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Commentary

The Art, Science, and Secrets of Scanning Young Children

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Millions of people worldwide have health conditions arising from altered brain development. Treatments for these conditions must be optimized through mechanistic understanding from rigorous and replicable research. Magnetic resonance imaging (MRI) can visualize and quantify brain structure and function throughout development. MRI is safe and noninvasive and can provide quantitative measurements of brain growth and maturation at high spatial resolution. Thus, MRI is a powerful and flexible tool for characterizing neurodevelopment (1).

An impediment to characterizing neurodevelopmental insights from MRI comes from the unique challenges of conducting MRI in children, particularly those younger than 3 years of age (2). In this commentary, we highlight that acquiring high-quality MRI data in young children is a science in and of itself—though it may feel more like an art than a science to those newer to the field. In addition, we emphasize the importance of adapting MRI acquisition in children to meet the unique needs of young participants and the communities from which they are recruited (Figure 1).

Advances in MRI Acquisition. A primary challenge in MRI is motion, which can degrade image quality. As a result, infants and young children—who have difficulty lying still inside the scanner—often require alternative strategies such as sedation or scanning during natural sleep (2) to generate high-quality images. While helpful in reducing motion artifacts, these approaches limit task-evoked and natural/nonsedated functional brain activity imaging; restrict comparability imaging done during wakeful periods, which is typically performed in older participants; require extended and off-hour scan times; and do not guarantee a lack of motion artifacts. Emerging motion correction strategies, including prospective methods that track real-time head motion and retrospective methods that correct for motion during image reconstruction, can reduce motion-related artifacts and improve the quality of developmental MRI.

Imaging acquisition during a short period of time is integral to developmental MRI (3). Shorter sequences can improve successful imaging of natural sleep and awake states. Acceleration with undersampling methods (e.g., compressed sensing, partial Fourier, and parallel imaging) and simultaneous multislice imaging methods that acquire multiple slices at a time reduce scan times while preserving image quality. Nevertheless, quicker acquisition times may necessitate corrections for confounds, such as physiological noise and head motion.

Loud acoustic noise poses another challenge in developmental MRI because it can wake sleeping infants and scare or startle children. Quiet and silent imaging sequences and other measures to reduce acoustic noise (e.g., MRI-compatible headphones) have great potential, particularly for imaging during natural sleep. These strategies are forthcoming.

Custom developmental head coils are another recent advance leading to novel brain function discoveries in young infants who are awake. Using custom size-adaptive developmental coils can increase the quantity of low-motion functional MRI data collected from sleeping and awake infants.

Advances in Acquisition Protocols. Including preparation time, child scanning sessions can take 3 hours or longer, often occurring after parents' workdays, at bedtime, or on weekends (4). The scanner must therefore be a welcoming environment. Thus, researchers have conceptualized a "research home" with various child-friendly themes and MRI-compatible furnishings. These also increase infrastructural requirements at the scanner, such as a dedicated space that allows the child being imaged to fall asleep while allowing safe transportation to the scanner. MRI-compatible, low-cost alternatives to hospital furniture (e.g., resin rocking chairs, playpens made of PVC piping, and mesh) help keep the infant comfortable. Recently, MRI-compatible cribs have also advanced, and these typically snap directly onto the scanner bed.

In addition to providing practical and physical accommodations for families in the scanning environment (e.g., places to sit and rock infants), researchers have learned to consider participants' social and psychological needs. For example, families are mailed packets of materials (e.g., ear protection, an audio recording of scanner sounds) to help acclimate young participants to novel sensory experiences before the scan day. During the scan, families interact with trained researchers—fondly called "baby whisperers"—who are attuned to the infant and family cues throughout the session and adapt accordingly in a semistructured approach (e.g., changing tone of voice or style of interaction, suggesting breaks in the protocol, offering preselected MRI-compatible toys or comfort objects). In addition, scanning environments can include dimmable lights and familiar sounds (e.g., lullabies) played in the background, and participants can wear noise-canceling headphones, all of which help increase participant comfort.

Another strategy that supports families in meeting participants' emotional responses and needs, particularly those of older babies and young toddlers, is using interactive social

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Figure 1. Schematic of the areas of innovation that are pivotal to successful high-quality neuroimaging with magnetic resonance imaging in young children.

stories to prepare participants to the expectations during the scan. For example, images of age-matched participants at the various steps throughout the visit are taken and compiled into a short story using simple language. A few weeks prior to the scan, participant families prepare by reading this story and modeling the use of the equipment that was mailed. In addition, trained researchers encourage the families to use the participants' names when interacting and using the social story.

To further acclimate participants to the scanning experience and help them prepare both mentally and physically for their scanning session, young participants may be given a mock scan session before entering the actual scanner. Mock scanners have evolved from low-tech rolling seats underneath a table to child-size scanners in a dedicated room with family-friendly décor. Prebuilt small-to-large toy mock scanners can also be sent to the participant's home before scanning (5).

Additional items such as pellet-filled positioning devices and custom-made weighted blankets filled with beans help increase participant comfort during scanning and reduce participant movement.

Advances in Public Awareness and Community Engagement. Human subject research requires willing participants. For developmental imaging, this includes the willingness of both children and their families. Preconceptions of MRI based on direct experiences (i.e., previous involvement in research, clinical MRI, and medical training) or information from media, friends, and family can reduce willingness to participate in an MRI session. Typical concerns include scanner noise and (mistakenly) radiation exposure (2), which must be addressed during recruitment. Thus, successful developmental MRI requires that researchers educate and engage with participants and their communities to reduce misunderstanding that can impede potential participation. Examples of successful outreach include community interactions through educational events about MRI (e.g., videos of stuffed animals being scanned) or partnering with local children's venues (e.g., children's museums and libraries) to develop education programs targeted to families (Figure 1). If these outreach efforts continue to be prioritized, they will aid developmental MRI research (and MRI research more broadly) by increasing public awareness and access to accurate information.

Increasing the accessibility of MRI research has received more attention to ensure greater participation in MRI research across the lifespan. A recent example is the availability of mobile MRI units (6) that allow MRI research to be feasible in all parts of the world, including remote regions. Successful collaboration within these regions requires scientists to proactively engage with remote communities with meaningful, bidirectional information exchanges between scientists and the participant population (7).

Conclusions. This commentary highlights the state-of-the-art science required to address the unique complexities and challenges of MRI research with infants and young children. Not only is there a need for hardware, software, and equipment tailored to this developmental population, but scientists' attitudes, attention, and efforts must be adapted and tuned to these young participants, their families, and their broader communities. Through this combination of science, and the art of human interaction, developmental MRI will continue to advance our understanding of brain growth, maturation, and function, opening essential avenues of research into both typical and atypical neurodevelopment.

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