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Editorial

The merits and future of data deep-dives for cognitive neuroscience

Modern cognitive neuroscience integrates approaches from various fields and, in turn, continues to advance and inspire other domains. Historically, and until relatively recently, single-case and small sample-size approaches dominated neuropsychology and psychophysics, providing in-depth examination of brain-behavior relationships within a limited number of individuals. More recently, technological advances have facilitated our ability to gather and process large amounts of observations, which has led to a shift towards "big data" approaches. This has in turn led to a gradual departure from approaches using traditional, modest sample size approaches and a growing trend towards increasing sample sizes in behavioral and neuroimaging studies alike.

At first glance, increasing the number of observations by acquiring data from larger cohorts may seem desirable to bolster the validity of a study's conclusions, and the generalizability of its findings. In the domain of neuroimaging, recent works highlight the power of datasets from large participant groups (Smith et al., 2013; Van Essen, Smith et al., 2013; Poldrack and Gorgolewski, 2014; Casey et al., 2018; Marek et al., 2022). While this approach befits the study of modest effect sizes by providing greater statistical power, very large cohort sizes may exacerbate biases and inferential errors (e.g. Kaplan et al., 2014; Lorca-Puls et al., 2018). An alternative to the approach of increasing sample sizes merits consideration: general efforts to enhance reproducibility (e.g. Schwab et al., 2022). This goal aligns with the notion that genuine knowledge advancements are achieved not by collecting *more*, but rather *the right* data (Ramon, 2021). Thus, it is crucial to improve both the *quantity* and *quality* of data.

Most current "deep data" approaches involve a departure from big data approaches with large cohorts. Instead, they represent a return to homing in on small-to-modest sample sizes of *neurotypical* individuals, using repeated measurements within-individuals with state-of-the-art methods, a variety of tasks, and complementary experimental designs (e.g., Stacchi et al., 2020; Naselaris et al., 2021; Ramon, 2021; Fysh and Ramon, 2022; Gratton et al., 2022; Rosenberg and Finn, 2022). In-depth characterizations of fewer individuals generate more reliable and reproducible findings and can reveal patterns in the data that would be obscured by group-level averaging. Given neuropsychology's *de facto* role in pioneering deep data approaches, we believe it should play a more prominent role in contemporary cognitive neuroscience for a number of reasons.

Neuropsychological single cases and small cohorts of individuals with rare conditions provide invaluable (re)sources for developing and validating research questions. Working in-depth with fewer individuals also allows questions and methods to be informed by patients' real-life experiences. Demonstrating the relevance of qualitative investigation of *phenomenology*, Maimon and colleagues (Maimon et al., 2022) describe an account of a blind person's experiences with using both a retinal implant and sensory substitution device. Such accounts can highlight unnoticed deficits and compensation approaches and provide the basis for long-term, in-depth investigation at both the behavioral and neural levels. In his two-part review, Rossion (2022a, 2022b) synthesizes findings from 20 years of investigation with the prosopagnosic patient PS. The impressive volume and range of studies reviewed, from studies drawing on her personal experiences as a kindergarten teacher (Ramon et al., 2016), to neuroimaging studies describing neurofunctional correlates of her profound impairment (Gao et al., 2019; Liu-Shuang et al., 2016), is testament to how in-depth characterizations of *single* patients can inform theories of visual cognition and neural functioning. Several new cases reported here pertaining to perception (Vannuscorps et al., 2021), action (Masson et al., 2021), language (Paul et al., 2022; Tuckute et al., 2022), and psychopathology (Genetti Gatfield, Péron et al., 2021), emphasize the continuing role of case studies in cognitive neuroscience.

Adopting a deep data approach implies a general expansion of our observational lens. In the first instance, this can imply rethinking our *procedures* at various levels. Focusing on behavioral measures used to characterize single-case dissociations, Toraldo (2022) provides an elaborate reflection on the usage of raw or standardized behavioral scores to decrease false positives via case-wise patterns. Investigating cognitive dissociations at the neural level via cross-sectional observations combined with longitudinal case testing in patients with aphasia, Meier and colleagues (Meier et al., 2022) report interindividual differences in dissociable recovery of language deficits and executive control impairments. Such findings may indicate that available *tools used for the assessment* of impairments warrant closer inspection. Similarly, comparing different tools used to assess face perception, Mishra et al. (2021) document differences in test sensitivity between tools developed for neurotypical and impaired cohorts, thereby adding to the wider discussion concerning appropriate test usage (cf. Fysh and Ramon, 2022; Bobak et al., 2022).

Further, a deep data approach can involve adopting a *multimodal* perspective toward rare syndromes that are typically investigated within a singular domain. Investigating the perception of facial identity and facial speech patterns, Albonico et al. (Albonico et al., 2022) report a multimodal deficiency among individuals with life-long visual deficits not caused by brain damage. This finding extends the previously advocated and increasingly recognized generalized *visual* nature of the deficit previously described as developmental prosopagnosia (Geskin and Behrmann, 2020). Similarly, studying multisensory integration in deafness, Whitton et al. (2021) and Villwock et al. (2022) show that early-onset deafness affects not just the auditory system, but also

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behavioral and neural correlates of binding across non-deprived sensory modalities.

Finally, a deep data approach is especially crucial when studying rare populations, which due to uncommon conditions can provide unique dissociations of functions or causal relations. Individuals with congenital sensory or motor loss are, albeit extremely rare, uniquely qualified to probe *causal* relationships between experience and neurocognitive development. This special issue features studies of people born with blindness (Bottini et al., 2022; Watkins et al., 2022) with early onset deafness and native sign language experience (Quandt et al., 2021; Whitton et al., 2021; Andin and Holmer, 2022, Villwock et al., 2022) and people born with gaze paralysis (Masson et al., 2021), including a particularly rare cohort of individuals with restored sight following early-onset blindness (Martinelli et al., 2021; Ben-Ami et al., 2022; Rubio-Fernandez et al., 2022). Going beyond sensory effects, Campbell and Bergelson (Campbell and Bergelson, 2022) review evidence for language development of sensory concepts in children born with blindness or deafness and propose how these children may acquire these concepts despite the absence of direct perceptual experience. Lastly, Musz et al. (2022) report that naturalistic auditory processing synchronizes the visual cortices only in congenital but not in late-onset blindness, illustrating the unique nature of early-onset deprivation on brain reorganization. These findings highlight the effects of early life experience on various levels of sensory and cognitive faculties, and their value for revealing causal relationships.

With this Special Issue, our aim was to showcase the diversity of empirical work and the value of case studies and rare populations, which can be leveraged to gain insights and develop resources to improve the reproducibility of neuropsychological research. Merging research from diverse fields demonstrates a collective appreciation for the need to continuously reevaluate and extend our approaches to studying brain-behavior relationships. Moving forward, we hope that current trends in neuropsychology and cognitive neuroscience will generate objective and reliable tools needed to advance our understanding of neurodiversity and neural life-span development, as well as provide empirical foundations within emerging applied disciplines (e.g., legal neuroscience).

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