

## Backstory

## Converging disciplines for assessing child development

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The failure of hundreds of millions of children to achieve their full developmental potential or having their development disrupted due to neurodevelopmental disorders is a formidable barrier to a healthier, more equal, and inclusive future for humanity (Lu et al., 2016). One major reason for the limited global response to this challenge, despite the accumulation of evidence on effective interventions (Aboud and Yousafzai, 2015), is the absence of a pragmatic and valid tool for assessing early life neurodevelopment (Boggs et al., 2019).

The current dependence on observation of a child in a clinical setting by highly trained child development experts, an extremely scarce and inequitably distributed human resource, and the reliance on proprietary tools that are prohibitively costly effectively means that there is no routine assessment of child development, such as what is done for growth, in any low- and middle-income country. If developmental surveillance is implemented at all, it is done using parent-report questionnaires, which depend on the caregiver's own knowledge of healthy development in childhood, or observations by trained non-specialists, which differ based on the level of skill of the observer and which need continuing fidelity monitoring to ensure sustained quality through repeated intensive training. Indeed, in most settings, the health system simply waits for a child's development to become so awry that the consequences become visible to the parent, teacher, or health worker. As a result, the precious developmental window for early intervention is squandered and millions of children struggle with their learning, which, in turn, leads to poorer employment prospects and, ultimately, fuels the vicious cycle of disadvantage and poverty.

The authors, Vikram Patel (a global mental health expert), Gauri Divan (a developmental pediatrician), and Supriya Bhavnani (a neuroscientist), along with a clinical psychologist and two neurobiologists, formed a small team that explored how their respective fields could collaborate to solve this challenge. In this backstory, they feature the tools that they have developed to easily assess early-life neurodevelopment that required the convergence of diverse disciplines.

**CONVERGING DISCIPLINES TO INNOVATE**

With the increasing accessibility of digital technologies, we challenged ourselves to consider whether we could innovate to close this monitoring and detection gap by designing scalable assessment tools. This approach was inspired by three strands of science:

- implementation science demonstrating the success of task-sharing, a strategy in which paraprofessionals are trained to deliver specific health care interventions, for other global health challenges, including parenting interventions for promoting early child development and managing neurodevelopmental disorders (Britto et al., 2017);
- neuroscience, which showed how diverse technologies such as eye-tracking and electroencephalography (EEG) could be used to assess the developing brain;
- developmental science, which showed that tasks delivered in a structured, engaging manner, typically with toys, could be used for direct assessments of child development.

Thus, we aimed to design technology-driven tools that could provide direct assessments of the child's developmental capabilities (as opposed to parent reported or observed behaviors) and that could be delivered by frontline workers in home settings to realize our goal.

We began this effort by adapting methods used in clinical settings and neuroscientific laboratory-based studies to assess cognitive, social-communication, and motor development into scalable tools by harnessing the potential of digital technology (see Figure 1). These adaptations included digitizing and gamifying

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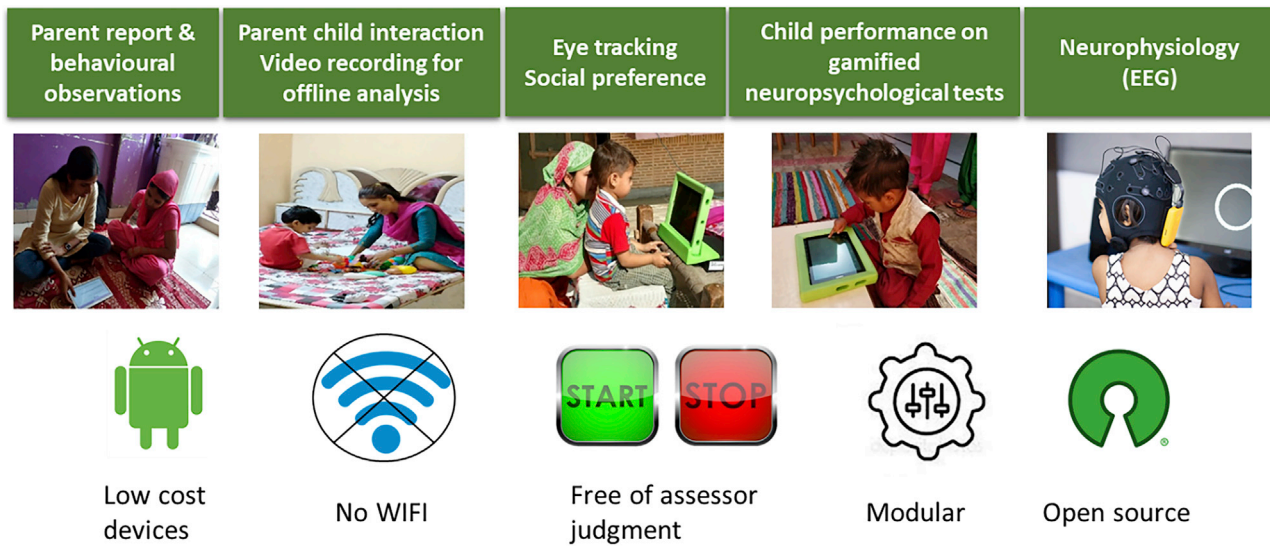
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**Figure 1. Highlights of the digital tools for assessment of development in early childhood that require many disciplines to come together to understand and facilitate their design and function.**

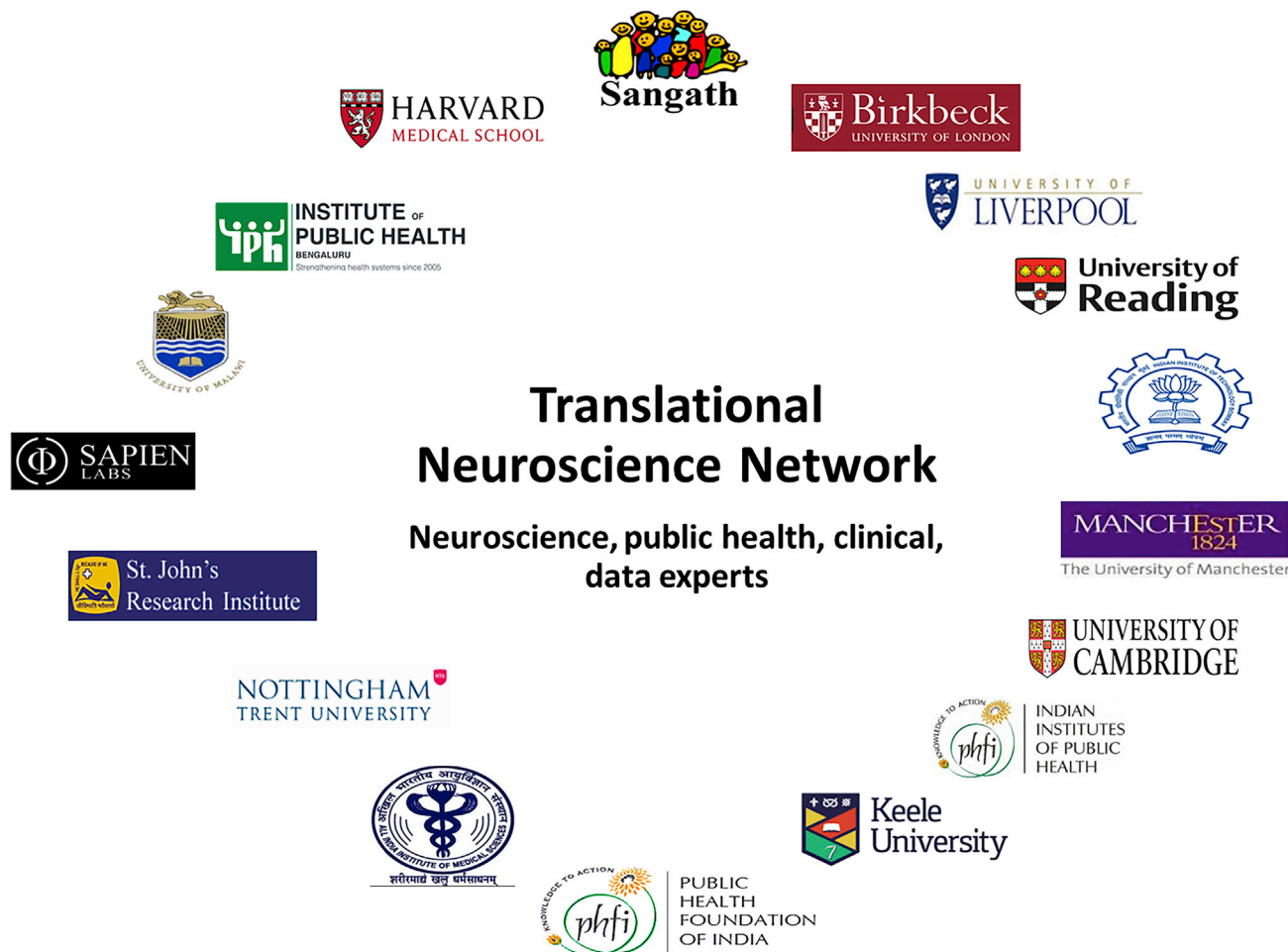
neuropsychological tests such that they could be administered on relatively low-cost Android tablet computers, which automatically record the child's performance on the test. We proposed to use computer vision analysis of videos recorded by the camera of the tablet computer to replace both infrared eye-tracking as well as manual coding of videos of parent-child interaction. We also wished to explore the potential of noninvasive measures of brain activity using portable EEG. Our guiding principles were to design tools to be modular, which could work offline at the time of administration to address connectivity barriers, could be delivered in home settings, be seamlessly integrated with one another, and be amenable to the use of cutting-edge machine learning analysis methods to allow for triangulation of data from diverse sources.

It was evident from the start that tackling a challenge as complex as this would require collaboration of experts from a variety of disciplines including global mental health, developmental pediatrics, developmental psychology, neuroscience, and computer science, all working closely with engineers and designers who could fashion the assessments onto mobile devices and present them in formats that are engaging for young children. This convergence of disciplines and expertise offered a unique opportunity to work across different perspectives that overlapped with one another in unexpected ways. For example, how game designers whose primary interest was engaging children's attention to play on digital devices coincided with the science team's interest in designing digital tasks that could serve to assess a range of neurodevelopmental traits.

### CHALLENGES

Working across these silos did pose some challenges such as the discomfort of having expertise that was only part of the solution, implicit hierarchies about which expertise was more salient, and difficulties in communication due to differing concepts and vocabularies (much of it, we would discover, was scientific jargon, which could be broken down into easily understood phrases). We overcame these challenges by emphasizing the critical value of each perspective and expertise to realize our goals, ensuring representation of all disciplines at every stage of the project, contributing to the planning, execution, analysis, and

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**Figure 2. Current Translational Neuroscience Network partners, highlighting the interdisciplinary and global nature of the research programme.**

dissemination of our research and minimizing the use of discipline-specific terminology, instead focusing on the guiding principles of our work.

### FROM IDEAS TO EVIDENCE

Our program of work, which was launched in 2015, has grown to evolve into a growing international and interdisciplinary “Translational Neuroscience Network” focused on child development (Figure 2). This network comprises like-minded academics drawn from Indian and international institutions, who recognize the potential for such cross-disciplinary collaboration to shift the needle on one of the most vexing of all scientific challenges. This network represents a highly effective collaboration between leading organizations including medical schools, universities, and civil society organizations in the global north and south.

Our first step was an ideation and proposal creation workshop in December 2015, which served as the foundation of our first grant applications in which we proposed the digital delivery of neuropsychological tests of child development and tablet-based eye-tracking as promising technological innovations. The initial knocks from proposal rejections was replaced by optimism when we received support for pilot projects, which allowed us to create our first digital assessment tools—the Developmental Assessment on an E-Platform (DEEP; <https://sangath.in/reach-2/>) funded through the

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Corporate Social Responsibility grant from Madura Microfinance Limited (an Indian company) and the Screening Tools for Autism Risk using Technology (START; <https://startproject.bhismalab.org/>) funded through an MRC-GCRF Foundation Award.

Our pilots allowed us to:

- 1) refine the theoretical framework on which these tools were based,
- 2) design them through iterative testing with young children with the incorporation of feedback from pilot studies, and
- 3) systematically demonstrate evidence of their acceptability to pre-school end-users, feasibility for delivery by frontline workers, and validity against gold-standard developmental assessments thereby moving us forward in the innovation cycle from ideation to proof-of-concept.

We have demonstrated that our innovative tools allow us to take gamified assessments of child developmental capabilities into the hands of frontline workers and assess young children in the comfort of their own home while they interact with evidence-based engaging assessments (Bhavnani et al., 2019). We have also shown that these assessments fare well against the gold standards of child development assessments (Mukherjee et al., 2020). Our efforts have led to the creative integration of diverse assessment technologies, for example, designing the lead character of the DEEP games to be a child who wears a special cap has facilitated the child being assessed to agreeing to wear a portable EEG cap, thus allowing us to collect both the digital game data and EEG data simultaneously.

As we published our encouraging results and disseminated them through conferences and workshops, we noted a growing interest in our tools. Two recent grants that have been awarded to our network (STREAM, funded by the MRC-GCRF grant [<https://research.reading.ac.uk/stream/>], and COINCIDE, funded by the Wellcome-DBT India Alliance Team Science Grant; <https://www.indiaalliance.org/news/tsg-crc-awardees>) will allow us to expand and strengthen our work. Our success in garnering funding is also representative of the ongoing shift in funding priorities of global health to promote cross disciplinary research.

In part, this is fueled also by the recognition that the massive inequity in science funding and research in brain science at the global level (>90% is spent researching less than 10% of the world's population) is a fundamental barrier to catalyzing discoveries that can transform our understanding of complex developmental and mental health conditions (Saxena et al., 2006).

## LOOKING AHEAD

Three fundamental principles underlie the success of our collaboration. First, the co-creation with our community partners and target audience through active engagement of these groups as our tools are being designed. Second, a focus on building capacity of early career researchers to equip a new generation of academics with skills that cut across the silos of disciplines to galvanize this convergent approach to research. We have encouraged senior faculty from diverse disciplines to mentor the early career researchers and encourage all team members to participate in capacity building opportunities outside their specific discipline, for example, by sharing research articles to the entire team and attending seminars and conferences that were cross-disciplinary. Third, constantly broadening our horizons by learning about and exploring new opportunities to collaborate with other research groups who share our vision to give children the best start in life.

Looking ahead, we hope to continue to leverage new resources and partnerships to realize our ultimate goal of **scalable, valid assessments of early child development**. One approach is to expand the testing of the existing tools (DEEP and START) to larger and more diverse populations with the expectation that this would improve the precision and generalizability of our machine learning models. Relatedly, we hope to make these tools accessible online so that parents can assess their own children using evidence-based tools and help us generate much larger volumes of data. A second approach, motivated by the success

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of our efforts, is exploring the potential of other non-invasive technologies that might be amenable to scale in community settings.

Above all, we will continue to be guided by the key lesson of our experience so far, that addressing complex challenges facing humanity requires catalyzing the translational pathway from fundamental science to population impact by converging diverse disciplinary perspectives.

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