FIT'NG
Fetal, Infant, & Toddler Neuroimaging Group

Program

1st Annual

Fetal, Infant, & Toddler Neuroimaging Group Conference

September 5-6, 2022
La Sorbonne Université
Paris, France

fitng.org

@FIT_NGIn
www.fitng.org
#fitng2022

Program At-A-Glance

	Monday 5-Sep		Tuesday 6-Sep	
8:00 AM	**Registration Check-In**	Registration /Information Desk Open 8am-5:00pm		Registration /Information Desk Open 8am-3:00pm
8:45 AM	**Opening Remarks**			
9:00 AM	**Session 1** *Fetal and Early Infant Symposium* 9:00am - 10:30am		**Session 4** NIH HBCD and Large Multisite and Cohort Studies Across Countries 9:00am - 10:30am	
9:15 AM				
9:30 AM				
9:45 AM				
10:00 AM				
10:15 AM				
10:30 AM	*Break 10:30am - 10:45am*		*Break 10:30am - 10:45am*	
10:45 AM	**Session 2** Beginnings of Development 10:45am - 11:30am		**Session 4 Cont'd** NIH HBCD and Large Multisite and Cohort Studies Across Countries 10:45am - 12:15pm	
11:00 AM				
11:15 AM				
11:30 AM	**Session 3** Early Substance/ Environmental Exposures and Early Brain Outcomes 11:30am - 12:15pm			
11:45 AM				
12:00 PM				
12:15 PM	**Lunch Break** *on your own* 12:15pm - 1:45pm		**Lunch Break** *on your own* 12:15pm - 1:45pm	
12:30 PM				
12:45 PM				
1:00 PM				
1:15 PM				
1:30 PM				
1:45 PM	Keynote Presentation ***Dr. Ghislaine Dehaene-Lambertz*** 1:45pm - 2:45pm		**Poster Session #2** 1:45pm - 3:15pm	
2:00 PM				
2:15 PM				
2:30 PM				
2:45 PM	*Break 2:45pm - 3:00pm*			
3:00 PM	**Supporting The Next Generation of FIT'NG Mentoring Session** **3:00pm - 4:15pm**		**Session 5** *Innovative methods and analysis techniques symposium* 3:15pm - 4:45pm	
3:15 PM				
3:30 PM				
3:45 PM				
4:00 PM				
4:15 PM	*Break 4:15pm - 4:30pm*			
4:30 PM	***EEG & fNIRS Talk***			
4:45 PM	***Sponsor Tech Time - NIRx***		**Closing Remarks**	
5:00 PM	**Flash Talks**		*Break 5:00pm - 5:15pm*	
5:15 PM				
5:30 PM	**Poster Session #1** 5:30pm - 6:45pm		**Session 6** Trainee Initiatives Panel 5:15pm - 6:45pm	
5:40 PM				
5:45 PM				
6:00 PM				
6:15 PM				
6:30 PM				
6:45 PM				
7:00 PM	**Trainee Committee Social Event**			
7:15 PM				
7:30 PM				
7:45 PM				
8:00 PM				
8:15 PM				
8:30 PM				
8:45 PM				
9:00 PM				
9:15 PM				
9:30 PM				

FIT'NG Conference Sponsors

NIRx

NIRx has established itself as a leading provider of research solutions for near-infrared spectroscopy (NIRS). At NIRx, we design and manufacture innovative NIRS devices and software. We integrate devices, software, and more into user-friendly and powerful research solutions. Our team of scientific consultants focuses on providing you and your team with training and outstanding support so you can focus on your research. Our fNIRS solutions are invented, designed, and manufactured in Berlin Germany, supported by an international team of scientists in Europe and North America, and distributed by a network of excellent local distributors worldwide.

nirx.net

Fralin BioMedical Research Institute at VTC – Virginia Tech

Founded in 2010 in Roanoke, Virginia, the Fralin Biomedical Research Institute at VTC is one of the nation's fastest-growing academic biomedical research enterprises and a destination for world-class researchers. The institute's Virginia Tech scientists focus on diseases that are the leading causes of death and suffering in the United States, including brain disorders, heart disease, childhood diseases, and cancer. In just 12 years, the research institute has opened an additional building in Roanoke to more than double its enterprise and lab facilities, and it has invested in brand-new laboratories on the Children's National Research & Innovation Campus in Washington, D.C.

fbri.vtc.vt.edu

Mass General Brigham

Mass General Brigham is an integrated academic health care system, uniting great minds to solve the hardest problems in medicine for our communities and the world. Mass General Brigham connects a full continuum of care across a system of academic medical centers, community and specialty hospitals, a health insurance plan, physician networks, community health centers, home care, and long-term care services. Mass General Brigham is a nonprofit organization committed to patient care, research, teaching, and service to the community. In addition, Mass General Brigham is one of the nation's leading biomedical research organizations with several Harvard Medical School teaching hospitals.

massgeneralbrigham.org

Columbia University, Department of Psychiatry

The Columbia University Department of Psychiatry is one of the largest in the country in terms of faculty size as well as state, federal, and foundation research support. We are currently among the top-ranked in the nation for Psychiatry in the US News & World Report Best Hospital rankings, as well as in psychiatric research funding from the National Institutes of Health. We have extraordinary clinical, educational, and research resources. Our faculty includes over 400 psychiatrists, psychologists, social workers, nurses, and neurobehavioral scientists. Clinical facilities and laboratories of the Psychiatry Department are located in a large number of institutions and healthcare systems. These include NewYork-Presbyterian Hospital, Columbia University Irving Medical Center, the New York State Psychiatric Institute, the New York State Office of Mental Health, and the Washington Heights Community Mental Health Center. The Department of Psychiatry also houses the Center for Neurobiology and Behavior, the Mind/Brain Institute, a Howard Hughes Research Institute and the Stanley Center for Applied Neuroscience of Bipolar Disorders.

columbiapsychiatry.org

The Nathaniel Wharton Fund

The Nathaniel Wharton Fund serves a unique function in support of innovative biomedical research at the intersection of mind, brain, and behavior with physical illness. The Fund supports a broad variety of projects in basic research, clinical care, and teaching at the Columbia University Medical Center. All activities are directed at finding practical ways to incorporate mind-body issues into the practices of medicine.

whartonfund.org

BioImage Suite

BioImage Suite is a web-based medical image analysis software package with image processing, image registration and visualization capabiliies.

bioimagesuiteweb.github.io/webapp

FIT'NG Conference Sponsors

Artinis Medical Systems

Artinis is an innovative Dutch company that develops user-friendly, high-tech and top-quality near-infrared (NIRS) devices. Our aim is to make optical imaging easy by providing fit to purpose solutions, focusing on usability and offering superior after-sales support. Coming from the research field ourselves, we cooperate with scientists from various institutes around the globe. We are a world leader in portable NIRS, resulting in more than 1,000 publications and additionally reached ISO 13485:2016 certification last year for our quality management system. We provide NIRS systems for subjects of all ages, including three devices that were especially designed to measure in infant and pediatric subjects.

artinis.com

Mangold International GmbH

Due to the enormous variety in the field of psychology there are unlimited research possibilities. The requirements on studies and their complexity get more extensive every day. Structured observation of human behavior and human brain development leads to very interesting results. Mangold International is a world leading provider of stationary and portable labs for observational studies on understanding of early neurodevelopmental processes. Mangold Labs integrate the latest hardware technologies for video and audio and offer the professional and easy-to-use software Mangold VideoSyncPro Studio for audio-video-synchronization. With Mangold INTERACT, the leading analysis software, we offer the perfect solution for data acquisition and analysis. Eye tracking, physiology and EEG devices complete the portfolio. Benefit from 30 years of excellence!

mangold-international.com

Mindware Technologies

Since 2001, MindWare Technologies Ltd. has been the leading provider of hardware and software solutions for psychology, psychophysiology, and broader life science research. Our wealth of domain knowledge and years of experience have allowed us to develop innovative data collection equipment and the industry gold standard data analysis software, all of which are built on a foundation of peer-reviewed scientific research. As your partner in research innovation, we will help you stay one step ahead. Whether you study life or social science, child or adult behavior, neuroscience or psycho-physiology, MindWare will be there. Our technology, integration, training, and unparalleled support ensure your research success. MindWare provides an array of physiological data collection devices, integrations with additional third-party data collection devices, and analysis software. Most commonly MindWare is used for the collection and analysis of EKG (for Heart Rate Variability), Skin Conductance, Impedance Cardiography, Blood Pressure, and Electromyography. We also provide complete laboratory design with comprehensive start to finish installations, analysis conducted by our trained professionals, in-person workshops/seminars, and much more!

mindwaretech.com

TracInnovations

TracInnovations is a Danish company established in 2015, focusing on innovative solutions for image-based diagnosis and treatment. TracInnovations has developed the Tracoline system, which is an MRI Markerless Motion Tracking System that records patient's head movements during brain scans. The system is used for MRI neurology within research to enable Retrospective and Prospective Motion Correction.

tracinnovations.com

NOUS Imaging, Inc.

We create advanced neuroimaging software tools to enable efficient acquisition of high-quality brain imaging data. Our core platform, FIRMM, reliably and accurately measures motion and its effects in real-time. FIRMM helps technologists know in real-time when the data they have collected will meet the predetermined quality thresholds for the study, saving time and eliminating the need for repeat scans. Recently, we developed a new application, FIRMM-pix, that combines gamification and biofeedback to coach patients to remain still during their scans.

nousimaging.com

Sorbonne University

Sorbonne University is a multidisciplinary, research-intensive, world-class university. Located in the heart of Paris, with a regional presence, it is committed to the success of its students and to meeting the scientific challenges of the 21st century. Thanks to its 55,300 students, 6,400 academic researchers and partner researchers, and 3,600 administrative and technical staff who make it a daily reality, Sorbonne University promotes diversity, creativity, innovation and openness to the world.

sorbonne-universite.fr/en

About FIT'NG

The Fetal, Infant, & Toddler Neuroimaging Group (FIT'NG) was founded in the Fall of 2018 by Drs. Marisa Spann (CUIMC), Dustin Scheinost (Yale), Alice Graham (OHSU), and Lilla Zöllei (MGH/HMS). It is composed of interdisciplinary scientists and clinicians who have an interest in elucidating neurodevelopmental processes, the role of the preconceptional, prenatal and postnatal influences on the developing brain, and linkages between early neural phenotypes and subsequent behaviors and health outcomes.

The network provides a forum for that supports this goal through bringing together scientists and clinicians across multiple disciplines (e.g. neuroscience, computer science, biomedical engineering, psychology, psychiatry, and public health), career stages, and geographic regions to encourage collaboration and innovation. We have three core focus areas: methodological development, education/training advancement, and data sharing and integration. A primary objective spanning these areas is to encourage the establishment and dissemination of guidelines to support best practices for methods used to study the developing brain, including EEG, fNIRS, MRI, MEG, OCT, histology, DOT, ultrasound, and others. These methods are rapidly evolving and present unique challenges when applied to the study of fetal, infant and toddler brains.

FIT'NG Vision

Advancing understanding of early brain development represents an imperative for basic science and for improving capacity to support lifelong health and prevention neuropsychiatric disorders. As there are unique challenges associated with studying early brain development, we believe the FIT'NG network provides an optimal setting for interdisciplinary efforts to solidify the field and methods garnering a sound position in within the larger scientific and medical community.

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Welcome!

Dear FIT'NG Community,

Welcome to the 1st Annual Conference for the The Fetal, Infant, and Toddler Neuroimaging Group (FIT'NG). We are thrilled to have you join us in Paris for this exciting inaugural event. Like the focus of our collective scientific endeavors, we are a young, dynamic and rapidly growing group. Having launched in 2018 we have not only weathered the ups and downs of the pandemic, but have made enormous gains towards fulfilling our mission. We have hosted multiple successful workshops, trainings and events, and been overwhelmed by the enthusiasm and support for our offerings. We see more clearly now than ever that our society has a critical role to fill amongst those who are committed to advancing understanding of early brain development. You are all integral to the success of the FIT'NG community and we cannot thank you enough!

Our inaugural meeting marks a significant time in FIT'NGs' development. Our society membership, which only launched in April of this year is now up to over 100 individuals with eleven countries represented. FIT'NG is also changing the face of our field with collaborative publications, including our most recent one with 70+ authors. Our papers from earlier this year include a history of the field of infant and early childhood MRI (Pollatou et al., 2022) and a reference for addressing common concerns mentioned by grant and manuscript reviewers (Korom et al., 2022). A commentary related to collaborative science opportunities in our field was recently accepted for publication (FIT'NG, in press). We also have a commentary that is currently under review in collaboration with the HEALthy Brain and Child Development (HBCD), Scanning Young Populations Workgroup. These achievements are all of ours to share and we look forward to continuing as a prolific, collaborative society.

OUR KEYNOTE

We are honored to have Ghislaine Dehaene-Lambertz as our our keynote speaker at this inaugural conference. She is a true pioneer in the study of early brain development. Her innovative work across multiple neuroimaging methods laid the groundwork for many advances in our field and will continue to inspire future discoveries. Ghislaine and her group are also graciously hosting a visit to their center, Neurospin, on Wednesday September 7th. Neurospin is a research center for innovation in brain imaging, located on the CEA Paris-Saclay site. At Neurospin, physicists, mathematicians, neuroscientists and doctors join forces to develop tools and models for better understanding the healthy and maladaptive brain functions, before or after treatment. Focused on neuroimaging, the research conducted ranges from technological and methodological developments (data acquisition and processing) to preclinical and clinical neuroscience, including cognitive neuroscience. Thank you, Ghislaine!

OUR AWARDEES

We would like to highlight the Young Investigator Award Winners, listed later in this brochure. The Program Committee received a large number of amazing applications and had the difficult decision to select the final list of awardees. The awardees represent a microcosm of FIT'NG and include a diverse range of scholars with scientific projects spanning a wide range of techniques, methods, and biological and clinical topics. Congratulations to you all!

OUR COMMITTEES

The commitment and collaborative nature shines brightly from our committee members. Many of you volunteered your time from the beginning, as the first FIT'NG workshop mobilized our community. We wanted more scientific content for us and by us. Your efforts over the past few years have made this idea a reality.

We would like to express our deep gratitude to our wonderful Program Co-Chairs, Drs. Sarah Shultz and Chad Sylvester. Drs. Shultz and Sylvester worked closely with Dr. Alice Graham and Lauren Moline to craft a program that spans a wide range of methodologies, age ranges, and scope. The committee has put together amazing content that provides a first hand view of technological advances in software and hardware, practical elements of scanning young populations, and cutting edge scientific content highlighting new discoveries about the developing brain across neuroimaging modalities. We are confident that attendees will thoroughly enjoy the expert symposia, poster sessions, trainee meetings, and keynote speakers. We are also indebted to the Scientific Program Committee, whose names are listed later in this brochure. The Program Committee worked tirelessly to review abstracts, select abstracts for poster and oral presentations, and make initial decisions on FIT'NG awards.

Our Communications Committee, led by Kelly Vaughn (Chair) and Claudia Lugo-Candelas (Co-chair), has been essential in expanding our membership and reach this year. Through our Twitter account **@FIT_NGIn** and the conference hashtag **#fitng2022**, the Communications Committee has gained over 250 new followers since January 2022. They also worked with the Trainee Committee to send FIT'NG and FIT'NG Together invitations to over 60 research teams. We hope that their efforts are the reason some of you are joining us here in Paris. Please continue to engage with us on Twitter for up-to-date information about the conference and the society: **@FIT_NGIn #fitng2022**.

We are so proud of our exceptional Trainee Committee led by the incredible Cat Camacho (Chair). They branded FIT'NG Together and created a unique learning environment for early childhood neuroimaging trainees across the world. The Trainee Committee organized and hosted 11 FIT'NG Together tutorials, journal clubs, fireside chats, and works in progress. In addition, they compiled resources, contributed to 4 society publications, and are executing several trainee events during the conference. These efforts have fostered a broader sense of community and connections across universities contributing to our goals of bringing together scientists and clinicians from across FIT disciplines and connecting trainees to resources and potential mentors. FIT'NG thanks the many experts who donated their time to mentor and teach the trainees in our field as part of FIT'NG Together: Mathias Goncalves, Tomoki Arichi, Ethan McCormack, John Gilmore, Sarah Shultz, Sonya Troller-Renfree, Ashley Nielsen, Chris Smyser, Chad Sylvester, Eric Feczko, Richard Betzel, and Muriah Wheelock. Their efforts have been invaluable for building our community and working towards our goal of creating shared resources and best practices for FIT'NG research.

We thank our Vision and Visibility committee that was led by Courtney Filippi and Jerod Rasmussen and had two extremely active members, Sam Wass and Lyndsay Bowman. With a focus on evaluating our adherence to the society mission/vision, proposing new initiatives in line with the vision, and increasing visibility of the society they have made outstanding progress. They mobilized quickly and have some exciting new initiatives in the works this upcoming year including EEG workshops and manuscript topics that cut across neuroimaging modalities.

OUR SPONSORS AND PARTNERS

FIT'NG did not grow alone! FIT'NG garnered sponsor support from our first pre-conference workshop at the Flux: Developmental Cognitive Neuroscience meeting in 2019 and the number of sponsors is growing strong. To our universities and their affiliates: Yale University School of

Medicine (Magnetic Resonance Research Center, Child Study Center, and BioImage Suite), Oregon Health & Sciences University (Neuroscience Department), Columbia University Irving Medical Center (Wharton Fund), and last but not least, Flux society, your belief in us and provision of support necessary to move our vision forward is invaluable! To our new and ongoing sponsors, thank you for ensuring that our inaugural meeting was possible. Bringing together researchers of the young brain truly does ensure a better future for humankind. They are listed above and on our website, but we also want to acknowledge them here: NIRx, Mangold, artinis, MindWare Technologies, TracInnovations, nous Imaging, Virginia Tech (Fralin Biomedical Research Institute at VTC), Sorbonne Universite, Mass General Brigham, and Columbia University (Department of Psychiatry). We also know that the COVID pandemic has taken a toll on everyone, so your support during this time is even more significant. This is only the beginning and we are so excited to continue this journey with you.

In order for this society to flourish we knew ongoing and continued support of our scientific mission would be essential. The National Institutes of Health is providing multi-year support through a NIH Support for Conferences and Scientific Meetings grant (R13 HD108938) titled, "Fetal, Infant, Toddler Neuroimaging Group (FIT'NG): Uniting Clinical, Computational, Engineering, and Neuroscience to advance discoveries for the young child". We are primarily supported by the Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD) and co-supported by the National Institute of Drug Abuse (NIDA) and the National Institute of Environmental Health Sciences (NIEHS). The grant allows us to provide a forum for investigators to disseminate novel methods to support better understanding of neural mechanisms disrupted due to prenatal and early childhood traumas, present the most cutting edge science that will shift and shape our understanding of the developing brain, sensitive periods of prevention and intervention, and novel mechanism integral for healthy brain development. It also primarily supports awards to support young and underrepresented minority investigators to participate in our meeting. A special thank you to Amanda Price, our extraordinary program officer!

To Bea Luna, Founder and Founding President of the Flux: Developmental Cognitive Neuroscience society and one of the first members of FIT'NG. We could not

have done this without you! The story of Flux's own adventure and the commitment necessary to start a society was invaluable. Your guidance on next steps; regarding our passion from the lens of us as partners in advancing the scientific knowledge exchange in early childhood neuroimaging; and foreseeing the benefits of having a comrade society has allowed the first week of September each year to become known for exceptional developmental neuroscience from womb to college dorm!!

To our beloved sponsor and partner Podium Conference, words cannot fully express our gratitude. We met with several companies that shared general advice and said to come back when we were an established society. Podium believed in our mission and wanted to ensure we had the skills to grow and develop into a viable and sustainable society. For that and more we are so grateful. To Marischal De Monde, the President and Founder for taking us on and providing us with unimaginable resources. To Cendrine De Vis for society management and Lauren Moline for conference management, and for being our weekly partners, counselors, and friends in this adventure. None of us could have imagined the knowledge necessary to move our society forward. Podium you provided this real world, experiential learning environment ensuring that we crawled before we walked. Un immense merci pour tout!

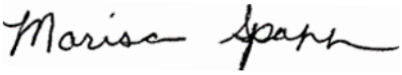
OUR MEMBERS

No person can build a conference home without a strong foundation. It is YOU, our members and partners in forming this society that allowed us to turn this idea into a reality. Year after year you have demonstrated FIT'NGs relevance, and your engagement and voices will continue to fuel the intellectual, social-community, and fiscal success of our society. There is a role and opportunity for everyone in this community, all you have to do is reach out! Join a committee, propose a new idea, and be an active member of this society so we can ensure our voices are heard in the sea of neuroimaging technologies that were not originally designed for but that we are ensuring are reimagined for the small brain. This is only our infancy, we cannot wait to see where we take FIT'NG Together.

Please tweet throughout the meeting at @FIT_NGIn using **#fitng2022**

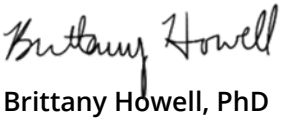
Sincerely,

Executive Board and Founders



Marisa Spann, PhD, MPH
President and Founding Member
Herbert Irving Associate Professor
Vagelos College of Physicians and Surgeons, Columbia University

Alice Graham, PhD
Incoming President and Founding Member
Assistant Professor
Oregon Health & Sciences University

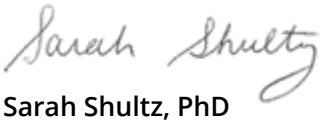


Brittany Howell, PhD
Secretary
Assistant Professor
Virginia Technical Institute

Dustin Scheinost, PhD
Treasurer and Founding Member
Associate Professor
Yale University School of Medicine

Lilla Zollei, PhD
Bylaws Officer and Founding Member
Associate Professor
Massachusetts General Hospital/Harvard University

Program Committee



Sarah Shultz, PhD
Program Committee Co-Chair
Assistant Professor
Emory University School of Medicine

Chad Sylvester, MD, PhD
Program Committee Co-Chair
Associate Professor
Washington University School of Medicine

FIT'NG Leadership & Committees

FIT'NG BOARD

Marisa N. Spann	President & Founding member, Columbia University
Alice Graham	Incoming President & Founding member, Oregon Health & Science University
Brittany Howell	Secretary, Virginia Tech
Dustin Scheinost	Treasurer & Founding member, Yale University
Lilla Zöllei	Bylaws Officer & Founding member, Massachusetts General Hospital / Harvard Medical School

VISION & VISIBILITY COMMITTEE

Courtney Filippi	(Chair), University of Maryland
Jerod M. Rasmussen	(Co-Chair), University Of California, Irvine, School Of Medicine
Lindsay Bowman	University Of California Davis
Sam Wass	University Of East London

COMMUNICATIONS COMMITTEE

Kelly Vaughn	(Chair), Children's Learning Institute, University of Texas Health Science Center at Houston
Claudia Lugo-Candelas	(Co-chair), Columbia University Irving Medical Center/New York State Psychiatric Institute
Roxane Licandro	Massachusetts General Hospital, Harvard Medical School And Medical University Of Vienna
Aiden Ford	Emory University & Marcus Autism Center
Elmo Pulli	Finnbrain Birth Cohort Study, University of Turku
Jetro Tuulari	Finnbrain Birth Cohort Study, University of Turku
Saara Nolvi	Finnbrain Birth Cohort Study, University of Turku

TRAINEE COMMITTEE

M. Catalina Camacho	(Chair), Washington University in St. Louis
Zeena Ammar	Emory University
Alexander Dufford	Yale University
Aiden Ford	Emory University
Marta Korom	University of Delaware

FIT'NG Leadership & Committees

2022 SCIENTIFIC PROGRAM COMMITTEE

The Scientific Program Committee was recruited to help select the content and review submissions for the inaugural conference of FIT'NG in 2022.

Sarah Shultz	(Co-Chair), Emory University
Chad Sylvester	(Co-Chair), Washington University in St. Louis
Alice Graham	(Board Liaison), Oregon Health & Science University
Nora Moog	Charité Universitätsmedizin Berlin
Ashok Panigrahy	Children's Hospital of Pittsburgh
Wei Gao	Cedars-Sinai Medical Center
Elizabeth Norton	Northwestern University
Courtney Filippi	University of Maryland
Natasha Marrus	Washington University in St. Louis
Cameron Ellis	Yale University
Gang Li	University of North Carolina at Chapel Hill
Duan Xu	University of California, San Francisco
Robert Hermosillo	Oregon Health & Science University
Jana Hutter	King's College London
Elina Thomas	University of Vermont
Cynthia Rogers	Washington University in St. Louis
Marc Seal	University of Melbourne

CONFERENCE & ASSOCIATION LOGISTICS

Podium Conference Specialists
Marischal De Armond
Cendrine DeVis
Lauren Moline

2022 FIT'NG Young Investigator Award Winners

Ezra Aydin	Columbia University
Meritxell Bach Cuadra	Lausanne University and University Hospital
Sarah Charpy	Hopital Necker Enfants Malades Institut Imagine
Liam Collins-Jones	University College London
Daniel Cromb	King's College London
Alexander Dufford	Yale University
Sonja Fenske	Cedars-Sinai Medical Center
Courtney Filippi	University of Maryland
Aiden Ford	Emory University
Collin Gregg	Fralin Biomedical Research Institute at Virginia Tech Carilion
Cassandra Hendrix	New York University Langone Health
Marta Korom	University of Delaware
Heather Kosakowski	Massachusetts Institute of Technology
Chiara Maffei	Athinoula A. Martinos Center for Biomedical Imaging, Massachusetts General Hospital and Harvard Medical School
Caroline Magnain	Martinos Center for Biomedical Imaging, MGH/HMS
Kathryn Manning	University of Calgary
Staci Meredith Weiss	Cambridge University
Oscar Miranda-Dominguez	University of Minnesota
Lindsey Mooney	University of California, Davis
Julia Moser	University of Minnesota
Ashley Nielsen	Washington University in St. Louis
Julian Ramirez	Child Mind Institute
Josué Rico-Picó	University of Granada
Céline Steger	University Children's Hospital of Zurich, University of Zurich
Athena Taymourtash	Medical University of Vienna
Clara Weber	Yale School of Medicine
Ting Xu	Child Mind Institute
Sarah Yosief	Virginia Tech Carilion
Hyukjin Yun	Boston Children's Hospital

General Conference Information

Venue
Sorbonne University
In the Auditorium & Foyer at the Pierre and Marie Curie campus
In the International Conference Center (CICSU)
4 Pl. Jussieu, 75005
Paris, France

All conference sessions will take place at this location, and the Trainee Social Committee will organize a session at an offsite venue.

Registration
Conference registration fees include access to all sessions including, speaker presentations, coffee breaks, and poster sessions.

Name Badges
Your name badge is your admission ticket to all conference sessions and coffee breaks. Please wear it at all times. At the end of the conference we ask that you recycle your name badge at one of the name badge recycling stations, or leave it at the Registration Desk.

Registration & Information Desk
The Registration and Information Desk, is located in the Foyer outside the main Auditorium, will be open during the following dates and times:

- Monday, September 5, 2022 from 8:00am-5:00pm
- Tuesday, September 6, 2022 from 8:00am–3:30pm

If you need assistance during the meeting, please visit the Registration Desk.

Staff
Conference staff and volunteers from Podium Conference Specialists can be identified by ribbons on their name badges. For immediate assistance, please visit us at the registration desk in the Foyer.

Complimentary Wifi Information
Each attendee will receive their own username and password, which will be printed on the back of your name page for use when onsite.

Poster Information

- **Set-Up / Removal**

There are two Poster Sessions during the Conference and posters have been allocated to one of the sessions based on poster themes. If your poster number starts with a 1, you're in Poster Session #1, and if your poster number starts with a 2, you're in Poster Session #2. Poster presenters must set-up and remove their posters during the following times.

- **Poster Session 1** – Monday, September 5

Poster Set-up: Monday, September 5 from 10:30am – 1:45pm
Poster Hours: Monday, September 5 from 5:30pm – 6:45pm

Removal of all posters by 7:00pm on September 5*

- **Poster Session 2** – Tuesday, September 6

Poster Set-up: Tuesday, September 6 from 8:00am – 3:00pm
Poster Hours: Tuesday, September 6 from 1:45pm – 3:15pm

Removal of all posters by 7:00pm on September 6*

**Any posters not removed by the assigned time will be disposed of.*

A Guide to Paris

FOOD

Near Sorbonne:

- Boulangerie l'Essentiel, Anthony Bosson
  - Bakery, great stop for lunch or pastries
- La Maison d'Isabelle
  - Bakery, another stop to try Parisian pastries and bread
- Chez René
  - Classic Parisian cafe
- Chez Gladines
  - Only go there for lunch
  - Traditional french food of the Basque region (south-western france)
- Chez Fernand
  - Classic Parisian cafe
  - Known for their Beef bourguignon
- The Créperie
  - The place for all your crepe desires
- Berthillion
  - Ice Cream & Tea Room
- Patisserie Viennoise
  - Really great hot chocolate
  - Only open on weekdays
  - Close to Luxembourg garden
- La Cuisine de Philippe
  - Vegetarian-friendly
  - Known for their souffles

Not within walking distance, but consider these spots for your own adventures!

- Pain Vin Fromage
  - Le Marais
  - Bread, Wine, and Cheese! What more do you need?
- Le Petit Marché
  - Local cafe and restaurant
  - Le Marais
- Paul's
  - Good chain for coffee/pastries/salad/sandwiches on the go
- Marché des Enfants Rouges
  - Food market in Le Marais.
- Food Courts
  - Flunch
  - Galleries de Lafayette
- Fairuz
  - Great middle eastern food
  - They have a sit down (which is kinda pricey) but a really good take away section where you can get AMAZING shawarma/falafel sandwiches
  - It's close to the Eiffel tower so good stop if you want to grab food for a picnic
- Cafe Angelina
  - For a sweet tooth splurge- they are known for their sipping chocolate and decadent desserts
- St. Michel (Close to Notre dame)
  - Good sandwich shops
  - Kabobs
  - Good for sandwiches to walk around with

- You don't need to tip in restaurants. Tip is included in the check they give you and you'll get a funny look if you leave anything.
- A lot of places will have a "fixed price" menu for lunch – for example, deals for either appetizer & entrée or entrée & dessert.
- By default they will bring you bottled water at a restaurant and charge you for it. Ask for tap water or "une carafe d'eau" which is free.
- No free refills on soft drinks, they are also all bottled and you will pay for each one.

Conference Event Floor plan

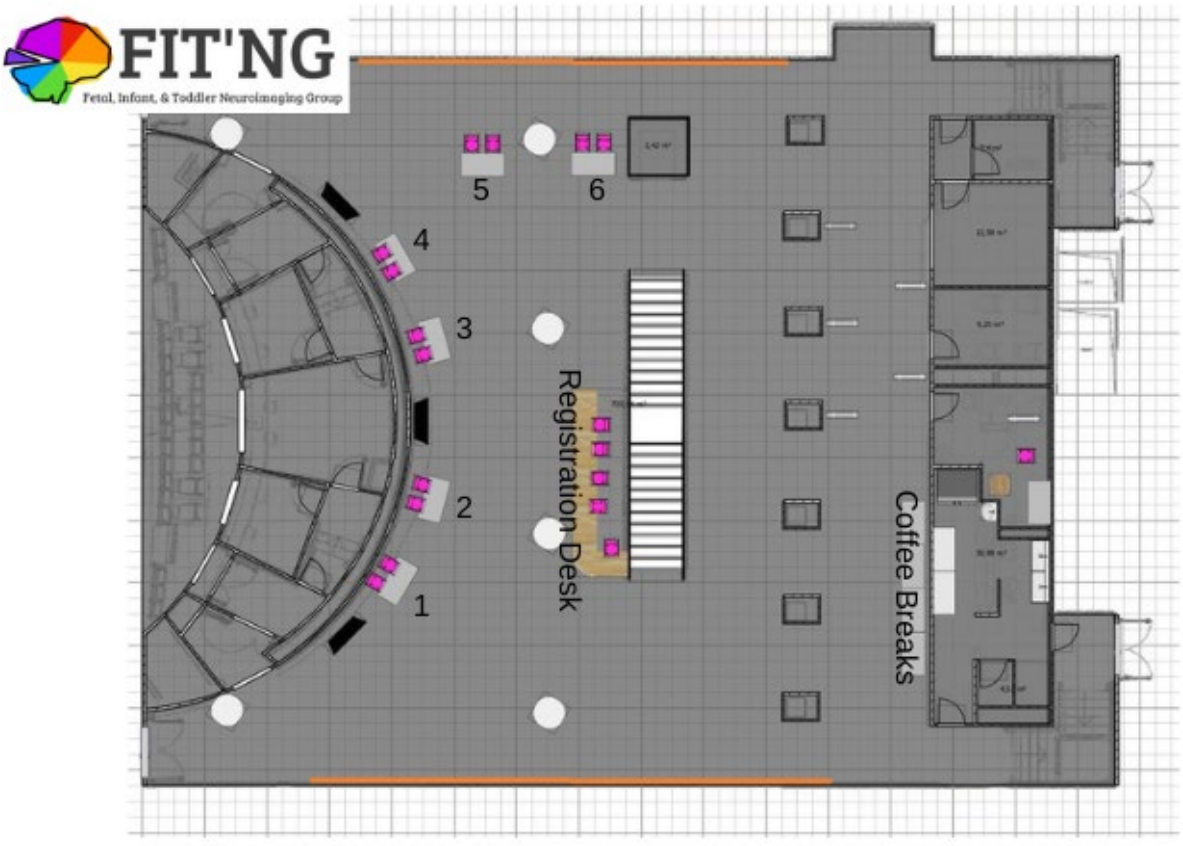
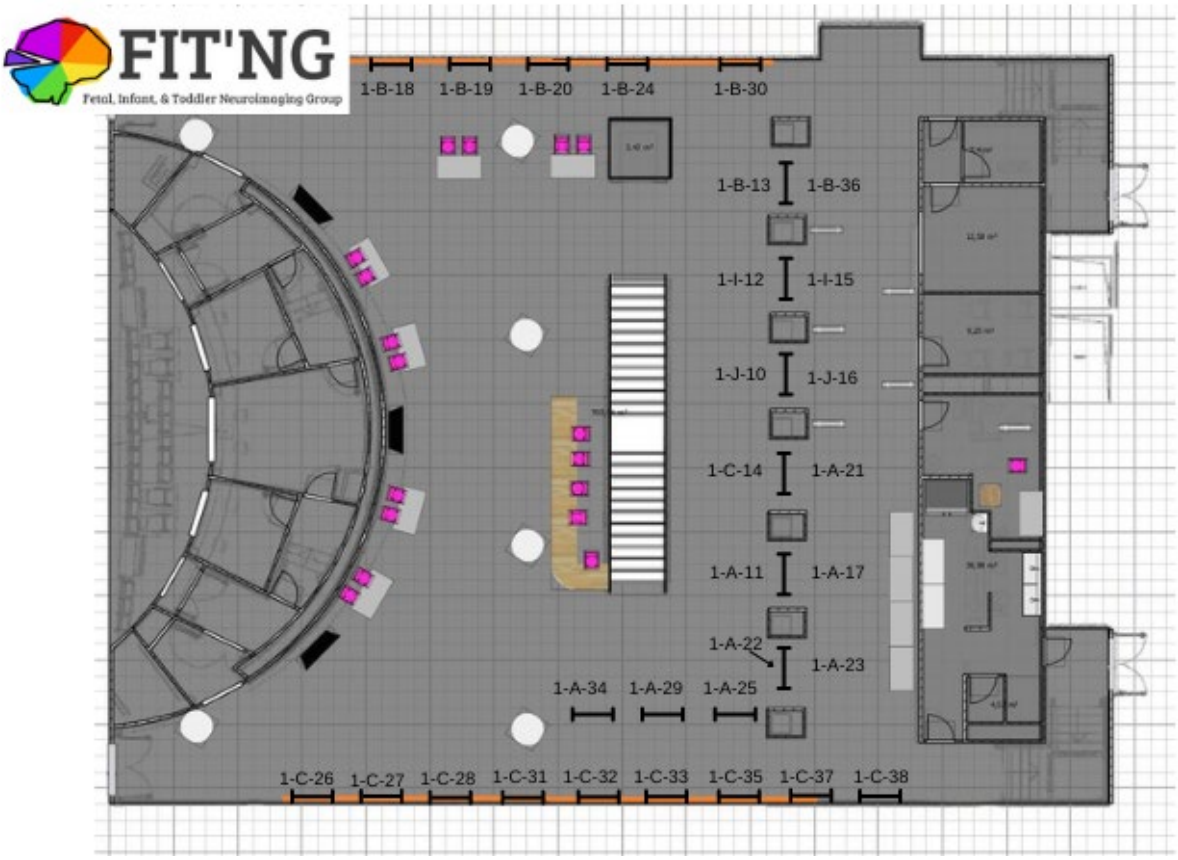


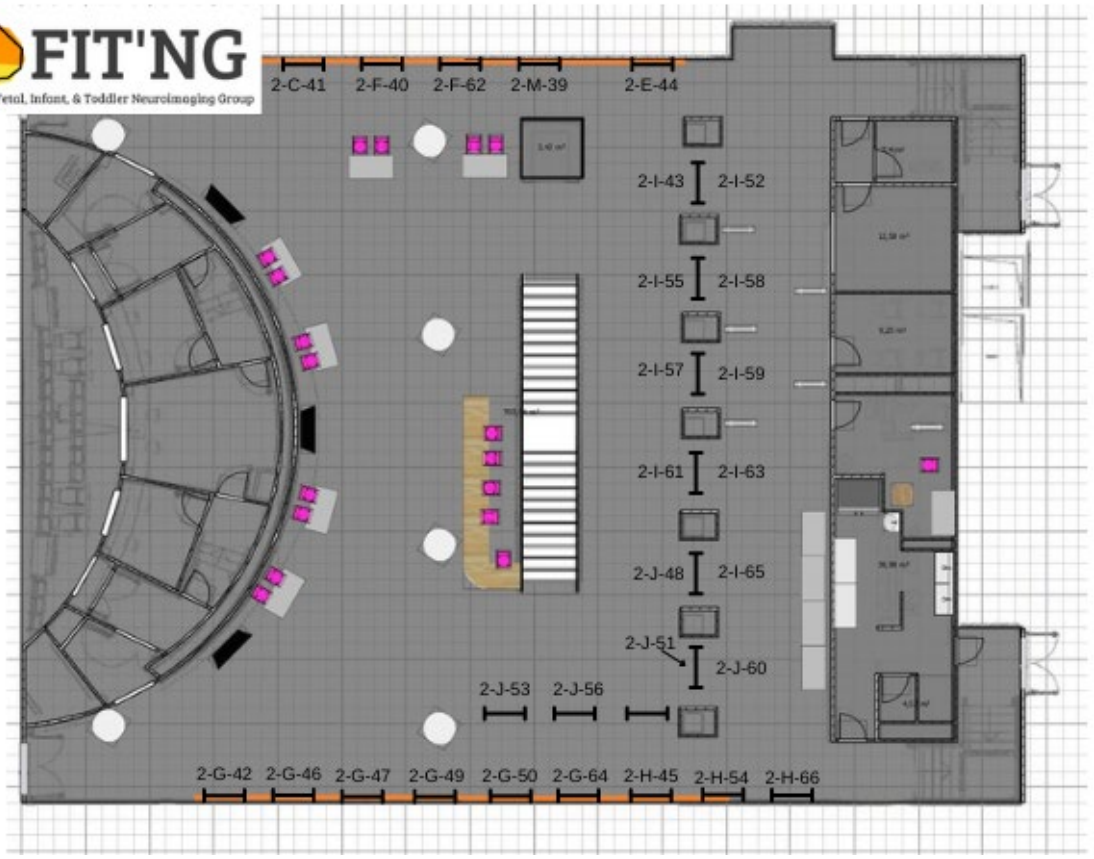
Exhibit Booths

1 - Mindware
2 - Mangold
3 - NirX
4 - Artinis
5 - NOUS Imaging
6 - TracInnovations



Poster Session #1

Poster Session #2



FIT'NG Conference Program Schedule

All sessions take place in the Auditorium & Foyer of the Pierre and Marie Curie campus at the International Conference Center (CICSU) at 4 Pl. Jussieu in Paris.

MONDAY, SEPTEMBER 6, 2022

8:45 – 9:00am **Opening Remarks from FIT'NG**

9:00 – 10:30am **Session #1 – Fetal and Early Infant Symposium**

Chair: Alice Graham, *Oregon Health & Science University*

S1.1 **Stunting in the first year of life is associated with atypical activation of dorsal and ventral attention networks**
Sobana Wijeakumar, *University of Nottingham*

S1.2 **Adversity before birth alters but does not accelerate infant functional networks**
Ashley Nielsen, *Washington University in St. Louis*

S1.3 **Fetal origins of emotion regulation: Fetal frontolimbic connectivity prospectively associates with aggression in toddlers**
Cassandra Hendrix, *New York University Langone Health*

S1.4 **The prenatal assessment of functional asymmetries in the developing human brain using in-utero fMRI**
Athena Taymourtash, *Medical University of Vienna*

10:30 – 10:45am **Break**

10:45 – 11:30am **Session #2 - The Beginnings of Development**

Chair: Lilla Zollei, *Massachusetts General Hospital/Harvard Medical School*

S2.1 **Fetal and placental MRI - fascinating insights into early human development**
Jana Hutter, *King's College London*

S2.2 **Mapping the fetal brain with ultrasound: challenges and opportunities**
Ana Namburete, *University of Oxford*

11:30 – 12:15pm **Session #3 – Early Substance/Environmental Exposures and Early Brain Outcomes**

Chair: Marisa Spann, *Columbia University*

S3.1 **Associations of prenatal polydrug abuse and newborn brain structure, tissue organization, and metabolite concentrations**
Bradley Peterson, *Children's Hospital Los Angeles & Keck School of Medicine of University of Southern California*

S3.2 **The intergenerational transmission of poor sleep: implications on brain development and mechanism**
Claudia Lugo-Candelas, *Columbia University*

12:15 – 1:45pm **Lunch, on your own**

1:45 – 2:45pm

Keynote – Neural bases of language acquisition in infants

Dr. Ghislaine Dehaene-Lambertz
Director of the developmental brain imaging lab, NeuroSpin Center, Inserm, Université Paris Cité, CEA

Chair: Lilla Zollei, *Massachusetts General Hospital/Harvard Medical School*

Pediatrician, director of the developmental brain imaging lab (CNRS, INSERM at Neurospin/CEA, Paris-Saclay, France), Ghislaine Dehaene-Lambertz and her team investigate the development of cognitive functions in infants and children using brain imaging techniques. Their goal is to understand how complex cognitive functions, such as language, music, mathematics, etc...

emerge in the human brain, thanks to a thorough description of the brain initial structural and functional organization. She published pioneering work using high-density event-related potentials (Nature 1994), functional resonance magnetic imaging (Science 2002) or optical topography (PNAS 2003-2013) to study language acquisition, and the neural signatures of consciousness (Science 2013) in the infant brain. She is the recipient of several national and international awards (Prix Justine and Yves Sergent 2013, Grand Prix Scientifique de la Fondation de France, 2015, et de L'Institut de France, 2016).

2:45 – 3:00pm **Break**

3:00 – 4:15pm **Supporting the next generation of FIT'NG Mentoring Session**
Chair: FIT'NG Trainee Committee

Join us for small group discussions led by faculty in the field! Attendees will be assigned to one of the topic groups below where faculty will lead a discussion on that topic. Assignments are made based on pre-submitted rankings.

- Applying for fellowships (led by Sarah Schultz)
- Finding a post-doc (led by Kelly Vaughn and Saara Nolvi)
- Applying for faculty jobs (Courtney Filippi and Tomoki Arichi)
- Non-fellowship grant writing (led by Lilla Zollei and Jana Hutter)
- Finding and maintaining strong collaborations (led by Alice Graham and Brittany Howell)

4:15 – 4:30pm **Break**

4:30 – 4:50pm **Pediatric EEG and fNIRS**
Chair: Marisa Spann, *Columbia University*

Sam Wass, *University of East London*
Emily Jones, *University of London, Birkbeck*

4:50 – 5:00pm **NIRx – Sponsor Tech Time**
Felix Töpfer, *Scientific Consultant, NIRx Medizintechnik GmbH*

5:00 – 5:30pm **Flash Talks**
Chair: Kelly Vaughn, *University of Texas Health Science Center at Houston*

FT1.1 **Early development of functional homotopic trajectories in Non-Human Primates (Poster #1-J-10)**
Julian Ramirez, *Child Mind Institute*

FT1.2 **The infant brainstem: postmortem multimodal and multiscale imaging of structure and connectivity (Poster #1-A-11)**
Caroline Magnain, *Martinos Center for Biomedical Imaging, MGH/HMS*

FT1.3 **Infant brain connectivity and the relationship with prenatal maternal distress during the COVID-19 pandemic (Poster #1-I-12)**
Kathryn Manning, *University of Calgary*

FT1.4 **Updates to the Melbourne Children's Regional Infant Brain software package (MCRIBS) (Poster #1-B-13)**
Christopher Adamson, *Murdoch Children's Research Institute*

FT1.5 **Connectome Edge Density Based on Functionally Defined Nodes Shows Autism Spectrum Disorder (ASD)-related Changes in Infants (Poster #1-C-14)**
Clara Weber, *Yale School of Medicine*

5:30 – 6:45pm **Poster Session #1**

7:00pm onward **FIT'NG Trainee Committee Social Event**
The FIT'NG Trainee Committee is hosting a picnic on the Seine! Grab some food and meet us either at the Sorbonne to walk over together at 7pm or at the Jardin Tino Rossi any time after 7:15pm.

TUESDAY, SEPTEMBER 6, 2022

9:00 – 10:30am **Session #4 - NIH HBCD and Large Multisite and Cohort Studies Across Countries**

Chair: Chad Sylvester, *Washington University in St. Louis*

Michelle Freund, *NIDA, HEALthy BCD (HBCD) Study* **"HBCD Initiatives"**
Dylan Tisdall, *University of Pennsylvania* **"HBCD structural MRI workgroup"**
Nathan Fox, *University of Maryland* **"HBCD EEG working group"**
Tracy Riggins, *University of Maryland, & Wei Gao, Cedars-Sinai* **"HBCD fMRI working group"**

10:30 – 10:45am **Break**

10:45 – 12:15pm **Session #4 - NIH HBCD and Large Multisite and Cohort Studies Across Countries (Cont'd)**

Chair: Brittany Howell, *Virginia Tech*
Moderator: Roxane Licandro, Medical University of Vienna

This session focuses on large multisite studies across European countries and renown panelists are invited representing the developing Human Connectome Project (Dr. Jonathan O'Muircheartaigh, King's College London, UK), the YOUth Cohort Study (Inge van Ooijen, MSc, Wilhelmina Children's Hospital at UMC Utrecht, Netherlands), the EPIRMEX/EPIPAGE study (Dr. Elie Saliba, University of Tours, France) and the BIDs Initiative (Dr. Melanie Ganz-Benjaminsen, University of Copenhagen, Denmark). The grand finale will be a joint panel discussion, where the audience is cordially invited to actively participate. The topics cover the challenges in setting up multi-site projects, lessons learned, how multi-site collaborations can be supported with standardization and what do we want to change in the future?

Panelists:

- Dr. Melanie Ganz-Benjaminsen, *University of Copenhagen, Denmark*
  Representative BIDS Initiative
- Dr. Jonathan O'Muircheartaigh, *King's College London, United Kingdom*
  Representative Developing Human Connectome Project
- Inge van Ooijen, *MSc, Wilhelmina Children's Hospital at UMC Utrecht, Netherlands*
  Representative Youth Cohort Study
- Dr. Elie Saliba, *University of Tours, France*
  Representative EPIRMEX and EPIPAGE study

12:15 – 1:45pm **Lunch, on your own**

1:45 – 3:15pm **Poster Session #2**

3:15 – 4:45pm **Session #5 - Innovative methods and analysis techniques symposium**

Chair: Sarah Shultz, *Emory University*

S5.1 **Wearable functional neuroimaging of the infant brain with high-density diffuse optical tomography**
Addison Billing, *University of Cambridge*

S5.2 **Time-varying regression methods reveal maturation of pyramidal tracts supports a critical transition in social visual engagement during early infancy**
Aiden Ford, *Emory University*

S5.3 **Quality transfer with TRACULInA: Training with multi-shell data to reconstruct pathways automatically in single-shell data**
Chiara Maffei, *Athinoula A. Martinos Center for Biomedical Imaging, Massachusetts General Hospital and Harvard Medical School*

S5.4 **Functional parcellation of the neonatal cortical surface**
Michael Myers, *Washington University School of Medicine*

4:45 – 5:00pm **Closing Remarks**

5:00 – 5:15pm **Break**

5:15 – 6:45pm **Session #6 – Trainee Initiatives Panel**

Chair: FIT'NG Trainee Committee

Curious about different career paths? Want career advice? Ask our panelists!

To begin, there will be a panel of faculty at various institutions, career stages, and with research programs spanning FIT ages and various modalities. Panelists will be asked questions (as sent ahead of time). In Part 2, the panelists will each head a small group in which attendees can ask questions of the panelist and get career advice.

- Ghislaine Dehaene-Lambertz, *Director of the developmental brain imaging lab, NeuroSpin center, Inserm, Université Paris Cité, CEA*
- Koraly Pérez-Edgar, *McCourtney Professor of Child Studies and Professor of Psychology; The Pennsylvania State University*
- Jana Hutter, *School of Biomedical Engineering and Imaging Science, King's College London*
- Tomoki Arichi, *Reader in Perinatal Imaging, Centre for the Developing Brain, King's College London & Consultant in Paediatric Neurodisability, Evelina London Children's Hospital*
- Jessica Dubois, *Researcher at NeuroDiderot Unit & NeuroSpin center, Inserm, Université Paris Cité, CEA*

FIT'NG Conference Oral Presentations

SESSION #1: ORAL PRESENTATIONS - FETAL AND EARLY INFANT SYMPOSIUM

Chair: Alice Graham, Oregon Health & Science University

S1.1 Stunting in the first year of life is associated with atypical activation of dorsal and ventral attention networks

Sobana Wijeakumar[1], Vincent Magnotta[3], Sean Deoni[4], Kiara Jackson[5], Vinay Singh[6], Aarti Kumar[6], John Spencer[5]

[1]University of Nottingham, [2]Durham University, [3]University of Iowa, [4]Brown University, [5]University of East Anglia, [6]Community Empowerment Lab

Stunting impacts approximately 162 million children worldwide, yet it is still unknown how it begins to influence cognition in the first year of life. Here, we investigated how stunting affects an important neurocognitive system, visual working memory (VWM), in 6-month-old and 9-month-old infants (N=223) in rural Uttar Pradesh, India. Infants engaged with a preferential looking VWM task, where two side-by-side blinking displays of colored squares were presented, with one side showing a change in colors, while the colors on the other side stayed constant. Portable eye-tracking and video recordings were used to examine looking behaviour and functional near-infrared spectroscopy was used to collect brain function data. The Ages-and-Stages questionnaire was administered to examine cognitive outcomes one year later. Stunted infants showed a poorer ability to detect change in the task. Consistent with this, they showed less activation in the left intraparietal sulcus (IPS), a part of the dorsal attention network involved in VWM maintenance, and greater activation in the right temporo-parietal junction, a part of the ventral attention network involved in attentional shifting. Stunted infants also had lower problem-solving scores when assessed one year later, while normal height infants with greater IPS activation in infancy showed higher problem-solving scores. Finally, short-for-age infants with poor physical growth indices but good VWM showed more positive outcomes suggesting that efforts should be focussed on improving VWM and reducing distractibility in infancy. This is the first study to identify a mechanism early in development through which stunting might lead to poor cognitive outcomes.

S1.2 Adversity before birth alters but does not accelerate infant functional networks

Ashley Nielsen[1], Regina Triplett[1], Lourdes Bernardez[1], Rachel Lean[1], Sydney Kaplan[1], Dimitrios Alexopoulos[1], Jeanette Kenley[1], Dominique Meyer[1], Tara Smyser[1], Joshua Shimony[1], Barbara Warner[1], Deanna Barch[1], Joan Luby[1], Cynthia Rogers[1], Chad Sylvester[1], Christopher Smyser[1]

[1]Washington University in St. Louis

Early life adversity (e.g., poverty, stress, trauma) is linked to poorer outcomes later in life and its impact on functional brain networks can be seen in childhood. One potential mechanism proposes that adversity activates the hypothalamic-pituitary-adrenal stress pathway and prematurely accelerates the maturation of functional networks. We investigated whether an effect of prenatal exposure to adversity on functional brain networks: 1) could be detected at birth and 2) reflected accelerated maturation during gestation or infancy. As a part of the Early Life Adversity and Biological Embedding study, we oversampled mothers facing adversity during pregnancy and measured whole-brain functional connectivity MRI in their healthy, term-born infants in the first weeks of life (n=262). Survey, health, and demographic measures were incorporated into two latent factors of prenatal adversity: Social Disadvantage and Psychosocial Stress. Support vector regression (SVR) was applied to detect multivariate patterns of infant functional connectivity related to each factor. Functional networks of offspring at birth differed as a function of the social disadvantage ($R^2 = 0.29$; $p<0.001$), but not the psychosocial stress ($R^2 = 0.04$; $p=0.03$), experienced by mothers before birth. Brain maturity estimated from functional connectivity with SVR was not significantly related to disadvantage or stress, suggesting that, unlike postnatal adversity, prenatal adversity may not accelerate functional networks near birth. However, the effects of prenatal disadvantage were most pronounced in "late developing" brain systems like the fronto-parietal, ventral attention, dorsal attention, and default mode networks, potentially setting the stage for altered trajectories later in life. These findings provide insights into when and how functional networks begin to diverge in the context of adversity while prompting further investigation into the persistence and malleability of these effects beyond infancy.

S1.3 Fetal origins of emotion regulation: Fetal frontolimbic connectivity prospectively associates with aggression in toddlers

Cassandra Hendrix[1], Lanxin Ji[1], Denise Werchan[1], Amyn Majbri[1], Christopher Trentacosta[2], Alexandra Burt[3], Moriah Thomason[1]

[1]New York University Langone Health, [2]Wayne State University, [3]Michigan State University

Background. Aggression is a major public health concern that emerges early in development and lacks optimized treatment, highlighting need for improved mechanistic understanding of aggression etiology. The present study leverages fetal resting-state functional MRI (rsfMRI) to identify candidate neurocircuitry for the onset of aggressive behaviors, prior to symptom emergence. Analyses focus on frontolimbic circuitry given its important role in emotion and behavioral regulation as well as its feasibility for examination in utero. Methods. Pregnant mothers were recruited during the third trimester of pregnancy to complete a 12-to-24-minute fetal rsfMRI scan. Mothers subsequently completed the Child Behavior Checklist to assess child aggression at 3 years postpartum (N=79). Independent component analysis was used to define frontal and limbic regions of interest. Results. Weaker functional coupling between the subcortical limbic network and medial prefrontal (mPFC) network in fetuses was prospectively associated with greater maternal-rated child aggression at 3 years of age (ß=-0.31, **Δ**R^2=0.09, p=0.002, 95%CI b[-12.02, -2.72]). Child aggression was not related to within network connectivity of subcortical limbic regions (ß=-0.004, **Δ**R^2<0.01, p=0.97, 95%CI b[-4.66, 4.50]) or within mPFC network connectivity in fetuses (ß=-0.15, **Δ**R^2=0.02, p=0.19, 95%CI b[-13.96, 2.89]). All analyses controlled for number of rsfMRI frames, motion parameters, GA at scan, fetal sex, birth weight, GA at birth, maternal education, maternal age, partner status, and maternal anxiety/depression symptoms at the 3-year follow up. Conclusion. Neural correlates of aggressive behavior are detectable in utero, well before the onset of aggression symptomatology. In particular, the functional connectivity undergirding emotion regulation circuitry prior to birth may play an important role in the onset of aggressive behavior early in life, likely via transactional processes with postnatal environments.

S1.4 The prenatal assessment of functional asymmetries in the developing human brain using in-utero fMRI

Athena Taymourtash[1], Ernst Schwartz[1], Karl-Heinz Nenning[1], Sara Glatter[1], Mariana Cardoso Diogo[1], Daniela Prayer[1], Gregor Kasprian[1], Georg Langs[1]

[1]Medical University of Vienna

Background: Hemispheric specialization of the brain functions such as handedness and language lateralization have been observed for over a century and thought to reflect evolutionary, hereditary, developmental, experiential and pathological factors. Cross-sectional studies of the language system in the early infancy and newborns suggest that the basic neural mechanisms are in place even before birth and the brain is primed for language while in utero. However, it remained unclear whether these functional asymmetries arise in utero, or whether they are shaped principally by postnatal experiences. Method: rs-fMRI was acquired from 72 singleton fetuses between 19 and 39 weeks of gestation. Customized image processing pipelines for fetal population including irregular fetal movement correction, and age-specific segmentation were used. Individualized functional connectivity (FC) matrices were then obtained by correlating regional brain activity over time and 24 cases were automatically excluded due to computational benchmarking of the resulting matrices. We calculated the lateralization index for each individual subject as the normalized difference in the degree of FC between two hemispheres after thresholding negative and weak connections. Results: According to the Kostovic timeline of brain development, we divided our observed period of gestation to three intervals of pre-expansion (19-26), expansion (26-32), and post-expansion (32-40). Number of significant functional connections increased significantly from first to second (average !.5 to %.7, p-val=0.032), and first to third (average !.5 to 0.7, p-val=0.0004) period. We found significant leftward laterality in Temporal-Superior (p=0.043, tstat: -2.071, CI=[-0.0567,-0.00082], sd=0.096), Temporal-Medial (p=0.047, tstat: -2.030, CI=[-0.0691,-0.00032], sd=0.118), and Temporal-Inferior (p=0.048, tstat: 2.031, CI=[0.0008,0.1818], sd=0.311) regions after correcting for multiple comparisons. We observed a significant increase in functional laterality with gestation age (slope: 0.025±0.0087, p=0.005) for Temporal-Inferior region with the adjusted R-squared of 0.156. Statistical tests of the functional asymmetry did not reach statistical significance for the rest of cortical regions. Conclusion: Our results support the hypothesis that functional asymmetries are present during prenatal brain development.

FLASH TALKS

FT1.1 Early development of functional homotopic trajectories in Non-Human Primates (Poster #1-J-10)

Julian Ramirez[1], Brian Russ[2], Karl-Heinz Nenning[1], Arnaud Falchier[2], Gary Linn[2], Damien Fair[3], Charles Schroeder[2], Michael Milham[1], Ting Xu[1]

[1]Child Mind Institute, [2]Nathan Kline Institute, [3]University of Minnesota

Study Objective Developmental changes in the brain occur rapidly during the early stages of life. Characterizing these changes can help us better understand typical development and areas where deviations could predispose later complications in life. Prior works studying networks using resting-state functional connectivity (RSFC) MRI have detected developmental shifts from childhood to adulthood, with networks changing from dispersed short-range connectivity to greater long-range, focal connectivity later in life (Fair et al. 2007) (Kelly et al. 2009). Interestingly, the degree of synchrony in BOLD activity between interhemispheric regions measured through homotopic connectivity (HC) has also been shown to change with age (Zuo et al. 2010) and can be used to identify abnormalities in pathological conditions. However, these studies have predominantly been conducted in young children, missing a critical window of rapid early development. These early changes are harder to capture in human populations. Short interval, repeated acquisitions during infancy are generally not feasible in humans making early trajectory models challenging. Here, we utilize Non-human Primates (NHPs) to characterize homotopic connectivity changes from infancy (3-weeks of age) to juveniles age using a rapid succession (2-week intervals) acquisition protocol. Methods A total of three macaques (Female=2) underwent structural and resting-state functional MRI scans every 2-weeks for the first year of life and 4-weeks thereafter, starting at 3-weeks of age. Data were processed through the nhp-abcd-bids-pipeline [https://hub.docker.com/r/dcanumn/nhp-abcd-bids-pipeline (dsturge et al. 2019; Ramirez et al. 2020)], and HC was calculated between the left and right hemispheres. HC was projected across age to identify differences in connectivity strength throughout development. Brain regions were organized into 5 clusters based on homotopic connectivity trajectories to identify different developmental patterns. Results While prior findings in humans have shown that homotopic connectivity decrease with age when starting at 7-years of age (Zuo et al. 2010), we were able to show that homotopic connectivity first increases with age during early development before plateauing (Fig 1 A). Specifically, homotopic connectivity development initially increased, reaching peak strength at different ages depending on the region (Fig1 B). Primary networks (Cluster 5) showed stronger homotopic connectivity, which developed earlier and faster, reaching a peak around 40 weeks of age (Fig 1C). Conclusion Using an NHP model allowed us to capture early developmental changes during infancy and to detect patterns of change that occur at much shorter intervals than are typically collected in human samples. Identifying the age at which homotopic connectivity plateaus for different regions could give us insight into early developmental processes and aid in our understanding of how differences in these time points could relate to subsequent developmental disorders.

FT1.2 The infant brainstem: postmortem multimodal and multiscale imaging of structure and connectivity (Poster #1-A-11)

Caroline Magnain[1], Erendira Garcia Pallares[1], Sam Blackman[2], Seoyoon Kim[2], Ream Gebrekidan[2], Brian Edlow[3], Robin Haynes[4], Hannah Kinney[4], Lilla Zöllei[1]

[1]Martinos Center for Biomedical Imaging, MGH/HMS, [2]Harvard College, [3]Center for Neurotechnology and Neurorecovery, MGH/HMS, [4]Boston Children's Hospital and Harvard Medical School

Sudden infant death syndrome (SIDS) is the leading cause of postneonatal infant mortality in industrialized nations with a rate of 0.39/1000 livebirths in the United States alone. Even though certain environmental factors increase the risk of SIDS, a subset of SIDS may be the result of an intrinsic defect in brain anatomy, in particular of the subcortical ascending arousal network (AAN) [1]. Arousal pathways of the AAN originate in the brainstem and activate awareness networks in the central cortex via synapses in the hypothalamus, thalamus, basal forebrain, or, alternatively via direct innervation of the cerebral cortex itself. In this work, we show how we use a multimodal and multiscale imaging approach to study the structure and the connectivity of the postmortem infant brainstem in a control subject. First, the whole brain is imaged at the macroscale level using MRI at 7T and diffusion MRI at 3T with a resolution

of 200 µm and 700 µm (90 directions), respectively. To further improve the resolution in our region of interest, the brainstem and cerebellum were separated and imaged again at 100 µm for the structural data on 7T and at 400 µm and 90 directions for the diffusion data on 3T. To study the brainstem connectivity and in particular the AAN, we need to identify important nuclei and tracts. However, even at this high resolution, ex vivo MRI is unable to provide sufficient contrast to delineate them due to their size and the lack of myelination. We turned to Optical Coherence Tomography [2], a 3D microscopy technique, to visualize these regions at an isotropic resolution of 3.5 µm. As only the top 100 µm can be imaged in one acquisition, we coupled our system with a vibratome. The imaging is done without contrast, relying solely on the tissue intrinsic optical properties, and prior to the sectioning which greatly limits tissue distortions. Contrary to MRI, OCT exhibits a high contrast which enables us to segment the brainstem, its nuclei, tracts and cranial nerves. We use a combination of manual segmentation and machine-learning-automated interpolation [3] tool to do so. Finally, the slices collected during the OCT imaging are used for histological validation of our segmentation. All the various modalities are then registered into a common space. The OCT segmentation can be transferred to the whole brain MRI and used as seed point to probe the brainstem connectivity. This work lays the foundation to compare the brainstem connectivity between SIDS cases and controls, with the potential to identify biomarkers and abnormalities of the disease not detectable by standard histopathological techniques. [1] Edlow, B.L., et al., Neuroanatomic connectivity of the human ascending arousal system critical to consciousness and its disorders. J Neuropathol Exp Neurol, 2012. 71(6): p. 531-46. [2] Huang, D. et al. ?Optical Coherence Tomography?, Science vol. 80, no. 254, pp.1178-1181, 1991. [3] Atzeni, Alessia, et al. A probabilistic model combining deep learning and multi-atlas segmentation for semi-automated labelling of histology. International Conference on Medical Image Computing and Computer-Assisted Intervention. Springer, Cham, 2018.

FT1.3 Infant brain connectivity and the relationship with prenatal maternal distress during the COVID-19 pandemic (Poster #1-I-12)

Kathryn Manning[1], Xiangyu Long[1], Dana Watts[1], Lianne Tomfohr-Madsen[1], Gerald Giesbrecht[1], Catherine Lebel[1]

[1]University of Calgary

BACKGROUND AND AIM: The COVID-19 pandemic has elevated anxiety and depression symptoms, especially in pregnant individuals. This could have an effect upon the infant brain development in utero that may underlie early cognitive development. In this study, we aimed to understand the association between prenatal distress and infant limbic network microstructure and function at 3-months of age, as well as the potential protective role of social support in any relationships. METHODS: Patient Reported Outcomes Measurement Information System anxiety, Edinburgh Depression Scale and Social Support Effectiveness Questionnaire (SSEQ) measures were collected through online surveys from a population-based sample of pregnant individuals living in Canada through the Pregnancy during the COVID-19 Pandemic Study. In a sub-sample of participants, we acquired diffusion and functional MRI data in their infants (N=75) during natural sleep. Diffusion tractography was used to identify the uncinate fasiculus and the amygdala-prefrontal white matter tracts. The average amygdala functional connectivity map is shown in Figure 1A and was used to identify regions of interest, and functional connectivity was calculated for each participant. General linear models were used to examine the association between prenatal maternal distress and amygdala functional connectivity or microstructural (fractional anisotropy (FA) or mean diffusivity (MD)) measures, including postnatal distress, household income and infant sex covariate, and social support interaction terms. RESULTS: Survey participants demonstrated significantly higher rates of clinically relevant anxiety and depression symptoms. After removing any imaging datasets with excessive motion or inadequate data collection, we retained 58 participants (38M/20F, 92+/-14 days old). Prenatal maternal distress was significantly related to FA in the right uncinate fasciculus ($T= 2.7$, $p = 0.0009$) and MD in the right amygdala-prefrontal white matter tract ($T = -2.3$, $p = 0.02$). Prenatal maternal distress was significantly related to right amygdala-superior orbitofrontal cortex ($T = -2.9$, $p = 0.007$) and right amygdala-inferior frontal gyrus ($T = -3.1$, $p = 0.004$) functional connectivity. Importantly, functional connectivity relationships involved a significant interaction between social support and prenatal distress. In particular, pregnant individuals who reported lower quality social support (SSEQ < 60) had a significant negative correlation between prenatal distress and functional connectivity ($R > -0.5$, $p < 0.05$), and those who reported higher social support did not (Figure 1B and C). CONCLUSIONS: Here we observed an association between prenatal distress in pregnant individuals during the COVID-19 pandemic and infant brain structure and functional architecture. We also found for the first time that social support may act as a possible moderator between prenatal distress and early infant brain development, where infant amygdala functional connectivity and prenatal distress relationships were only present in pregnant individuals who reported relatively lower social support. These findings provide timely evidence to inform clinical policy surrounding the care of families and highlight the potential of social support to play a role in infant brain development.

FT1.4 Updates to the Melbourne Children's Regional Infant Brain software package (MCRIBS) (Poster #1-B-13)

Christopher Adamson[1], Bonnie Alexander[1], Claire Kelly[1], Gareth Ball[1], Richard Beare[1], Jeanie Chong[1], Alicia Spittle[1], Lex Doyle[1], Peter Anderson[2], Marc Seal[1], Deanne Thompson[1]

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Objective The delineation of cortical areas on magnetic resonance images (MRI) are important for understanding the complexities of the developing human brain. The Melbourne Children's Regional Infant Brain (M-CRIB-S) is a software package that performs whole-brain segmentation and surface-based extraction and parcellation of the neonatal cerebral cortex, enabling cortical surface measures to be derived for 31-34 regions based on the Desikan-Killiany or Desikan-Killiany-Tourville parcellation schemes; which are compatible with the adult schemes used in Freesurfer. The whole-brain segmentation component assigns subcortical grey, cerebellar hemispheres, cortical white and grey matter structures using label fusion. Cortical surface extraction and parcellation are performed using the Deformable tool and a Freesurfer-like pipeline, respectively. We present a major update to the software package which aims to improve the accuracy of whole-brain segmentation and cortical surface extraction. The improved cortical surface extraction accuracy increases the robustness of measures such as surface area, cortical thickness, and cortical volume. Methods Whole brain voxel labelling, using label fusion, has been updated from the previous MIRTK/DrawEM pipeline to an ANTs' registration/label fusion pipeline. Additionally, the M-CRIB training data replaces the ALBERTs training data to provide higher resolution (0.6mm3 vs 1mm3) images along with Freesurfer-compatible whole-brain segmentation labels. Label fusion requires registration of the novel image to each training image; ANTs' non-linear registration tool was used. In addition to intensity-based costs, masks for lateral ventricles, and cortical grey matter were estimated on

the novel image to facilitate high degrees of warping needed to account for significant inter-subject variations of cortical folding. Cortical surface extraction is performed by firstly estimating the white, then the pial surface. Errors in the white matter surface would typically occur at the inlets of thin gyri, such as the pericalcarine cortex, due to misclassification. This occurs despite erroneously classified voxels having visibly higher intensities than their neighbors. We introduce a second step that includes a force image that outward normal force when surface vertices overlap GM-classified voxels that are brighter compared to their neighbors. Results After running the second step described above, we see improved penetration into thin strands of white matter in these tertiary folds. Figure 1(i) shows the results of the second step (light blue) improves penetration of the white matter surface of the first step (yellow). Figure 1(ii) shows the final surfaces overlaid onto the voxel segmentation and cortical parcellation for that subject. Note that the whole-brain segmentation is consistent with an adult-like labeling generated with Freesurfer. This method has been executed successfully on a cohort of 300 neonatal images, data not shown. Conclusions We have presented an update to the MCRIBS software package that achieves two goals: 1. A whole-brain segmentation that is compatible with the MCRIB labels and, 2, improved white matter surface extraction, enabling more accurate cortical surface measures to be obtained from infant brain images. The software is available for download from GitHub at (https://github.com/DevelopmentalImagingMCRI/MCRIBS).

FT1.5 Connectome Edge Density Based on Functionally Defined Nodes Shows Autism Spectrum Disorder (ASD)-related Changes in Infants (Poster #1-C-14)

Clara Weber[1], Evelyn Lake[1], Ali Mozayan[1], Pratik Mukherjee[2], Dustin Scheinost[3], Nigel Bamford[1], Laura Ment[1], Todd Constable[1], Sam Payabvash[1]

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Purpose: In previous reports, we found evidence of impaired white matter (WM) microstructural integrity and reduced connectome Edge Density (ED) based on tractography links connecting structural nodes associated with ASD. These alterations were present in adolescents and adults, but not detectable in pediatric cohorts. Here, we use a cohort of infants at risk of ASD to evaluate connectome ED based on tractography between functionally defined nodes that showed correlation with from ASD severity in a separate cohort. Methods: We retrieved DTI from n=155 infants in the National Database of Autism Research (Original study: Longitudinal MRI study of infants at Risk for Autism). Subjects median age at scan was 7 months; assessment of ASD symptoms followed at 24 months. In a previous study based on rs-fMRI from n=260 children, cerebral regions (nodes) were identified that showed significant positive, and respectively negative, functional correlation with symptom severity as measured by ADOS (Autism Diagnostic Observation Schedule) scores (Lake et al.: Biol Psychiatry 2019;86(4):315-26). These regions were coregistered into each individual's FA space and used as seed points in subsequent probabilistic tractography to generate ED maps. We subset those nodes into two different levels with increasing sensitivity, and used them separately as tractography seeds. After extraction of mean ED values within each tract defined in the JHU White Matter Labels atlas, we assessed correlation of ED metrics with ASD diagnosis. Results: ED within major white matter tracts shows correlation with ASD diagnosis (Figure 1). While present both for ED generated based on positively and negatively correlated cortical regions, positively correlated regions showed more widespread ASD-related changes. Comparing correlation coefficients between different sensitivity levels revealed that ED based on more sensitive nodes shows stronger correlation to ASD diagnosis group. Conclusion: We could show significant and pervasive ASD-related ED alterations in major white matter tracts when guiding tractography through functionally defined nodes. Correlation coefficients increased significantly when more sensitive functional nodes were utilized. These alterations could not be detected when using generic anatomical nodes in probabilistic tractography, hinting towards future implications of combining functional and diffusion-weighted imaging.

SESSION #5: INNOVATIVE METHODS AND ANALYSIS TECHNIQUES SYMPOSIUM

Chair: Sarah Shultz, Emory University

S5.1 Wearable functional neuroimaging of the infant brain with high-density diffuse optical tomography

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Introduction: Functional magnetic resonance imaging (fMRI) is a fundamental tool for the study of infant neurodevelopment. However, its cost and low tolerance for motion makes it impractical for the study of awake infants, particularly in naturalistic and resource-poor environments. Partly as a result of these limitations in fMRI, functional near infrared spectroscopy (fNIRS) has become increasingly popular for functional neuroimaging. However, traditional fNIRS technologies rely on large bundles of heavy optical fibres, which are uncomfortable for infants, increase vulnerability to motion artifacts, and limit spatial sampling density. fNIRS systems typically use a sparse array of 10s of optical fibres that yield a limited field of view. As image resolution scales with array density, traditional fNIRS data exhibit poor signal-to-noise ratio. Recent technological developments have allowed wearable high-density diffuse optical tomography (wHD-DOT) to overcome many of the hurdles faced by traditional fNIRS systems and dramatically improved spatial resolution over a wide field of view. Our group is undertaking a series of wHD-DOT studies across the first days and months of life to explicitly demonstrate the utility of this new technology in the acquisition of both stimulus-evoked and resting-state based measures of brain function. Methods: We are employing the LUMO wHD-DOT system (Gowerlabs Ltd, UK) in a variety of contexts. This system permits the formation of dense networks of near-infrared source-detector pairs (channels) using miniaturised hexagonal sensor modules that are mounted to a cap worn by our participants. To demonstrate the efficacy of wHD-DOT in infants, we began by replicating a well-established fNIRS audiovisual social paradigm (Lloyd-Fox et al., 2012) in N=17 6-month-old infants. We then used wHD-DOT to map cortical haemodynamics during free-play in infants aged 6-8 months (N=15), and also to examine functional networks in term-age newborn infants in a clinical setting (N=28). Results: Our initial replication study in 6-month old infants demonstrated that the technology is very well tolerated, with rapid application times (<15 minutes). Furthermore, wHD-DOT yielded significantly higher spatial specificity, and better SNR than traditional fNIRS applications (Frijia et al. 2021). This was especially valuable during the free-play experiment, where the infants were unconstrained to maximise ecological validity. In our study of term-age infants in a clinical setting, infants were able sleep comfortably in their cot while wearing the device for long durations (up to two hours). Functional networks were

examined using seed-based and network-based statistics approaches, and classic homotopic functional maps were apparent at the group level. Conclusion: These studies highlight the feasibility of obtaining spatially resolved, high-SNR, three-dimensional maps of infant cerebral haemodynamics using wHD-DOT in almost any environment. wHD-DOT now offers a genuine alternative to fMRI where studies involve extensive infant movement, naturalistic experimental environments, and/or deployment in resource-limited settings.

S5.2 Time-varying regression methods reveal maturation of pyramidal tracts supports a critical transition in social visual engagement during early infancy

Aiden Ford[1], Xiongtao Dai[2], Longchuan Li[1], Zeena Ammar[1], Ami Klin[1], Warren Jones[1], Sarah Shultz[1]

[1]Emory University, [2]Iowa State University

Objective: Preferential attention to the eyes of others is a foundational social behavior that emerges in the first 6 months of life and supports continued social-cognitive development, including face processing and language acquisition. Present at birth, early eye-looking is reflex-like, but undergoes a transition at 2 months to become a voluntary social action. During this transition, reflex-like eye-looking declines, replaced by an increase in volitional eye-looking. This social transition holds significant import for both basic and translational science, as it is known to be disrupted in autism spectrum disorder (Jones & Klin 2013, Nature), however its underlying neural processes remain unknown. Contributing to this gap is the limited statistical infrastructure for testing associations between non-linear trajectories. This study leverages functional regression methods to test the hypothesis that a neurodevelopmental shift from subcortical to cortical neural control underlies this critical social transition. Methods: Longitudinal eye-tracking and diffusion tensor imaging data were collected from 73 (30f, 43m) typically developing infants from 0-6 months, at up to 6 and 3 timepoints, respectively. 12 major, cortical white matter tracts were delineated using atlas-based probabilistic tractography. Fractional anisotropy values indexed tract maturity. Percent fixation to the eyes, mouth, and non-social regions of eye-tracking video stimuli were calculated to measure social visual engagement. Trajectories of brain and behavior development were computed using Functional Principal Components Analysis and Functional Linear Regression was used to test time-varying associations between developmental trajectories. Results: In the first 6 months of life, only early maturation of the pyramidal tracts originating in the motor cortex (PT-M1) significantly predicted the development of eye-looking ($R2 = .62$, $p<.004$) (Figure 1). Time-varying R2 values showed that maturation of PT-M1 before 3 months was most significantly predictive of eye-looking trajectories ($R2 = .75$-$.78$, $p<.05$). Time-varying beta coefficients showed infants with greaterPT-M1 maturation looked less to the eyes of others before 2.5 months and more to the eyes of others after 2.5 months. This association was stronger for male infants than female infants. Later maturation of PT-M1 was associated with less mouth-looking ($R2 = .50$, $p<.05$) and no associations were found between PT-M1 and non-social stimuli. Conclusions: These results provide the first insight into the neural mechanisms underlying a critical transition in a foundational social behavior with important clinical relevance. Moreover, this study design showcases the value of testing associations between longitudinal trajectories to discover the dynamic nature of brain and behavior development. We find that the maturation of cortical pathways, specifically pyramidal tracts, both dampens reflex-like eye-looking in early infancy and supports the subsequent emergence of preferential attention to eyes. This intriguing association, displaying the time-varying contribution of tract maturation to behavioral development, is uniquely revealed by a regression approach that takes advantage of the complex change within nonlinear developmental trajectories.

S5.3 Quality transfer with TRACULInA: Training with multi-shell data to reconstruct pathways automatically in single-shell data

Chiara Maffei[1], Sydney Kaplan[2], Jeanette Kenley[2], Josh Shimony[2], Dominique Meyer[2], Dimitrios Alexopoulos[2], Nathan Ngo[1], Maitreyee Kulkarni[1], Cynthia Rogers[2], Christopher Smyser[2], Lilla Zollei[1], Anastasia Yendiki[1]

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Introduction: Automated methods for reconstructing white matter (WM) pathways in infants are crucial for enhancing the clinical analysis of diffusion measures. We had shown that TRACULInA (TRActs Constrained by UnderLying INfant Anatomy)(Zollei et al, 2019), an automated global probabilistic tractography tool with anatomical priors specifically designed for newborn infants, can robustly reconstruct known WM bundles in infants. In adults, we have recently shown that when these anatomical priors are derived from high-quality dMRI data, global probabilistic tractography with anatomical priors can improve the accuracy of the automated reconstruction in lower-quality data (Maffei et al., 2021). Here, we present an updated training dataset for TRACULInA obtained from multi-shell high spatial and angular resolution dMRI data from 15 newborns and use it to obtain accurate automated reconstruction of these bundles in single-shell data. Methods: Acquisition: Data were acquired on a Siemens 3T Prisma at the Washington University. The dMRI data included 3 shells (24 b=500, 96 b=1,500, 96 b=2,500 s/mm2 directions) and 14 b=0 volumes with 1.75mm isotropic spatial resolution. The T1-weighted data were acquired with a multi-echo MEMPRAGE sequence at 0.8mm isotropic resolution (TR=2400ms, TE=2.22ms). Processing: dMRI data were corrected for susceptibility induced distortions, eddy current distortions, and head motion (Andersson et al., 2003, 2016). Cortical parcellations and subcortical segmentations were obtained from the T1 data using an infant-specific framework (Zollei et al, 2020). Manual labeling: We fit fODFs using the MSMT-CSD algorithm (Jeurissen et al., 2014; Dhollander et al., 2019) to the bmax=2,500s/mm2 data. We performed whole-brain probabilistic tractography (50 seeds/voxel in WM mask; step-size: 0.87mm, angle-threshold: 45°)(Tournier et al., 2010). We used a manual, multi-ROI approach to delineate 20 WM bundles in Trackvis (author C.M.) following our previously described protocols (Maffei et al., 2021). Automated reconstructions: For each subject, we used the bundles manually labeled in the bmax=2,500s/mm2 data from the other 14 subjects to train TRACULInA (Zollei et al., 2019; Yendiki et al., 2011, 2016) and automatically reconstruct the same bundles in the b=1,500s/mm2 data. Accuracy: We quantified the proportion of the overlap between the tracts reconstructed automatically and those labeled manually in the same subject by computing the true positive and false positive rate (TPR, FPR). We quantified the reconstruction error by computing the modified Hausdorff distance (MHD) between the automatically reconstructed and manually labeled pathways (Dubuisson et al., 1994). Results Figure 1A shows the manually labeled pathways. The highest sensitivity achieved by TRACULInA across all 20 pathways was 84%, showing high coverage of the manually labeled pathways. At this TPR the MHD was 2.33 +-0.06mm, an error very similar to what we had recently reported in adults (Maffei et al., 2021). Conclusions: We have presented a new set of manually annotated WM bundles in multi-shell data from 15 newborns and demonstrated that these can be used as training data to obtain accurate automated reconstruction of these bundles in single-shell data. Obtaining accurate reconstructions of WM bundles in routine-quality clinical neonatal data promises unique opportunities to characterize normal or atypical brain development and predict neurodevelopmental outcome.

S5.4 Functional parcellation of the neonatal cortical surface

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INTRODUCTION: Functional brain areas are key units of brain organization. Neuroimaging studies have operationalized "parcels" as areas of the cortical surface with homogenous functional properties, and parcels may reflect functional brain areas. In recent years, several functional parcellations of the adult cortical surface have been described in the literature and made publicly available; yet their applicability to the study of the neonatal brain is unclear. The goal of the present study was to derive and validate a set of neonatal cortical surface parcels.
METHODS: Using a recently acquired resting-state fMRI dataset of 262 healthy neonates, we derived a set of parcels based on the algorithm used to derive the Gordon parcels in adults (Gordon et al. Cerebral Cortex 2016). To improve generalizability of our results, we used only the n=132 neonates from our sample having at least 16.5 minutes of low-motion data. To generate the parcels, we first transformed the group functional connectivity matrix into a "boundary map," a topographical map with basins where connectivity patterns are homogeneous and high ridges where connectivity patterns change abruptly. To segment the cortex into discrete parcels, the boundary map is flooded from its local minima. In our variant of the algorithm tuned for neonates, basins are filled to the 45th percentile of all height values, such that the resulting parcels represent only the deepest regions of strongest inter-subject agreement. Validity of the parcellation scheme is determined by assessing the homogeneity of parcels (defined as the percent of variance explained by the first component in a principal components analysis), relative to a null distribution of homogeneities obtained in 1000 variants of the same parcellation randomly rotated along the cortical surface.
RESULTS: To test the reliability of the parcellation method across subject samples, we split our sample in half and evaluated parcellations generated from each half against the other. In either case, parcels were far more homogeneous than chance ($z = 8.4$ and 8.5), and the two parcellations overlapped significantly with each other (Dice = 0.71, $z = 18.8$), suggesting that we have identified a reliable and reproducible set of regions. We then combined the two split halves to generate a final parcellation, resulting in 236 parcels. All results generalize well to two external validation datasets: for the final parcellation, homogeneity z-scores obtained for these out-of-sample datasets were 6.9 and 6.3.
SIGNIFICANCE: We present a group-level neonatal cortical surface parcellation that we believe will have high utility for researchers in neonatal fMRI. Specifically, this set of homogeneous a priori regions of interest can be used as a standard parcellation for developmental studies of human neonates.

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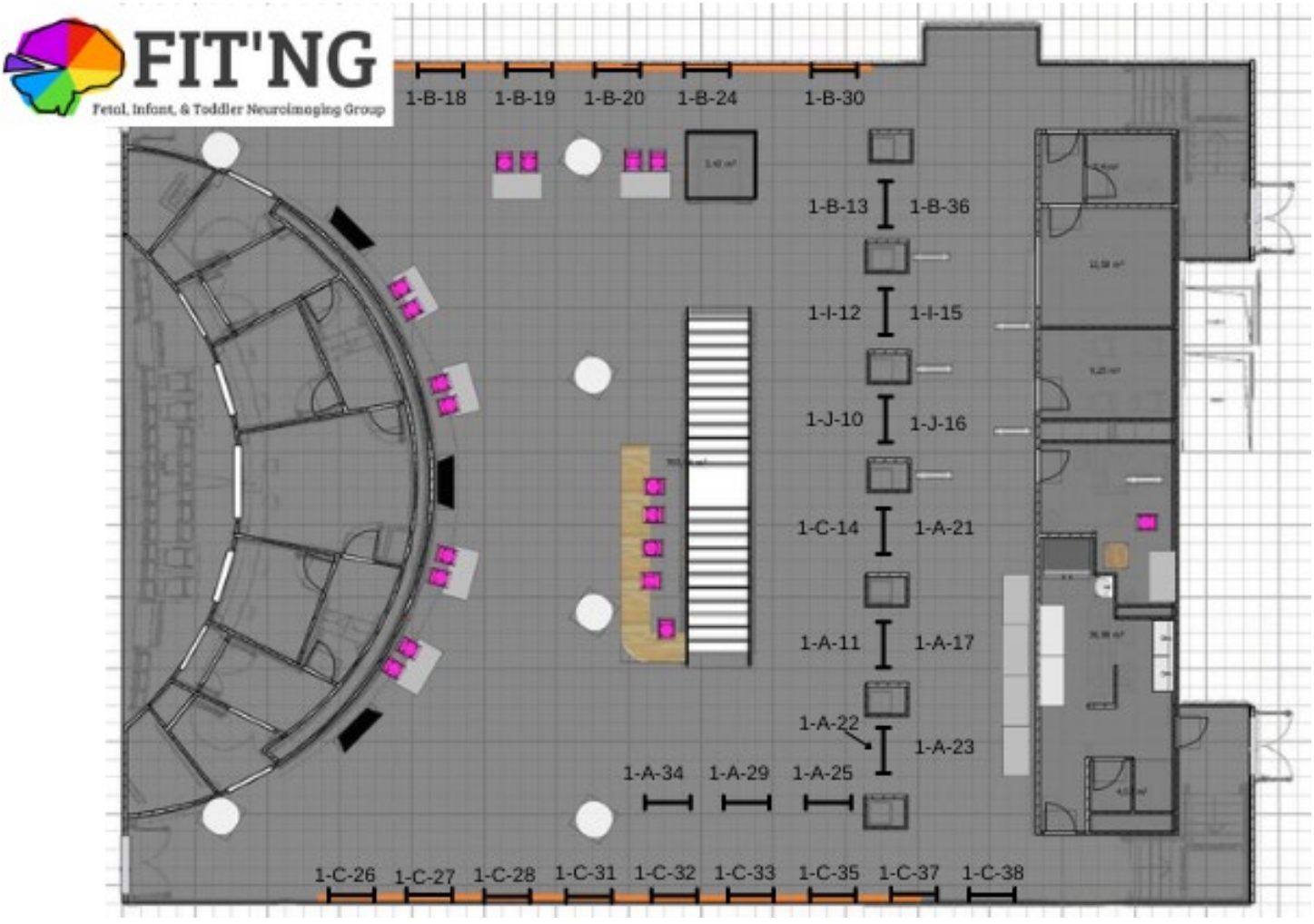

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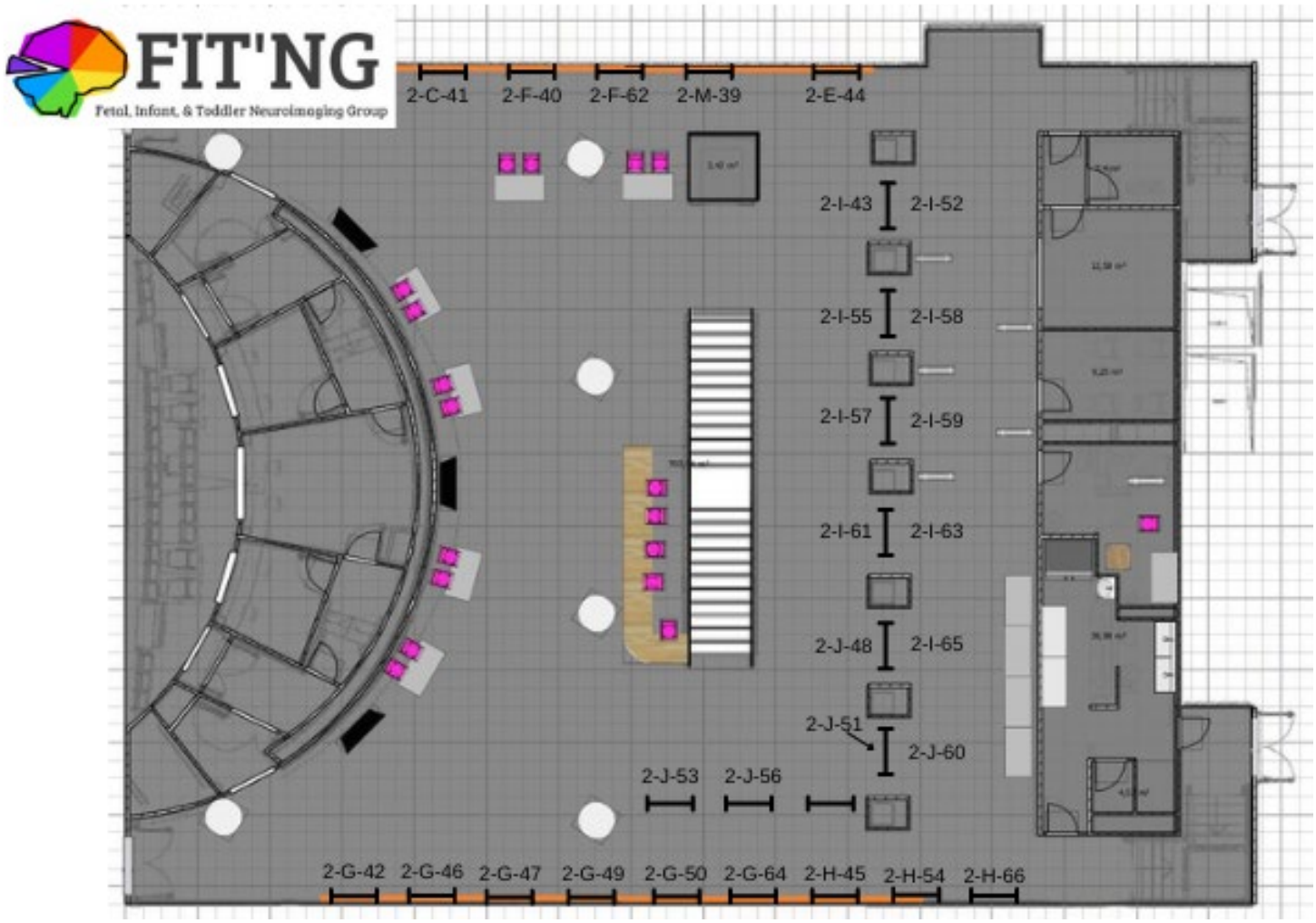

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FIT'NG Congress Posters | Titles, Authors and Affiliations

POSTER SESSION 1
MONDAY, SEPTEMBER 5
5:30–6:45PM

1-A-11 The infant brainstem: postmortem multimodal and multiscale imaging of structure and connectivity

Caroline Magnain[1], Erendira Garcia Pallares[1], Sam Blackman[2], Seoyoon Kim[2], Ream Gebrekidan[2], Brian Edlow[3], Robin Haynes[4], Hannah Kinney[4], Lilla Zöllei[1]

[1]Martinos Center for Biomedical Imaging, MGH/HMS, [2]Harvard College, [3]Center for Neurotechnology and Neurorecovery, MGH/HMS, [4]Boston Children's Hospital and Harvard Medical School

1-A-17 Variability of optimal echo times in a developmental population - insights from multi-echo fMRI recordings

Julia Moser[1], Thomas Madison[1], Sanju Koirala[1], Lucille Moore[1], Sooyeon Sung[1], Jed Elison[1], Chad Sylvester[2], Damien Fair[1]

[1]University of Minnesota, [2]Washington University in St. Louis

1-A-21 Utilizing the mesoSPIM 3D light-sheet microscope to study the 3D structure of the developing human fetal brain

Maria Karatsoli[1], Rahel Kaestli[2], Christoph Ruegger[3], Christian Haslinger[3], Peter Bode[3], Dominic Gascho2, Mark Augath[4], Daniel Razansky[4], Theofanis Karayannis[2], Andras Jakab[5]

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1-A-22 Factors Predicting Data Acquisition Success in Infant and Toddler MRI Neuroimaging Studies

Sooyeon Sung[1], Brittany Howell[2], Essa Yacoub[1], Jed Elison[1]

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1-A-23 LIT: An awake fMRI language task for toddlers

Halie Olson[1], Emily Chen[1], Kirsten Lydic[1], Somaia Saba[1], Rebecca Saxe[1]

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1-A-25 Face responses present in multiple regions of the human infant brain.

Heather Kosakowski[1], Nancy Kanwisher[1], Rebecca Saxe[1]

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1-A-29 Reduced Myo-Inositol Levels during Infant Early Brain Development using In Vivo Magnetic Resonance Spectroscopy

Ronald Instrella[1], Marisa Spann[1], Martin Gajdosik[1], Karl Landheer[1], Dustin Scheinost[2], Christoph Juchem[1]

[1]Columbia University, [2]Yale University

1-A-34 Maternal Trait Anxiety and Successful Infant MRI During Natural Sleep

Eunkyung Shin[1], Brittany Howell[1]

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1-B-13 Updates to the Melbourne Children's Regional Infant Brain software package (MCRIBS)

Christopher Adamson[1], Bonnie Alexander[1], Claire Kelly[1], Gareth Ball[1], Richard Beare[1], Jeanie Chong[1], Alicia Spittle[1], Lex Doyle[1], Peter Anderson[2], Marc Seal[1], Deanne Thompson[1]

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1-B-18 Optimum selection of neonatal structural priors for portable functional neuroimaging modalities

Liam Collins-Jones[1], Clare Elwell[1], Robert Cooper[1]

[1]University College London

1-B-19 Towards a comprehensive numerical model of white matter to simulate realistic in utero magnetic resonance acquisitions of the fetal brain

Meritxell Bach Cuadra[1], Andrés Le Boeuf Fló[1], Mériam Koob[2], Ferran Marques[3], Meritxell Bach Cuadra[1], Hélène Lajous[1]

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1-B-20 Synthesis of realistic fetal MR images from labels using generative adversarial networks

Rodrigo Gonzalez Laiz[1], Marina Fernandez Garcia[1], Hui Ji[1], Kelly Payette[1], Andras Jakab[1]

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1-B-24 Brain perfusion abnormalities in Prader-Willi infants: an arterial spin labelling ? MRI study

Sarah Charpy[1], Volodia Dangouloff-Ros[1], Jennifer Boisgontier[1], Ludovic Fillon[1], Ana Saitovitch[1], Arthur Delage[1], Alice Vinçon-Leite[1], Monica Zilbovicius[1], Nathalie Boddaert[1]

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1-B-30 Quantification of sulcal emergence in the fetal brain and its statistical comparisons for hemispheric asymmetry and sex difference

Hyuk Jin Yun[1], Hyun Ju Lee[2], Joo Young Lee[2], Tomo Tarui[3], Caitlin Rollins[1], Cynthia Ortinau[4], Henry Feldman[1], P. Ellen Grant[1], Kiho Im[1]

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1-B-36 Motion Correction and Volumetric Reconstruction for in-utero Functional Magnetic Resonance Imaging Data

Daniel Sobotka[1], Michael Ebner[2], Ernst Schwartz[1], Karl-Heinz Nenning[3], Athena Taymourtash[1], Tom Vercauteren[2], Sebastien Ourselin[2], Gregor Kasprian[1], Daniela Prayer[1], Georg Langs[1], Roxane Licandro[4]

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1-C-14 Connectome Edge Density Based on Functionally Defined Nodes Shows Autism Spectrum Disorder (ASD)-related Changes in Infants

Clara Weber[1], Evelyn Lake[1], Ali Mozayan[1], Pratik Mukherjee[2], Dustin Scheinost[3], Nigel Bamford[1], Laura Ment[1], Todd Constable[1], Sam Payabvash[1]

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1-C-26 Fetal heart rate and heart rate variability associate with brainstem connectivity in neonates

Angeliki Pollatou[1], Bradley Peterson[2], Dustin Scheinost[3], Catherine Monk[1], Marisa Spann[1]

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1-C-27 Functional parcellation of the neonatal cortical surface

Michael Myers[1], Chad Sylvester[1], Evan Gordon[1], Timothy Laumann[1], Ashley Nielsen[1], Christopher Smyser[1]

[1]Washington University in St. Louis

1-C-28 Feeding Practice During the First Year of Life and Amygdala Growth

Sarah Yosief[1], Brittany Howell[2], Martin Styner[3], Weili Lin[3], Jed Elison[4]

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1-C-31 Brain age prediction in fetuses with ventriculomegaly using a deep learning network with fetal brain MRI

Hyuk Jin Yun[1], Hyun Ju Lee[2], Joo Young Lee[2], Jerjes Aguirre-Chavez[1], Lana Vasung[1], Caitlin Rollins[1], Cynthia Ortinau[3], P. Ellen Grant[1], Kiho Im[1]

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1-C-32 Differences in infant functional network controllability in infants with high-likelihood for autism spectrum disorder in the first year of life

Huili Sun[1], Alexander Dufford[1], Dai Wei[1], Dustin Scheinost[1]

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1-C-33 Big-data era tools to unveil the development of brain surrogates of emotion dysregulation

Oscar Miranda-Dominguez[1], Elina Thomas[2], Lucille More[1], Eric Feczko[1], Jerod Rasmussen[3], Pathik Wadhwa[3], Claudia Buss[4], Damien Fair[1], Alice Graham[5]

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1-C-35 A spatio-temporal atlas of the foetal brain with agenesis of the corpus callosum

Fleur Gaudfernau[1], Aurélie O'Keane[1], Fleur Gaudfernau[2], Eléonore Blondiaux[3], Stéphanie Allassonière[1]

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1-C-37 Function precedes structure in the fetal brain in the second to third trimester.

Sian Wilson[1], Vyacheslav Karolis[1], Eugene Duff[2], Jucha Willers Moore[1], Daan Christiaens[1], Maximilian Pietsch[1], Lucilio Cordero-Grande[1], Jana Hutter[1], Anthony Price[1], Jacques-Donald Tournier[1], Joseph V. Hajnal[1], A. David Edwards[1], Jonathan O' Muircheartaigh[1], Tomoki Arichi[1]

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1-C-38 Development of functional gradients in the lateral motor network of the fetal brain across the third trimester of human gestation

Jucha Willers Moore[1], Vyacheslav Karolis[1], Siân Wilson[1], Marianne Oldehinkel[2], Christian Beckmann[2], Lucilio Cordero-Grande[1], Anthony Price[1], Emer Hughes[1], Eugene Duff[3], Jonathan O'Muircheartaigh[1], Joseph Hajnal[1], A David Edwards[1], Tomoki Arichi[1]

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1-I-12 Infant brain connectivity and the relationship with prenatal maternal distress during the COVID-19 pandemic

Kathryn Manning[1], Xiangyu Long[1], Dana Watts[1], Lianne Tomfohr-Madsen[1], Gerald Giesbrecht[1], Catherine Lebel[1]

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1-I-15 Child Inhibitory Control in Toddlerhood: Associations with Child Interaction Quality and Preliminary Neural Structural Correlates

Pauliina Juntunen[1], Riikka Korja[1], Eeva Eskola[1], Hetti Hakanen[1], Eeva Holmberg[1], Anniina Karonen[1], Marika Otranen[1], David Bridgett[2], Elmo Pulli[1], Jetro Tuulari[1], Hasse Karlsson[1], Linnea Karlsson[1], Saara Nolvi[1]

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1-J-10 Early development of functional homotopic trajectories in Non-Human Primates.

Julian Ramirez[1], Brian Russ[2], Karl-Heinz Nenning[1], Arnaud Falchier[2], Gary Linn[2], Damien Fair[3], Charles Schroeder[2], Michael Milham[1], Ting Xu[1]

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1-J-16 Functional interactions during consolidation of memories in newborns

Silvia Benavides-Varela[1], Roma Siugzdaite[2]

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POSTER SESSION 2
TUESDAY, SEPTEMBER 6
1:45–3:15PM

2-C-41 Lateralization of major white matter tracts from 0-6 months is time-varying and tract-specific

Zeena Ammar[1], Aiden Ford[1], Sarah Shultz[1], Longchuan Li[1]

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2-E-44 Striatal development in the neonatal period: Using brain tissue iron to probe prenatal and postnatal development

Laura Cabral[1], Finn Calabro[1], Jerod Rasmussen[2], Will Foran[1], Ashok Panigrahy[1], Bea Luna[1]

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2-F-40 Early Parenting Intervention Effects on Amygdala Volume in Infants Exposed to Opioids In-utero: A Randomized Clinical Trial

Marta Korom[1], Emma Margolis[1], Bianca Asencio[1], Brittany Howell[2], Mary Dozier[1]

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2-G-42 Exploring the association between fetal brain and placental T2* values in fetuses with congenital heart disease

Daniel Cromb[1], Johannes Steinweg[1], Milou Van Poppel[1], Ayman Al-Wakeel[1], Kuberan Pushparajah[1], Mary Rutherford[1], Serena Counsell[1], Jana Hutter[1]

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2-G-46 Altered thalamocortical connectivity in newborns after fetal surgical correction of spina bifida: weak link to neurodevelopmental outcomes

Hui Ji[1], Kelly Payette[1], Luca Mazzone[1], Martin Meuli[1], Ueli Moehrlen[1], Beatrice Latal[1], Andras Jakab[1]

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2-G-47 Altered development of excitation-inhibition balance, as quantified from fMRI using the Hurst Exponent, in medial prefrontal cortex in young children with autism spectrum disorders

Annika Linke[1], Bosi Chen[1], Lindsay Olson[1], Stephanie Peña[1], Adriana Rios[1], Madison Salmina[1], Zoe Damon[1], Ralph-Axel Müller[1], Inna Fishman[1]

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2-G-49 Relating neonatal neural responses from stimulus-evoked functional MRI to behavioral inhibition at 12 months: a pilot study

Rebecca Schwarzlose[1], Michael Myers[1], Courtney Filippi[2], Jennifer Harper[1], Tara Smyser[1], Christopher Smyser[1], Cynthia Rogers[1], Barbara Warner[1], Joan Luby[1], Deanna Barch[1], Daniel Pine[3], Nathan Fox[2], Chad Sylvester[1]

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2-G-50 Gray Matter Volume in the Language Network and Vocabulary Size of Toddlers Born Preterm

Kelly Vaughn[1], Hana Taha[1], Johanna Bick[2], Susan Landry[1], Dana DeMaster[1]

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2-G-64 Hypoconnectivity between anterior insula and amygdala associates with future vulnerabilities in social development in a neurodiverse sample of neonates

Dustin Scheinost[1], Joe Chang[1], Cheryl Lacadie[1], Emma Brennan-Wydra[1], Rachel Foster[1], Alexandra Boxberger[1], Suzanne Macari[1], Angelina Vernetti[1], R. Todd Constable[1], Laura Ment[1], Katarzyna Chawarska[1]

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2-H-45 Characterisation of fetal to neonatal brain growth asymmetries using deformation-based morphometry

Céline Steger[1], Kelly Payette[1], Alexandra De Silvestro[2], Thi Dao Nguyen[3], Giancarlo Natalucci[3], Raimund Kottke[2], Ruth Tuura[2], Walter Knirsch[2], Andras Jakab[2]

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2-H-54 Brain morphometry of toddlers with language delay: A pilot study

Courtney Filippi[1], Elizabeth Smith[2], Elizabeth Redcay[1], Audrey Thurm[3]

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2-H-66 Characterizing cerebellar growth during the first year of life following a preterm birth

Sarah Palmis[1], Véronique Mallet[1], Pia Wintermark[2], Guillaume Gilbert[3], Christine Saint-Martin[2], Marie Brossard-Racine[4]

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2-I-43 Infant gut microbiota composition associates with negative reactivity and fear in sex-specific manner

Venla Huovinen[1,2], Anna Aatsinki[1], Eeva-Leena Kataja[1], Eveliina Munukka[1], Anniina Keskitalo[1], Santosh Lamicchane[1], Peppi Raunioniemi[1], David Bridgett[3], Leo Lahti[1], Siobhain O'Mahony[4], Alex Dickens[1], Riikka Korja[1], Hasse Karlsson[1], Saara Nol

[1]University of Turku, [2]Doctoral Student, [3]Northern Illinois University, [4]University College Cork

2-I-52 Hippocampal volume and spatial working memory performance in preterm toddlers

Hana Taha[1], Kelly Vaughn[1], Josselyn Muñoz[2], Johanna Bick[3], Susan Landry[1], Dana DeMaster[1]

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2-I-55 Oscillatory brain activity predicts the development of inhibitory control from infancy to toddlerhood

Josué Rico-Picó[1], M. Carmen García de Soria[1], Ángela Conejero[1], Sebastián Moyano[1], Ángela Hoyo[1], M. Ángeles Ballesteros-Duperón[1], Karla Holmboe[1], M. Rosario Rueda[1]

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2-I-57 Concurrent and Prospective Associations Between Frontoparietal and Default Mode Network Connectivity and Negative Affectivity in Infancy

Sanjana Ravi[1], M. Catalina Camacho[2], Brooke Fleming[1], Michael Scudder[1], Kathryn Humphreys[1]

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2-I-58 Increased Cortical Thickness in Regions Supporting Executive Functions Predicts Reading Comprehension in Children with Music Experience

Rola Farah[1], Tzipi Horowitz-Kraus[1]

[1]Technion- Israel Institute of Technology

2-I-59 Early Social Environments and Relationships with the Social Brain Network

Cristin Holland[1], Isabelle Mueller[1], Antonette Davids[1], Cristin Holland[1], Bradley Peterson[2], Dustin Scheinost[3], Catherine Monk[1], Marisa Spann[1]

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2-I-61 Mapping a dynamic interplay: Auditory attention and receptive language network development across the first eight months of life

Isabelle Mueller[1], Catherine Monk[1], Bin Cheng[1], Thirsten Stockton[1], Tove Rosen[1], Bradley Peterson[2], Dustin Scheinost[3], Marisa Spann[1]

[1]Columbia University, [2]University of Southern California, [3]Yale University

2-I-63 Brain Segregation over Early Development in Non-Human Primates

Ting Xu[1], Julian Ramirez[1], Karl-Heinz Nenning[2], Arnaud Falchier[2], Gary Linn[2], Damien Fair[3], Charles Schroeder[2], Michael Milham[1], Brian Russ[2]

[1]Child Mind Institute, [2]Nathan Kline Institute, [3]University of Minnesota

2-I-65 Hippocampal function and memory across contexts in 18-22-month-olds

Lindsey Mooney[1], Alireza Kazemi[1], Simona Ghetti[1]

[1]UC Davis

2-J-48 Using fMRI to study one-month-old infants' responses to music and speech in auditory cortex

Heather Kosakowski[1], Samuel Norman-Haignere[2], Anna Mynick[3], Atsushi Takahashi[1], Rebecca Saxe[1], Nancy Kanwisher[1]

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2-J-51 From Fetal and Newborn Kinematics to Neuro-developmental Risk: Bayesian approaches to identifying developmentally-salient motor activity in 1-month old infants

Staci Meredith Weiss[1]

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2-J-53 Environmental effects on crafting the future reading network: Neurobiological correlates for literacy and screen exposure in children

Tzipi Horowitz-Kraus[1,2]

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2-J-56 Insights into the complex immune environment during pregnancy and its association with the developing human connectome

Ezra Aydin[1], Catherine Monk[1], Manya Balanchander[1], Bin Cheng[1], Bradley Peterson[2], Dustin Scheinost[3], Marisa Spann[1]

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2-J-60 Sex differences in brain-behavior relationships during infancy

Sonja Fenske[1], Haitao Chen[2], Marcio Diniz[1], Rebecca Stephens[3], Emil Cornea[3], John Gilmore[3], Wei Gao[1]

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2-M-39 A preliminary investigation of relations among early feeding practices, gut microbiome diversity, and amygdala growth during the first year of life

Collin Gregg[1], Liangjun Chen[2], Li Wang[2], Gang Li[2], Martin Styner[2], Brittany Howell[3], Weili Lin[2], Jed Elison[4]

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POSTER SESSION 1
MONDAY, SEPTEMBER 5 5:30–6:45PM

1-A-11 The infant brainstem: postmortem multimodal and multiscale imaging of structure and connectivity

Caroline Magnain[1], Erendira Garcia Pallares[1], Sam Blackman[2], Seoyoon Kim[2], Ream Gebrekidan[2], Brian Edlow[3], Robin Haynes[4], Hannah Kinney[4], Lilla Zöllei[1]

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Sudden infant death syndrome (SIDS) is the leading cause of postneonatal infant mortality in industrialized nations with a rate of 0.39/1000 livebirths in the United States alone. Even though certain environmental factors increase the risk of SIDS, a subset of SIDS may be the result of an intrinsic defect in brain anatomy, in particular of the subcortical ascending arousal network (AAN) [1]. Arousal pathways of the AAN originate in the brainstem and activate awareness networks in the central cortex via synapses in the hypothalamus,thalamus, basal forebrain, or, alternatively via direct innervation of the cerebral cortex itself. In this work, we show how we use a multimodal and multiscale imaging approach to study the structure and the connectivity of the postmortem infant brainstem in a control subject. First, the whole brain is imaged at the macroscale level using MRI at 7T and diffusion MRI at 3T with a resolution of 200 µm and 700 µm (90 directions), respectively. To further improve the resolution in our region of interest, the brainstem and cerebellum were separated and imaged again at 100 µm for the structural data on 7T and at 400 µm and 90 directions for the diffusion data on 3T. To study the brainstem connectivity and in particular the AAN, we need to identify important nuclei and tracts. However, even at this high resolution, ex vivo MRI is unable to provide sufficient contrast to delineate them due to their size and the lack of myelination. We turned to Optical Coherence Tomography [2], a 3D microscopy technique, to visualize these regions at an isotropic resolution of 3.5 µm. As only the top 100 µm can be imaged in one acquisition, we coupled our system with a vibratome. The imaging is done without contrast, relying solely on the tissue intrinsic optical properties, and prior to the sectioning which greatly limits tissue distortions. Contrary to MRI, OCT exhibits a high contrast which enables us to segment the brainstem, its nuclei, tracts and cranial nerves. We use a combination of manual segmentation and machine-learning-automated interpolation [3] tool to do so. Finally, the slices collected during the OCT imaging are used for histological validation of our segmentation. All the various modalities are then registered into a common space. The OCT segmentation can be transferred to the whole brain MRI and used as seed point to probe the brainstem connectivity. This work lays the foundation to compare the brainstem connectivity between SIDS cases and controls, with the potential to identify biomarkers and abnormalities of the disease not detectable by standard histopathological techniques. [1] Edlow, B.L., et al., Neuroanatomic connectivity of the human ascending arousal system critical to consciousness and its disorders. J Neuropathol Exp Neurol, 2012. 71(6): p. 531-46. [2] Huang, D. et al. ?Optical Coherence Tomography?, Science vol. 80, no. 254, pp.1178-1181, 1991. [3] Atzeni, Alessia, et al. A probabilistic model combining deep learning and multi-atlas segmentation for semi-automated labelling of histology. International Conference on Medical Image Computing and Computer-Assisted Intervention. Springer, Cham, 2018.

1-A-17 Variability of optimal echo times in a developmental population - insights from multi-echo fMRI recordings

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T2 decay curves which form the basis of functional magnetic resonance imaging (fMRI) show a developmental trend, being slower in newborns, compared to infants and adults. This implies that the optimal echo times (TE) for fMRI data acquisition vary with participant's age. However adjustment of TEs for different developmental populations is not an applied practice and optimal TEs for different ages have not been investigated systematically. Usage of multi-echo (ME) fMRI recordings makes it possible to easily calculate the optimal TE (T2*) for each voxel in the brain by fitting a decay curve to the signal of the acquired echos. This not only allows one to look at T2* times between participants but also between tissue types within one participant. We compared data from ME fMRI with five echos (14ms, 38ms, 63ms, 88ms, 113ms) in two newborns, one two-year-old and one adult to examine the variability in T2* times. Overall, we see longer optimal TEs in infants with a broader spread of T2* values particularly in newborns. Cortical grey matter shows a median of 79.9ms (Q1: 48.9ms, Q3: 104.2ms) and 68.2ms (Q1: 41.2ms, Q3: 93.9ms) in the two newborns, 67ms (Q1: 57ms, Q3: 74.9ms) in the two year old and 47.6ms (Q1: 39.8ms, Q3: 54.4ms) in the adult. In ME fMRI, these differential T2* values will lead to a different weighting scheme of the acquired echos for the optimally combined time series data which is used for further processing and analysis for each participant. As variability in the BOLD signal (percent signal change) differs between echos, optimal weighting is essential for later analyses. Inspection of connectivity matrices generated with ME and single echo (TE 37ms) data from the same newborn participant show an advantage of ME data acquisition particularly in areas with very short or very long T2* times. This example showcases a potential advantage of ME data acquisition in developmental and especially longitudinal developmental studies. Further analyses of additional datasets of a larger number of infants with different ages will make it possible to model the development of T2* times. For our investigation of these example datasets we implemented a developmental ME-processing pipeline to make the usage of ME feasible for future developmental fMRI studies. The pipeline uses Tedana multi echo processing combined with the Nibabies and XCP-D workflows and is openly available.

1-A-21 Utilizing the mesoSPIM 3D light-sheet microscope to study the 3D structure of the developing human fetal brain

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Studying the developing human brain in 3D at multiple spatial scales (micro- and macro) requires specialized tissue processing and imaging techniques. It has more recently become possible to visualize unsectioned whole rodent brains as well as larger blocks of human organs with 3D light-sheet microscopy (3D-LSM). The aim of our study is to implement a framework for the neuroimaging of mid-gestational human fetal brains at this spatial scale. Our study utilized occipital cortex block samples from three human fetal brains from terminated pregnancies at a gestational age of 20 weeks. First, we prepared the tissue for optical imaging via clearing using the iDISCO+ technique(1), which included successive steps of methanol dehydration/rehydration, bleaching, delipidation and refractive index matching as well as whole-mount immunolabeling possibilities. To optimize the bleaching step, we tried 5% and 15% concentration of H2O2 for 8 hours and more aggressive approaches like 20% H2O2 for 12 or 48 hours. Additionally, we extended our tissue processing protocol with SHANEL pretreatment (2) with NMDEA (permeabilization) and CHAPS (decolorization) solution. Optical cleared samples were imaged with mesoSPIM 3D-LSM (3) using different excitation wavelengths (488, 561, 591, 647 nm). Additionally, before combining iDISCO+ with whole-mount immunolabeling we validated antibodies that we expect to be compatible with methanol treatment and performed on-slide stainings. FIJI and Imaris software and custom-made scripts were utilized for the analysis. To study MRI - microscopy correlations, the fetal brains were imaged on a 9.4T scanner at 100 micron isotropic resolution. iDISCO+ alone or combined with SHANEL pretreatment yields efficiently cleared samples in centimeter sized blocks of tissue. Despite of the different bleaching approaches, the strong heme-induced autofluorescence signal is not reduced. 3D-LSM reveals with isotropic resolution structures like marginal zone, ventricular zones at midgestation occipital lobe and the brainstem region. Tracking the autofluorescence signal we discern the developing fetal vasculature. On-slide staining promisingly uncover axonal projection in the brainstem and neuronal cell bodies in the developing cortex. Studying MRI - microscopy correlations will necessitate successful 3D staining of fiber structures, which we have not yet achieved. Our approach revealed major cortical structures in the developing midgestational human fetal cortex and brainstem as well as the developing vasculature in 3D space. Our upper target is to amplify whole-mount immunolabeling to characterize structurally and molecularly developing fetal cortex, expanding our repertoire of antibodies to study simultaneously structure and neuronal populations of interest in the developing brain. (1) Renier et al., 2014, Cell (2) Zhao et al., 2020, Cell (3) Voight et al., 2019, Nature Methods

1-A-22 Factors Predicting Data Acquisition Success in Infant and Toddler MRI Neuroimaging Studies

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Magnetic resonance imaging (MRI) techniques have been widely used to understand the extensive growth of the human brain during the first years of life. However, the acquisition of MR images from healthy infants and toddlers during natural sleep poses unique challenges. This study aims to provide the field with helpful information regarding factors that influence scan success for children during natural sleep. The UNC/UMN Baby Connectome Project (BCP) is a longitudinal neuroimaging project designed to characterize brain and behavioral development of typically developing children between birth and five years. At the UMN site only, we have conducted 923 sleep MRI sessions in 257 infants/toddlers (125 females) aged 1 month to 60 months, and have collected at least one usable sequence from 643 sessions. Per visit, participants were invited for a second attempt when the core sequences (T1, T2, and rsfMRI) were not collected. Among 923 scan sessions, 191 were second attempt sessions. We identified and examined two categories of factors that could affect data acquisition success: (1) demographics, including age, sex, and firstborn vs. not firstborn, and (2) variables related to scanning protocol, including second attempt, days between attempts, and order of sequences. Outcomes of interest were (1) scan success, defined as collecting at least one usable sequence, and (2) time participants stayed asleep before they first woke up once the scan started. Models were tested using linear and logistic mixed-effects regression. The overall scan success rates were 73.0% and 57.1% for the first and second attempt scans, respectively. Sex and birth order did not predict the scan success. Age at scan significantly predicted success, β = -0.041, SE = 010, $p < .000$, with older children less likely to have successful scans. Predicting the second attempt success only, however, age at scan was no longer significant. Days between attempts did not predict the second attempt success. The first attempt success was the only significant predictor for the second attempt success, with the odds of success 2.43 times higher when the first attempt was successful, OR = 2.43 [95% CI: 1.21,5.10], p = 0.01. Predicting the time participants stayed asleep before they first woke up, age at scan was the only significant predictor, β = 0.23, SE = 011, $p < .023$, with older children staying asleep longer. The order of sequence, DWI prioritized vs. rsfMRI prioritized, did not significantly predict the time participants stayed asleep. Combining these two results, it appears that older children were less likely to fall asleep at the scan, but stayed asleep longer once the scan started. It could be recommended to have second attempts, especially for participants who fall asleep at their first attempt, with the overall 57.1 % of success rate. Given the null findings with regard to scan protocol and demographic variables other than age, more age-specific examinations of scan success (e.g., number of disruptions of scan, the likelihood of restart of scan, etc.) remain to be done.

1-A-23 LIT: An awake fMRI language task for toddlers

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Objective: Collecting usable neuroimaging data from awake toddlers is an enormous challenge. Not only do they need to remain still and watch the stimuli, but in order to isolate a particular experimental contrast of interest, they specifically need to remain still and attend to both the condition of interest and the control condition. Here, we aim to study language processing by contrasting forward and backward speech in awake toddlers. To do so, we developed two tasks that manipulate the auditory speech stream in video clips from Sesame Street. Methods: The first task presents 20-second edited audiovisual clips from Sesame Street during which either a single puppet addresses the viewer or two puppets speak to each other, while the auditory speech stream is played either forwards or

backwards. The second task presents 1-3 minutes of continuous dialogue, in which the speech of only one character is played in reverse. We first collected pilot behavioral looking-time data from toddlers over Zoom to determine if they would attend equally to our different experimental conditions. We next scanned 20 adults on our novel tasks, and on a previously validated auditory language localizer (Scott et al, Cognitive Neuroscience, 2017), using functional magnetic resonance imaging (fMRI). Finally, we conducted a feasibility fMRI pilot on a toddler using our first task. Results: In our behavioral pilot sample (N=51), toddlers looked equally to all of our conditions. This is encouraging from a neuroimaging task design standpoint, as it suggests that we may be able to collect usable data from both the forward and backward speech conditions. In our adult fMRI sample (N=20), we successfully localized language regions with both of our novel tasks: the forward>backward contrast overlapped with the intact>degraded speech contrast from the auditory language localizer at both the group level and at the level of individual participants, individually-defined functional regions of interest for language responded more to forward than backward speech conditions, and using a leave-one-subject out approach, the time course of brain activity in language regions during the interleaved dialogue task was more similar for adults who heard the same speech stream paired to each video, compared to adults who heard the opposite (i.e., opposite characters forward and reversed), in continuous dialogue. Finally, we were able to collect fMRI data from a 34-month-old toddler using one of our new tasks. Conclusion: The present data support the idea that combining naturalistic stimuli (e.g., videos from Sesame Street) with an experimentally-controlled manipulation of language (e.g., forward vs. backwards speech) is a promising approach for studying language processing in the toddler brain.

1-A-25 Face responses present in multiple regions of the human infant brain.

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Faces are easily identifiable visual objects and a rich source of social information. How does the infant brain develop the ability to recognize faces and identify potential social partners? In adults, the fusiform face area (FFA) supports face perception, the superior temporal sulcus (STS) supports social perception, and the medial prefrontal cortex (MPFC) supports social evaluation. A prominent framework, which we call the Serial Hypothesis, predicts that cortical function emerges in a sequential bottom-up manner. Specifically, the Serial Hypothesis predicts that face-selective responses will emerge in FFA in ventral temporal cortex (VTC), next in STS, and last in MPFC. Alternatively, it is possible that as soon as infants' FFA process the visual features of faces, STS and MPFC also evaluate social-emotional face features. This framework, which we call the Parallel Hypothesis, predicts that face-selective responses will be present in STS and MPFC at the same time in development as VTC. To test whether infants' face responses emerge sequentially, we collected functional magnetic neuroimaging (fMRI) data from human infants (n=49, 2.5-9.7 months) while they watched movies of faces, bodies, objects, and scenes. We observed a face response that was significantly greater than the response to other visual categories in VTC, STS, and MPFC (all Ps<0.05) but we did not observe an effect of age in any region (all Ps>0.1). In only higher-resolution data (n=20), we localized infants' VTC face-selective response to FFA (all Ps<0.001). We next asked if just the youngest infants (n=15; 2.5-4.6 months) would exhibit face-selective responses in visual-perception regions but not yet in social-emotional regions. In the youngest infants there was weak evidence for face-selectivity in VTC (all Ps≤0.09) and strong evidence for face-selectivity in STS and MPFC (all Ps≤0.03), which does not support the Serial Hypothesis. In a last effort to find evidence for the Serial Hypothesis, we randomly selected subsets of 15 infants and asked if any subset of infants would exhibit face-selective responses in VTC but not yet in STS or MPFC. Of 2500 random sub-samples, 1.2% of subsets (31 instances), had face-selective responses in VTC but not STS or MPFC whereas 85% of subsets (2131 instances) had face-selective responses in STS and/or MPFC. Thus, subsets of infants who have face-selective responses in VTC but not STS or MPFC are very rare and non-representative. In sum, using fMRI we observed face-selective responses in VTC, STS, and MPFC of young infants, providing initial evidence in support of the Parallel Hypothesis. What mechanisms might explain the parallel emergence of face-selective responses? Perhaps infants are born with a modality-independent social brain network that readily responds during human interactions. Alternatively, perhaps social interactions engage reward mechanisms resulting in the simultaneous emergence of face-selective responses across cortex. Whatever the answer turns out to be, our results suggest that the Serial Hypothesis of cortical development is not a sufficient account to explain the emergence of face selectivity; with only a couple of months of experience infants' brains process faces as more than just a common visual pattern in their environment.

1-A-29 Reduced Myo-Inositol Levels during Infant Early Brain Development using In Vivo Magnetic Resonance Spectroscopy

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In vivo magnetic resonance spectroscopy (MRS) is a non-invasive technique for measuring metabolite concentration in an interrogated region of interest in the brain, and has been used to characterize neurochemical changes associated with various mood disorders and psychiatric conditions.1 One such metabolite, myo-inositol (mIns) has been measured in adults using in vivo MRS and is associated with neuroinflammation, an accepted risk factor for psychiatric disorders.2 In infants, changes in myo-inositol levels have been associated with neonatal encephalopathy and brain white-matter damage.3,4 However, this metabolite has yet to be examined in healthy infants, specifically during the early post-natal development period. The purpose of this study is to demonstrate that myo-inositol can be measured in infants using MRS, and to furthermore examine the variation in myo-inositol levels during early infant brain development. An analysis will be conducted on MRS data acquired on a GE SIGNA 3T scanner using a custom-designed semi-LASER sequence5 at the New York State Psychiatric Institute (NYSPI). A preliminary analysis will include scans from a total of 15 subjects between the ages of 0 and 9 months. A breakdown of subject demographics is provided in Table 1. Spectra were acquired using isotropic voxels located in the anterior cingulate cortex (ACC), cerebellum (CERE), occipital lobe (OCC), prefrontal cortex (PFC), and temporoparietal junction (TPJ). The acquired data will be preprocessed using the software tool INSPECTOR,6 and subsequently quantified using LCModel.7 The following metabolites of interest will be included in the basis set for quantification: mIns Glyncine (Gly), NAA, choline (Cho), glutamate glutamine (Glx), and lactate (Lac), and each resulting concentrations will be reported as a ratio with respect to creatine (Cr) across all scans. Repeated measurements of myo-inositol will be analyzed as a function of recorded postnatal age, organized by the interrogated region of interest (e.g. ACC, PFC, TPJ, OCC, CERE). The total number of successfully quantified spectra will be reported as quality control. An example quantified spectrum from a single subject is shown in Figure 1, with the mIns signal peaks labeled in red. To determine the association between mIns concentration estimates and age, linear mixed effect models will be reported across each region of interest for all successfully quantified subjects. In this study, we hypothesize that MRS can be used to precisely

measure variations in myo-inositol in the postnatal brain, and that this concentration rapidly decreases over the first year of infancy. This analysis will have important implications for future efforts aimed at identifying links between maternal immune activation (MIA) and the onset of psychiatric conditions in offspring, potentially providing a preliminary baseline for characterizing neurochemical changes that occur during healthy early brain development.

1-A-34 Maternal Trait Anxiety and Successful Infant MRI During Natural Sleep

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Infant brain research has been revolutionized by the use of neuroimaging methodologies, particularly magnetic resonance imaging (MRI), by allowing researchers to investigate infant brain structure and function beginning very early in development. However, acquiring infant MRI data during non-sedated natural sleep is challenging. Getting babies to fall asleep in the scanning environment is challenging and stressful for not only the research team but also for the infant's mother. In the worst-case scenario, repeated failed attempts to get babies to fall asleep may lead to the cancellation of the whole scan session--a frustrating and costly situation for families and the research team. The acute stress of getting the baby to sleep combined with evidence that maternal mental health is linked to their children's sleep problems including difficulties in falling asleep, short sleep, and night wakings (Nulty et al., 2022; Pennestri et al., 2018), we examined the relation of maternal depression and anxiety to success in MRI scan. Infants and their mothers (N = 17, boys = 9, girls = 8) participated in non-sedated sleep MRI scans at 3 and 6 months (scan visits N = 31). Within a week of their infant's scan, mothers completed the State-Trait Anxiety Inventory (STAI; Spielberger et al., 1983) and the Beck Depression Index (BDI; Beck, et al., 1961) to assess their anxiety and depression, respectively. The STAI was designed to assess both current (state) and chronic (trait) anxiety. For these analyses, we defined the success of a scan as collecting both T1 and T2 images. Logistic regression analysis tested the relation of maternal depression and anxiety (both state and trait) to their child's scan success. The results suggest that mothers' trait anxiety (B = -.37, p<. 05) was significantly associated with scan. The more anxious a mother is generally, the less successful scans are. There was no significant association between maternal depression and state anxiety and the success of MRI scans. This finding suggests that mothers' trait anxiety could be linked to infants' sleep difficulties during MRI data collection. Strategies to address mothers' anxiety such as sufficient communication about the scan environment may help mothers and infants have a more fruitful research experience.

1-B-13 Updates to the Melbourne Children's Regional Infant Brain software package (MCRIBS)

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Objective The delineation of cortical areas on magnetic resonance images (MRI) are important for understanding the complexities of the developing human brain. The Melbourne Children's Regional Infant Brain (M-CRIB-S) is a software package that performs whole-brain segmentation and surface-based extraction and parcellation of the neonatal cerebral cortex, enabling cortical surface measures to be derived for 31-34 regions based on the Desikan-Killiany or Desikan-Killiany-Tourville parcellation schemes; which are compatible with the adult schemes used in Freesurfer. The whole-brain segmentation component assigns subcortical grey, cerebellar hemispheres, cortical white and grey matter structures using label fusion. Cortical surface extraction and parcellation are performed using the Deformable tool and a Freesurfer-like pipeline, respectively. We present a major update to the software package which aims to improve the accuracy of whole-brain segmentation and cortical surface extraction. The improved cortical surface extraction accuracy increases the robustness of measures such as surface area, cortical thickness, and cortical volume. Methods Whole brain voxel labelling, using label fusion, has been updated from the previous MIRTK/DrawEM pipeline to an ANTs' registration/label fusion pipeline. Additionally, the M-CRIB training data replaces the ALBERTs training data to provide higher resolution (0.6mm3 vs 1mm3) images along with Freesurfer-compatible whole-brain segmentation labels. Label fusion requires registration of the novel image to each training image; ANTs' non-linear registration tool was used. In addition to intensity-based costs, masks for lateral ventricles, and cortical grey matter were estimated on the novel image to facilitate high degrees of warping needed to account for significant inter-subject variations of cortical folding. Cortical surface extraction is performed by firstly estimating the white, then the pial surface. Errors in the white matter surface would typically occur at the inlets of thin gyri, such as the pericalcarine cortex, due to misclassification. This occurs despite erroneously classified voxels having visibly higher intensities than their neighbors. We introduce a second step that includes a force image that outward normal force when surface vertices overlap GM-classified voxels that are brighter compared to their neighbors. Results After running the second step described above, we see improved penetration into thin strands of white matter in these tertiary folds. Figure 1(i) shows the results of the second step (light blue) improves penetration of the white matter surface of the first step (yellow). Figure 1(ii) shows the final surfaces overlaid onto the voxel segmentation and cortical parcellation for that subject. Note that the whole-brain segmentation is consistent with an adult-like labeling generated with Freesurfer. This method has been executed successfully on a cohort of 300 neonatal images, data not shown. Conclusions We have presented an update to the MCRIBS software package that achieves two goals: 1. A whole-brain segmentation that is compatible with the MCRIB labels and, 2, improved white matter surface extraction, enabling more accurate cortical surface measures to be obtained from infant brain images. The software is available for download from GitHub at (https://github.com/DevelopmentalImagingMCRI/MCRIBS).

1-B-18 Optimum selection of neonatal structural priors for portable functional neuroimaging modalities

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Introduction: Portable functional imaging modalities such as diffuse optical tomography (DOT) and electroencephalography (EEG) enable infant brain function to be studied in naturalistic contexts. Such modalities overcome many of the movement constraints imposed by functional magnetic resonance imaging (MRI) but have the disadvantage of not acquiring structural neuroimaging datatypes. A structural prior of head anatomy is often employed to improve localisation accuracy and aid data interpretation. Previously, we developed a database of individual-level structural priors for neonates [Collins-Jones et al., Hum. Brain. Mapp., 42,

2021] produced using data from the Developing Human Connectome Project [Makropulos et al., NeuroImage, 173, 2018]. Based on cotside-accessible features, here we examine the optimum approach to selecting and spatially registering a matched model. Methods: Each head model in the database (N=214) acted in turn as the target in a leave-one-out analysis. Head models with a head circumference within 4 cm and a gestational age within 2 weeks of the target were selected, which we term the potential matches. The offsets between target and each potential match in five external features (head circumference, gestational age, 10/20 positions, cranial landmarks positions and scalp surface mesh nodes, see Figure 1A) were computed in a common coordinate space. Such cotside-accessible features (attainable via photogrammetry or digital positioning devices) were used to identify appropriate methods to select a matched model. Each potential match was then spatially registered to the target using five registration methods. Affine registration was employed based on the 10/20 positions (10/20-affine) and the cranial landmarks positions (landmarks-affine). Three other registration methods employed coherent point drift (CPD) [Myronenko & Song, IEEE PAMI, 32(12), 2010] based on the 10/20 positions (10/20-CPD), cranial landmarks positions (landmarks-CPD), and scalp surface alignment (surface-CPD). A model matching the target's anatomy as closely as possible is desired, especially the scalp (where sensors are placed) and the cortex (where the signal of interest usually originates). We quantified scalp error between target and registered potential matches as the mean Euclidean distance between equivalent 10/5 positions. We quantified cortical error as the mean surface distance between cortical surfaces. Results: Figure 1B depicts anatomical error as a function of offset in the five external features. Offsets in age and head circumference have a weak relationship with anatomical error. A much clearer relationship is seen with offsets in 10/20 positions, landmarks and scalp. Anatomical errors are plotted for the best matching models for 10/20, landmarks and scalp offsets for different registration methods in Figure 1C. Selecting a head model that minimises the 10/20 offset often resulted in a lower anatomical error. Figure 1D depicts anatomical errors for the matching method that minimises the scalp error for each registration method. For scalp error, 10/20-affine performs best; for cortical error, surface-CPD performs best. Conclusion: Acquiring subject MRI data is often infeasible, particularly in global health applications where necessitating MRI undermines the benefit of portable modalities. This work is an advance towards optimising structural prior selection to improve spatial precision in portable neonatal functional neuroimaging.

1-B-19 Towards a comprehensive numerical model of white matter to simulate realistic in utero magnetic resonance acquisitions of the fetal brain

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BACKGROUND AND PURPOSE: Magnetic resonance imaging (MRI) is commonly used as a complement to the ultrasound gold-standard to investigate equivocal patterns in the developing fetal brain. FaBiAN is an open source Fetal Brain magnetic resonance Acquisition Numerical phantom that simulates clinical T2-weighted (T2w) magnetic resonance images of the in utero fetal brain throughout maturation (Lajous et al., Zenodo-2021; Lajous et al., arXiv-2021). It mimics as closely as possible the MR acquisition scheme and therefore provides a ground truth to assess and validate postprocessing methods used to mitigate motion artifacts caused by stochastic movements of the fetus (Lajous et al., UNSURE PIPPI-2021). Moreover, these numerical simulations can complement clinical databases of fetal brain MR images which remain scarce, and therefore be used to train deep neural networks for tissue segmentation (de Dumast et al., ISBI-2022). However, FaBiAN was originally built on a three-class model (white matter (WM), gray matter and cerebrospinal fluid) which does not allow to take into account key maturation processes that occur in the WM throughout gestation. To overcome this limitation, we present in this work a new numerical fetal brain model that incorporates MR signal changes in the WM over different gestational ages (GA). METHODS: Synthetic T2w fast spin echo images are built on a normative spatiotemporal MRI atlas of the fetal brain (Gholipour et al., Scientific Reports-2017). We use unsupervised machine learning methods such as Gaussian Mixture Models (GMM) to separate two different classes within a WM mask derived from the available atlas segmentations in the GA range of 21 to 38 weeks, and thus to account for hydrated tissue regions as opposed to dense WM fibers (Figure 1). This 2-class GMM is initialized with a K-means approach for a GA of 21 weeks. For older subjects, consecutive initializations are performed with the parameters of the previous runs until a GA of 38 weeks. 3D GMM posterior probability maps are then used to weight the mean T1 and T2 values in the WM given as inputs to FaBiAN (T1/T2: 3000 ms/232 ms at 1.5T, Figure 2). Upper and lower bounds of T1 and T2 values are set after weighting so that the adjusted values in the WM cannot deviate more than 20% from the average ones to ensure realistic tissue properties. RESULTS: Figure 1 shows how the WM changes are well captured by the GMM segmentation throughout development. Especially, our method depicts the multilayer aspect of WM which progressively disappears after 27 weeks of GA, although some residues can still be observed at the subplate level. Figure 3 shows two representative examples of fetuses at 21 and 32 weeks of GA where the 2-class GMM segmentation of WM allows to refine FaBiAN simulations and get even closer to real cases. DISCUSSION: Unsupervised segmentation methods have proven to be very effective in identifying local spatial regions of variable water content. We hypothesize that such a simple approach, without any spatial constraints, performs properly thanks to the smooth and noise-free appearance of the T2w images of the atlas that are averaged across several subjects. We expect that the even more realistic appearance of the fetal brain MR images simulated throughout maturation using this improved modeling of WM heterogeneity could further support the use of FaBiAN for data augmentation and domain adaptation strategies in deep learning segmentation.

1-B-20 Synthesis of realistic fetal MR images from labels using generative adversarial networks

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Fetal brain magnetic resonance imaging (MRI) serves as an emerging modality for prenatal counselling and diagnosis in disorders affecting the central nervous system. In research, machine learning based segmentation plays an important role for the quantification of brain development. However, an important limiting factor is the lack of sufficiently large, labeled training data. Our study explored the application of SPADE (1), a conditional general adversarial network (cGAN), which learns the mapping from the label to the image space, playing an emerging role in synthetic data augmentation for training segmentation methods. T2-weighted single shot fast spin echo images of 120 fetuses (gestational age range: 20 - 35 weeks, normal and pathological) were acquired in three orthogonal planes, acquired on a 1.5T or 3T MRI. These scans were motion corrected and reconstructed into a super-resolution volume for each subject.

Each volume was manually annotated into seven cerebral tissues. 80 datasets were used for training SPADE and 40 for testing. SPADE networks were trained on 256 x 256 2D slices of the reconstructed volumes (image and label pairs) in each orthogonal orientation. To combine the generated volumes from each orientation into one image, a simple mean of the outputs of the three networks was taken. The network was trained on an Nvidia RTX A6000 GPU, using a learning rate of 2E-4, 50 epochs and a batch size of 1. To evaluate our network, structural similarity index measure (SSIM) and correlation coefficient were calculated between the synthetic and original datasets. Based on the label maps only, SPADE successfully synthesized highly realistic images, where all tissue types were clearly distinguishable and non-annotated details, such as the choroid plexus and germinal matrix were visualized. However, some finer details, like small vessels were not synthesized. In the validation set, an SSIM score of 0.972 ± 0.016 and correlation coefficient of 0.974 ± 0.008 were achieved. To demonstrate the capacity of the cGAN to create new anatomical variants, we artificially dilating the ventricles in the segmentation map and created simulated MR images of different stages of hydrocephalus (Figure 1). cGANs such as the SPADE algorithm allow the generation of hypothetically unseen scenarios and anatomical configurations in the label space, which data in turn can be utilized for training various machine learning algorithms. In our study, we demonstrated synthesizing MRI from the original as well as simulating various degrees of hydrocephalus. In the future, we will explore how such synthetic data can improve the performance of deep learning based brain segmentation networks through synthetic data augmentation. 1: Park, T., Liu, M. Y., Wang, T. C., & Zhu, J. Y. (2019). Semantic image synthesis with spatially-adaptive normalization. In Proceedings of the IEEE/CVF conference on computer vision and pattern recognition (pp. 2337-2346).

1-B-24 Brain perfusion abnormalities in Prader-Willi infants: an arterial spin labelling ? MRI study

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Prader-Willi syndrome (PWS) is a genetic neurodevelopmental disorder characterized by a severe hypotonia at birth, feeding difficulties for infants and later hyperphagia and increased risks of obesity. Patients with PWS also present cognitive and behavioral dysfunctions, such as learning difficulties, stubbornness, manipulative and compulsive behaviors, psychosis, and temper tantrums. PWS is also highly associated with autism spectrum disorders (ASD) since patients present social interaction deficits as well as communication difficulties and show repetitive and restrictive behaviors. There are very few brain imaging studies performed in patients with PWS, and no studies have investigated brain perfusion abnormalities in infants with PWS. Thus, the aim of this work was to perform arterial spin labelling magnetic resonance imaging (ASL-MRI) to investigate brain perfusion abnormalities in very young infants with PWS. This study included ten patients with PWS (5 males, Mage= 11.1 ±3.3 weeks) and seven controls (3 males, Mage=13.29 ± 3.0 weeks). The controls underwent a brain MRI for various non-neurological reasons and presented strictly normal scans. All infants underwent ASL-MRI sequences on a General Electric 3T MRI scanner. Using a voxel-wise whole brain analysis, we compared the cerebral blood flow (CBF) between patients with PWS and controls. The statistical analyses were conducted within the framework of general linear model (GLM) in SPM12 software, on normalized and smoothed CBF images, using age as a covariate. Statistical thresholds were set at $p \leq 0.05$ corrected for family wise error (FWE). Compared to controls, the voxel-wise whole brain analysis showed a significant increase of CBF in the left superior temporal gyrus (corrected for cluster FWE; $p < 0.001$), in the right pallidum (corrected for cluster FWE; $p < 0.05$) and the right insula (corrected for cluster FWE; $p < 0.05$) in infants with PWS. No decrease of CBF was observed in patients with PWS compared to controls. To our knowledge, this is the first study to investigate brain perfusion abnormalities in infants with PWS using ASL-MRI. Our results indicate perfusion abnormalities in infants with PWS, supporting the relevance of CBF investigations in PWS. These changes could reflect abnormal cortical maturation processes associated with PWS. Interestingly, a previous PET-scan study showed an hypoperfusion of the superior temporal lobe in adolescents with PWS compared to controls, supporting perfusion abnormalities in this region, a key cortical region for social cognition processing, in PWS patients. Further ASL-MRI investigations in longitudinal studies are needed to better understand the evolution of these perfusion abnormalities across the development in patients with Prader-Willi syndrome.

1-B-30 Quantification of sulcal emergence in the fetal brain and its statistical comparisons for hemispheric asymmetry and sex difference

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Introduction: Human fetal brains show regionally different temporal patterns of sulcal emergence following a regular timeline. The sulcal emergence timing and its inter-subject variability may be associated with spatiotemporal patterns of gene expression among cortical regions (1-4). Therefore, the timing and inter-subject variability of sulcal emergence in typically developing (TD) fetuses can provide crucial information to define normal range of fetal brain development and can be used as a reference to detect potential abnormalities in early brain development. We aimed to quantitatively measure the timing of sulcal emergence and its inter-subject variability. In addition, we statistically investigated hemispheric asymmetry and sex difference in the timing and variability of sulcal emergence. Methods: A total of 106 TD fetuses and their magnetic resonance imaging (MRI) were included in this study (gestational weeks [GW]: 19.0 - 36.4], sex: 61/43/2 [male/female/unknown]). After extracting cortical surfaces from fetal MRI, 19 fetal sulci in were anatomically labeled (Figure 1) (5). To estimate the timing and variability of sulcal emergence, we fitted a binary logistic curve to quantify the relationship between GW and the absence/presence of a sulcal label (Figure 2A). We estimated sulcal emergence timing using GW at 0.5 of probability in the fitted curve. We also calculated interquartile range (IQR) of GWs between probability at 0.25 and 0.75 as the inter-subject variability. To analyze hemispheric asymmetry and sex difference, we statistically compared two logistic curves modeled in each group (hemisphere or sex) (Figure 2B), Standard error (SE) of the timing and variability in a group were calculated, respectively. The statistical difference in the timing and variability were calculated by z transformation of the timings and SEs. Results: Emergence of the STS and CS occurred first around 24 GW (Table 1). The bilateral MFS and OTS emerged after 27 GW. Majority of sulci showed similar temporal variability between 1 and 2 weeks, while the left CS and PostCS showed small variability (< 1 week) and the bilateral OTS and left STS had large variability (> 2 weeks). Statistically significant right-earlier-than-left sulcal emergence was found in the STS (Table 1). For sex difference (Table 2), females showed significantly earlier timing than males in the right STS. In addition, significantly larger

temporal variability of sulcal emergence timing in male fetuses was found in the right IPS, while the right PreCS showed significantly lower variability in males. Discussion: The sequence of emergence timing estimated by our quantitative may be related the temporo-parieto-occipital pattern of brain maturation (6-8). While the visual inspection studies supported our results with uniform variabilities across most of sulci, our quantitative approach found the regionally diverse variability that may be associated with different genetic influence in each region. The right-earlier-than-left emergence timing in the STS is supported by its structural asymmetry in children and adult brain (9-11). Sex difference in emergence timing and its variability reported in this study may be associated with sex difference in regional volumes in the fetal brain (15). In conclusion, our approach provided a quantitative timetable of sulcal emergence that could be a reference to assess normality of fetal gyrification, and to allow further statistical analysis of fetal

1-B-36 Motion Correction and Volumetric Reconstruction for in-utero Functional Magnetic Resonance Imaging Data

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Study Objective: Motion correction is an essential processing step in functional magnetic resonance imaging (fMRI) of the fetal brain to remove image artifacts caused by fetal movement and to suppress erroneous signal correlations. Here, we propose a novel motion correction and volumetric reconstruction methodology, which estimates an outlier-robust high-resolution reference volume for slice to volume motion correction and introduces Huber L2 regularization for volumetric reconstruction. Further, we demonstrate the ability of the proposed framework to improve signal interpretability, functional connectivity estimates and reproducibility, which is clinically desirable for the establishment of prognostic noninvasive biomarkers. Methods: The motion correction and volumetric reconstruction framework consists of three components: First, an outlier-robust 3D high-resolution reference volume is estimated using the first 15 time points of the timeseries. Second, motion correction is performed, by rigidly registering each axial slice of a fMRI time point to the estimated reference volume. Third, motion corrupted time points are reconstructed by using Huber L2-based regularization for intra-stack volumetric reconstruction. Further, we present a benchmark to assess the framework's performance and the influence of motion correction and reconstruction techniques on the fetal fMRI signal. Three intensity based and one functional connectivity based benchmark metrics are introduced. Results: We evaluated our framework on two datasets. For both datasets 96 time points are recorded for each subjects. The first 1.5 Tesla dataset contains a total of 15 subjects , and the second 3.0 Tesla dataset contains a total of 6 subjects recorded on two different 3.0 Tesla scanners. The underlying motion correction method reduces mean absolute error for rotation (from 1.17 degrees to 0.30 degrees) and translation (from 0.67mm to 0.50mm). We performed an extensive parameter study for the proposed Huber L2-based regularization and evaluated the reconstruction performance with outlier ratio (percentage of rejected time points for a subjects) and specific functional connectivity based metrics to assess reproducibility of the processed fMRI signal. Our approach with a Huber L2 regularization parameter of 0.1 outperforms state of the art reconstruction and motion correction methodology demonstrating a decreased outlier ratio from 12.71% to 8.62% for the 1.5T dataset and from 10.59% to 6.25% for the 3T dataset. Conclusions: The proposed motion correction and volumetric reconstruction framework provides several advantages especially in the setting of clinically diagnostic fetal fMRI. It allows the use of motion corrupted fMRI acquisitions for further analysis which would traditionally be discarded. Further, it could mitigate the need for repeated fMRI acquisitions and therefore leading to a reduction of scan time of fetal imaging and more efficient use of existing data.

1-C-14 Connectome Edge Density Based on Functionally Defined Nodes Shows Autism Spectrum Disorder (ASD)-related Changes in Infants

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Purpose: In previous reports, we found evidence of impaired white matter (WM) microstructural integrity and reduced connectome Edge Density (ED) based on tractography links connecting structural nodes associated with ASD. These alterations were present in adolescents and adults, but not detectable in pediatric cohorts. Here, we use a cohort of infants at risk of ASD to evaluate connectome ED based on tractography between functionally defined nodes that showed correlation with from ASD severity in a separate cohort. Methods: We retrieved DTI from n=155 infants in the National Database of Autism Research (Original study: Longitudinal MRI study of infants at Risk for Autism). Subjects median age at scan was 7 months; assessment of ASD symptoms followed at 24 months. In a previous study based on rs-fMRI from n=260 children, cerebral regions (nodes) were identified that showed significant positive, and respectively negative, functional correlation with symptom severity as measured by ADOS (Autism Diagnostic Observation Schedule) scores (Lake et al.: Biol Psychiatry 2019;86(4):315-26). These regions were coregistered into each individual's FA space and used as seed points in subsequent probabilistic tractography to generate ED maps. We subset those nodes into two different levels with increasing sensitivity, and used them separately as tractography seeds. After extraction of mean ED values within each tract defined in the JHU White Matter Labels atlas, we assessed correlation of ED metrics with ASD diagnosis. Results: ED within major white matter tracts shows correlation with ASD diagnosis (Figure 1). While present both for ED generated based on positively and negatively correlated cortical regions, positively correlated regions showed more widespread ASD-related changes. Comparing correlation coefficients between different sensitivity levels revealed that ED based on more sensitive nodes shows stronger correlation to ASD diagnosis group. Conclusion: We could show significant and pervasive ASD-related ED alterations in major white matter tracts when guiding tractography through functionally defined nodes. Correlation coefficients increased significantly when more sensitive functional nodes were utilized. These alterations could not be detected when using generic anatomical nodes in probabilistic tractography, hinting towards future implications of combining functional and diffusion-weighted imaging.

1-C-26 Fetal heart rate and heart rate variability associate with brainstem connectivity in neonates

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Background: The autonomic nervous system (ANS) matures during the fetal period and forms the basis of brain-body interactions. As brain development progresses from the 2nd to 3rd trimester, fetal parasympathetic activity and fetal heart rate variability (FHRV) increases, while fetal heart rate (FHR) decreases. In this way, FHR and FHRV provide an index of the development of the fetal autonomic nervous system and future neurobehavioral regulation. FHR and FHRV have been associated with behavior, particularly temperament, in infancy and toddlerhood. However, their associations with post-birth autonomic brain systems, such as the brainstem have not been investigated. We hypothesize that FHR and FHRV will associate with brainstem functional connectivity in newborns. Methods: Data were obtained from 48 pregnant women at 34-37 weeks gestation using a Toitu MT 325 fetal actocardiograph which detects FHR via a transabdominal Doppler transducer. Their infants also underwent an fMRI scan during their first weeks of postmenstrual life (PMA at scan 40-47) while asleep and without sedation. The FHR data were analyzed offline using custom Matlab programs and the mean FHR and standard deviation of FHR (our index of FHRV) were derived. We manually defined the brainstem as a region of interest in the reference brain. After standard preprocessing, we generated a map of brainstem seed connectivity, representing the strength of connectivity with the seed for each participant. Imaging data were analyzed using voxel-wise linear models controlling for sex and PMA and corrected for multiple comparisons. Results: We found that 3rd trimester FHR and FHRV associates significantly ($p<0.05$, corrected) with brainstem functional connectivity. Specially, higher FHR associates with weaker brainstem-posterior cingulate cortex connectivity and stronger brainstem-cerebellar connectivity. Higher FHRV associates with stronger brainstem-basal ganglia and brainstem-occipital lobe connectivity. Conclusion: Our findings relate fetal heart metrics to brainstem connectivity, demonstrating the involvement of, and connections to, higher order brain regions supporting the early regulatory control system and the utility of FHR monitoring for neurodevelopmental studies focused on the prenatal period. Brain regions involved in motor coordination, attention, and reward reflect the complex coordination required for ANS development. Despite the association between noninvasive fetal heart rate metrics and future child development, the mediating effects of the brain have not been explored. Our findings can help to bridge this gap.

1-C-27 Functional parcellation of the neonatal cortical surface

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INTRODUCTION: Functional brain areas are key units of brain organization. Neuroimaging studies have operationalized “parcels” as areas of the cortical surface with homogenous functional properties, and parcels may reflect functional brain areas. In recent years, several functional parcellations of the adult cortical surface have been described in the literature and made publicly available; yet their applicability to the study of the neonatal brain is unclear. The goal of the present study was to derive and validate a set of neonatal cortical surface parcels. METHODS: Using a recently acquired resting-state fMRI dataset of 262 healthy neonates, we derived a set of parcels based on the algorithm used to derive the Gordon parcels in adults (Gordon et al. Cerebral Cortex 2016). To improve generalizability of our results, we used only the n=132 neonates from our sample having at least 16.5 minutes of low-motion data. To generate the parcels, we first transformed the group functional connectivity matrix into a “boundary map,” a topographical map with basins where connectivity patterns are homogeneous and high ridges where connectivity patterns change abruptly. To segment the cortex into discrete parcels, the boundary map is flooded from its local minima. In our variant of the algorithm tuned for neonates, basins are filled to the 45th percentile of all height values, such that the resulting parcels represent only the deepest regions of strongest inter-subject agreement. Validity of the parcellation scheme is determined by assessing the homogeneity of parcels (defined as the percent of variance explained by the first component in a principal components analysis), relative to a null distribution of homogeneities obtained in 1000 variants of the same parcellation randomly rotated along the cortical surface. RESULTS: To test the reliability of the parcellation method across subject samples, we split our sample in half and evaluated parcellations generated from each half against the other. In either case, parcels were far more homogeneous than chance ($z = 8.4$ and 8.5), and the two parcellations overlapped significantly with each other (Dice = 0.71, $z = 18.8$), suggesting that we have identified a reliable and reproducible set of regions. We then combined the two split halves to generate a final parcellation, resulting in 236 parcels. All results generalize well to two external validation datasets: for the final parcellation, homogeneity z-scores obtained for these out-of-sample datasets were 6.9 and 6.3. SIGNIFICANCE: We present a group-level neonatal cortical surface parcellation that we believe will have high utility for researchers in neonatal fMRI. Specifically, this set of homogeneous a priori regions of interest can be used as a standard parcellation for developmental studies of human neonates.

1-C-28 Feeding Practice During the First Year of Life and Amygdala Growth

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Background & Objective: The amygdala contributes to socioemotional development, and is sensitive to caregiving in early life. In addition to providing nutrition directly, feeding practice is serves as a very salient caregiver behavior. Thus, this study sought to explore the impact of feeding practice on amygdala growth over the first year of life. Methods: This study utilized a subset of data from the UNC/UMN Baby Connectome Project (BCP), a prospective, longitudinal observational cohort study of mothers and their infants examining brain and behavioral development across the first five years of life. Data collected included structural neuroimaging and feeding practice data (i.e., whether the infant was fed exclusively milk, no formula, during the first year of life) from 415 children with the ultimate goal of mapping patterns of structural and functional connectivity, examining brain-behavior associations, and establishing a foundation for exploring growth trajectories. Structural MRI of the whole brain was acquired on a 3T Siemens Prisma MR scanner during natural sleep. Bilateral amygdalae were automatically segmented using multi-atlas segmentation as implemented in the AutoSeg software and results were visually inspected by a trained assessor for accuracy. Demographics and other covariate data. After excluding individuals with incomplete data the final dataset consisted of n = 85 mother-infant dyads, with 42 exclusively milk-fed (EMF), and 43 non-exclusively milk-fed (NEMF) (at least partially formula-fed) infants. We applied smoothing spline models and assessed greater-than-chance

differences between groups using the R package splinectomeR. SplinectomeR is appropriate as it is able to detect non-linear changes between groups. Finally, the Wilcoxon Rank Sum test was used to detect differences in amygdalae volumes between the two groups at a time range around 10 months of age, as this is around the time when infant amygdala begins to contribute to adult-like behaviors related to threat learning. Results: When comparing left and right amygdalae volume growth trajectories of infants who were EMF with those who were NEMF in the first 12 months of life, there was no significant difference with p = 0.2 (left) and p = 0.14 (right) (Figure 1). At approximately 400 days, the overall permuted spline of EMF vs that of NEMF demonstrates some divergence following a mild plateau among the NEMF group. At ages 280 to 330 days, the volumes of both left and right amygdalae of EMF infants were significantly less than NEMF infants, with p = 0.04 (left) and p = 0.03 (right). Conclusion: Though no significant differences in amygdala growth trajectories between the two groups were found, the data demonstrate that there is variability between individual growth trajectories. Analysis of a range of ages demonstrating a significant difference in volume between the two groups may also suggest the presence of significant differences at more specific time points. Such modeling was not achievable due to sample size This study provides a preliminary look into the possibility, with more robust data through high-density longitudinal sampling, to identify subtle time-dependent differences that may implicate the role of feeding practices in infant neurodevelopment. Moreover, this study may contribute to a more nuanced understanding of the maternal-infant bond through feeding practice and its role in amygdala growth.

1-C-31 Brain age prediction in fetuses with ventriculomegaly using a deep learning network with fetal brain MRI

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Introduction: Ventriculomegaly (VM) is one of the most diagnosed fetal anomalies with an enlargement of the lateral cerebral ventricle caused by an excess of cerebrospinal fluid. Using ultrasound (US), fetal VM is diagnosed when the ventricular atrial diameter at the level of the glomus of the choroid plexus is greater than 10 mm during the second and third trimesters of gestation (1). Along with US, in utero fetal brain magnetic resonance imaging (MRI) has been employed to identify additional central nervous system (CNS) abnormalities in VM fetuses (2) that may be better predictor of impaired neurodevelopmental outcome than degree of the ventricular dilation by US (3). Recently, deep learning-based brain age prediction method using structural MRI has been used to detect brain disorders showing large prediction age difference (PAD; predicted brain age - chronological age) (4). Our recent study established a novel fetal brain age prediction method using a deep learning network in typically developing (TD) fetuses (5). Our method revealed that the ventricle and cortex regions largely contributed to prediction of fetal brain age compared to other regions. Since VM showed larger ventricle size and is often associated with CNS abnormalities, in this study, we evaluated the differences in the PADs and absolute PAD (AAD) between fetuses with VM and TD fetuses and between the presence and absence of CNS abnormalities in fetuses with VM. Method: The use of fetal MRIs was approved by the institutional review board of Boston Children's Hospital. A total of 60 TD and 105 VM fetuses were included in this study. Using visual inspection of MRI, 10 VM fetuses were identified as presence of additional CNS abnormalities such as subdural hemorrhage, cerebellar hypoplasia, germinal matrix bleed, temporal lobe hemorrhage, aquductal steosis, hydrocephalaus, holoprosencephaly, dysgenesis of corpus callosum, hypoplasia of corpus callosum. To predict brain ages using MRI, we adopted our previous deep learning method that used a 2D single-channel convolutional neural network (CNN) (5). In each fetus, gestational week (GW) was subtracted from predicted fetal brain age to obtain the PAD and AAD. The PAD and AAD were statistically analyzed by analysis of covariance (ANCOVA) and Quade's nonparametric rank ANCOVA, respectively. GW and fetal sex were included as covariates. We performed two comparisons of the PAD and AAD: between TD and VM fetuses, and between VM fetuses with presence and absence of additional CNS abnormalities. Results: Fetuses with VM showed significantly higher PAD than TD fetuses (Table 1). The AAD in VM fetuses was also significantly larger than TD fetuses. Significantly larger AAD were found in VM fetuses with additional CNS abnormalities than ones without additional CNS abnormalities (Table 2). Discussion: Significantly larger PAD and AAD in VM fetuses compared to TD fetuses may be associated with their cortical overgrowth and large ventricular volume (6). These results are also supported by our previous study that showed significant contribution of ventricles and cortex to the prediction of fetal brain age (5). To the best of our knowledge, this is the first study to reveal higher AAD in VM fetuses with additional CNS abnormalities. Our findings demonstrated that the discrepancy between GW and brain age can be a biomarker for identification of atypical brain development and CNS abnormalities in early fetuses with VM.

1-C-32 Differences in infant functional network controllability in infants with high-likelihood for autism spectrum disorder in the first year of life

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Autism spectrum disorder (ASD) is a neurodevelopmental disorder that affects 2.3 in every one hundred children and is associated with significant social and communication challenges. However, less is known about the functional architecture of the brain in infancy and how trajectories of brain development in early life may underlie the onset of ASD. Here, we applied controllability analysis to functional connectivity of 70 infants with high or low likelihood for ASD. All participants were divided into high-likelihood (n=37) and low-likelihood (n=33) groups based on having a sibling with ASD, and scanned at 1 month and 9 months old during resting state and native-language listening sessions. Standard preprocessing was performed and functional connectivity matrices were created to study the controllability of each brain region. We employed two measurements: the average controllability (AC) to measure its ability to drive nearby brain state transition and the modal controllability (MC) to measure its ability to drive distant brain state transition. Infants with higher whole-brain average controllability also had higher modal controllability (Spearman correlation: r=0.574, p<e-16), suggesting that brain networks that support nearby brain state transitions also support those transitions at longer distances. On the whole-brain level, both average and modal controllability during the language-listening task (AC mean =1.1118; MC mean = 0.9773) were significantly higher than those during the resting state (AC mean = 1.0987; MC mean = 0.9142), which supports that the language task is more demanding for the brain than resting. On the network level, average controllability and modal controllability for 1-month-old infants showed no significant difference between the high-likelihood and low-likelihood groups. For 9-month-olds, the average controllability of the temporal lobe

for the low-likelihood group was significantly higher than that of the high-likelihood group (P = 0.026, t = 2.284); the modal controllability of the motor network for the low-likelihood group is significantly lower than that of the high-likelihood group (P = 0.045, t = -2.058). In sum, we implemented network control theory to analyze infant functional connectivity in a sample with high and low-likelihood for ASD, quantified controllability under different task circumstances, and across the first year of life. Our results suggest that regional controllability differences between high- and low-likelihood infants were found in regions previous implicated in ASD (e.g., temporal lobe and motor network).

1-C-33 Big-data era tools to unveil the development of brain surrogates of emotion dysregulation

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Foundational emotion regulation skills emerge early on in life and their development continues across childhood and adolescence. Emotion dysregulation is a transdiagnostic risk factor for neurodevelopmental disorders and is associated with poor quality of life. Identifying the neural circuitry supporting emotion regulation can lead to a better understanding of the development of this core skill, individual differences, and opportunities for intervention to support acquisition of effective emotion regulation skills. Emotion regulation is supported by multiple brain regions and networks, although findings in animal models and human data have frequently identified connections between the amygdala and medial and lateral prefrontal cortex. However research linking brain connectivity with emotion regulation are dominated by small effects leading to a plethora of conflicting findings. In this study we used a whole brain approach to identify the brain areas associated with emotion regulation. We used a Genetic-Wide Association-like approach where global effects are considered together. It requires a large discovery sample to model the association between brain areas and the score of interest. Resulting models are used to predict scores in an independent sample. For the discovery sample, we used high-quality data from the ABCD study, a multi-site longitudinal study of development (N~12,000,9-10 yo) with neuroimaging and clinical domain data. We also include data from 65 infants from a longitudinal study conducted at UC Irvine. MRI data was processed using surface-based registration and stringent quality checks were used to exclude low-quality data. Brain areas were delineated using the Gordon parcellation schema (352 brain areas grouped into 14 functional networks) and functional connectivity maps from the left and right amygdala regions were calculated for each participant. Emotion dysregulation was parameterized for each ABCD participant at baseline using the parent report measure of the Childhood Behavior Checklist (CBCL). The CBCL queries the child's parents about the child's behavior in the past 6 months. Emotion dysregulation was calculated based on the sum of the CBCL Attention Problems, Aggressive Behavior, and Anxious-Depressed t-scores. Emotion regulation was calculated in UCI infants based on behavioral coding of latency to distress during the still-face episode of the Still-Face paradigm, administered when infants were 6-months-old. In the ABCD dataset, scores of emotion dysregulation were predicted significantly using data from the left amygdala but not the right amygdala. Connectivity between the left amygdala and brain areas located in the frontal-parietal, ventral- and dorsal-attention network predicted scores of emotion dysregulation using hold-out cross-validation. The same brain features also significantly predicted scores of emotion dysregulation in the independent infant sample. Interestingly only in the infant sample, brain areas located in the retrosplenial network increased predictive power. Analyses at a higher spatial resolution (92,000 voxels/vertices) led to similar results. Our findings highlight the relevance of fronto-parietal and attention systems in regulation of emotion and suggest a potential transition from retrosplenial areas to more frontal areas from infancy to pre-adolescence. This work highlights the potential utility of novel neuroimaging analytic approaches to address the crisis in reproducibility.

1-C-35 A spatio-temporal atlas of the foetal brain with agenesis of the corpus callosum

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Objective: Magnetic Resonance Imaging (MRI) atlases provide reference brain templates to model the evolution of the foetal brain during pregnancy. With one exception focusing on brains with spina bifida aperta [4], such atlases have targeted healthy brain development. Here, we focus on prenatally diagnosed corpus callosum agenesis (CCA). Because of its variable postnatal prognosis, CCA represents a challenging situation during prenatal counselling, especially when there is no apparent associated lesion [2]. Our aim is to estimate a representative trajectory of the prenatal structural development of brains with CCA. To enforce consistency between different gestational ages, we develop a method based on geodesic regression and compare it to classic kernel regression. Methods: 84 T2-weighted MRIs of foetuses with partial or complete CCA were acquired between 25-37 gestational weeks (GW) and volume-reconstructed in the standard anatomical planes [3]. Atlas construction was performed between 27-35 GW using Deformetrica software [1] which is based on the Large Deformation Diffeomorphic Metric Mapping framework [5]. Geodesic regression, the generalisation of linear regression to shapes, estimates a template that is representative of the population anatomy at a given age, along with the diffeomorphism that transforms this average brain as time evolves. We compared two atlas estimation methods: 1-Kernel regression: at each gestational age, a template was estimated using diffeomorphic atlas estimation. The contribution of each subject was kernel-weighted. 2-Global geodesic regression of all subjects Visual comparison of the atlases was performed by a radiologist. Results: Compared to kernel regression, the atlas obtained through geodesic regression led to less noisy images. At early stages of development, geodesic regression allowed better delineation of cerebral structures (including deep grey nuclei and the ventricles). At later stages though, geodesic regression tended to smooth out some of the inter-individual variability, particularly in cortical regions with a strong attenuation of gyrification. Conclusion: Relying on a large dataset of foetal MRIs, we built a continuous spatio-temporal atlas of foetal brains with CCA. We compared different methods for atlas construction, including less-used geodesic regression. Its usability in a pathological context opens up new perspectives, such as the identification of deformations characterizing high-risk subjects, in line with [6]. References: [1] Bône, A. et al. (2018). Deformetrica 4: An open-source software for statistical shape analysis. [2] DAntonio, F. et al. (2016). Outcomes associated with isolated agenesis of the corpus callosum: A meta-analysis. PEDIATRICS. [3] Ebner, M. et al. (2020). An automated framework for localization, segmentation and super-resolution reconstruction of fetal brain mri. NeuroImage. [4] Fidon, L.

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1-C-37 Function precedes structure in the fetal brain in the second to third trimester.

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Introduction Brain structural connections form the anatomical backbone that are thought to underlie patterns of functional activity, but there is an ongoing debate about whether functional activity also facilitates the development of these structural connections in early life. We used in utero functional and diffusion MRI from the developing Human Connectome Project (dHCP) to characterise whole-brain connectomes and calculated the correlations between structural and functional connectivity across the second to third trimester. To understand if the development of structural connectivity precedes functional organisation (or vice versa), we compared three different scenarios (A) Structure vs. Function + 1 week, (B) Age-matched Structure vs. Function, (C) Function vs. Structure + 1 week. Objective To explore whether there is any directionality in the development of structure-function coupling in the fetal brain across the second half of human gestation. Methods Fetal fMRI and multi-shell diffusion MRI data were acquired on a Philips Achieva 3T system with a 32-channel cardiac coil[1]. Data was pre-processed using a bespoke pipeline that included dynamic distortion correction and slice-to-volume motion correction[2,3]. Fibre orientation density functions (ODFs) were estimated in 180 fetal subjects using MRtrix3 multi-shell multi-tissue constrained spherical deconvolution(4). Individual subject ODFs were then compiled into weekly templates and probabilistic streamline tractography was used to reconstruct whole brain tractograms of 100 million fibres in each weekly template, followed by Spherical-deconvolution Informed Filtering of Tractograms (5). The brain was then parcellated into 50 regions using independent component analysis to identify areas that functionally co-mature. A functional connectome was defined in each subject by calculating the pairwise partial correlation between regions. The mean functional connectome for each gestational week was calculated by averaging age-matched subjects. The structural connectome was defined by calculating the connectivity density (sifted streamlines) between regions in each gestational week. Structure-function coupling for each node was calculated by correlating the structural and functional connectivity matrices for three different scenarios (Fig 1). The upper quartile of each matrix was used to test the null hypothesis that there was no significant difference between the structure-function coupling in conditions A, B and C. Results Across gestational age, there was a higher correlation between structural and functional topology when comparing structure to the functional connectivity of the previous gestational week (condition C). Two-sample t-tests (100,000 permutations) returned a significant difference between structure-function coupling in (A) and (C) ($p = 0.00004$), (B) and (C) ($p = 0.017$), but not between (A) and (B) (Fig 2). Conclusion Our results suggest there is more similarity between structural and functional connectivity profiles when structure and function are offset by one week, with functional preceding structural. We identified significant age-related trends in individual node structure-function coupling, that showed linear increases with age in certain brain regions. References 1. Hutter, J. et al. MagnReson, 2018 2. Christiaens, D. et al. Neuroimage, 2021 3. Cordero-Grande, L. et al. Neuroimage, 2019 4. Tournier, J. D. et al. NeuroImage, 2019 5. Smith, R. et al. NeuroImage, 2015

1-C-38 Development of functional gradients in the lateral motor network of the fetal brain across the third trimester of human gestation

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Background A fundamental feature of functional connectivity in the adult brain is topographic organisation of connectopic gradients. During the third trimester of human gestation however, the fetal brain is undergoing rapid structural and functional development which lay the foundation for the brain's life-long connectivity framework. Therefore, whether connectopic gradients are present or are developing during the fetal period is unclear. Objective To characterise the development of functional connectivity within an exemplar resting state network (the motor network) throughout the third trimester of gestation. Methods Fetal fMRI data were collected in 142 fetuses (25.0-37.8 weeks gestational age, GW, mean: 31.6 GW) as part of the Developing Human Connectome Project (dHCP). Data were acquired with a Philips Achieva 3T scanner and a 32-channel cardiac coil using a multiband (MB3) EPI sequence with 2.2mm isotropic resolution. fMRI data were pre-processed using a state-of-the-art pre-processing pipeline specific to the dHCP, including MB-SENSE image reconstruction, slice-to-volume motion correction and temporal denoising. The spatial organisation of voxel-wise functional connectivity within the lateral motor resting state network (defined in an independent sample of neonates 1) with cortical grey matter was mapped in the fetal brain using the Congrads toolbox (2). Connectopic mapping was performed in each hemisphere independently and in groups corresponding to each of the gestational weeks. A cubic trend surface model was fitted to the connectopic gradients to obtain nine coefficients summarising the spatial statistics of the gradient in the x, y and z directions (3). The spatial statistic coefficients were then correlated with gestational age using a post-hoc Pearson correlation test. Results Connectopic mapping of the lateral motor network in the fetal brain revealed a principal superior-inferior gradient of functional connectivity that was consistent across each gestational week (Fig. 1A). A cubic trend surface model explained >80% (mean 89.4%, range 83.8% - 95%) of the variance of the principal connectopic gradient in each gestational week (Fig. 1B). The y and z quadratic trend surface models in the left hemisphere significantly correlated with gestational age ($r=-0.8245$ and $r=-0.8398$ respectively). Conclusion We demonstrate that a gradient organisation of functional connectivity is already present in the lateral motor area in the fetal brain, and that features of this change with increasing gestational age from 25 to 37GW. This is concurrent with known rapid increases in structural connectivity within the fetal brain. The principal connectopic gradient identified here in the fetal lateral motor area is reminiscent of the superior-inferior connectopic gradient in the adult motor area which reflects somatotopy. This suggests the motor area already shows mature characteristics early during development. Here we chose to study the motor areas as in term age neonates they are highly connected hub regions, whilst conversely

in adults, higher information processing areas are the most densely connected hub regions. Therefore, further work will characterise connectopic gradients in other regions of the fetal brain which may show different developmental trajectories during gestation. References 1. Eyre et al. (2021) Brain, 7:2199-2213 2. Haak et al. (2018) NeuroImage, 170:83-94 3. Oldehinkel et al. (2022) eLife, 11:e71846

1-I-12 Infant brain connectivity and the relationship with prenatal maternal distress during the COVID-19 pandemic

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BACKGROUND AND AIM: The COVID-19 pandemic has elevated anxiety and depression symptoms, especially in pregnant individuals. This could have an effect upon the infant brain development in utero that may underlie early cognitive development. In this study, we aimed to understand the association between prenatal distress and infant limbic network microstructure and function at 3-months of age, as well as the potential protective role of social support in any relationships. METHODS: Patient Reported Outcomes Measurement Information System anxiety, Edinburgh Depression Scale and Social Support Effectiveness Questionnaire (SSEQ) measures were collected through online surveys from a population-based sample of pregnant individuals living in Canada through the Pregnancy during the COVID-19 Pandemic Study. In a sub-sample of participants, we acquired diffusion and functional MRI data in their infants (N=75) during natural sleep. Diffusion tractography was used to identify the uncinate fasiculus and the amygdala-prefrontal white matter tracts. The average amygdala functional connectivity map is shown in Figure 1A and was used to identify regions of interest, and functional connectivity was calculated for each participant. General linear models were used to examine the association between prenatal maternal distress and amygdala functional connectivity or microstructural (fractional anisotropy (FA) or mean diffusivity (MD)) measures, including postnatal distress, household income and infant sex covariate, and social support interaction terms. RESULTS: Survey participants demonstrated significantly higher rates of clinically relevant anxiety and depression symptoms. After removing any imaging datasets with excessive motion or inadequate data collection, we retained 58 participants (38M/20F, 92+/-14 days old). Prenatal maternal distress was significantly related to FA in the right uncinate fasciculus ($T = 2.7$, $p = 0.0009$) and MD in the right amygdala-prefrontal white matter tract ($T = -2.3$, $p = 0.02$). Prenatal maternal distress was significantly related to right amygdala-superior orbitofrontal cortex ($T = -2.9$, $p = 0.007$) and right amygdala-inferior frontal gyrus ($T = -3.1$, $p = 0.004$) functional connectivity. Importantly, functional connectivity relationships involved a significant interaction between social support and prenatal distress. In particular, pregnant individuals who reported lower quality social support (SSEQ < 60) had a significant negative correlation between prenatal distress and functional connectivity ($R > -0.5$, $p < 0.05$), and those who reported higher social support did not (Figure 1B and C). CONCLUSIONS: Here we observed an association between prenatal distress in pregnant individuals during the COVID-19 pandemic and infant brain structure and functional architecture. We also found for the first time that social support may act as a possible moderator between prenatal distress and early infant brain development, where infant amygdala functional connectivity and prenatal distress relationships were only present in pregnant individuals who reported relatively lower social support. These findings provide timely evidence to inform clinical policy surrounding the care of families and highlight the potential of social support to play a role in infant brain development.

1-I-15 Child Inhibitory Control in Toddlerhood: Associations with Child Interaction Quality and Preliminary Neural Structural Correlates

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Objective: Inhibitory control (IC) is a predictor of academic achievement and social-emotional development. IC develops rapidly in early childhood and is considered moderately stable from preschool-age onwards. Even though the significance of IC for later development has been widely reported, its role in early childhood interaction skills and its neural correlates in toddlerhood have not yet been studied. We explored the associations between child IC at 24 and 30 months and child interaction quality (responsiveness and involvement) with the mother at 30 months. We conducted a preliminary exploration of structural neural correlates of IC and child interaction quality in a subsample of children. Methods: We measured IC using the Snack Delay task and child interaction quality with the mother using the Emotional Availability Scales (EAS) at 30 months in a sample of N=350 toddlers from the FinnBrain Birth Cohort Study. In a subsample, IC was measured also at 24 months (N=27) and structural MRI scans were acquired at 18-24 months (N=9). VBM analysis at the threshold of $p < .05$ and FDR-corrected at alpha <.05 was performed to detect grey matter clusters associated with IC. Results: Better IC was positively related to better child interaction quality both cross-sectionally at 30 months (B=.12, p=.010) and longitudinally between 24 and 30 months (B=.14, p=.044). For IC at 24 months, the analysis revealed a cluster with less grey matter in the right calcarine sulcus ($p<.001$) and for IC at 30 months, clusters with more grey matter in the left cerebellum (p=.007), right middle frontal gyrus (p=.018) and right superior occipital gyrus (p=.037) were identified. Implications: These results suggest that better IC in toddlerhood is associated with better child interaction quality with the parent. They also give preliminary support for associations between IC and more grey matter in areas involved in frontoparietal network and visual processing. Replication studies are needed.

1-J-10 Early development of functional homotopic trajectories in Non-Human Primates.

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Study Objective Developmental changes in the brain occur rapidly during the early stages of life. Characterizing these changes can help us better understand typical development and areas where deviations could predispose later complications in life. Prior works studying networks using resting-state functional connectivity (RSFC) MRI have detected developmental shifts from childhood to adulthood, with networks changing from dispersed short-range connectivity to greater long-range, focal connectivity later in life (Fair et al. 2007)(Kelly et al. 2009). Interestingly, the degree of synchrony in BOLD activity between interhemispheric regions measured through homotopic

connectivity (HC) has also been shown to change with age (Zuo et al. 2010) and can be used to identify abnormalities in pathological conditions. However, these studies have predominantly been conducted in young children, missing a critical window of rapid early development. These early changes are harder to capture in human populations. Short interval, repeated acquisitions during infancy are generally not feasible in humans making early trajectory models challenging. Here, we utilize Non-human Primates (NHPs) to characterize homotopic connectivity changes from infancy (3-weeks of age) to juveniles age using a rapid succession (2-week intervals) acquisition protocol. Methods A total of three macaques (Female=2) underwent structural and resting-state functional MRI scans every 2-weeks for the first year of life and 4-weeks thereafter, starting at 3-weeks of age. Data were processed through the nhp-abcd-bids-pipeline [https://hub.docker.com/r/dcanumn/nhp-abcd-bids-pipeline (dsturge et al. 2019; Ramirez et al. 2020)], and HC was calculated between the left and right hemispheres. HC was projected across age to identify differences in connectivity strength throughout development. Brain regions were organized into 5 clusters based on homotopic connectivity trajectories to identify different developmental patterns. Results While prior findings in humans have shown that homotopic connectivity decrease with age when starting at 7-years of age (Zuo et al. 2010), we were able to show that homotopic connectivity first increases with age during early development before plateauing (Fig 1 A). Specifically, homotopic connectivity development initially increased, reaching peak strength at different ages depending on the region (Fig1 B). Primary networks (Cluster 5) showed stronger homotopic connectivity, which developed earlier and faster, reaching a peak around 40 weeks of age (Fig 1C). Conclusion Using an NHP model allowed us to capture early developmental changes during infancy and to detect patterns of change that occur at much shorter intervals than are typically collected in human samples. Identifying the age at which homotopic connectivity plateaus for different regions could give us insight into early developmental processes and aid in our understanding of how differences in these time points could relate to subsequent developmental disorders.

1-J-16 Functional interactions during consolidation of memories in newborns

Silvia Benavides-Varela[1], Roma Siugzdaite[2]

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Introduction and Aim The capacity to memorize speech sounds is crucial for language acquisition. Only a few days after birth human infants can recognize the sound of one word, even if interleaved with other word sounds during encoding [1]. However, newborns do not recognize a previously learned word when interfering information is presented immediately after encoding, i.e. in the retention interval between the encoding and the recognition test [2]. At least two proposals can explain this retroactive interference phenomenon in the first stages of development: A. a storage-based hypothesis, which presupposes a failure in recognition due to limitations in the number of items that can be stored, or B. a consolidation-based hypothesis, which assumes that newborns form weaker memory traces short after learning. The aim of the present study was to evaluate the second hypothesis. Methods Forty healthy full-term newborns (13 males; mean age: 2.8 days, range: 2-5 days) were tested on their ability to recognize the sound of a word after an interfering word. The structure of the experiment consisted of an encoding phase and a test phase separated by a retention interval of 4 minutes that comprised two minutes of silence followed by two minutes of auditory stimulation (interference). During the test phase, brain hemodynamic responses to the familiarized word (Same-word condition) and a completely novel word sound (Novel-word condition) were assessed. Hemodynamic responses were measured with functional near-infrared spectroscopy (fNIRS; ETG-4000, Hitachi) over 24 channels grouped on 6 regions of interest (ROIs) on the frontal, temporal, and parietal areas of both hemispheres [see also 1,3 for a similar approach]. Effective connectivity analysis among the areas of interest was performed with structural equation modeling. Differences between the models were assessed using the "stacked model" approach [4]. Results and Conclusions Permutation tests showed significant differences between conditions (same word vs. novel word) in the first block of the test phase ($p = 0.006$, Bonferroni-corrected). In agreement with previous studies on newborn's recognition memory [2,3], there were relatively stronger hemodynamic responses to the novel than to the familiar sounds. The differences were evident in the right-frontal region, which showed the strongest effective connections with the parietal areas bilaterally. The parietal cortex is implicated in the process of consolidation and long-term retrieval of memories in human adults and non-human animals [5-6]. The findings support the hypothesis that short silent resting periods are effective to consolidate newborns' fragile memories, turning them resistant to interference. References 1. Benavides-Varela, et al. (2017). PNAS, 201617589. 2. Benavides-Varela, et al., (2011). PLoS One, 6(11), e27497. 3. Benavides-Varela, S., et al. (2017). PNAS, 109(44), 17908-17913. 4. Mclntosh & Gonzalez-Lima, F. (1994). Human brain mapping, 2(1-2), 2-22. 5. Brodt, et al. (2018). Science, 362(6418), 1045-1048. 6. Sestieri, et al. (2017). Nature Reviews Neuroscience, 18(3), 183-192.

POSTER SESSION 2
TUESDAY, SEPTEMBER 6 1:45–3:15PM

2-C-41 Lateralization of major white matter tracts from 0-6 months is time-varying and tract-specific

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Objective: Mapping asymmetries within the brain is key to our understanding of typical brain development. Lateralization patterns are a major structural feature of brain white matter and have been investigated as a neural architecture that is indicative of and supports the specialization of cognitive processing and observed behaviors, e.g., language skills. Moreover, multiple neurodevelopmental disorders and disabilities, including autism spectrum disorder, attention hyperactive deficit disorder, dyslexia, and schizophrenia, have been associated with atypical lateralization, reinforcing the need for careful measurement and study of this structural feature. Unfortunately, there is little consensus on the direction and magnitude of lateralization in major white matter tracts during the first years, or even months, of life - the period of most rapid brain growth and cognitive maturation. Different studies report rightward, leftward, or no asymmetry within the same tract. In addition, no studies have examined white matter lateralization in a longitudinal sample - preventing confirmation of if and how white matter lateralization may change over time. Methods: Diffusion MRI data were collected at up to 3 time points between birth and 6 months in N=78 typically developing infants (31f, 47m). Template-based probabilistic tractography delineated

left and right masks for whole brain white matter and 9 major white matter tracts: the arcuate fasciculus (AF), anterior thalamic radiation (ATR), cingulum (Ci), fornix (Fx), inferior fronto-occipital fasciculus (IFOF), inferior longitudinal fasciculus (ILF), pyramidal tracts from the motor (PT-M1) and sensorimotor cortices (PT-S1), and the uncinate fasciculus (UF). Fractional anisotropy was the primary diffusion metric used to assess lateralization. Trajectories were fit using Functional Principal Components Analysis. Left-right bias was quantified using a lateralization index (Dubois et al. 2016) and developmental windows of significant difference were determined by bootstrapped, simultaneous 95% confidence bands. Results: 7 of 9 tracts lateralize before 6 months. Patterns of lateralization are time-varying and tract-specific, with the UF and Ci showing no lateralization, the AF, ATR, and Fx, changing between lateralized and not lateralized, and the IFOF, ILF, PT-M1, and PT-S1 showing constant lateralization. In 8 of 9 tracts, the rate of lateralization is constant, only the fornix shows a nonlinear pattern with an acceleration from 4-5 months. Whole brain white matter was constantly lateralized with a rightward bias. Conclusions: Using a densely sampled longitudinal dataset from typically developing infants aged 0-6 months, we map trajectories of structural lateralization in 9 major white matter tracts to 1) determine whether lateralization is a time-varying process and 2) bring consensus to cross-sectional findings within the current literature. Our study is the first to provide longitudinal evidence that white matter lateralization is time-varying in a tract-specific manner. Our results also indicate that differences between existing lateralization studies may stem from the use of cross-sectional designs, which mask the dynamic nature of lateralization through development. Ultimately, this study provides a reference point for typical white matter lateralization during the first 6 postnatal months, an early and critical window of postnatal neural development.

2-E-44 Striatal development in the neonatal period: Using brain tissue iron to probe prenatal and postnatal development

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During the prenatal period there is unique and significant brain maturation, with genetic and environmental influences, setting up a template that will later be refined, influencing trajectories. Striatal regions, involved in cognitive and motor function and later reward processing, are vulnerable to prenatal stressors but remain a critical and understudied portion of early development. A window into neonatal striatal development is through striatal physiology, measuring brain tissue iron that accrues primarily in the basal ganglia. Iron plays an important role in development, including in myelination, energy metabolism, and as a critical step for dopamine synthesis, where PET [11C]dihydrotetrabenazine, a marker of presynaptic dopamine, is related to striatal brain iron in adolescence. Limited work has characterized striatal brain iron in infancy, only finding age-related change after 3 months. However, previous work had small samples and failed to separate gestational and postnatal age. Here, we leverage T2* from MRI resting state scans, which provide a measure of brain tissue iron, in data from the Developing Human Connectome Project (N=516, Modal PMA 40 weeks). Results showed that when including gestational and postnatal age as independent terms in linear models, strong postnatal increases in tissue iron were found for the ventral striatum, putamen, and pallidum but not the caudate. Interestingly, gestational age was only related to deposition in the ventral striatum, where decreases in signal were associated with greater gestational age. To identify changes that aren't specific to regional definitions from atlases and find patterns that are robust to shifts in regional organization, we use a voxel-wise approach, where support-vector regression predicts which voxels are changing with age. For the first time in neonates, we demonstrate significant gestational and postnatal change in striatal iron. The postnatal increases, for the ventral striatum, putamen, and pallidum, that are absent in the caudate, could reflect early motor and reward development in the first weeks of life. It is possible that the cognitive function often associated with the caudate causes later postnatal change as these systems gradually develop. The tissue iron measurement used here is relative to the development of the rest of the brain. Therefore, it's possible that the age-related decreases observed for gestational age in the ventral striatum could represent stable development in the context of brain wide maturation. The multivariate approach used here provides specificity and characterizes the gradients of developmental change, better mapping future trajectories critical for understanding normative development.

2-F-40 Early Parenting Intervention Effects on Amygdala Volume in Infants Exposed to Opioids In-utero: A Randomized Clinical Trial

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Prenatal exposure to opioids results in morphometric changes in the brain, including reduced amygdala volume postnatally. Prior research suggests that sensitive caregiving can buffer the negative impacts of prenatal opioid exposure, perhaps through effects on brain development. We examined the causal effect of an early attachment-based parenting program that promotes sensitive caregiving (modified Attachment and Biobehavioral Catch-up; mABC) on amygdalae volume in a group of infants exposed to opioids in utero. Participants included 18 infants whose mothers had been randomly assigned to participate either in the mABC (N = 10, M/SD ages at time of MRI scan= 7.33/1.31 months, M/SD of number of parenting program sessions: 8.9/2.51), or a control parenting intervention (N = 8, M/SD ages at time of MRI scan = 7.2/.96 months; M/SD of number of parenting program sessions: 6.25/4.5). Both interventions include a session during the third trimester, and 11 sessions post birth. Infants underwent T1-weighted structural MRI scans as the mother-infant dyads continued to receive the parenting program. Infant FreeSurfer was used to process the MRI data. Covariates of no interest, but included in the analysis, included age, sex, number of sessions completed, and total brain volume. We found significant intervention differences in right amygdala volume ($t(12) = -2.837$; $p = .014$) and marginally significant intervention differences in left amygdala volume ($t(12) = -1.92$; $p = .079$), such that infants who had received the mABC intervention had larger amygdalae than infants who had received the control intervention. Considering that opioid exposure leads to reduced amygdala volume in untreated infants, these preliminary results of an ongoing study suggest that the mABC intervention may causally mitigate the negative effects of in-utero opioid exposure on structural amygdala development.

2-G-42 Exploring the association between fetal brain and placental T2* values in fetuses with congenital heart disease

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Background: Congenital heart disease (CHD) is common and associated with adverse developmental outcomes. The cardiovascular abnormalities associated with certain types of CHD may compromise cerebral oxygen delivery (Mebius 2019). This reduced cerebral oxygen delivery may be partly responsible for the abnormal brain development seen in fetuses with CHD, including reduced global brain volumes (Sun 2015), impaired regional brain growth (Paladini 2021), and delayed cortical development (Ortinau2019). Placental development is also affected by CHD (Schlatterer 2019; Andescavage 2020) and MRI studies have identified impaired placental function in CHD, with the level of impairment related to the underlying cardiac diagnosis (Steinweg 2021). Despite a growing acceptance that placental function and brain development in CHD are intimately linked, in-vivo assessments investigating these together are rare. MRI T2* relaxometry exploits the blood oxygen level dependent effect, linking a shorter T2*-value to higher concentrations of deoxygenated haemoglobin, thus serving as a proxy for tissue oxygenation. While a decrease in both placental and fetal brain T2* values (Hutter 2019; Vasylechko 2015) over gestation have been established in normal pregnancies, these relationships haven't been explored in the context of CHD. Objective: To explore the association between fetal brain and placental T2* values in pregnancies affected by CHD, compared to healthy controls. Methods: Data from 23 pregnant women with a fetus affected by CHD and 15 healthy controls were acquired on a 1.5T MRI scanner, using a multi-echo gradient-echo sequence (2.5mm3 isotropic resolution, 5 echoes). All imaging was performed after 30 weeks gestational age (GA). T2* maps were obtained using monoexponential fitting and the placenta and fetal brain were manually segmented (Fig. 1a) to calculate mean T2* values for these regions. Analysis of Covariance was performed, comparing mean placental and mean fetal brain T2* values and placental:brain T2* ratios, between CHD and controls, accounting for GA at scan. Results: We identified a significant difference in fetal brain T2* over gestation in CHD compared to controls ($F(1,35)=6.99$, $p=0.012$) (Fig. 1b), but no significant difference in placental T2* (Fig. 1c) or placental:brain T2* ratio (Fig. 1d) between the two groups. Fetal brain T2* decreased significantly over GA in the control cohort ($R2=-0.541$, $p<0.01$). Conclusions: We identified significantly reduced fetal brain T2* values in fetuses with CHD compared to controls, suggesting impaired cerebral oxygenation in-utero in CHD fetuses. The lack of a significant relationship in placental T2* values between the two groups may be due to the limited range of GAs included and because CHD is not an homogenous condition, with only certain subtypes being associated with functional placental impairment. This can be explored in future work. This work hints at the mechanisms behind the adverse developmental outcomes that are seen in CHD.

2-G-46 Altered thalamocortical connectivity in newborns after fetal surgical correction of spina bifida: weak link to neurodevelopmental outcomes

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Spina bifida (SB) is a congenital disorder identified by the protrusion of spinal cord and meninges through a spinal defect, characterized by the heterogeneity of neurodevelopmental outcomes. Our first aim was to determine whether the two main forms of open spina bifida, myelomeningocele (MMC) and myeloschisis (MS) show differences in the development of thalamocortical connectivity (TC) development. Our second aim was to reveal possible associations between the TC and cognitive, language and motor abilities of these individuals at two years Our initial dataset was 64 newborns, who underwent fetal surgical repair for SB (n=43/21 MMC/MS), and included 44 subjects who had both newborn MRI examinations (gestational age (GA) at MRI: 37.0-44.7 weeks) and 2-year neurodevelopmental assessment scores (Bayley III Scales of Infant and Toddler Development) in our study. Neonatal MRI was acquired on a 3.0T scanner using structural and diffusion tensor imaging sequences (DTI). DTI was carried out with an echo-planar imaging sequence with 35 diffusion encoding directions. Slice-to-volume reconstruction and eddy correction was carried out. A custom spina bifida MRI template and region-of-interest (ROI) system was created. Lateral ventricle volumes were measured after manual annotation to quantify the degree of hydrocephalus. To characterize TC, we performed probabilistic diffusion tractography. All target cortical parcellations and seed thalamus masks were transformed to custom SB template space using ANTs after the estimation of fiber orientations using BedpostX in FSL. TC was characterized as the proportion of thalamocortical (TC) fibers reaching the frontal, parietal, occipital and temporal lobes for the voxel-wise tests, and as volumes of these TC subdivisions after connectivity-based clustering. We tested group effects (MS vs. MMC) with univariate ANOVA and correlation of TC with neurodevelopmental scores with multivariate linear regression using the randomise tool with TFCE correction in FSL. Ventricular volume and gestational age at birth were not different between the MMC and MS. We found no group differences in the TC connectivity between MMC and MS subtypes. We found a significant, weak, positive correlation between the 2-year language composite score and left thalamo-temporal connectivity (minimum $p=0.04$). Gross and composite motor scores were correlated with the volume of the thalamo-occipital connectivity cluster in models including GA at birth, GA at MRI and ventricle volumes (Table 1 and Table 2). We have shown that in SB, the 2-year language abilities are weakly correlated with altered thalamo-temporal connectivity development. 2-years motor abilities correlated with thalamo-occiptal connectivity development. These results provide indirect, initial evidence that developmental outcomes may not only be induced by concomitant hydrocephalus but may be associated with the TC structural changes seen in SB.

2-G-47 Altered development of excitation-inhibition balance, as quantified from fMRI using the Hurst Exponent, in medial prefrontal cortex in young children with autism spectrum disorders

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Atypical balance of excitation (E) and inhibition (I) in the brain is thought to contribute to the emergence and symptomatology of autism spectrum disorders (ASD). The E/I ratio can be estimated from resting state functional magnetic resonance imaging (fMRI) using the Hurst Exponent (HE). A recent study (Trakoshis et al. 2021) reported decreased ventromedial prefrontal cortex (vmPFC) HE in male, but not female, adults with ASD compared to typical controls. As part of the default mode network (DMN), vmPFC plays an important role in

emotion regulation, decision making, and social cognition. It has frequently been reported to show altered function and connectivity in children, adolescents, and adults with ASD. The current study aims to extend previous findings and presents the first fMRI evidence of altered early development of vmPFC HE and its link to DMN functional connectivity (FC) and emotional control in a cohort of toddlers and preschoolers with ASD. 45 children with ASD (n=32 male) and 38 typically developing (TD) children (n=21 male), ages 15-65 months, underwent natural sleep fMRI as well as comprehensive diagnostic and developmental assessments as part of a longitudinal study on brain development. In a cross-sectional analysis, vmPFC HE decreased with age in children with ASD, reflecting increasing E/I ratio, but not in TD children (group-by-age interaction: F(1,76)=5.1, p=.027; ANCOVA controlling for in-scanner head motion). This effect remained significant when additionally controlling for gestational age at birth, socioeconomic status, or ethnicity. The same pattern was also observed in the subset of children with longitudinal fMRI acquisitions (n=21; average time between scans 23 months), with vmPFC HE decreasing in children with ASD but increasing in the TD group. Lower vmPFC HE was further associated with reduced FC within the DMN as well as with reduced emotional control (as measured with the Preschool BRIEF Emotional Control scale). These results suggest an early onset of E/I imbalances in vmPFC in ASD with likely consequences for the maturation of the DMN and neurodevelopmental outcome.

2-G-49 Relating neonatal neural responses from stimulus-evoked functional MRI to behavioral inhibition at 12 months: a pilot study

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Behavioral inhibition (BI) is a pattern of behavior in young children characterized by avoidance of unfamiliar situations and people that signals risk for subsequent anxiety disorders. It is believed to result from enhanced neural reactivity to novel sensory stimuli in infancy, however the specific neural bases remain unclear. OBJECTIVE: We conducted a pilot study to identify differences in newborn neural responses to deviant auditory stimuli that are associated with observational measures of BI at 12 months of age. METHODS: Using an auditory oddball paradigm entailing random presentations of white-noise bursts, neural responses to these deviant sounds were recorded in 45 sleeping neonates (mean age 28 days) with functional MRI. Blood-oxygenation-level-dependent (BOLD) responses to auditory deviants were modeled with separate finite impulse response regressors for 40 frames (32 sec) following stimulus onset. Using an established observational assessment of BI involving exposure to novel stimuli and people, BI measures were collected for 27 of these children one year later (mean age 13 months). These measures were used to generate regions of interest (ROIs) demonstrating a significant interaction between framewise neonatal neural response to auditory deviants and 12-month BI scores. To achieve a whole-brain cluster-wise error rate of p<.01, we identified ROIs using a voxelwise significance threshold of p<.001 (z=3.3) and minimum cluster size of 28 adjacent (NN=1) voxels. RESULTS: The analysis produced 45 ROIs (Figure 1), including 21 prefrontal ROIs that fell predominantly within default or frontoparietal networks according to adult parcellation schemes. Multiple ROIs in the parahippocampal gyrus and cerebellum were also identified. The relationship between neonatal auditory oddball responses and subsequent BI scores in these ROIs depended on response timing as well as magnitude. BOLD responses in default and frontoparietal ROIs were positively associated with BI in the initial 8 to 16 seconds after stimulus presentation and/or negatively associated with BI at longer latencies, whereas responses in parahippocampal and cerebellar ROIs exhibited the opposite pattern. CONCLUSIONS: The results of this pilot study highlight the timing of neonatal neural responses to deviant auditory stimuli in specific prefrontal, parahippocampal, and subcortical regions as candidate neural markers that may precede the development of BI. Future studies applying these techniques in larger samples will be needed to determine whether the neonatal stimulus responses described here are indeed neural precursors of behavioral inhibition.

2-G-50 Gray Matter Volume in the Language Network and Vocabulary Size of Toddlers Born Preterm

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Preterm birth has been associated with risk for long-term language impairment, which may be explained by an interruption of typical in-utero language network development. Research with infants demonstrates that the brain's language networks, including the bilateral inferior frontal gyrus (IFG) and superior temporal gyrus (STG), are altered in infants born preterm compared to full-term. The current set of analyses focused on toddlerhood, a key period of early language development, to investigate the relationship between gray matter volume in the language network, prematurity, and vocabulary size. These results are part of a larger study focused on toddler brain and cognitive development following preterm birth. The first analysis focused on parent-reported vocabulary size from toddlers born very or extremely preterm (n =16; adjusted age M =20.40 months; SD = 5.19 months; gestational weeks at birth: M = 26.13; SD = 2.42), including English monolinguals (n = 8), Spanish monolinguals (n = 2), and Spanish-English bilinguals (n =6). Parents completed the MacArthur-Bates Communicative Development Inventory Short Form in English and/or Spanish and composite scores were calculated for bilingual children. Results indicated that, on average, the preterm toddlers understood 59.50 words (SD = 26.20) and produced 20.44 words (SD = 5.80). Based on their term-corrected ages and genders, these vocabulary sizes reflect scores in the bottom 25th percentile, with large variability (SD = 29 percentile points). Next, we compared gray matter volume in the language network from a subset of the preterm toddlers with MRI data (n = 9) to an age-matched sample of toddlers born full-term (n = 8). We processed their T1- and T2-weighted images using the Infant Brain Extraction and Analysis Toolbox (iBEAT V2.0 Cloud), resulting in segmented gray and white matter. We then applied an age-appropriate atlas [8] and extracted gray matter volume from the bilateral IFG (pars opercularis and pars triangularis) and the bilateral STG. Results indicated that, when controlling for total gray matter volume, preterm toddlers had smaller bilateral IFGs only in the pars triangularis region (left: t = 3.13, p = 0.007, Cohen's d = 1.75; right: t = 4.61, p < 0.001, Cohen's d = 2.59). Similar results were observed in the left STG (t = 3.00, p = 0.01, Cohen's d = 3.00). Finally, we examined the relationship between vocabulary size and gray matter volume in the bilateral IFG and STG within the preterm sample. Results indicated that receptive vocabulary size was related to gray matter volume only in the left STG, while controlling for total gray matter volume and gestational age at birth (b -1.14, partial r = -0.96, p =0 0.02). These results reveal language delays and reduced gray matter volume in the left STG and

bilateral pars triangularis for preterm toddlers, and highlight the left STG as a region that may explain some of their language delays. Future research is needed to understand how these relationships unfold across the first few years of life and whether high-quality language environments support early brain development for children born preterm.

2-G-64 Hypoconnectivity between anterior insula and amygdala associates with future vulnerabilities in social development in a neurodiverse sample of neonates

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Altered resting state functional connectivity (FC) involving the anterior insula (aINS), a key node in the salience network, has been reported consistently in autism. Here we examined, FC between the aINS and the whole brain in a sample of full-term, postmenstrual age (PMA) matched neonates (mean 44.0 weeks, SD=1.5) who due to family history have high likelihood (HL) for developing autism (n=12) and in controls (n=41) without family history of autism (low likelihood, LL). Behaviors associated with autism were evaluated between 12 and 18 months (M=17.3 months, SD=2.5) in a subsample (25/53) of participants using the First Year Inventory (FYI). Compared to LL controls, HL neonates showed hypoconnectivity between left aINS and left amygdala. Lower connectivity between the two nodes was associated with higher FYI risk scores in the social domain (r(23) = -.561, p=.003) and this association remained robust when maternal mental health factors were considered. Considering that a subsample of LL participants (n=14/41) underwent fMRI during the fetal period at PMA 31 and 34 weeks, in an exploratory analysis, we evaluated prospectively development of the left aINS-left amygdala connectivity and found that the two areas strongly coactivate throughout the third trimester of pregnancy. The study identifies left lateralized anterior insula - amygdala connectivity as a potential target of further investigation into neural circuitry that enhances likelihood of future onset of social behaviors associated with autism during neonatal and potentially prenatal periods.

2-H-45 Characterisation of fetal to neonatal brain growth asymmetries using deformation-based morphometry

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Objective Interhemispheric asymmetries have been shown to develop during prenatal brain development. We aimed to capture interhemispheric asymmetry changes during the critical perinatal period in normally developing subjects and used different registration toolboxes to explore the reproducibility of our results. Methods and Materials Our longitudinal dataset included 17 normally developing subjects. T2-weighted MRI was acquired in two time points: fetal (gestational week (GW) = 32.5 +-SD 1.0) and neonatal (GW = 41.7 +-SD 1.6). A slice-to-volume reconstruction algorithm was used (1) to create 3D T2 super-resolution images. For each subject, the fetal image was registered to the neonatal image using serial rigid, affine and non-linear registration. Multiple registration toolboxes were tested for non-linear registration: NIFTIREG (2), Elastix (3) and ANTs (4). The logarithmic Jacobean determinant (JD) was computed with each toolbox. All JD were then registered to a symmetrical template of a 42. GW newborn, masked and smoothed. The change of interhemispheric asymmetry was determined by testing the hemispheric differences in the JD map. JD maps were flipped and rigidly aligned to the template. We tested group effects between the "not-flipped" and "flipped" using FSL randomise with TFCE correction. The model included age at fetal scan (GW) and time between the two scans (weeks) as covariates. We evaluated our results across the registration algorithms. Results Asymmetric growth was found using the ANTs SyN registration with mutual information (MI) and cross-correlation (CC) metrics, as well as "AggroSyN" (setting in ANTsPy) and the Elastix toolbox, but asymmetry results did not overlap between toolboxes after correction of p-values. While the maximum effect using the two SyN-based methods (SyN(MI), SyN(CC)) was co-localized with the planum temporale (larger growth on the left side), the Elastix method revealed more anteriorly located growth asymmetry around the perisylvian area, and around the occipital horn of the lateral ventricle (larger growth on the left side, Figure 1) and AggroSyN revealed larger growth around the lateral ventricle on the right side. For the other registration settings, we only found interhemispheric differences with uncorrected p-values ($p < 0.005$, Figure 1). Conclusion We revealed left dominant growth in the perisylvian area in the perinatal period with two SyN-based algorithms. We found a discrepancy across different registration toolboxes, with only uncorrected p-value tests revealing interhemispheric differences for some registration methods. In conclusion, our finding highlights the importance of a careful evaluation of image registration quality and possible cross-validation across different toolboxes. Our findings suggest that some perisylvian regions continue to become more asymmetric around the perinatal period. From the clinical perspective, characterization of longitudinal changes in asymmetry patterns may shed light on impaired development, which can serve as a marker of cognitive development or reflect a risk for developmental delay. References: (1) Kuklisova-Murgasova, M. (2012) (2) Modat, M. (2010) (3) Klein, S. (2010) (4) Avants, B.B. (2007)

2-H-54 Brain morphometry of toddlers with language delay: A pilot study

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Objective: Delays in the attainment of key language milestones in toddlerhood are often the first warning signs for neurodevelopmental disorders (e.g., autism). To date, we know very little about the neural origins of language delay in toddlerhood, particularly in individuals who exhibit profound language delay that does not resolve over time. This study aims to identify how language delay in toddlerhood is associated with brain structure. Methods: 62 toddlers enrolled in a pilot study on brain and language development (Mage=21 months). The Mullen Scales of Early Learning (MSEL; Mullen, 1995) were administered to classify children as either language delayed (LD; n=19) or typically developing (TD; n=42). 55 of the 62 (88%) toddlers participated in an MRI visit between 14 and 40 months of age. High-quality T1-weighted images were collected in 29 of the 55 (53%) toddlers (8 LD, 21 TD). Infant FreeSurfer was utilized to extract estimates of whole-brain cortical thickness and surface area. Linear regression was utilized to examine whether cortical thickness/surface area differed as a function of language delay. All models were corrected for multiple comparisons using a vertex-wise threshold p<.001, a cluster-wise threshold p<.05, and were corrected for both hemispheres. Results: Results demonstrated that language delayed toddlers

exhibited a significantly thicker left insula (peak MNI coordinates: -36.3 -9.7 -1.4; cluster size=122.44 mm2; Cohen's d=.03; See Figure 1) and left superior frontal cortex (peak: -8.6 47.1 24.8; cluster size: 96.74 mm2; Cohen's d=.188) relative to typically developing toddlers. In contrast, typically developing toddlers exhibited significantly greater surface area in the left superior parietal cortex (peak MNI coordinates: -10.8 -86.7 28.7; cluster size=557.34 mm2; Cohen's d=.289; See Figure 1) and left precuneus (peak MNI coordinates: -5.8 -62.2 29.2; cluster size=141.49 mm2; Cohen's d=.394). There were no other significant group differences in cortical thickness and surface area. Additional exploratory analyses examined the association between cortical thickness/ surface area in these regions and verbal developmental quotient scores from the MSEL. Results indicated no significant associations (ps>.11). Conclusions: This pilot study provides novel evidence that toddler brain structure differs as a function of early language delay. These findings converge with those found in autistic samples demonstrating similar associations with language and parietal regions of the brain (Smith et al, 2016).

2-H-66 Characterizing cerebellar growth during the first year of life following a preterm birth

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The cerebellum undergoes its most intense period of postnatal growth during the first year of life. Alteration of cerebellar development, as seen following a preterm birth, may result in long-lasting behavioural and socio-emotional issues. In fact, altered cerebellar circuitry is believed to be responsible for many neurodevelopmental disorders, including autism spectrum disorder and attention deficit disorders. Although these disorders are frequent, most of them are only diagnosed after school entry when the child cannot keep up with the environmental demands and the problems have become overwhelming. Studies of trajectories have the potential to identify subtle variation patterns that cannot be detected by cross-sectional analyses only and may provide novel insight toward the development of novel diagnostic approaches. Therefore, this study aims to compare typical and atypical cerebellar growth trajectories, as assessed by quantitative MRI, during the first year following term age in the hope of identifying novel biomarkers of abnormal neurodevelopment. As part of an ongoing study, 30 newborns born very preterm (VPT) without severe brain lesion were enrolled and paired with 44 healthy term-born controls from the Baby Connectome Project's database. Enrolled participants in both groups were invited to complete a brain MRI under natural sleep using 3.0 Tesla scanner every 3 months (i.e., term equivalent age (TEA), 3, 6, 9, 12 months). A total of 164 high-resolution T1w images (71 VPT, 93 controls) were considered of sufficient quality to be included in our analyses. Preprocessing of the images included bias field correction and each image was linearly registered to appropriate age-matched templates. Using Infant Freesurfer, we then segmented the vermis and two cerebellar hemispheres (grey and white matter). Trajectories were characterized using mixed-effects models for repeated measured, and linear, quadratic, logarithmic and exponential regressions were compared using r squared values to determine the best fit. Different growth trajectories functions were identified between the two groups and across the five regions assessed. With the exception of the right hemispheric grey matter, all regions followed a quadratic trajectory in the VPT group. In contrast, regions in the control group followed either an exponential, linear or a quadratic trajectory. We found steadily larger cerebellar vermis and bilateral hemispheric grey matter in VPT when compared to controls. The most important volume difference between the two groups seems to occur around 6 months corrected age. However, term-born infants seem to progressively catch up with VPT around 12 months corrected age. In contrast, hemispheric bilateral white matter was consistently smaller in the VPT when compared to the controls across the evaluated period without signs of recovery. Our preliminary results suggest that atypical cerebellar volumes characterizing VPT children are already present during the first year of life and are characterized by both, regional under- and overgrowth. These cerebellar alterations may be related to the frequent developmental disorders observed in this population. Future structure-function studies with long-term follow-up assessment of outcomes are needed to confirm the clinical significance of our findings.

2-I-43 Infant gut microbiota composition associates with negative reactivity and fear in sex-specific manner

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Gut-brain axis has been studied mostly in rodents but during the past year increasingly also in humans. Studies indicate that gut microbiota is related to neurodevelopmental and behavioral outcomes. Accordingly, early gut microbiota composition (GMC) has been linked to child temperament, but research is still scarce. The aim of this study was to examine how early GMC at 2.5 months of age is associated with child negative reactivity and fear reactivity at 8 and 12 months of age, since they are potentially important intermediate phenotypes of later child psychiatric disorders. Our study population was 330 infants belonging to the longitudinal FinnBrain Birth Cohort Study. GMC was analysed using stool sample 16S rRNA sequencing and negative reactivity and fear reactivity were assessed using the Laboratory Temperament Assessment Battery (Lab-TAB) at the child's age of 8 months and the maternal reports of Infant Behavior Questionnaire-Revised Short Form (IBQ-R) at the child's age of 12 months. We found sex-specific associations between alpha diversity and reported fear reactivity as well as observed negative reactivity. The overall composition, i.e. beta diversity, was associated with reported and observed negative reactivity for boys. However, we did not observe any associations between temperament traits and the major short chain fatty acids (SCFAs). Finally, several genera were associated with temperament measurements with most prominent negative associations between genus [Ruminococcus] gnavus group and reported negative reactivity (LogFC=-2.1, p<.01) and fear (LogFC=-1.2, p<.05) and positive associations between genus Clostridium sensu stricto 1 and observed fear reactivity (LogFC=1.6, p<.01). This study adds to the growing literature on infant GMC and temperament and highlights the possible sex-specificity in these associations and adds to the emerging knowledge on the human gut-brain axis development.

2-I-52 Hippocampal volume and spatial working memory performance in preterm toddlers

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Children born preterm are at an increased risk of disorders related to executive functioning (including attention, memory, and inhibition). The hippocampus is a brain region that is critical for learning and memory, and children born prematurely often have reduced hippocampal volume. The purpose of this study is to examine how hippocampal volume might explain preterm toddlers' executive function difficulties. This study assessed 25 preterm toddlers with gestational ages at birth between 22-34 weeks (M = 26.04, SD = 2.53). After adjusting for prematurity, testing ages were 15-30 months (M = 17.68, SD = 4.27). We also collected a comparison sample of 8 full-term toddlers whose gestational age at birth was greater than 36-weeks and who had chronological ages of 17-34 months (M = 26.75 SD = 2.92). Hippocampal volume was measured based on T1- and T2-weighted brain images that were processed using the Infant Brain Extraction and Analysis Toolbox (iBEAT V2.0 Cloud). Executive function was measured using a spatial working memory task (i.e., the 3-6-9 box task). The 3-6-9 box task presents children with an array of boxes (see Figure 1). Each box is bated with a reward (a snack) while the child watches. The child's goal is to correctly choose a box with a reward. In order to successfully complete the task, the child must remember which boxes are empty and which contain rewards. The task gets more difficult after each level by adding three boxes after successful completion (i.e., 3-box, 6-box, 9-box). We compared hippocampal volume and 3-6-9 box task performance, number of successful trials out of total number of trials, between the two groups. Then we conducted regressions in which we examined the interaction between prematurity and hippocampal volume in each hemisphere on performance on the 3-6-9 box task. As expected, preterm toddlers had significantly smaller bilateral hippocampal volumes compared to full term toddlers (Left hemisphere: $F(1, 31) = 14.09$, $p < .001$, Cohen's $d = 1.53$; Right hemisphere: $F(1, 31) = 10.61$, $p = 0.003$, Cohen's $d = 1.32$). Preliminary results also indicate that after controlling for total gray matter volume and adjusted age, there was a significant interaction between right hippocampal volume and prematurity (full term vs. preterm) in regard to their performance during the 6-box condition $F(1, 27) = 9.99$, $p = 0.004$. We did not observe a significant interaction in the easier 3-box condition between the preterm and full-term toddlers, perhaps because many of the children, particularly in the full-term group, reached ceiling levels of performance on the 3-box condition. However, overall the full-term toddlers had fewer errors in their reward-finding attempts in both 3 and 6-box conditions (3-box condition: $F(1, 31) = 12.56$, $p = 0.001$, Cohen's $d = 1.44$; 6-box condition: $F(1, 31) = 22.99$, $p < 0.001$, Cohen's $d = 1.95$). The preliminary results suggest important differences in the relationship between hippocampal volume and executive function for full and preterm toddlers. Future research should focus on effects related to gestational age, medical complications, NICU stay, and task difficulty.

2-I-55 Oscillatory brain activity predicts the development of inhibitory control from infancy to toddlerhood

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Changing responses in accordance with variations in the context is key to self-regulate behavior. Adjusting to infrequent contingencies requires inhibition of the most frequent, dominant responses. In the last trimester of the first year of life, infants start to show basic inhibition and switching skills. The ECITT task has been recently designed to measure inhibitory control (IC) in infancy, which requires touching a button that appears on one side of a tablet device in 75% of trials (prepotent location) and only 25% on the opposite side (inhibitory location). Infants of 10 months of life are able to flexibly change responses, but there is a substantial development of this capacity during the second year of life. On the other hand, patterns of intrinsic brain electrophysiological (EEG) signals change considerably during infancy and toddlerhood and the relative power of different frequencies has been associated with observed individual differences in attention. Data from resting-state EEG indicate that the power of theta (3-5Hz) and gamma (20-45Hz) frequency bands decrease with age while it increases in the alpha (6-9Hz) frequency band. In this study, we aimed at studying the possible association between patterns of oscillatory activity at rest and the early development of IC. For that purpose, we used the ECITT with a cohort (N=100) of 9-month-old infants who were longitudinally followed at 17 months of age. We found that the accuracy in the ECITT task increased between sessions due to an improvement in the performance of inhibitory trials. Although the EEG was concurrently uncorrelated, higher power in alpha predicted a smaller switching cost at 17 months of age, while the association was negative with the relative power of gamma frequency. Our study showed a maturation of IC in infants and shows a predictive association between the intrinsic brain oscillations and IC.

2-I-57 Concurrent and Prospective Associations Between Frontoparietal and Default Mode Network Connectivity and Negative Affectivity in Infancy

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Internalizing disorders are linked to differences in frontoparietal (FPN) and default mode (DMN) brain networks which have a protracted period of development. It is theorized that these networks govern higher level interpretation of environmental cues and response execution. Differences in these networks have been found to emerge before the onset of psychopathology symptoms, suggesting a neurodevelopmental origin to their associated dysfunctions in internalizing disorders. Child negative affectivity (e.g., fearful behaviors, crying, etc.) is a strong predictor of later internalizing disorders. Previous work has suggested that differences in infant regional functional connectivity are associated with negative affectivity. Thus, it is possible that the foundational functioning of these networks confers risk for negative affectivity and later internalizing psychopathology. The present study aims to explore associations between newborn FPN and DMN connectivity and measures of negative affectivity in infancy. As part of an ongoing longitudinal study, newborn infants (N=77) underwent 12-18 minutes of resting state functional magnetic resonance imaging (fMRI) during natural sleep. Measures of negative affectivity were obtained at both newborn (~ 1 month) and 6 months (current N=52). Parent-reported internalizing symptoms were obtained at age 18 months. fMRI data will be processed in surface space and sample-specific networks will be generated using the Infomap community detection algorithm. Linear regression models will be used to characterize the concurrent and prospective associations between newborn DMN and FPN connectivity and negative affectivity, covarying infant age at scan and sex. Exploratory

analyses may examine associations among newborn connectivity, infant negative affectivity, and later internalizing symptoms. Preliminary analyses were conducted with N=32, M±SD age=4.57±0.88 weeks; 44% male (usable data=11.53±1.66 minutes) in volume space and using an adult network atlas. We operationalized negative affectivity as parent-reported hours of crying for a one-week period (averaged across days; N=32 for newborn and N=25 for 6-month) and parent-reported temperamental negative affectivity (N=25 at 6-month). Newborn FPN intra- and FPN-DMN internetwork connectivity were each positively associated with infant crying (FPN: β=0.57 [0.21, 0.93], p=.003; FPN-DMN: β=0.48 [0.09, 0.87], p=.017) and temperamental negative affectivity (FPN: β=0.45 [0.07, 0.84], p=.024; FPN-DMN: β=0.48 [0.09, 0.86], p=.017) at 6 months, but were not statistically significantly associated with concurrent crying (FPN: β=0.30 [-0.05, 0.65], p=.097; FPN-DMN: β=0.35 [0.00, 0.70], p=.052). DMN intra-network connectivity was not statistically significantly associated with crying at 6 months (β=0.32 [-0.07, 0.72], p=.105), temperamental negative affectivity (β=0.27 [-0.14, 0.67], p=.184), or concurrent crying (β=0.28 [-0.07, 0.64], p=.115). These findings point to a potential neurobiological indicator of risk for internalizing disorders. Given this risk is present shortly after birth, it suggests that inherited risk and/or prenatal influences may account for some of the variance in the neural circuitry and negative affectivity. Further, longitudinal mapping of postnatal influences, neurodevelopmental changes, and negative affectivity will be important for understanding whether subsequent environmental experiences impact neuro- and socio-emotional development.

2-I-58 Increased Cortical Thickness in Regions Supporting Executive Functions Predicts Reading Comprehension in Children with Music Experience

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Introduction: Music experience/training engages various neural circuits and employs several cognitive capabilities, including executive functions (EF). Existing data suggest that music experience is related closely to reading fluency and comprehension. While music training has been linked to improvement in cognitive and language abilities both underlie reading, the relationship between music training, reading fluency and comprehension, and EFs is still scarce. The current study examines the predictive role of EFs on reading comprehension through reading fluency in children with and without music experience from the toddlerhood period using cortical thickness (CT) measures. Methods: A high-resolution T1-weighted anatomical scan was acquired from children with (N=50, mean age: 9.94 ± 1.39 years) and without music experience (N=57, mean age: 9.49 ± 1.44 years). Reading fluency, reading comprehension and EF abilities were assessed and CT within EF brain regions was examined between the groups. A moderated-mediation analysis was conducted with CT of EFs as the predictor variable, reading comprehension as the outcome variable, reading fluency as the mediator and music group as the moderator. Results: Children with no music experience demonstrated lower reading fluency, comprehension and EF abilities compared to children with music experience. Furthermore, in children with music experience, CT in the anterior cingulate gyrus predicted reading comprehension via the indirect, mediated path, through reading fluency (B= 21.1, 95% CI = [5.521, 38.614]) compared to children without music experience where neither the direct effect, nor the indirect effect were significant (B= 11.198, 95% CI: [-6.061, 27.696]). Conclusions: Results suggest that children with music experience utilize neural circuits supporting EF more than children without music experience. It also provides a neurobiological account for the relative challenges in reading and EF in children with no music experience. Findings indicate that EFs are involved in reading comprehension through reading fluency and that the contribution of EFs and reading fluency to reading comprehension are enhanced due to music experience from early developmental stages.

2-I-59 Early Social Environments and Relationships with the Social Brain Network

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Objective: The social environment in which we reside holds immense value for offspring, and can set the stage for future social development. Prenatally, the social support environment of women during pregnancy can have moderating effects on the neonate brain morphology and infant unpredictability (Spann et al., 2020; Takács et al., 2021). After birth, the relationship between the primary caregiver, most typically mothers, and offspring has long been understood as important for building early social and relational foundations. For example, maternal sensitivity has influence on both child attachment security and social development (Braungart-Rieker et al., 2014; Gagné, 2021; Landry et al., 2006; Pearson et al., 2011). Within neuroscience, a 'social brain' network of brain regions has been hypothesized as involved in social cognition. The lateral fusiform gyrus, portions of the parietal cortex, medial prefrontal cortex, superior temporal sulcus, amygdala and interconnected frontal-limbic regions, and the extrastriate body area are often referenced as important areas to this network (Pelphrey & Carter, 2008ab). However, little research exists linking these network areas in early life to commonly used behavioral social constructs that are also investigated in early life. This study aims to explore the relationships between early maternal and offspring social engagement and offspring social brain network from the prenatal period to 14 months of child age. Hypothesis: We expect that social brain connectivity will be positively correlated with prenatal social support, maternal sensitivity, and child language and social development. Sample: This study sample consists of pregnant adolescents (ages 14-19) that were part of a larger study. A social support questionnaire was completed during the second or third trimester. Their infants underwent an fMRI scan during the first weeks of postmenstrual life (PMA 40-47 weeks) during natural sleep. At four months of infant age, mothers and infants participated in a ten-minute free play together that was videotaped for later behavioral coding of maternal sensitivity and child social development (responsiveness). Additionally, infant language and social development were assessed using the Bayley Scales of Infant and Toddler Development-III. At 14 months, infants underwent the Strange Situation paradigm to assess their attachment security category. Analytic Plan: Multivariate analysis will be used to assess relationships between social brain network connectivity and prenatal social support, maternal sensitivity, child language and social development, and attachment. Conclusions: This study will further elucidate how early maternal and offspring social engagement sets the foundation for later social learning and building of relationships in other environments.

2-I-61 Mapping a dynamic interplay: Auditory attention and receptive language network development across the first eight months of life

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Background: Attention and language are important cognitive functions that develop rapidly in the first years of life and have been shown to predict later emerging higher-order cognitive capacities. Deficits in attention and language have been linked to premature birth (Kavsek & Bornstein, 2010; Bosch, 2011), exposure to neurotoxins (Bandstra et al., 2011; Minnes et al., 2011), and are found across neurodevelopmental disorders (Toth et al., 2006; Swensen et al., 2007; Messinger et al., 2013). Clinically, it can be challenging to discern deficits in auditory attention from those of receptive language in particular. There is a lack of studies during infancy that evaluate these fundamental cognitive capacities concurrently with brain measures to understand how brain changes mediate the development of cognition and the integral brain regions involved in the development of these skills over the first year of life. Further, we do not fully understand whether the same brain regions known to be involved in attention or language during adulthood are also recruited during infancy when the systems are first developing. The goal of this study is to address the gaps. We aim to determine the brain regions and connections across brain regions from newborn to eight months of postnatal life that are integral for auditory attention and receptive language. Methods: Expectant women were recruited in the second or third trimesters. After birth, their infants participated in one or more MRI scans between birth and 8-months (n=127) of postnatal age, including functional resting-state data. They also completed a developmental assessment that included the Bayley Infant Scales of Infant and Toddler Development - Third Edition, while their mothers completed questionnaires about their socio-emotional, receptive, and expressive language development. Proposed Analytic Plan: After standard preprocessing of functional imaging data, first, functional connectivity matrices or connectomes will be generated using an existing infant-specific functional parcellation for all participants. Each edge in the connectome will then be correlated with the concurrently collected attention and language variables to generate an "attention-language network". We will control for age at scan, sex, and attention and language measures completed at non-concurrent time points. A priori hypotheses are that regions of interest known to be involved in attention and language in adult, such as, inferior frontal, superior and middle temporal, superior and inferior parietal gyri, precuneus, thalami, and posterior cingulate regions, are also recruited during infancy when systems are first developing. In addition, we expect to identify changes in functional connectivity in networks of attention and language in the maturing brain from birth to 8-months of life. Conclusion: Identifying the circuits associated with the neural maturation of receptive language and auditory attention will add to our knowledge on typical brain and concurrent cognitive development.

2-I-63 Brain Segregation over Early Development in Non-Human Primates

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Objective The brain is a modular system, not random. The connections between brain regions are often organized into segregated networks to support efficient neural communication and information integration. In healthy development, the maturation of network segregation in adults is also associated with cognition and behavior across different domains, including sensorimotor processes, executive function, attention and memory (Sporns 2013; Wig 2017). Many fetal studies have shown that the modularity of various brain networks emerges early in the fetus (Thomason 2020). After birth, how network segregation develops from infancy, toddler, to juvenile is less studied in humans due to the challenges in data collection. Here, we aim to characterize early development of brain segregation using a highly sampled longitudinal nonhuman primate (NHP) dataset, which was collected at 3-weeks of age and followed up every 2-weeks from infancy to juvenile. Methods Data were collected from three rhesus macaques (2 females, age=3-50 weeks). Each animal was scanned every 2-weeks with 2-4 resting-state fMRI runs over the first year. The fMRI data were preprocessed using an HCP-style DCAN pipeline (dsturge et al. 2019). For each scan, we calculated the parcel-wise resting-state functional connectivity (RSFC) and system segregation - defined as the difference in mean between- and within-network connectivity as a proportion of mean within-network connectivity (Chan et al. 2014). A regression model was used to characterize the development of system segregation over time. Results Consistent with human findings, the segregation of primary systems was higher than the association systems across all age points (Wig 2017). Visual and auditory systems showed increased segregation with increasing age while the somatomotor system remained the same. For the association cortex, insular-opercular, attention, and default mode networks (DMN) showed increased segregation with age while the limbic system had no age-related changes (Fig A-B). Intriguingly, the midline core subsystem of DMN had negative segregation values, reflecting the higher between-system connectivity relative to within-system connectivity in early development (Fig A). Across age, posterior cingular cortex (PCC) showed decreased segregation but highly increased between-network connectivity (Fig C). In contrast, the ventral medial prefrontal cortex (VMPFC) exhibited a positive segregation score that increased across age. Conclusion Using a longitudinal NHP model, we characterized early changes in system segregation. Our results suggest that functional modularization of brain system starts early and continues from infancy to childhood. However, the development of subsystems within the DMN is not synchronized. VMPHC develops its modular organization very early while PCC prioritizes its interconnections with other systems first. These findings provide insights into temporal sequencing of early development in brain modularity.

2-I-65 Hippocampal function and memory across contexts in 18-22-month-olds

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The development of the hippocampus has been linked to the ability to remember past events with specific details. Previous work has shown that the hippocampus is recruited, during sleep, in response to previously learned songs and words during the third year of life. However, it is not known whether this is the case in younger participants and whether hippocampal function tracks similarities and differences in learning contexts. Toddlers aged 18-22 months (current N= 3; expected by September, N=20) will learn four novel words across two contexts. Each context will be additionally associated with one novel song. A visual paired comparison paradigm via

eyetracker will be used to assess children's memory for objects associated with the newly learned words as well as the association between songs and objects. Following testing, toddlers will undergo a nighttime scanning session in which we will obtain both structural and functional scans during natural, nocturnal sleep. We expect stronger hippocampal activation for learned compared to novel songs and words. Moreover, if hippocampal activation tracks context similarity, we additionally expect that Representation Similarity Analysis (RSA) will reveal that songs and words encountered in the same context will exhibit higher pattern similarity of hippocampal activation compared to songs and words encountered in different contexts.

2-J-48 Using fMRI to study one-month-old infants' responses to music and speech in auditory cortex

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A population of neurons in human non-primary auditory cortex responds selectively to music, and a distinct neural population responds selectively to speech. These selective responses cannot be explained by the differing low-level acoustic properties of speech and music. Does newborn infant cortex exhibit a similarly selective response to speech and music? To answer this question, we collected functional magnetic resonance imaging (fMRI) data from 45 sleeping infants (2.0- to 11.9-weeks-old) while they listened to single-source instrumental lullabies and female-produced infant-directed speech. To match acoustic variation between music and speech sounds we (1) recorded music from instruments that had a similar spectral range as female infant-directed speech, (2) used a novel excitation-matching algorithm to match the cochleagrams of music and speech stimuli, and (3) produced "model-matched" stimuli that had matched spectrotemporal statistics to those of the music and speech stimuli. As expected, we found that cocheleagram-matched music and speech stimuli and modulation-matched music and speech stimuli activated primary auditory cortex similarly. Additionally, we found a set of voxels in non-primary auditory cortex with a preferential response to speech that could not be explained by the spectrotemporal features of speech, and another set of voxels that had a response to music that could not be explained by the spectrotemporal features of music. Taken together, these results provide preliminary evidence that shortly after birth, humans have music and speech responses in auditory cortex that cannot be explained by the acoustic features of these stimulus categories.

2-J-51 From Fetal and Newborn Kinematics to Neuro-developmental Risk: Bayesian approaches to identifying developmentally-salient motor activity in 1-month old infants

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Birth is the single most dramatic change in environment in the lifetime of the human brain, triggering a rapid period of reorganization in neuronal function and motor activity. Building upon fetal exploration of their own bodies and the womb milieu, infants navigate their novel visual environment and exploit their maturing physical capacities. Our longitudinal Perinatal Imaging Partnership (PIP) probes continuity and change across the transition from fetal to neonatal life, breathing new life into the nature-nurture debate with Bayesian computational theories of development. We apply semi-automatic Bayesian kinematic and visual feature analysis to identify developmentally-salient aspects of prenatal and postnatal motor activity. Recordings of 30 babies spontaneous movement for 15 minutes is undertaken prenatally via ultrasound and again by videorecording newborns within the first week life, then again at 1 and 5 months of age in the lab tracked with sensors. The kinematics are utilised to track each infant's unique perinatal trajectory of motor development and associated with subsequent behavioral assessment. Leveraging existing videos of 60 1-month old newborns collected from the UK, OpenPose extracted time series data of infant kinematics to this sample and applied these models to the sample of infants with ultrasound data. Entropy and efficiency from kinematic descriptive of targeted movements are then calculated, identified via computer-vision and Naïve Gaussian Bayesian Surprise learning techniques (Chambers et al., 2020). The kinematic properties of infants differed by mode of delivery, such that infants born C-section were more similar to older infants at 1-month and less similar to their fetal ultrasound data relative to infants born transvaginally. Prior studies in children as young as 4 months have identified characteristics of infant actions indicative of severity of neurodevelopmental disorder, teratogenic exposure and precocious motor development. Few studies assessed the prototypical kinematics of motor activity in newborns, but in older children smoother kinematic trajectory of infant motor actions such as face touches are associated with greater maturity and predict later motor development. This is grounded in fetal patterns of motor activity: for example, face touches to sensitive areas of the face such as the mouth are more frequent with advancing gestational age and might be relevant for latching after. However, previous research has not treated gesture detection in as much detail as observation-based coding of actions identified as developmentally-salient, such as detecting goal-directed movement of the hands occluding mouths, nose or eyes. To explore how combinations of fetal and neonatal movement features relate to clinically-assessed risk for delayed motor development using the Mullen scale, we apply matrix decomposition to our set of apriori kinematic features. Potential clinical applications and implications for fetal body schema are discussed.

2-J-53 Environmental effects on crafting the future reading network: Neurobiological correlates for literacy and screen exposure in children

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Despite ongoing studies pointing at the effect of genetics on reading development, environmental factors such as literacy and screen exposure may significantly contribute to children's future reading abilities. Whether these environmental components "compete" over the same neural circuits is yet to be known, In a series of studies, we examined the neurobiological correlates of home literacy environment and screen exposure, focusing on executive functions, language, and visual processing- all part of the reading network- in young children. In pre-schoolers, we tested the effect of storytelling via a computer screen vs. an in-person storyteller on changes in EEG patterns related to cognitive control and visual processing. We then examined the differences in functional connectivity in neural circuits supporting these abilities in children listening to a story vs. children watching a video functional MRI in children at the same age. Finally, we calculated the relations between screen exposure time and literacy exposure, and white matter integrity in a different cohort at the same age. Results demonstrate a greater engagement of neural circuits supporting executive functions and visual processing when

children were exposed to a storyteller vs. watching stories on the screen using EEG. Children at reading age showed increased functional connections between visual processing, language and executive functions regions (mainly left-lateralized) in correlation with literacy time, with the opposite direction (negative functional connectivity) in relation to screen time. The storytelling condition was also accompanied by better executive function and language abilities. We also pointed at increased functional connections on networks associated with visual attention and visual processing for the storytelling vs. video watching conditions in the MRI. A positive correlation between literacy exposure and structural organization was found when correlating fractional anisotropy values in white matter tracts related to executive functions, visual processing and language abilities. However, the opposite correlation was found when correlating fractional anisotropy measures with screen time in these pre-schoolers. We conclude that screen exposure competes with neural circuits used originally for reading and narrative comprehension, and therefore, exposure to screens should be monitored carefully. We also suggest that children exposed less to a home literacy environment and increased screen time may affect the efficiency of their future reading network.

2-J-56 Insights into the complex immune environment during pregnancy and its association with the developing human connectome

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Background: Maternal health and intrauterine exposures during pregnancy play a major role in molding and shaping the health and neurodevelopment of our offspring--one such influence is maternal immune activation (MIA). Animal models have shown MIA affects brain structure, neuronal morphology and function and synaptic and neuronal connectivity and can disrupt regulation of developing neurotransmitter systems in offspring. These models have also shed light on the developing immune system and its long-term consequences (e.g., alterations in cytokine expression, and susceptibility to chronic diseases). Conversely human studies of MIA and its relationship with early brain development are sparse, but increasingly show the complex role of multiple immune markers in later risk for neurodevelopmental conditions in offspring. However, to date, the influence of MIA on newborn brain organization and function has been limited research to only a few markers. Aim: This study proposes an analysis of 46 markers of immune activation from the third trimester of pregnancy to understand potential unique phenotypic profiles and common associations of expressed maternal immune markers during pregnancy with the developing human connectome. A secondary exploratory analysis using immune markers from the second trimester will also be conducted. Hypothesis: Based on existing research, we predict that nodes related to the limbic system (e.g., anterior cingulate/medial prefrontal, amygdala) will be significantly correlated with maternal immune markers, however we expect the direction of the association to differ by immune marker clusters, and gestational age. Sample: 80 healthy women with singleton pregnancies were recruited and underwent blood draws at two-time points during pregnancy: (1) 24-27 weeks gestation, (2) 34-37 weeks gestation. Both adaptive (e.g., IgG) and innate (e.g., cytokines and acute phase reactants) immune markers were extracted samples, totaling 46 markers of maternal immune activation. In addition, an MRI was also acquired from their offspring between the ages of 0-6 months. Analysis plan: A principal component analysis (PCA) will be performed for the reduction of the immune markers to help identify latent profiles of immune expression. After standard preprocessing functional connectivity matrices or connectomes will be generated using an existing infant specific functional parcellation. Each edge in the connectome will then be correlated with the latent immune profiles, while controlling for age at scan and sex. The network-based statistic will be used corrected for multiple comparisons. Summary: We aim to explore how the complex interaction between the maternal immune system shapes the developing brain and identify nodes of aspects of the connectome that engage with specific immune profiles. This will provide a blueprint for future longitudinal studies to understand

2-J-60 Sex differences in brain-behavior relationships during infancy

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Objective: Sex differences in functional connectivity (FC) during infancy have been previously reported. Recent findings also suggest the existence of brain-behavior relationship heterogeneities during infancy. However, little is known about whether sex may underlie part of such brain-behavior relationship heterogeneities during this critical period when sex-related behavioral differences emerge. Here, we aim to answer this question based on functional connectivity measures during infancy and 4-year behavioral outcomes. Methods: We used rsfMRI from 324 infants scanned at neonate, 1, and 2 years of age. A multiple linear regression model was used to test significant interactions between sex and FC to predict 4-year behavioral outcomes (anxiety, working memory, inhibitory control, and IQ). An infant specific functional atlas was used to examine all regional FC. Results: Significant sex*FC interactions on 4-year-old behavior outcomes were found in 6 connections ($p \leq 0.05$ after Bonferroni corrections for multiple comparisons). These include FC between left dorsolateral superior frontal gyrus and left superior occipital gyrus in its association with intelligence in neonates; FC between right dorsolateral superior frontal gyrus and right medial superior frontal gyrus and FC from right middle cingulate gyrus to left fusiform gyrus in their relationship with working memory in 1-year-olds; FC between right rectus gyrus and frontal/ parietal regions in their relationships with working memory/inhibitory control; as well as FC between left supramarginal gyrus and left temporal pole in its association with intelligence in 2-year-olds. Conclusions: These results confirm our previous findings of brain-behavior relationship heterogeneity during infancy and highlight sex as an important factor underlying such heterogeneity. The largely age-specific patterns may imply intricate interplay between genetic and postnatal environmental factors on such sex-related effects.

2-M-39 A preliminary investigation of relations among early feeding practices, gut microbiome diversity, and amygdala growth during the first year of life

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The subcortical structures of the human brain and the human gut microbiome undergo rapid change early in development, yet little is known about how they are related. There are several neurological disorders with developmental roots that involve amygdala disfunction that have been associated with alpha diversity alterations (i.e., Autism Spectrum Disorder, Major Depressive Disorder, and General Anxiety Disorder). Furthermore, alpha diversity is impacted by early feeding practices (e.g., formula feeding, breastfeeding). Formula-feeding in particular has been shown to alter gut microbiome composition in favor of pro-inflammatory gut microbiota that have been associated with previously mentioned neurological disorders. However, these associations have not yet been looked at together in the context of infant neurodevelopment during the first year of life. We hypothesize that child feeding practices and gut microbiome alpha diversity between birth and 4 months old will be associated with rate of amygdala volume expansion between birth and 12 months old. Bacterial constituents were identified using 16S rRNA amplicon sequencing from infant fecal samples (N = 34) using DADA2, and Chao1 alpha diversity was calculated for each sample. MR structural images (T1- and T2-weighted) were collected at approximately 3 and 12 months. Images were processed by first skull stripping, applying intensity inhomogeneity correction, and histogram matching for MR images. Amygdala segmentation was accomplished using a Dilated-Dense U-Net. The processed images were then visualized and QCed using ITK-SNAP. A linear regression model was used to examine the association between gut microbiome diversity, child feeding practices, and linear amygdala growth independently in the left and right hemispheres. There was a significant association ($p = 0.0166$) between formula feeding (N=5) and slower right amygdala growth during the first year of life. This association was diminished in the left ($p = 0.0877$). There was no significant association between Chao1 and amygdala growth rate (left, $p = 0.9549$; right, $p = 0.0943$). However, there was a significant interaction ($p = 0.0396$) between Chao1 and formula feeding for right amygdala growth rate, suggesting that in formula fed infants lower alpha diversity is potentially related to slower growth of the right amygdala. Our results warrant further investigation of the impact of early feeding practices on the development of the amygdala through modulation of the gut microbiome of infants. Studies using a larger sample size with more balanced early feeding practices are needed to confirm or refute these preliminary findings. Future research should include additional MRI analyses (e.g., whole brain tissue segmentation) to investigate if this slower growth rate in the amygdala is also observed in gray matter and white matter. Lastly, future research should investigate not only structural changes in the amygdala but if these structural changes lead to alterations in functional connectivity of the amygdala.

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