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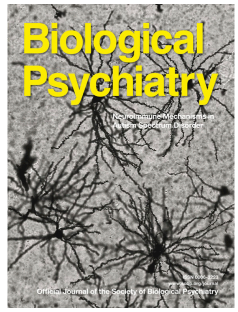

An opportunity to increase collaborative science in fetal, infant, and toddler neuroimaging

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The field of fetal, infant, and toddler (FIT) neuroimaging research—including magnetic resonance imaging (MRI), electroencephalography (EEG), magnetoencephalography (MEG), and functional near-infrared spectroscopy (fNIRS) among others—offers pioneering insights into early brain development and has grown in popularity over the past two decades. In broader neuroimaging research, multisite collaborative projects, data sharing, and open-source code have increasingly become the norm, fostering "big data", consensus standards, and rapid knowledge transfer and development. Given the aforementioned benefits, along with recent initiatives from funding agencies to support multisite and multimodal FIT neuroimaging studies, the FIT field now has the opportunity to establish sustainable, collaborative, and open science practices. By combining data and resources, we can tackle the most pressing issues of the FIT field, including small effect sizes, replicability problems, generalizability issues, and the lack of field standards for data collection, processing, and analysis—together. Thus, the goal of this commentary is to highlight some of the potential barriers that have waylaid these efforts, and discuss the emerging solutions that have the potential to revolutionize how we work together to study the developing brain early in life.

Although FIT development encompasses only about three years of time, from gestation to late toddlerhood, it represents the most rapid and dynamic period of brain and behavior maturation within the lifespan[1]. Infant mental health work suggests that this incredibly plastic period is when antecedents of psychiatric risk are instantiated in neural systems, before a formal diagnosis can be made. Therefore, charting healthy brain development in support of basic and translational science goals will require densely sampled and flexible measures across this period.

The parallel unfolding of neurophysiological processes like synaptogenesis, myelination, neurovascular development, and synaptic pruning impacts different neuroimaging modalities such that certain techniques are more or less appropriate depending on the developmental stage and questions to be addressed. For example, structural MRI has changing soft tissue contrast throughout the first year of life due to rapid changes in myelination and neural water content; therefore, different contrasts and sequences may be needed for different ages during infancy. Task-friendly modalities like EEG and fNIRS cannot be used during the fetal period, and more appropriate methods like fetal MEG are not yet widespread. Behavioral approaches that enhance neuroimaging studies like eye-tracking are traditionally designed for older infants and toddlers. MRI, compared to EEG and fNIRS, is more challenging with toddler participants, whether applying an asleep or awake protocol, but it is unmatched in spatial resolution. These methodological subtleties that vary due to the age of the participant naturally have led to FIT researchers to tailor methodology to specific ages. These complementary strengths of different modalities (e.g., MRI for superior spatial resolution, EEG for superior temporal resolution) are also a reason for the FIT field to commune. As the neurophysiological processes measured by each method mature and refine in the FIT period[2,3], and interest in these developmental cascades connects FIT researchers with disparate specializations, increased cross-modal collaboration will provide accelerated and systemic insight into the developing brain.

Efforts towards collaboration and sustainability are further complicated by the inherent challenges of collecting data from FIT participants[4]. Increased movement, reduced task compliance, and unpredictable engagement increase experimental expense and labor, which may decrease the ability or willingness to share data. For instance, curating shareable datasets takes significant time, a scarce commodity among researchers when each session can range from 4-8 hours and often require 3-4 people to perform. Further, curation can take longer when datasets have variable quality and contents (e.g., repeats of the same sequence, differing orders of acquisition between participants, few participants with all sequences). These difficulties are compounded in protocols that include longitudinal sampling, multi-modal data, high-risk groups (e.g., premature birth or substance exposure), or recruitment from rural areas, where resources for neuroimaging research may be more limited. Moreover, if institutions reward novel discovery over contributions to open science, there may be hesitancy for researchers to share data that are potentially the first of its kind. Further, there is a lack of funding offered to support neuroimaging data curation and sharing, which can be costly both in terms of computational resources and personnel time.

Finally, many of the challenges of FIT imaging demand the development of new software and hardware for data analysis. Unfortunately, the computational experts needed to create these tools (developers) are often siloed from the experimentalists and clinicians who will ultimately use them (appliers). Developers may depend on appliers to provide data that can be used to refine data analysis tools. Without opportunities for communication and collaboration among developers and appliers, and without a culture of data sharing, the development of new software and hardware for data analysis may be limited or prolonged. These collaborations are also integral for ensuring that the tools developed are made publicly-available and user-friendly. Thus, appliers sharing their data openly would give developers more resources to create cutting-edge tools, and developers sharing their tools would make cutting-edge analyses more feasible for appliers, ultimately benefiting the entire field.

Several solutions have been proposed to facilitate and reward collaborative science in FIT neuroimaging. Funding agencies have been major contributors in a top-down shift to prioritize funding for FIT neuroimaging research and core data processing resources, which has alleviated some of the impeding factors for collaboration in this field. Over the past decade, several large, multisite, and multimodal studies have been funded by NIH and the European Research Council such as the Developing Human Connectome Project (dHCP; http://www.developingconnectome.org/), the Baby Connectome Project (BCP; https://babyconnectomeproject.org/), the FinnBrain Study (https://sites.utu.fi/finnbrain/en) and the HEALthy Brain and Child Development study (HBCD; https://heal.nih.gov/research/infants-and-children/healthy-brain). Furthermore, private organizations such as the Bill and Melinda Gates Foundation (https://www.gatesfoundation.org/) and Wellcome Leap (https://wellcomeleap.org/) have provided millions of dollars in funding for early life health and development research. Such funding initiatives are critical for incentivizing and facilitating collaborative and open research in FIT populations whose data requires more resources to obtain relative to older children.

An indispensable shift towards collaborative FIT neuroimaging research is also evident in the emergence of societies whose missions include bolstering collaborations and connecting experts within the FIT neuroimaging communities with other stakeholders[5]. Examples of such societies include the Fetal Infant and Toddler Neuroimaging Group (FIT'NG; https://fitng.org/), the Newborn Brain Society (https://newbornbrainsociety.org/), the PerInatal, Preterm and Paediatric Image (PIPPI) workshop (https://pippiworkshop.github.io/) , and the International Perinatal Brain and Behavior Network (https://babybrain.isdp.org/). These groups make explicit efforts to foster collaboration and cross-communication within our diverse field by hosting meetings, distributing resources, and facilitating networking among their membership. Other collaborative efforts within FIT neuroimaging communities include data analysis challenges, such as lesion detection and age estimation (BabyStepsChallenge https://www.babystepschallenge.com); fetal brain segmentation (Fetal Tissue Annotation and Segmentation Challenge https://feta.grand-challenge.org); and infant cerebellum segmentation (cSeg Challenge https://tarheels.live/cseg2022). These FIT organizations and events are critical for enabling and encouraging collaborative and open science in FIT neuroimaging.

A vital mechanism for fostering open and collaborative science comes from the bottom-up: training the next generation of scientists to conduct their work collaboratively and openly. Indeed, there is evidence to suggest that early-stage investigators have favorable opinions on open science practices and are likely to use such practices themselves[6,7]. Those who do not take part in open science often cite perverse incentive structures as a barrier at their respective institutions[8]. It is therefore critical that institutions value open science and collaborative efforts by positively considering these practices in hiring and promotion decisions as well as by recognizing these efforts with awards and monetary compensation. In other words, we as a field—as funding agencies and many institutions are already doing—must nurture and reward teamwork over the lone scientist model.

There are notable successes in other research areas that can be leveraged to make FIT data increasingly available to others. Databrary (https://nyu.databrary.org/) has an excellent format for sharing video, image, and speech data with varying levels of access corresponding to what participants have consented to share. OpenNeuro (https://openneuro.org/) is an outstanding repository for imaging data broadly, but use is not widespread among FIT neuroimagers. This means that there is no centralized repository for collating FIT neuroimaging datasets. The NIH data archive (https://nda.nih.gov/) may one day be able to serve this need; however, users often report difficulties with accessing all the information needed to analyze the available data because information such as session protocols, notes, or other key details are often omitted from the archive. Consistent use of a well-developed database that is tailored for FIT neuroimaging data would improve data sharing efforts within the FIT neuroimaging community and would also reduce barriers for early career researchers who may not yet have access or funding to collect new data.

The field of FIT neuroimaging includes individuals from a wide range of backgrounds and research interests, who are separated in a number of ways. Bringing these individuals together through open and collaborative science efforts will energize the field towards greater scientific discoveries.

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