The anatomy of reliability: A must read for future human brain mapping

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Abstract

Human brain mapping (HBM) is increasingly becoming a multi-disciplinary field where some scientific issues are fundamental for all scientists and applications of using the technology to investigate individual differences. Reliability represents a significant issue for all scientific fields and has particularly been overlooked for decades by the HBM field [1]. Meanwhile, recent advances in open science have offered the field big data for developing novel methodological frameworks as well as performing large-scale investigations of the brain-mind associations based upon the individual differences assessed with HBM [2]. A systematic investigation of reliability seems still far behind these HBM developments. It is critical that reliability is evaluated ahead of these applications, motivating the current commentary on delineation of the anatomy of reliability for future HBM.

Full Text

Preamble

The Anatomy of Reliability: A Must-Read for Future Human Brain Mapping

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Main Text

Human brain mapping (HBM) is increasingly becoming a multi-disciplinary field where certain scientific issues are fundamental for all scientists and applications using this technology to investigate individual differences. Reliability represents a significant issue for all scientific fields and has been particularly overlooked for decades by the HBM community [1]. Meanwhile, recent advances in open science have provided the field with big data for developing novel methodological frameworks as well as performing large-scale investigations of brain-mind associations based upon individual differences assessed with HBM [2]. However, a systematic investigation of reliability still seems far behind these HBM developments. It is critical that reliability be evaluated ahead of these applications, motivating the current commentary on delineating the anatomy of reliability for future HBM.

Reliability has a specific meaning in probability theory and is defined as a statistic for characterizing stochastic processes of individual variability. Given an HBM measure, intra-individual difference refers to the variability of repeated measurements across different occasions within an individual or subject undergoing HBM (i.e., within-subject variability). Inter-individual difference is the variability of measurements between different individuals or subjects (i.e., between-subject variability). The following equation mathematically defines reliability, where Vb and Vw represent between-subject and within-subject variability, respectively:

$$ICC = \frac{V_b - V_w}{V_b + V_w}$$

Mapping reliability as a function of Vb and Vw generates a figure representing the anatomy of reliability (see Figure 1 [Figure 1: see original paper]). This anatomy map clearly indicates that reliability is a composite metric of both Vb and Vw, making it a relative rather than absolute measurement. Any location on the reliability field map describes a combination of both within-subject and between-subject variability (Figure 1a). High reliability of an HBM measure requires that the within-subject variability of the measure be relatively small compared to its between-subject variability. This is particularly crucial for clinical applications [3], which call for a measure that is both stable across time for an individual (i.e., low within-subject variability) and distinguishable between different individuals (i.e., high between-subject variability) [1].

Reliability is typically quantified by intra-class correlation (ICC). For practical guidance on evaluating reliability, ICC values can be categorized into common intervals, among which the two most popular classifications are: 1) $0 < \text{ICC} \leq 0.2$ (slight), $0.2 < \text{ICC} \leq 0.4$ (fair), $0.4 < \text{ICC} \leq 0.6$ (moderate), $0.6 < \text{ICC} \leq 0.8$ (substantial), $0.8 < \text{ICC} \leq 1.0$ (almost perfect) [4]; and 2) $0 < \text{ICC} \leq 0.5$ (poor), $0.5 < \text{ICC} \leq 0.75$ (moderate), $0.75 < \text{ICC} \leq 0.9$ (good), $0.9 < \text{ICC} \leq 1$ (excellent) [5]. Figure 1b depicts the ICC contour plot of the reliability field map using the second category. In clinical practice, a minimum reliability of almost perfect level (≥ 0.8) is needed [6].

Open neuroscience has begun establishing rich data resources for evaluating reliability with HBM [7]. It is becoming feasible for researchers to incorporate the reliability of measures employed in their studies by using the reliability field map. This should become a standard for reliable HBM, particularly for studies proposing novel methodology [8,9]. We believe that reliable HBM will greatly advance clinical practice in the future [10-12].

Conflict of Interest

The authors declare that they have no conflict of interest.

Acknowledgments

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Figure 1. The anatomy of reliability. (a) The ICC field map (b) The ICC contour map

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Note: Figure translations are in progress. See original paper for figures.