Infant brain activity predicts social flexibility, stress recovery in first year

November 15 2023, by Lauren Otolski

Credit: Unsplash/CC0 Public Domain

Caregivers celebrate many milestones between a baby's birth and their first birthday. During these 12 months, many infants go from being unable to support their head to crawling and standing, and from watching their parents to smiling, babbling, and waving at them. Some babies even say their first words or take their first steps.

Infant brain functioning in the first few months may set the basis for this significant growth, and researchers in the Interdisciplinary Lab for Social Development at the University of Illinois Urbana-Champaign worked with families to explore this crucial developmental period. Through an initiative called the Infant Development Project, the ILSD recently published two studies exploring how early brain activity relates to the flexibility of infants' social interactions and their ability to recover from stress.

"The main impetus for the project was to better understand the interplay between infants' neural functioning and environmental supports—particularly interactions with caregivers—in shaping infants' capacity to regulate stress and focus their attention," said Nancy McElwain, a researcher at the Beckman Institute of Advanced Science and Technology and a research professor of human development and family studies at UIUC. McElwain leads the ILSD, which focuses on early social and emotional development in the context of caregiving relationships.

At 3 months of age, 35 infants participated in a functional MRI session at the Beckman Institute to assess their brain development—no easy feat, considering these scans had to be conducted while the infants were naturally asleep. Infants were placed in a special cradle to support them within the MRI machine and were outfitted with several levels of ear protection.

At 3, 6, and 9 months, the same infants completed various interactive tasks with their mothers, including an exercise called a still-face session. The session begins with the pair playing face to face for 2 minutes. This is followed by a social stressor for the infant, during which the mother holds a neutral expression and does not respond to them. After 2 minutes, or sooner if the infant becomes very upset, the mother resumes normal interaction with the infant for another 2 minutes.

Many infant neuroscience studies rely on caregiver questionnaires and reports to assess infants' behaviors, but this project involved direct observation of mothers and their infants. Videos of the infants and their mothers were analyzed frame by frame, with details of their expressions, vocalizations, and gaze directions noted in milliseconds. This allowed the researchers to capture very brief but potentially important changes in behavior.

In the first study, published in Cerebral Cortex, ILSD researchers investigated whether an infant's brain activity correlates with dyadic flexibility—the extent to which the infant and their mother promptly and easily modify their own emotions, vocalizations, and attention in response to each other's behaviors. The extent of this flexibility was observed during the first part, or play episode, of the still-face session. Even children less than a year old display this flexibility when interacting with their caregivers, which can indicate both the functioning of a parent-child relationship and how nimbly the pair can adapt to changing demands in the environment or internal states of the infant.

The researchers were especially interested in two key networks in the social brain: the default-mode network, which is involved with introspection and an infant's perception of their feelings during social interactions; and the salience network, which is linked with identifying meaningful details in the environment (for example, conversation cues like a caregiver's smile). Both networks develop rapidly during the first year of life and play important roles in adults' social interactions, but limited research exists on their relevance for infants.

Researchers found that greater simultaneous activity—known as functional connectivity—of components within the default-mode and salience networks at 3 months old correlated with greater infant-mother dyadic flexibility at 6 months of age. This study also found that greater anticorrelation between the two networks at 3 months—one network

increasing in activity while the other decreases—correlated with greater dyadic flexibility at 6 months.

"By the third month of life, we are witnessing initial patterns of synchronization within these social brain networks, as well as anticorrelations between them. The early functioning of these neural networks may underlie how well the baby is able to interact with the caregiver in a flexible manner, perhaps by supporting the development of an infant's ability to process internal and social information," said Xiaomei Li, lead author of this study and a current postdoctoral fellow at Queen's University. She was a Ph.D. student in the ILSD when the paper was published.

Li hopes that these findings will help parents see babies as active contributors to their relationship, with their interactions shaped by infants' individual differences.

"Differences may be reflected in infants' social interactions as how well they're able to register their parents' cues, or how well they're able to perceive their own needs and communicate them to others," she said. "In these ways, infants co-construct their interactions with their parents. Recognizing that infants are active contributors can enable parents to better structure their interactions with their babies."

In a second study published in *Developmental Science*, the ILSD researchers investigated how the strength of connections between brain networks correlated with infants' abilities to recover from stress. They focused on the amygdala network, an emotional processing region, and its connections with the default mode and salience networks. The stressor for this study was the second episode of the still-face session, in which the mother stops responding to the infant. An infant's ability to recover from this stress was observed as the extent to which they socially engaged when mothers resumed normal responses.

"We want to know the neural mechanisms underlying early development of stress regulation because stress regulation is very important both early on and for emotional regulation and mental health while children grow up," said Yannan Hu, the lead author of this study and a current postdoctoral research associate at the Beckman Institute. She was a Ph.D. student in the ILSD at the time of its publication.

Increased positive connectivity between the amygdala and salience networks at 3 months was linked to a decreased ability to recover from stress at 6 months. To recover from a stressful situation, it is helpful for infants to recognize positive cues and perceive the environment as safe. Although strong connections between the amygdala and salience networks may help infants recognize stressors or potential threats in the environment, excessive focus on identifying such negative cues may have the downside of reducing the infant's ability to attend to positive cues.

"Results that link neurological observations with an infant's ability to manage stress have the potential to inform early mental health screening and intervention work," Hu said. "By pinpointing potential indicators of later emotion dysregulation or mental health issues, children at risk of developing these issues can be identified and supported."

Due to the complexity of child development, insight from multiple fields is valuable. This project involved researchers from human development and family studies, bioengineering, and neuroscience. The processing and analysis of fMRI data required expertise from collaborators including Brad Sutton, a professor of bioengineering and the technical director of the Biomedical Imaging Center at the Beckman Institute; Ryan Larsen, a physicist and researcher at the Beckman Institute; Wei Gao, a professor of biomedical sciences at Cedars Sinai Medical Center; and Haitao Chen, a Ph.D. student at the University of California Los Angeles.

More information: Xiaomei Li et al, Functional neural network connectivity at 3 months predicts infant-mother dyadic flexibility during play at 6 months, *Cerebral Cortex* (2023). DOI: 10.1093/cercor/bhad117

Yannan Hu et al, Associations between infant amygdala functional connectivity and social engagement following a stressor: A preliminary investigation, *Developmental Science* (2023). DOI: 10.1111/desc.13418

Provided by Beckman Institute for Advanced Science and Technology