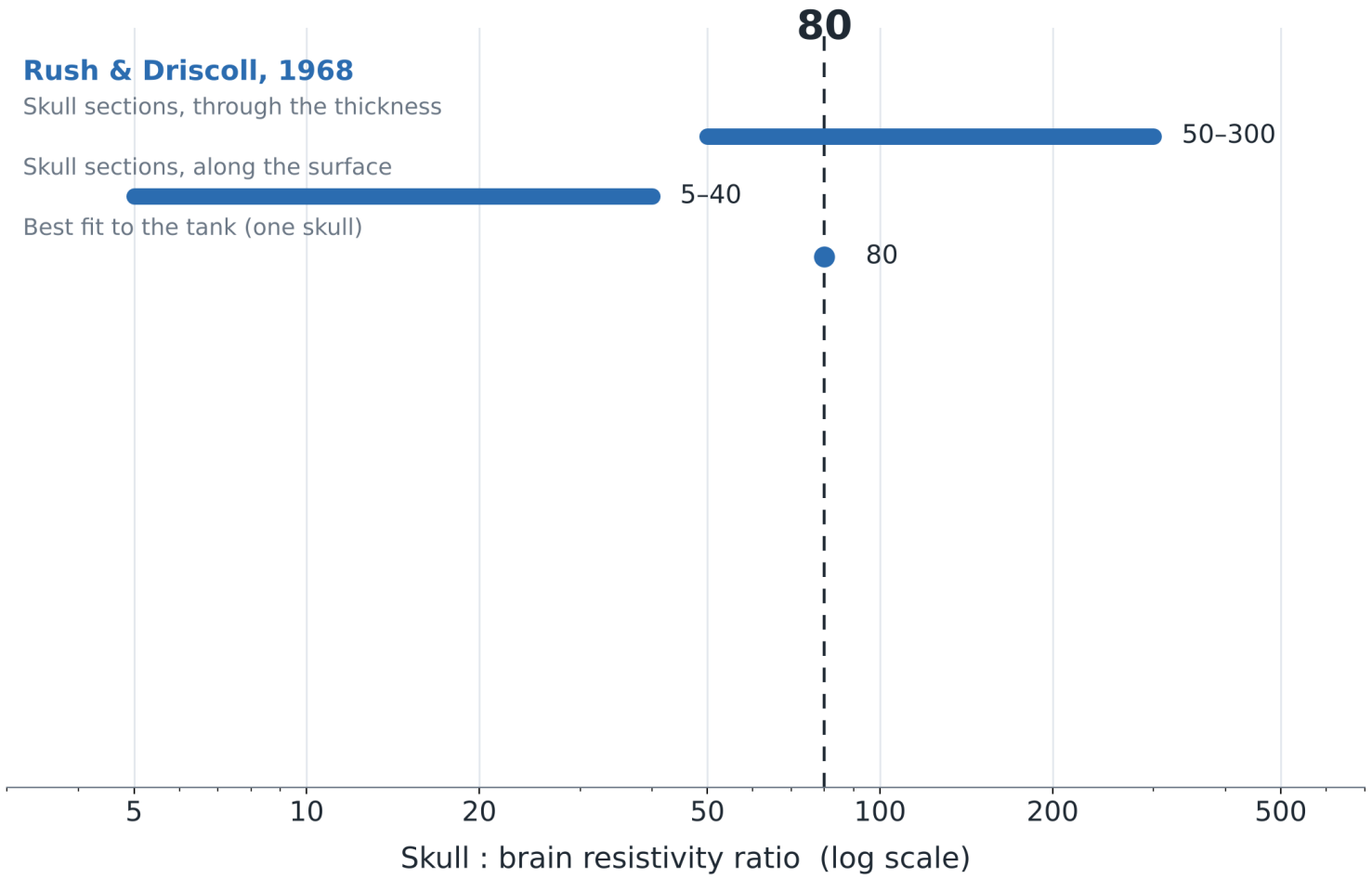
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Rush & Blanchard (1966)

> In subsequent measurements, the resistivity ratio with current flow parallel to the surface was found to range from 5 to 40. The variability of resistivity ratio with direction is a reflection of the structure of the skull. It is faced with two dense "tables" between which a spongy, open diploe exists. The

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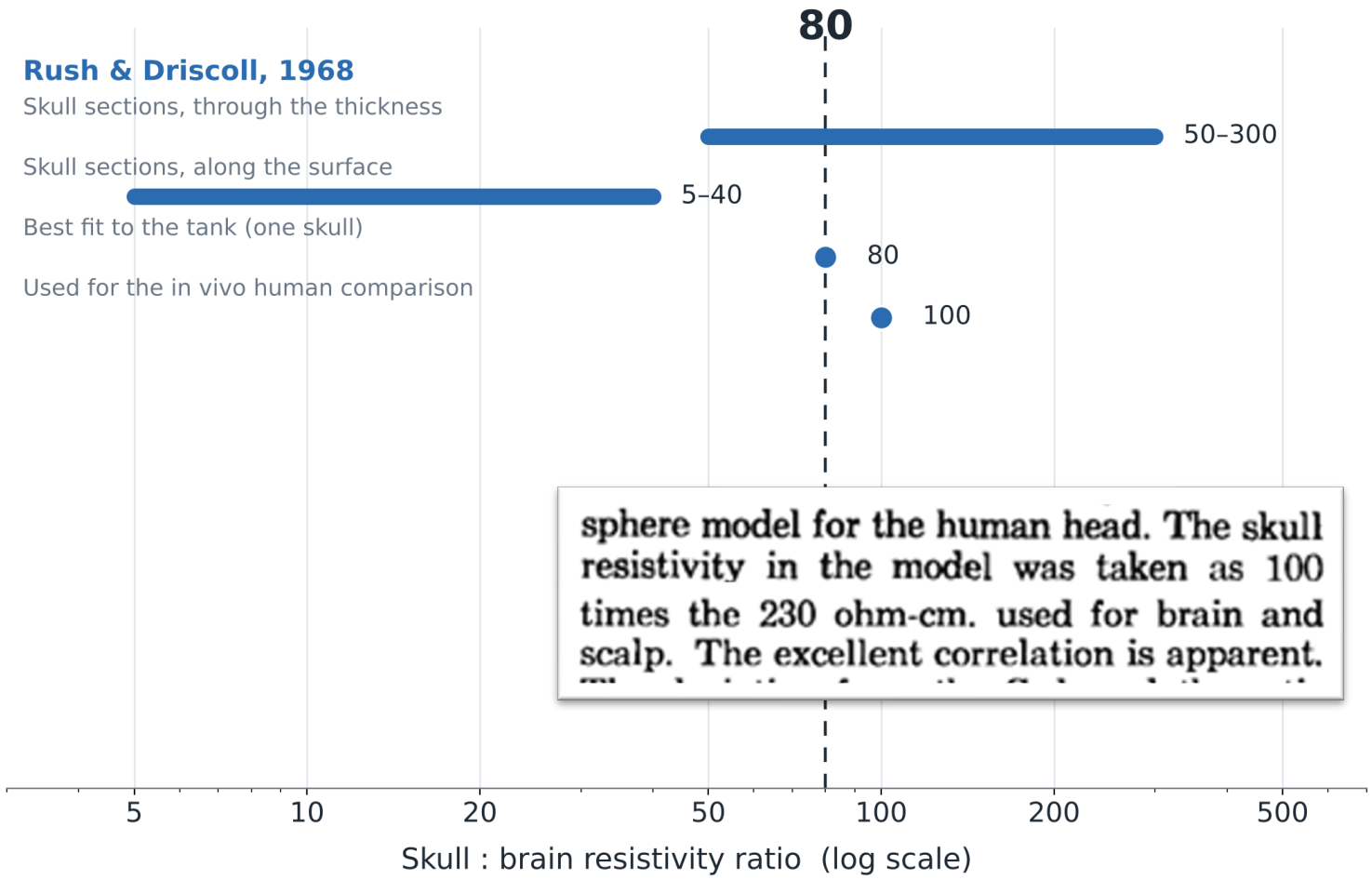
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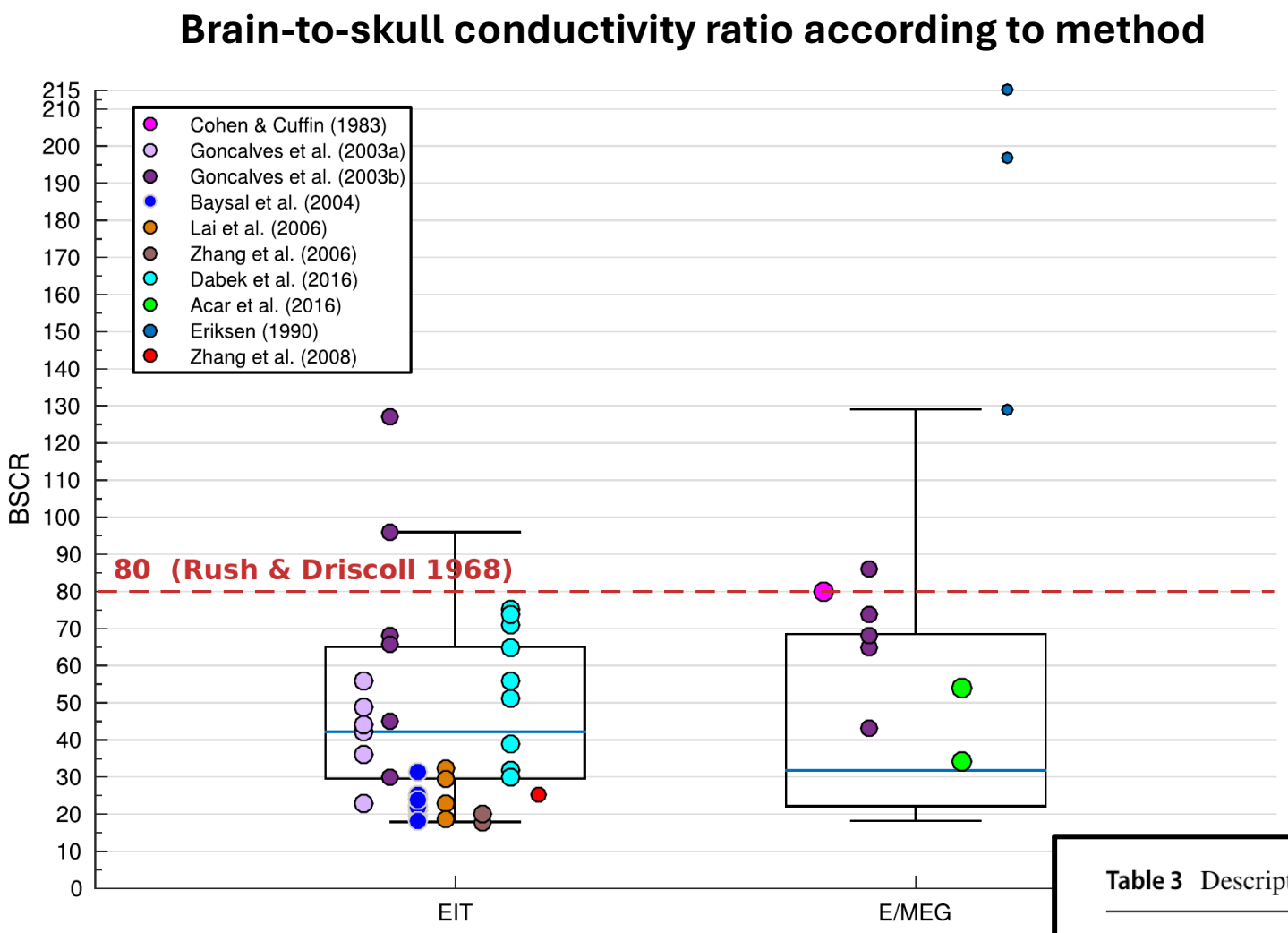
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Rush & Driscoll (1968)

Pooled across studies: 17.9 to 290, weighted mean 50.4



10 living-head studies, 51 values, 47 participants

Most values lie below 80

Weighted mean 50.4 ± 39

Table 3 Descriptive statistics for each tissue type

	Minimum	Maximum	Mean	Weighted mean	Standard deviation
			▯ other tissues omitted ▯		
BSCR	17.9	290	58.69	50.4	38.93

!

Software defaults today

FieldTrip

…tation / faq / source / conductivity_defaults /

What is the conductivity of the brain, CSF, skull and skin tissue?

There are multiple literature references from which you can get estimates for the conductivity, e.g.

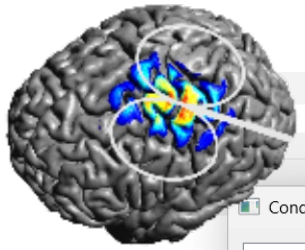
- McCann H, Pisano G, Beltrachini L. *Variation in Reported Human Head Tissue Electrical Conductivity Values.* Brain Topogr. 2019
- Gabriel S, Lau RW, Gabriel C. *The dielectric properties of biological tissues: II. Measurements in the frequency range 10 Hz to 20 GHz.* Phys Med Biol, vol. 41, pp. 2251-69, Nov 1996.
- Manola L, Roelofsen BH, Holsheimer J, Marani E, Geelen J. *Modelling motor cortex stimulation for chronic pain control: electrical potential field, activating functions and responses of simple nerve fibre models.* Med Biol Eng Comput, vol. 43, pp. 335-43, May 2005.

In a spherical or realistic three-shell EEG volume conduction model, conductivity ratio's of 1, 1/80, 1 are commonly specified for scalp, skull and brain. The proper conductivities are then 0.3300, 0.0042 and 0.3300 S/m respectively. For a four-shell EEG volume conduction model the conductivities of scalp, skull, CSF and brain are commonly specified as 0.3300, 0.0042, 1.7900 and 0.3300 S/m.

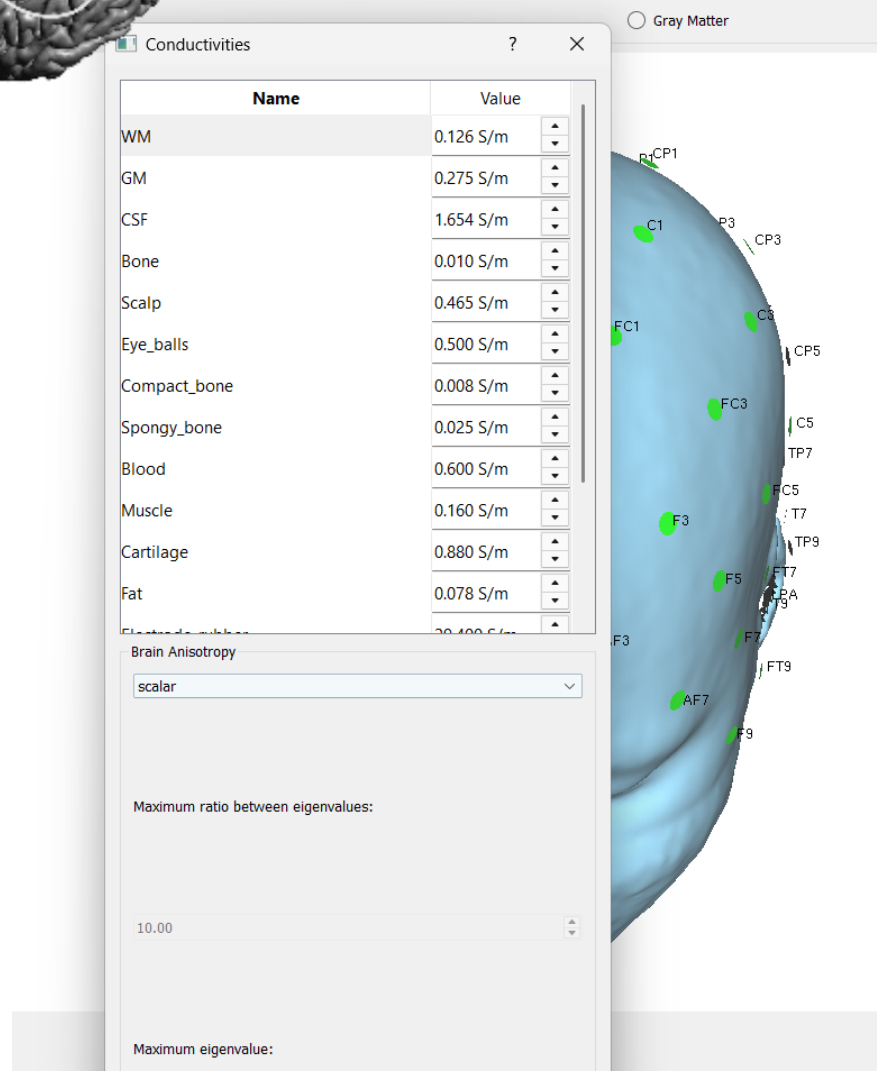
Note however that there is no agreement on the correct conductivity values of the skull. For example in

- Hoekema R, Wieneke GH, Leijten FS, van Veelen CW, van Rijen PC, Huiskamp GJ, Ansems J, van Huffelen AC. "Measurement of the conductivity of skull, temporarily removed during epilepsy surgery." Brain Topogr. 2003;16(1):29-38

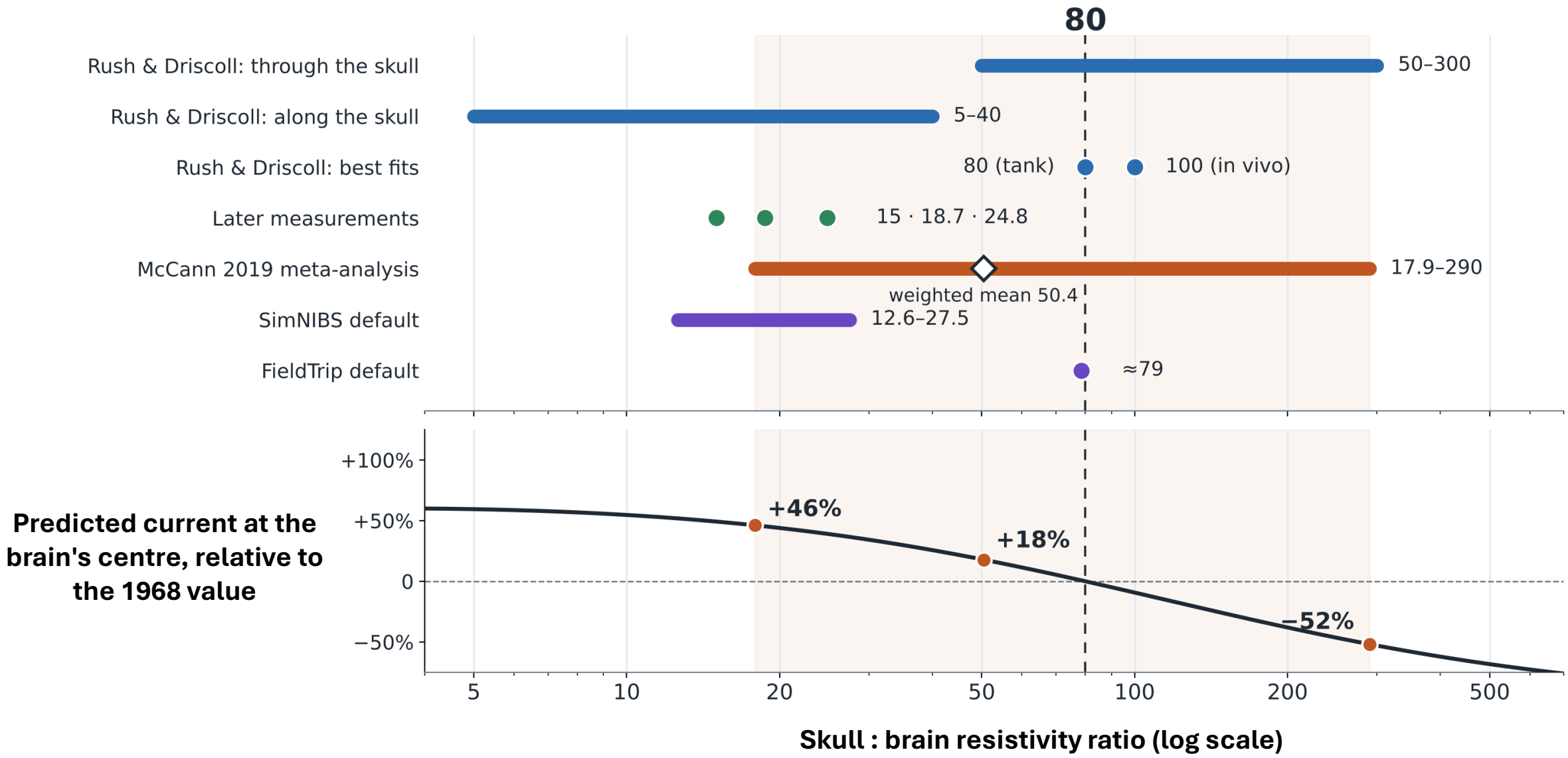
skull conductivities of 0.0320 to 0.0800 are reported, which are 8-20 times larger than the value mentioned above.



SimNIBS



Summary slide



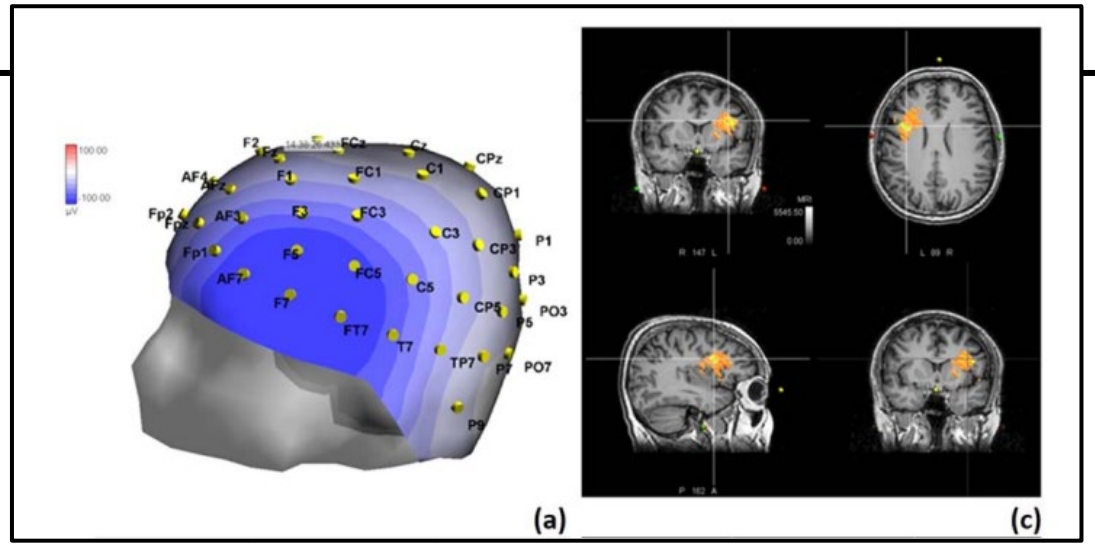
Predicted current at the brain's centre, relative to the 1968 value

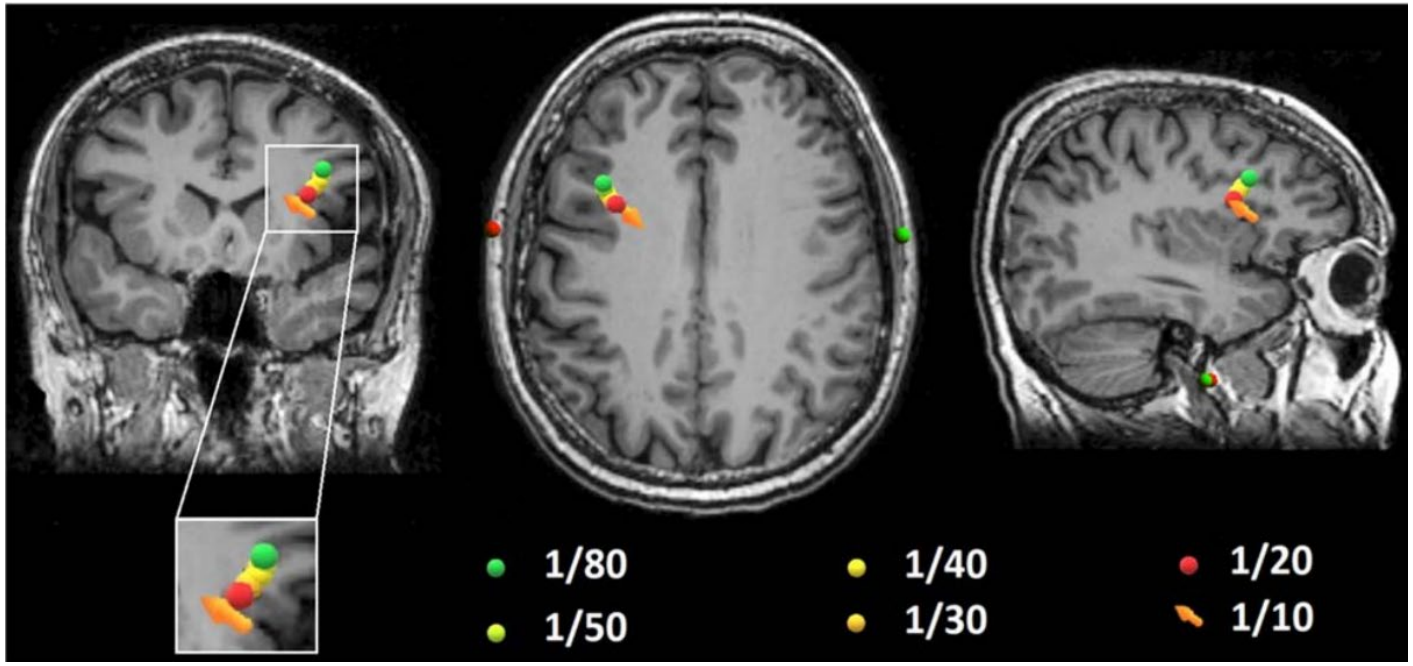
Real life consequences

20 epilepsy patients

When the assumed ratio changed from **1/40** to **1/80**

source-localization shifted by **5.3 mm**;
across the wider reported range, by **14.2 mm**.

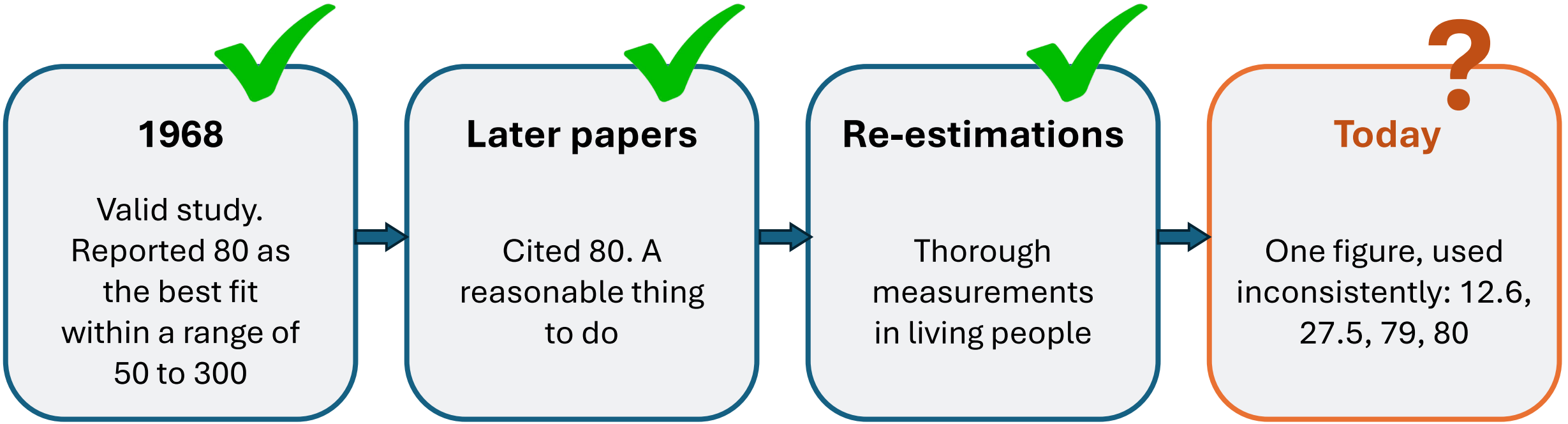




A parameter almost never reported in standard pipelines is worth 1.4 cm of error in where a seizure focus gets placed clinically!

Demoulin et al., 2021

Why this is a reproducibility problem?



The number stayed. Its range and context wore away.

Two kinds of reproducibility

Parametric here = about the input values a model assumes

Lab A

- ✓ Code shared
- ✓ Analysis plan preregistered
- ✓ Sample size adequate

Assumed skull:brain ratio

17.9

+46%

Current density at brain centre relative to ratio 80

=

Same procedure

Lab B

- ✓ Code shared
- ✓ Analysis plan preregistered
- ✓ Sample size adequate

Assumed skull:brain ratio

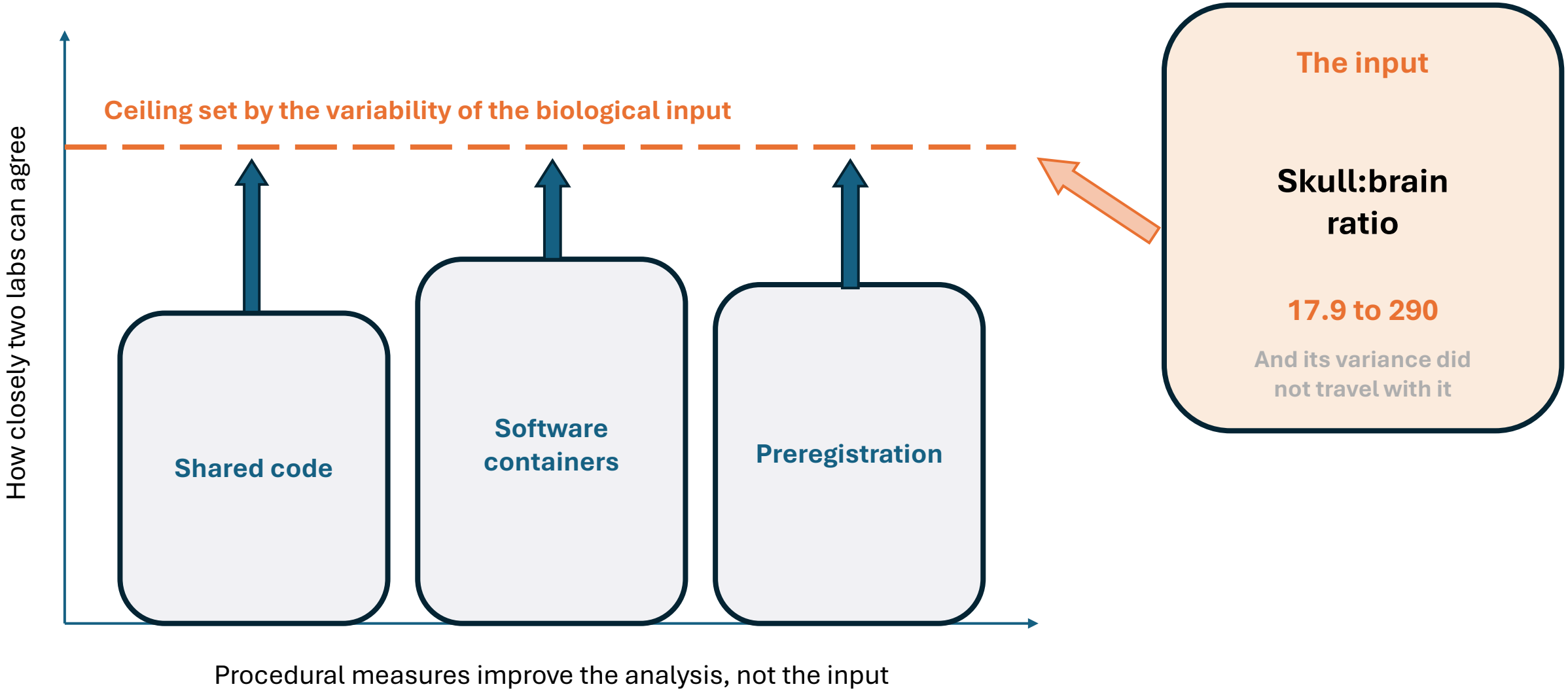
80

0% (reference)

Current density at brain centre relative to ratio 80

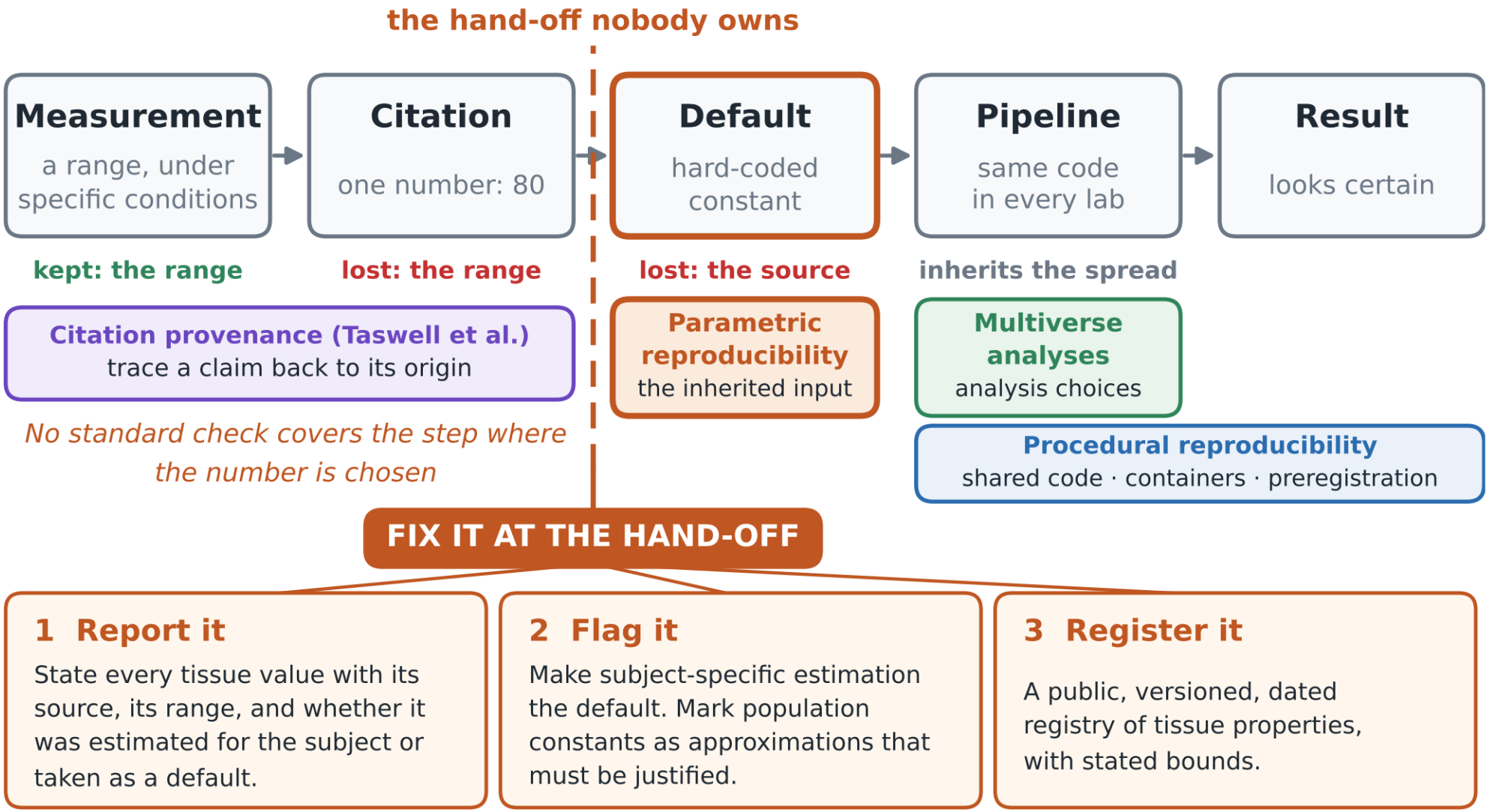
Procedural checks agree, results don’t

Why sharing code can’t fix it

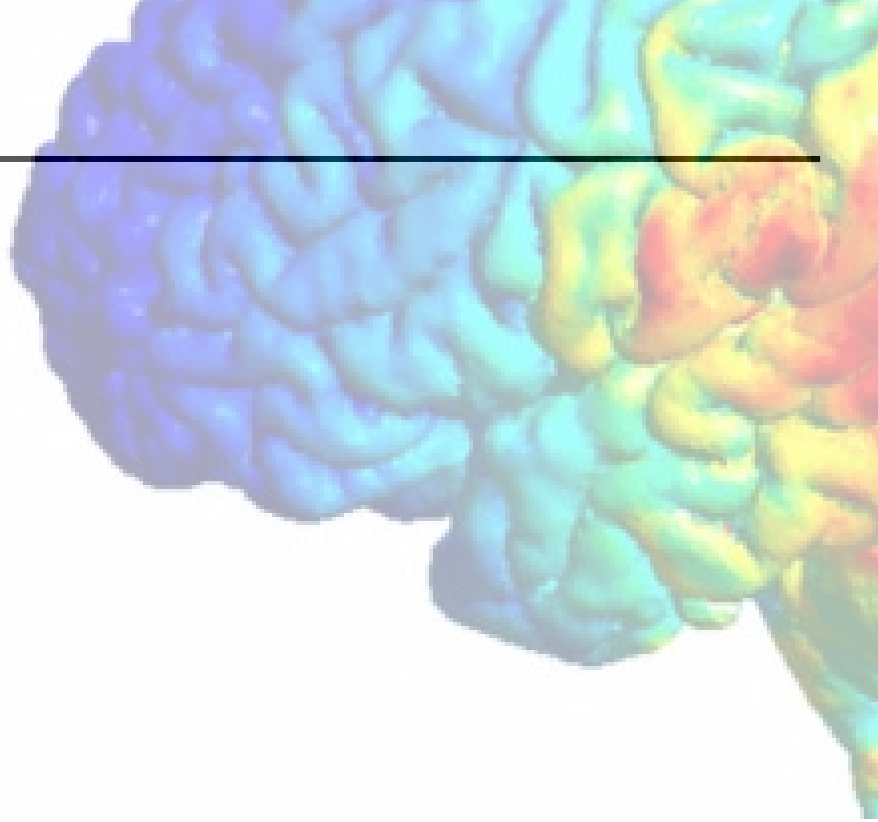


Procedural measures improve the analysis, not the input

Three reforms







Thank you!

Reference list

- Rush & Driscoll (1968)
- Rush & Blanchard (1966)
- McCann, Pisano & Beltrachini (2019)
- Zhang et al. (2006) and Lai et al. (2005), the paediatric values mentioned in the slide 9 notes
- Demoulin et al. (2021)
- Vorwerk et al. (2019)
- Craig & Taswell (2025)
- Taswell et al. (2021), "Truth in Science"
- Taswell et al. (2020), the hitchhiker's guide
- Taswell (2022), citational justice
- Steegen et al. (2016)
- Short et al. (2025), which is also where the CoScience 18 million pipelines figure comes from
- SimNIBS and FieldTrip, listed as software