SUSAN B. MEISTER CHILD HEALTH EVALUATION AND RESEARCH CENTER

MICHIGAN MEDICINE

ANNUAL REPORT
JANUARY 2024 - JUNE 2025

Overview

This report summarizes the research, training, and operational activities of the Susan B. Meister Child Health Evaluation & Research Center (CHEAR) for January 2024 – June 2025. These activities are directly supported by the generous naming gift provided by Susan and Paul Meister.

Faculty Highlights

Faculty Honors & Awards:

Ryan Barbaro, MD, MSc, was the recipient of the 2024 Department of Pediatrics Chair's Outstanding Mentorship Award. This award recognizes an individual who has been exceptional in supporting the professional development of students, house-officers, research trainees, and/or faculty (Appendix 1).

Kao-Ping Chua, MD, PhD, won the Nemours Child Health Services Research Award from AcademyHealth in 2024. He was also promoted to Associate Professor, with tenure, Department of Pediatrics, and Associate Professor, Department of Health management and Policy.

Sarah Reeves, PhD, MPH, was promoted to Associate Professor, with tenure, Department of Pediatrics, and Associate Professor, Department of Epidemiology.

David Sandberg, PhD, was the recipient of the 2024 Department of Pediatrics Chair's Established Faculty Investigator Award. This award recognizes an Associate or full Professor on any track who have produced a significant and coherent body of impactful scholarship (Appendix 1).

Joyce Lee, MD, MPH, is completing the Health Management Academy AWS Technology Fellows Program for rising CMIOs, CNIOs & clinical technology executives, and is a 2024 graduate of the Executive Leadership in Health Care (ELH) program at Drexel University, which is a nationally recognized leadership training program for women in academic medicine.

Staff Honors & Awards:

Missy Plegue, MA, received the Health Services Research Awardee for abstract "Differences in Healthcare Utilization, Complications and Procedures Among Privately and Publicly Insured Children with Sickle Cell Anemia" at the 2024 University of Michigan Pediatric Research Symposium (PRS).

Missy Plegue, MA, was the recipient of the Highest Scoring Poster Abstract in the HSR Track for Other (MA/MS) for abstract "Differences in Healthcare Utilization, Complications and Procedures Among Privately and Publicly Insured Children with Sickle Cell Anemia" at 2024 Pediatric Academic Societies (PAS).

Krista Latta, MPH, received the DEI Awardee for abstract "Identifying Pain Trajectories during Inpatient Hospitalizations for Children and Young Adults with Sickle Cell Disease at Michigan Medicine" at the 2024 University of Michigan Pediatric Research Symposium (PRS).

New Faculty Affiliate:

Yi Tak Tsang (Daisy), PhD, Clinical Assistant Professor, Department of Pediatrics, Division of Pediatric Psychology (Appendix 2).

New Staff:

William Gillespie, MSc, joined CHEAR in January of 2024. He is a SQL Data Analyst and assists researchers and clinicians by investigating and retrieving Electronic Health Records (EHR), defining data dictionaries, performing statistical analysis, and creating data visualizations (Appendix 3).

Sijia (Scarlett) He, MS, joined CHEAR in June 2024 as a Research Area Specialist Associate. She provides statistical modeling as part of the team for Dr. Lisa Prosser and Dr. Kao-Ping Chua (Appendix 3).

Jessica Bielawski, MA, joined CHEAR in September 2024 as an Administrative Manager Associate Healthcare. As the Center Manager, she works with the administrative team to coordinate the overall operations of the center (Appendix 3).

Elinor Artsy Navon, MD, joined CHEAR as a Research Area Specialist Senior in October 2024 supporting PEACH and other child health equity initiatives led by Drs. Freed and Woolford (Appendix 3).

Miao Yu, MS, joined CHEAR in January 2025. She is the Lead Data Analyst for the Equity Team, working on the PEACH, PSCIP, Mi-CHEC, and Mi-CHIME projects under the leadership of Drs. Woolford and Freed (Appendix 3).

Chiu-Mei Chen, MS, is a BI Analyst Lead on Dr. Lee's team. She joined CHEAR in May 2025 (Appendix 3).

Jung Eun Lee, MS, became part of CHEAR in June 2025 as a Lead Data Analyst for Dr. Lee's team (Appendix 3).

Training and Educational Programs

CHEAR Fellowship:

Departing Fellow:

Melinda Rushing, PhD, LMSW, began her fellowship program in July 2021 under the primary mentorship of Sarah Reeves, PhD. Her mentorship team also included

Drs. Susan Woolford, Kevin Dombkowski, David Sandberg, and Tom Braun. In September 2024, Dr. Rushing began as an Assistant Professor of Health Administration position at Rutgers University in the School of Planning and Public Policy.

Continuing Fellow:

Joanne Constantine, PhD, MPH, began her postdoctoral research fellowship in September 2023 under the mentorship of Drs. Sarah Reeves, Kao-Ping Chua, and Lisa Prosser. Dr.

Constantine is working with Dr. Chua on NIDA-funded projects evaluating the effect of opioid prescribing policies on opioid prescribing after surgery and the effect of Medicaid unwinding on buprenorphine use. She is also assessing the association between telehealth initiation of stimulant therapy and substance use disorders in the context of the extensions of the COVID-19 pandemic-related flexibilities to initiate stimulants via telehealth through December 2024. Additionally, Dr. Constantine is working with Dr. Reeves on a Center for Disease Control and Prevention (CDC) Funded Sickle Cell Data Collection program, evaluating enrollment in the Children's Special Health Care Services program following program expansion.

New Fellow:

Nina Hill, MD, research focuses on the role of food security in maintaining cardiovascular health across the lifespan. Dr. Hill is passionate about health equity and conducting policy- relevant research to improve healthcare and health policies serving vulnerable families.

Following fellowship she plans to pursue a physician scientist career. In addition to her research work, Dr. Hill provides primary and preventative care to kids and adults at the Canton Health Center.

Fellowship Leadership and Steering Committee:

Sarah Reeves, PhD, MPH, and **Kao-Ping Chua, MD, PhD,** continued as the Director and Co-Director of Fellowship Programs, respectively. Steering Committee members include Drs. Jeremy Adler, Ryan Barbaro, Gary Freed, Zubin Modi, and Lisa Prosser. The Steering Committee continues to conduct interviews of potential fellows, provide program insight, and guide fellows and mentors through a successful fellowship experience.

CHEAR Seminars:

The CHEAR Center continued to host our seminar series through the academic year: CHEAR Seminars, Methods Seminars, Fellows Seminars, and Faculty Work in Progress (WIP) Seminars.

Again, this year, seminars have been offered in a hybrid platform allowing participants to join both virtually and in person (Appendix 4).

CHEAR Summer Internship (CSI) Program:

The CHEAR Summer Internship (CSI) runs annually from June-August and accepts undergraduate students with an interest in pediatric health services research. Each year we have accepted internal candidates from a range of disciplines (e.g., Public Health, Information sciences, College of LS&A, Engineering) and several students from other universities across the country (e.g., Wayne State University, Western Michigan University, and UCLA). During the internship, trainees work closely with a CHEAR mentor and have numerous opportunities to interact and learn from faculty, both at the CHEAR Center and at the Institute for Healthcare Policy & Innovation (IHPI). The internship culminates with student presentations, which are attended by faculty and staff within the CHEAR Center. Interns have submitted abstracts that have been accepted for presentation at national conferences and have contributing authors on manuscripts.

Our Summer 2024 Cohort included:

- **Morenikeji Ojubanire (U-M):** Mentor, Susan Woolford
    - She examined the potential for inequities resulting from variation in the prescribing weight loss mediations for children and teens by clinicians.
- **Anita Sejdiu (U-M):** Mentor, Jeremy Adler
    - She evaluated data from a multi-center cohort of children with Crohn's disease to identify the implications of abnormal blood tests in children who are otherwise asymptomatic.

CHEAR also collaborated with the Division of Pediatric Cardiology in 2024 to incorporate two Cardiology sponsored students into the CSI sessions:

- **Sarah Mekhald** and **Shriya Das:** Mentors, Caren Sue Goldberg and Amanda DeLong McCormick
    - They worked together with Pediatric Cardiology faculty pursuing work to uncover and to reduce disparities in care and had the opportunity to learn about clinical research approaches, congenital heart disease, and tools pertinent to research related to disparities.

Additionally, CHEAR is dedicated to supporting the efforts of future health service researchers. In 2024, CHEAR faculty participated in the first annual Pediatric Fellow Innovation Tournament.

Program for Equity in Adolescent & Child Health (PEACH):

CHEAR also works closely with the Program for Equity in Adolescent & Child Health (PEACH) team, with our staff and faculty often overlapping. Between January 2024 – June 2025, PEACH hosted eight Work-in-Progress talks and three seminars.

CHEAR Visitors

These last 18 months, CHEAR was proud to host six visitors.

Kim Dalziel, PhD, was in residence at CHEAR from January 8, 2024 – January 3, 2025. Working in collaboration with Dr. Lisa Prosser and Dr. Sarah Reeves' research group. Dr. Dalziel conducted full-time (40 hours per week) research regarding health economic evaluation measurement and designs to support priority setting for children with special health care needs. Our collaboration will generate high quality research that directly informs health policy to ensure better delivery and fairer financing of health services for children. Dr. Dalziel's research specifically aims to: generate measures of quality adjusted life years in economic evaluation of interventions for young children; develop new empirical research to use the Pediatric Quality of Life Inventory (PEDsQL) scores in economic evaluation; quantify inequities in the design and financing of health systems for vulnerable children including those with high needs; and bring advanced pediatric health economics methods alongside clinical research to strengthen translation to policy, thus reducing waste and improving fairness.

Matthew Aalsma, PhD, MA, came to CHEAR as a visiting professor on April 25, 2024. During this visit, Dr. Aalsma gave the Department of Pediatrics Grand Rounds presentation on Addressing Adolescent Mental Health and Addiction Crises through Workforce Task-Shifting. He is the Director of the Division of Children's Health Services Research at Indiana University School of Medicine.

Michael Dolgin, PhD, visited CHEAR in June 2024 from Ariel University in Israel. During this visit, Dr. Dolgin presented a CHEAR seminar on Meaningful Clinical Change and Treatment Responsivity in Pediatric Psychology Intervention Research on June 18, 2024. He is a Licensed Psychologist and Supervisor in Clinical and Medical Psychology with over 40 years of experience in clinical care, training, and research in Pediatric Psychology. Currently he is an Associate Professor of Psychology, Senior Clinical and Medical Psychologist at Ariel University.

Raghu Lingam, PhD, MSc, MBChB, visited CHEAR in September from the University of New South Wales in Australia. On September 19, 2024, he presented a joint seminar with CHEAR and the PEACH program on Strengthening Child Health Systems. Dr. Lingam leads the Population Child Health and Health Services Research Group, UNSW Sydney, the NSW Centre for Child Health Services Research and Innovations (CHRIS) and its national counterpart Child Unlimited. He has developed and evaluated large-scale child health intervention programs in low and high income settings to optimize the health, and development of children and young people.

Stephen Patrick, MD, MPH, MS, FAAP, Professor and Chair of the Department of Health Policy and Management at the Rollins School of Public Health, Co-Director of the Center for Health

Services Research, and a practicing neonatologist at Emory University, visited CHEAR on November 19, 2024. During his stay, he met with several CHEAR faculty, fellows, and pediatric specialty divisions. Dr. Patrick also presented the Annual Opipari Lecture for the Department of Pediatrics.

Hamoud Alhazmi, PhD, student in Computer Science and Engineering from Ohio State University, visited CHEAR November 13 – 14, 2024. He presented his work at a CHEAR "Lunch and Learn" session on November 14th. Mr. Alhazmi is interested in research utilizing AI to empower patients. He previously worked as a software engineer and has a degree in cyber security.

Amy Hanson, MD, was the inaugural participant in our pilot pediatric fellow exchange program. She visited us from Indiana University (IU). Dr. Hanson is a 3rd year PICU fellow at Riley Hospital for Children in Indianapolis, IN, where she is doing a concurrent Children's Health Services Research (CHSR) fellowship along with her PICU training. At her CHEAR seminar on Tuesday, December 3, 2024, she talked about her CHSR journey and the basis for her fellowship project.

Pilot Funding

Ongoing Projects:

PI	Project
Joseph Kohne, MD, MS	FOCI: Following Outcomes after Critical Illness
Kao-Ping Chua, MD, PhD	The Michigan COVID-19 Research Program in Peds (MI-CORP)
Erin Carlton, MD, MSc	Financial Impact on PICU Hospitalization on Families

Research Highlights

To capture the important and impactful work the CHEAR Center is accomplishing, faculty have drawn attention to their most significant work from 2024 including grants, published papers, and projects.

Jeremy Adler, MD, MSc

- **Adler J**, Gadepalli S, Rahman M, Kim S. Early tumour necrosis factor antagonist treatment prevents perianal fistula development in children with Crohn's disease: post hoc analysis of the RISK study. Gut. 2024 Dec 12;gutjnl-2024-333280. doi: 10.1136/gutjnl-2024-333280. Epub ahead of print. PMID: 39667905.

- Ali S, Pasternak B, Moses J, Suskind DL, Samson C, Kaplan J, Creps J, Manning L, Baker M, Singer D, Patel P, Trombler B, Anandakrishnan A, Khorrami C, Feldman M, McGoldrick M, **Adler J**. Characterization of Biologic Discontinuation Among Pediatric Patients with Crohn's Disease. Clin Gastroenterol Hepatol. 2024 Oct;22(10):2075-2083.e1. doi:

10.1016/j.cgh.2024.03.043. Epub 2024 May 8. PMID: 38723980.

Ryan Barbaro, MD, MS

- Alexander PMA, Di Nardo M, Combes A, Vogel AM, Antonini MV, Barrett N, Benedetti GM, Bettencourt A, Brodie D, Gómez-Gutiérrez R, Gorga SM, Hodgson C, Kapoor PM, Le J, MacLaren G, O'Neil ER, Ostermann M, Paden ML, Patel N, Rojas-Peña A, Said AS, Sperotto F, Willems A, Vercaemst L, Yoganathan AP, Lorts A, Del Nido PJ, **Barbaro RP**; Extracorporeal Life Support Organization (ELSO); International ECMO Network (ECMONet); Pediatric Acute Lung Injury and Sepsis Investigators (PALISI); Pediatric ECMO subgroup of PALISI and ELSO (PediECMO); European Society of Paediatric and Neonatal Intensive Care (ESPNIC); Australian and New Zealand Intensive Care Society Paediatric Study Group (ANZICS PSG); Intensive Care Society (ICS); Pediatric Cardiac Intensive Care Society (PCICS); Advanced Cardiac Therapies Improving Outcomes Network (ACTION); Children's Hospitals Neonatal Consortium (CHNC); American Pediatric Surgical Association (APSA); Society of Thoracic Surgeons (STS); Society of Critical Care Medicine (SCCM). Definitions of adverse events associated with extracorporeal membrane oxygenation in children: results of an international Delphi process from the ECMO- CENTRAL ARC. Lancet Child Adolesc Health. 2024 Oct;8(10):773-780. doi: 10.1016/S2352- 4642(24)00132-9. PMID: 39299748.

- Submitted Grant: UG3HL:1/2 ECMO Circuits Optimized to Reduce adverse Events (ECMO CORE)
  PI: Ryan Barbaro, $20,246,472

Erin Carlton, MD, MSc

- 1R03HS029196-01, Receipt, disparities, and impact of early primary care follow-up after pediatric crucial illness, Agency for Healthcare Research and Quality
  PI: Erin Carlton, $100,000

- 1R03TR004798-01, Timing and risk factors for developing chronic respiratory failure after pediatric sepsis, National Center for Advancing Translational Sciences
  PI: Erin Carlton, $158,933

Kao-Ping Chua, MD, PhD

- **Chua KP**, Volerman A, Zhang J, Hua J, Conti RM. Antidepressant Dispensing to US Adolescents and Young Adults: 2016-2022. Pediatrics. 2024 Mar 1;153(3):e2023064245. doi: 10.1542/peds.2023-064245. PMID: 38404197.

- Lee JM, Sharifi M, Oshman L, Griauzde DH, **Chua KP**. Dispensing of Glucagon-Like Peptide-1 Receptor Agonists to Adolescents and Young Adults, 2020-2023. JAMA.

2024;331(23):2041– 2043. doi:10.1001/jama.2024.7112

- **Chua KP**, Conti RM, Lagisetty P, Bohnert AS, He S, Nguyen TD. Association Between Cost Sharing and Naloxone Prescription Dispensing. JAMA. 2024;332(2):124–132. doi:10.1001/jama.2024.8378

- **Chua KP**, Bicket MC, Bohnert ASB, Conti RM, Lagisetty P, Nguyen TD. Buprenorphine Dispensing after Elimination of the Waiver Requirement. N Engl J Med. 2024 Apr 25;390(16):1530-1532. doi: 10.1056/NEJMc2312906. PMID: 38657250.

Kevin Dombkowski, DrPH, MS

- **Dombkowski KJ**, Arzt NH, Robison SG. Implications of the COVID-19 Pandemic on IIS Operations, Performance, and Future Readiness: Not the New Normal. J Public Health Manag Pract. Mar-Apr 01 2024;30(2):155-157. doi:10.1097/phh.0000000000001867

Gary Freed, MD, MPH

- Project: Pediatric Sickle Cell Improvement Program (P-SCIP) recently received $750,000 of funding from the Michigan Department of Health and Human Services to expand from Southeast Michigan to a statewide effort to improve the quality of care for children with sickle cell anemia.

Gary Freed, MD, MPH and Susan Woolford, MD, MPH

- Project: Launched Michigan Community Hospitals Improving Equity for Children (Mi-CHIME), which is funded by a $500,000 grant from the Michigan Health Endowment Fund. Mi-CHIME is a quality collaborative of three community hospitals in Michigan – MyMichigan Medical Center Alpena, Covenant Children's Hospital in Saginaw, and Munson Medical Center in Traverse City.

Joyce Lee, MD, MPH

- **Lee JM**, Sharifi M, Oshman L, Griauzde DH, Chua KP. Dispensing of Glucagon-Like Peptide-1 Receptor Agonists to Adolescents and Young Adults, 2020-2023. JAMA. 2024 Jun 18;331(23):2041-2043. doi: 10.1001/jama.2024.7112. PMID: 38776113.

Zubin Modi, MD

- Project: Leads the Kidney Research Network (KRN), a 7-site electronic health record network focused on both kidney disease across the lifespan. In the past year, this network has committed to a machine learning project with an industry sponsor looking at outcomes in pediatric glomerular disease. Additionally, KRN has been a vital component of the PARASOL initiative a multi-stakeholder effort to develop a regulatory

endpoint for clinical trials for a rare glomerular disease (Focal Segmental Glomerulosclerosis). Dr. Modi has been a key contributor to this effort through the contribution of KRN data and participation in the development of the study design.

- Project: Received a NIH supplement to the Cure Glomerulonephropathy study to pilot a novel mobile health application. In this successful pilot, Dr. Modi and his team developed and deployed a kidney disease specific application with the MyDataHelps platform (Care Evolution, Ann Arbor). The application allows for a patient centered approach to electronic health record data where participants are able to consent to have their data used for ongoing research. The pilot yielded up to a 400% increase in key end point data vital for kidney disease research. It also showed the near complete accuracy between EHR data and data collected via traditional participant facing data collection. Based on these results, Dr. Modi and his team are working to deploy their mobile health application across the entire study with funding from the most recent 5-year renewal of the study.

Sarah Reeves, PhD, MPH

- Project: Sickle Cell Disease Evaluation Projects: Funded by the Michigan Department of Health and Human Services to provide a quantitative assessment of sickle cell disease metrics for clinics and for the state of Michigan to inform the development of a 5-year strategic plan for sickle cell disease.

- Peng HK, Dombkowski KJ, Plegue MA, Latta K, Malosh R, Creary MS, **Reeves SL**. COVID-19 Immunization Coverage Among People With Sickle Cell Disease. JAMA Netw Open. 2024 Jan 2;7(1):e2351618. doi: 10.1001/jamanetworkopen.2023.51618. PMID: 38190186.

David Sandberg, PhD

- Khorashad BS, Kaabi O, Gardner MD, Getahun D, Goodman M, Lash TL, Lee PA, May J, McCracken C, Muzik M, Vupputuri S, Yacoub R, **Sandberg DE**. Prevalence of psychiatric comorbidities in females with classic congenital adrenal hyperplasia. J Clin Endocrinol Metab. 2024 Dec 4:dgae831. doi: 10.1210/clinem/dgae831. Epub ahead of print. PMID: 39656806.

Courtney Streur, MD, MS

- Advancing the Understanding of the Reproductive Health of Women with Cerebral Palsy: Preliminary Evidence to Tailor a Novel, Online Reproductive Health Educational Intervention (“Ability for Life”) to Adolescent Girls with Cerebral Palsy, American Academy of Cerebral Palsy and Developmental Medicine
  PI: Courney Streur, $30,000

- Expanding AbilityForLife.org, an online video-based sexual health educational platform for adolescent girls with physical disabilities, Department of Obstetrics and Gynecology's Women's Health Innovation Award
  PI: Courney Streur, $20,000

- Okanlami OO, Kreschmer JM, Gupta S, Lee A, Sarma AV, **Streur CS**. "I'm a bathroom expert": a qualitative study exploring how students with physical disabilities manage toileting during college. Front Pediatr. 2024 Sep 27;12:1397229. doi: 10.3389/fped.2024.1397229. Erratum in: Front Pediatr. 2024 Oct 28;12:1514828. doi: 10.3389/fped.2024.1514828. PMID: 39398418.

Administrative and Community Building Initiatives

In 2024 and early 2025, CHEAR faculty and staff have continued to grow in our new space at the North Campus Research Complex. Being co-located with so many of our collaborators in other departments and units has strengthened our relationships and spurred many unique ideas for ongoing projects and partnerships. CHEAR faculty and staff continue to work in a hybrid environment. Teleconferencing capabilities continue to advance, allowing for seamless communication and connection between on-site and remote teams.

CHEAR Community Building:

These past 18 months have also seen an increased focus on community building within CHEAR. An employee picnic was hosted in July 2024 with catered food and games. Everyone had a blast trying to sink Division Administrator Deb Boyd and Interim Director Jeremy Adler in the dunk tank! This tradition was continued in June 2025 where all of CHEAR sat down for lovely bar-b-que lunch together.

The first annual CHEARsgiving was in hosted in November 2024. This event was pot-luck style with lots of delicious food and camaraderie had by all. We also continued one of the most fun CHEAR traditions, the annual employee appreciation winter celebration event. It was so wonderful to bring the faculty and staff together to enjoy a catered lunch and dessert potluck. No surprise, but the White Elephant gift exchange led to many laughs and jokes that won't soon be forgotten.

To kick off 2025, CHEAR hosted a "you are soup-er" day where everyone enjoyed a collection of different soups, a perfect fit for a cold, January day. And in February, we took a moment together, decorating cookies and brownies to celebrate Valentine's Day. We also hosted three all-staff meetings within the last 18 months where CHEAR connects and receives state of the center updates.

CHEAR Philanthropy:

CHEAR continued to showcase their giving spirit, participating in the Michigan Medicine School

Supply Drive, the Annual Holiday Toy Drive for C.S. Mott Children's Hospital, and at a Food Gatherers Volunteer Event.

Michigan Medicine Annual Supply Drive:

As a result of in-kind and cash donations, CHEAR contributed: 17 backpacks, 20 notebooks/packages of loose-leaf paper, 4 binders, 2 packs of colored pencils, 26 packs of markers, 10 packs of index cards, 20 glue sticks, 2 calculators, 160 pencils & 60 ink pens, 24 deodorant sticks, 12 packages of period products, 11 toothbrushes & 14 tubes of toothpaste, 39 body wash, shampoo/conditioner, soap, lotion, and sanitizers, 86 pairs of underwear, and 85 pairs of socks.

Food Gatherers Volunteer Event:

A group of six CHEAR staff spent an afternoon working in the Food Gatherers warehouse, sorting produce and canned goods, repackaging bulk foods, and keeping the warehouse clean and food safe.

Annual Holiday Toy Drive for C.S. Mott Children's Hospital:

Thanks to in-kind and cash donations, CHEAR contributed: 6 arts and craft kits, 3 large books, 12 infant/toddler toys, 4 princess barbies, 2 Lego kits, 15 hot wheel cars, 1 playdoh kit, 10 games, and a 12 pack of stuffed animals.

Communications and Outreach

The CHEAR External Newsletter was revamped and sent out for the Fall of 2024. This publication, designed to highlight priority research, policy contributions and high-impact publications from CHEAR faculty, was very well received and reaches our colleagues and collaborators on a broad level.

Internal communication has also been increased. October 2024 saw the return of the internal newsletter showcasing CHEAR and University updates, celebrating faculty and staff, and shining a spotlight on things that may otherwise go unacknowledged. CHEAR also hosted two all-team meetings, one in the spring and the other in the fall, for important community updates and broad information sharing.

Events

Annual Susan B. Meister Lecture in Child Health Policy:

2024 saw a well-attended and impactful Annual Susan B. Meister Lecture in Child Health Policy. **Adrianne Todman**, Acting Secretary, U.S. Department of Housing and Urban Development, presented, *"The Impact of Neighborhoods on Child Health: opportunities for Better Policy."*

Panelists included **Sara Adar, ScD, MHS**, Associate Chair and Associate Professor of Epidemiology; **Jennifer Erb-Downward, MPH**, Director of Housing Stability Programs and Policy

Initiatives, Poverty Solutions; **Alison L. Miller, PhD**, Professor, Health Behavior and Health Education, School of Public Health; and **Carla O'Connor, PhD**, University Diversity and Social Transformation Professor and Arthur F. Thurnau Professor, Marsal Family School of Education. **Kathleen Cagney, PhD, MPP**, Director, Institute for Social Research, delivered closing remarks.

We were pleased to honor **Meredith Pedde, PhD, MPH, MPP**, Assistant Research Scientist in Epidemiology, School of Public Health at the University of Michigan, with the 2024 Best Paper in Child Health Policy award. Her article *"Randomized design evidence of the attendance benefits of the EPA School Bus Rebate Program,"* published in *Nat Sustain*, correlated the relationship between replacing older, highly polluting buses and positive impacts on the student attendance rate (Appendix 5).

2025 was one of the most energetic and collaborative Susan B. Meister Lecture in Child Health Policy to date. **Anthony White**, Artistic Director for the Detroit Youth Concert Choir and Performing Arts Company gave a keynote all about how "Music Matters" and attendees were treated to a 30-minute performance by the inspiring **Detroit Youth Choir**.

Speakers of the event included **Matthew Van Besien**, President, University Musical Society who gave opening remarks; panelists Kate Fitzpatrick-Harnish, PhD, Associate Dean for Undergraduate Academic Affairs, School of Music, Theatre, and Dance, Karl Grosh, PhD, MS, Professor of Mechanical Engineering, College of Engineering, **Meredith Irvine, MHA, MT-BC**, **NICUMT**, Sophie's Place Studio Manager, Michigan Medicine, and **Victoria Shaw, PhD**, Detroit School and Arts Partnerships Lead, Marsal Family School of Education; closing remarks were delivered by **John Z. Ayanian, MD, MPP**, Director, Institute for Healthcare Policy and Innovation. The entire event was moderated by **Jeremy Adler, MD, MSc**, interim Director, Susan B. Meister Child Health Evaluation and Research Center.

We were very pleased to honor **Jessica Bezek, MS**, PhD candidate in Clinical Psychology, with the 2025 Best Paper in Child Health Policy Award. Her paper, "*Functional Brain Network Organization and Multidomain Resilience to Neighborhood Disadvantage in Youth*," published in *American Psychology*, found advance support for multidimensional resilience models and reveal distinct neural mechanisms supporting resilience to neighborhood disadvantage across specific domains in youth (Appendix 6).

Appendix 1

Faculty Honors & Awards

Outstanding Mentorship Award

Presented by: Joseph Kohne

This award recognizes an individual who has been exceptional in supporting the professional development of students, house-officers, research trainees, and/or faculty.

Outstanding Mentorship Award

Ryan Barbaro, CHEAR, Critical Care Medicine

- Dr. Barbaro approaches mentorship with an intentionality and focus on supporting an individual to achieve their goals.
- Ryan established the Pediatric Intensive Care Research Workgroup to support collaboration, peer mentorship, and the development of junior pediatric health services researchers, including physicians and nurse-scientists.
- He has established a format for PICU fellows to lead weekly discussions on ECMO care, including challenging initiation and discontinuation decisions, with thorough, ethically grounded guidance.
- Dr. Barbaro has boosted the national profiles of learners and junior faculty, helping them to secure speaking invitations at national conferences.

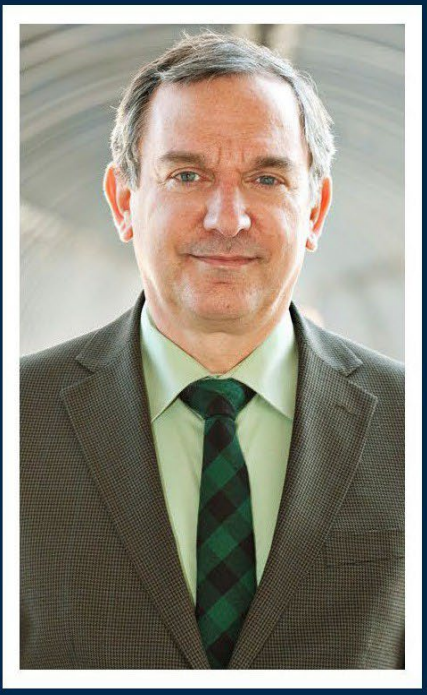
Established Faculty Research Award

Presented by: Emily Fredericks

This award recognizes an Associate or full Professor on any track who have produced a significant and coherent body of impactful scholarship.

Established Faculty Research Award

David Sandberg, CHEAR, Pediatric Psychology



- Dr. Sandberg has over 140 peer-reviewed manuscripts, 24 book chapters, 68 invited editorial commentaries, over 230 conference proceedings, and nearly 175 invited presentations (64 international).
- David is internationally recognized as one of few clinical psychologists with expertise in differences of sex development (DSD) and serves as a PI and co-PI on multiple NIH-funded projects, including a 16-site clinical research network.
- Dr. Sandberg's research has been recognized by the Society of Pediatric Psychology and has received the Dennis Drotar Distinguished Research Award in Pediatric Psychology.

Appendix 2

New Faculty Affiliates

Yi Tak (Daisy) Tsang, PhD
Department of Pediatrics, Division of Pediatric Psychology

Dr. Tsang has been conducting research on the dissemination and integration of behavioral health into medical settings. Currently, she is focusing on quality improvement related to how trauma impacts the medical experience of children and families. She is dedicated to the continuous improvement of trauma-informed practices in various pediatric settings, including primary care clinics. Her vision is to develop evidence-based trauma-informed care protocols such that families would feel more comfortable in medical settings and providers would feel more equipped to provide high-quality family-centered care.

Appendix 2

New Staff

William Gillespie
SQL Data Analyst

William Gillespie is a Data Architect for the Program for Equity and Child Health (PEACH). He assists researchers and clinicians by investigating and retrieving Electronic Health Records (HER), defining data dictionaries, performing statistical analysis, and creating data visualizations. He enjoys automation of EHR tasks and creating dashboards and visualizations for end users. He holds a Master of Science in Computer Programming from Eastern Michigan University. He has previously worked in health technology at UM, programming in military contracting, and teaching English as a second language. In his free time, he has interests in photography and foreign languages.

Sijia (Scarlett) He
Research Area Specialist

Scarlett's work focuses on statistical modeling as part of the team for Dr. Lisa Prosser and Dr. Kao-Ping Chua. She holds a master's degree in Biostatistics from the University of Michigan. Scarlett loves to spend time with her furry friends in her free time.

Jessica Bielawski
Center Manager

Jessica is the Center Manager and works with the administrative team to coordinate the overall operations of the center. She holds a Masters in Higher Education Administration from Madonna University. Outside of work, she enjoys spending time with her family, baking, and doing crosswords.

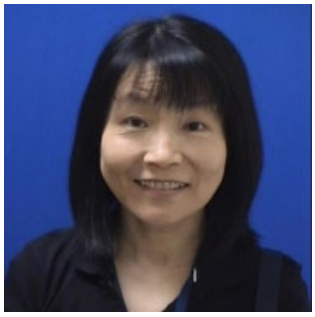
Elinor Artsy Navon
Research Area Specialist

Elinor is a senior researcher supporting PEACH and other child health equity initiatives led by Drs. Freed and Woolford. She has extensive experience in clinical neurology/neuroscience research in both academia and industry, as well as experience in health disparity research (while at the NIH, Harvard/MGH/MIT and abroad). A New Hampshire native, she earned her MD from the Technion Institute of Technology in Israel, worked as a physician in neurology and rehabilitation medicine, and has made her way back to the states to resume her path toward public health. In her free time, she enjoys spending time with her family, making fancy coffee drinks, volunteering for the Epilepsy Foundation, and exploring the best places for nature walks within Michigan.

Miao Yu
Applications Programmer / Analyst Lead

Miao Yu is the Lead Data Analyst for the Equity Team, working on the PEACH, PSCIP, Mi-CHEC, and Mi-CHIME projects under the leadership of Drs. Woolford and Freed. She manages the data analytics deliveries and support the data team for PEACH and other projects. She has dual Master's degrees in Computational Math and Statistics. With extensive experience in healthcare data management and analysis, she serves as a liaison bridging between equity clinical researchers and the data team. Her responsibilities include investigating and retrieving electronic health records (EHR), reviewing data dictionaries, performing statistical analyses, and creating data visualizations and project reports. Ms. Yu has a deep expertise in epidemiology and biostatistics and has previously worked as a statistical geneticist focused on identifying risk biomarkers for chronic disease prevention and understanding their interactions with social and environmental factors. Additionally, she has spent several years as a health data scientist working on mental health improvement initiatives within healthcare systems, aiming to enhance outcomes for patients and their caregivers.

Chiu-Mei Chen
Business Intelligence Analyst Lead



Chiu-Mei Chen is a Business Intelligence Analyst on the team led by Dr. Joyce Lee. She gathers, analyzes, and interprets data to support operational, clinical care, quality improvement, and research initiatives. Chiu-Mei holds a Master of Science in Information Systems from Eastern Michigan University. She has previously worked at the University of Michigan in various departments, including the Emergency Department, UMMG, Ophthalmology, DOCTR, Radiology, CIDSS, and HMRC.

Jung Eun Lee
Lead Data Analyst

Jung Eun Lee is a Lead Data Analyst collaborating with Dr. Joyce Lee on research projects centered on diabetes and obesity. She specializes in designing, developing, and managing research databases, as well as creating data visualizations and performing statistical analyses to support clinical, operational, and research goals. Prior to joining CHEAR, Jung Eun conducted research utilizing large-scale medical databases and developed a drug repositioning algorithm at Asan Medical Center in Seoul, Korea. She also contributed to biometric identification research at Michigan State University, collaborating with law enforcement agencies including the FBI—work that led to multiple publications and licensed technologies. She holds dual master's degrees in Computer Science and Biostatistics from Michigan State University.

Appendix 4

Seminars & Work-in-Progress Sessions,
January 2024 - June 2025

Date	Meeting	Place
01/09/2024	Methods Seminar – Kevin Dombkowski, DrPH, MS: Introduction to Health Informatics 101.	Hybrid
01/16/2024	CHEAR Seminar – Stephanie Mayne, PhD, MHS: Linking Geographic Exposures to Pediatric Primary Care HER Data for Epidemiologic and Health Equity Research	Hybrid
01/23/2024	Fellows Seminar – Joanne Constantine, PhD: Association between the Children's Special Health Care Services Expansion and Health- Related Outcomes Among Adults with Sickle Cell Disease in Michigan	Hybrid
02/06/2024	CHEAR Seminar – Toby Lewis, MD, MPH: Promoting Equity in patient portal access and usage for children and adolescents with asthma	Hybrid
02/13/2024	Methods Seminar – Mariam Kayle, PhD, RN, CCNS: Using Group- Based Trajectory Analysis to Model Health Outcomes	Hybrid
03/05/2024	CHEAR Seminar – Alison Miller, PhD: Firearm Safety and Injury Prevention in Early Childhood: A Parent Engagement Approach	Hybrid
04/02/2024	CHEAR Seminar – Kim Dalziel, PhD: Advances in measurement and valuation of health-related quality of life in young children	Hybrid
04/09/2024	Methods Seminar – Lisa Prosser, PhD, MS: Introduction to cost-effectiveness analysis	Hybrid
04/16/2024	CHEAR Seminar – Zubin Modi, MD: Bridging Health Services and Clinical Research: The Kidney Research Network	Hybrid
04/23/2024	Fellows Seminar – Melinda Rushing, PhD, LMSW: Investigating Antibiotic Prophylaxis Initiation and Initial Adherence Trajectories among Young Children with Sickle Cell Anemia	Hybrid
05/07/2024	CHEAR Seminar – Tiffany Munzer, MD: Young Children's Development and Novel Technologies	Hybrid
05/21/2024	CHEAR Seminar – Ryan Barbaro, MD, MSc: Lessons from a big dose of critical illness	Hybrid
05/28/2024	Fellows Seminar – Joanne Constantine, PhD: Association between Telehealth Initiation of Stimulant Therapy and New Substance Use Disorders	Hybrid
06/04/2024	Fellows Seminar – Hannah Peng & Krista Latta, Statisticians: Linking Datasets - What's the Big deal?	Hybrid

06/18/2024	CHEAR Seminar – Michael Dolgin, PhD: Meaningful Clinical Change in Clinical Trials	Hybrid
09/10/2024	CHEAR Faculty WIP – Joanne Constantine, PhD: Comparative Enrollment Timing in Medicaid and Children's Special health Care Services and Health Services Utilization for Sickle Cell Disease Patients Post Program Expansion in Michigan	Hybrid
09/17/2024	CHEAR Seminar – Joanne Constantine, PhD: Quasi-experimental Analytic Methods for Health Services Research.	Hybrid
10/01/2024	CHEAR Seminar – Lonnie Barnett, MDHHS: Michigan Children's Special Health Care Services: Opportunities for Collaboration	Hybrid
10/08/2024	CHEAR Faculty WIP – Joseph Kohne, MD: Necrotizing Enterocolitis Labeling and Computer- Enhanced Diagnosis	Hybrid
10/15/2024	CHEAR Seminar – Samir Gadepalli, MD, MS, MBA: The Next Generation of Pediatric Surgeons	Hybrid
11/19/2024	CHEAR Seminar – Kim Dalziel, PhD: Co-designing & Evaluating a Generic Pediatric Patient Reported Outcome Measure (P-PROM) Intervention in Tertiary Hospital Outpatient Care.	Hybrid
12/03/2024	CHEAR Seminar – Amy Hanson, MD: My Path to Children's Health Services Research	Hybrid
12/10/2024	Fellows Seminar – Nina Hill, MD: "Filling My Plate"- Upcoming Project Ideas in Food Insecurity Screening, Interventions & Policy	Hybrid
12/17/2024	CHEAR Seminar – Matt Hall, PhD: The Pediatric Health Information System: Learning from Children's Hospital Data	Hybrid
01/07/2025	CHEAR Seminar – David Sandberg, PhD, & Melissa Gardner: High Stakes Proxy Decision Making in Pediatrics: AI as Decision Coach?	Hybrid
01/21/2025	CHEAR Seminar – Debra Chopp, JD: Education Rights for Children: Current Guarantees, Emerging Problems, and Potential Solutions	Hybrid
02/04/2025	CHEAR Seminar – Margherita Fontana, DDS, PhD: A Case for Risk-Based Targeted Caries Management, and Evidence behind SDF use in Children 1-5	Hybrid
02/11/2025	Fellows Seminar – Nina Hill, MD: Analysis of Childhood Chronic Conditions with Food Insecurity, NHIS 2019-2023	Hybrid

03/18/2025	CHEAR Seminar – Stephanie Ettinger De Cuba, PhD, MPH: Co-Enrollment in Safety-Net Programs Among Families with Young Children: A Multistate Analysis of Enrollment Gaps, Design and Implementation	Hybrid
04/01/2025	CHEAR Seminar – Christina Weiland, EdD, Med: The impacts of Michigan Transitional Kindergarten through Third Grade	Hybrid
04/08/2025	CHEAR Faculty WIP – Hadley Stevens Smith, PhD, MPSA: A Tale of Two Perspectives: State of the Science on Proxy-Reported Quality of Life and Guidance for Researchers	Hybrid
04/15/2025	CHEAR Faculty WIP – Sarah L. Reeves, PhD, MPH: R01 Application: Family Need for and Perception of Financial Interventions for Children with Sickle Cell Disease	Hybrid
04/22/2025	Fellows Seminar – Nina Hill, MD: Dispensing of HIV Pre-Exposure Prophylaxis Medications to U.S. Young Adults, 2016-2023	Hybrid
04/29/2025	CHEAR Faculty WIP – Kevin Gochenour, MD: Respiratory Failure Management Variation in Adolescent and Young Adults in Pediatric and Adult ICUs	Hybrid
05/06/2025	CHEAR Seminar – Sarah A. Stoddard, PhD, RN, CNP, FASHM, FAAN: Substance Misuse Among School Disengaged Youth: Opportunities for Prevention	Hybrid
05/13/2025	CHEAR Faculty WIP – Abigail Gibbs, MD: Evaluating CPAP Use for Term Newborns in Michigan from 2020-2024	Hybrid
05/20/2025	CHEAR Seminar – Susan Woolford, MD, MPH: The Role of Lifestyle Management in the Era of Incretin Mimetics	Hybrid

Appendix 5

Best Paper in Child Health Policy, 2024

JAMA Network Open

Original Investigation | Public Health

Perceptions of COVID-19 Vaccine Incentives Among Adolescents and Young Adults

Caroline M. Hogan, MD; Marika E. Waselewski, MPH; Parker Szachta; Clara Wolff; Xochitl Amaro; Tammy Chang, MD, MPH, MS

Abstract

IMPORTANCE Vaccine incentives have been used across the US to encourage COVID-19 vaccine uptake and include programs targeted to adolescents and young adults. However, little is known about youths' views regarding these initiatives.

OBJECTIVE To assess experiences and perceptions of COVID-19 vaccine incentives in a nationwide sample of US youth.

DESIGN, SETTING, AND PARTICIPANTS A qualitative survey study was conducted using the MyVoice text message-based polling platform from October 22 to October 29, 2021. Participants were US adolescents and young adults aged 14 to 24 years, who were sent 5 open-ended questions to assess their experiences and perceptions of COVID-19 vaccine incentives. Qualitative responses were analyzed thematically. Descriptive statistical analysis was performed in January 2022.

MAIN OUTCOMES AND MEASURES Experiences, perceptions, and opinions related to COVID-19 vaccine incentives as measured by survey response.

RESULTS A total of 1125 of 1206 youth (93%) responded to the survey and had a mean (SD) age of 20 (2) years, 664 (59%) identified as male, and 769 (68%) identified as non-Hispanic White. Of respondents, 871 (79%) reported having heard of vaccine incentives, and 892 (82%) believed they were a good idea or had positive attributes. Notably, 305 youth (28%) expressed concerns about vaccine incentives, citing uncertainty about their effectiveness (86 [28%]), their ethical use (63 [21%]), the impact on vaccine motivations (51 [17%]), and confidence (39 [13%]), and lack of fairness (35 [11%]). Only 73 youth (7%) reported that an incentive influenced their decision to get a COVID-19 vaccine. When asked what they thought would motivate others to get a COVID-19 vaccine, youth with an opinion (536 of 1032 [52%]) most commonly reported incentives (112 [21%]) and additional COVID-19 vaccine testing, safety, or regulation (115 [21%]).

CONCLUSIONS AND RELEVANCE COVID-19 vaccine incentives are well known to youth but not a significant self-reported motivator for vaccination. Although generally viewed favorably, more than a quarter of youth expressed concerns regarding vaccine incentives, including but not limited to their ethics, effectiveness, fairness, and impacts on vaccine motivation and confidence. Policymakers considering targeted use of COVID-19 vaccine incentives should weigh youths' perspectives on these initiatives alongside objective effectiveness and cost-effectiveness data.

Key Points

Question Whatdo US adolescents and young adults know and think about COVID-19 vaccine incentives?

Findings In this qualitative study of 1125 adolescent and young adult respondents, youth awareness of COVID-19 vaccine incentives was high, and their opinions were generally favorable. However, more than a quarter of youth expressed concerns about incentives, including but not limited to their effectiveness, ethical use, fairness, and impact on vaccine motivations and confidence.

Meaning These findings suggest that more research is needed to understand the incidence, characteristics, and effectiveness of COVID-19 vaccine incentives targeted to children and young adults. Policymakers considering interim implementation of incentive programs should consider youths' perspectives on these public health measures.

Author affiliations and article information are listed at the end of this article.

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Introduction

Throughout 2021, US state and local governments, public health organizations, insurers, and private businesses introduced incentives to encourage COVID-19 vaccine uptake. Some of these programs were targeted to adolescents and young adults, who make up approximately 14% of the population and thus represent a key demographic in the country's COVID-19 vaccination campaign.[1,2] Lotteries, scholarships, cash payments, event tickets, and free items are just some of the incentives that have been offered to vaccinated adolescents, college students, and other young adults.[3,4]

While there has not yet been a comprehensive characterization of youth COVID-19 vaccine incentives, news reports suggest they are relatively common and can be significant in scope. For example, California offered children 12 years of age and older who received at least 1 dose of a COVID-19 vaccine the opportunity to enter a lottery with $1.5 million prizes,[5] and, in Minnesota, fully vaccinated 12 to 17-year-olds could win $100 000 college scholarships.[6]

Despite the implementation of COVID-19 vaccine incentives, little is known about youths' views regarding these initiatives. Understanding youth perspectives is important given the significant financial resources made available for COVID-19 vaccine incentives[7]; a lack of consensus around incentive effectiveness[8-14]; and the ethical considerations of offering incentives to promote vaccine uptake,[15-17] particularly to minors less than 18 years of age who, in most states, can neither independently consent to vaccination nor participation in COVID-19 incentive programs. This qualitative survey study aims to identify adolescent and young adults' experiences and perceptions of COVID-19 vaccine incentives, with the goal of shaping future public health campaigns and investments targeted to these groups.

Methods

This qualitative study was approved by the University of Michigan institutional review board with a waiver of parental consent for minors given the minimal risk to participants. All participants provided written consent during online enrollment. This study followed American Association for Public Opinion Research (AAPOR) reporting guideline for survey research[18,19] and the Standards for Reporting Qualitative Research (SRQR) reporting guideline.[20]

The survey was fielded using MyVoice, a national text message-based polling platform of US youth. Participants ranged from age 14 to 24 years and were recruited from social media based on national benchmarks from the American Community Survey.[21] Demographic information, including self-reported age, gender, race and ethnicity, education level, parental education level, free or reduced lunch status, and region were collected at study enrollment.[22] Participants received a small payment of US $1 for responding to the survey.

Data on race and ethnicity were collectedto ensure the MyVoice youth cohort mirrors, as much as possible, weighted demographic characteristics from the American Community Survey. Participants were asked the question, "What is your race? Check all that apply." They were given the following response categories to choose from: "American Indian or Alaska Native, Asian, Black or African American, Native Hawaiian or other Pacific Islander, White or Caucasian, and other (please describe)." To collect ethnicity data, participants were also asked, "Are you Hispanic or Latino?" with a yes or no response option.

Five open-ended questions focused on COVID-19 vaccine incentives were sent to 1206 youths on October 22, 2021. These questions were developed and analyzed by a team of researchers with clinical experience in pediatrics and adolescent medicine and methodologic expertise in qualitative mixed methods research. The questions included: (1) Have you heard about incentives for getting the COVID-19 vaccine (lotteries, scholarships, free stuff, etc)? If yes, what have you heard of? (2) Do you think incentives are a good idea? Why or why not? (3) Did an incentive influence your decision about getting vaccinated? Tell us about it. (4) If you have not gotten vaccinated against COVID-19, what would it take for you to get vaccinated? (5) If someone you know has not gotten vaccinated, what

would it takefor them to get vaccinated? The survey was closedto additionalresponses on October 29, 2021.

Data Analysis

Qualitative responses were analyzed thematically using a grounded theory approach. Four investigators (C.M.H., M.E.W., P.S., C.W.) iteratively identified response categories for the 5 questions and created a shared codebook based on these themes. Each question was then coded by a pair of investigators (C.M.H., M.E.W., P.S., C.W., or X.A.), who independently analyzed all responses to that question. Any discrepancies in coding were discussed until consensus was reached. Frequency statistics were calculated using Excel 2016 (Microsoft) in January 2022.

Results

Among the 1125 participants who responded to at least 1 question (1125 of 1206; 93% response rate), the mean (SD) age was 20 (2) years, 664 (59%) identified as male, 769 (68%) identified as non-Hispanic White, and 462 (41%) qualified for free or reduced lunch (**Table 1**). We did not directly ask participants if they were vaccinated against COVID-19; however, 832 of 1043 (80%) of respondents reported receiving a COVID-19 vaccine in their free text responses. Representative quotes from respondents for each question can be found below and in **Table 2**, along with notable code frequencies.

Table 1. Demographic Charac teristics of Survey Responden s and Nonrespondents From the MyVoice Cohort

Characteristics	No. (%) Respondents (n = 1125)	Nonrespondents (n = 81)	ACS 2019, weighted %
Age, mean (SD)	20 (2)	19 (2)	NA
Gender			
Male	664 (59)	37 (46)	51.2
Female	360 (32)	36 (44)	48.8
Other	101 (9)	8 (10)	NA
Race and ethnicity			
Hispanic	100 (9)	20 (25)	23.4
Non-Hispanic			
Black	72 (6)	14 (17)	13.8
White	769 (68)	32 (40)	52.5
Other[a]	182 (16)	15 (19)	10.3
Education level			
Less than high school[b]	256 (23)	26 (33)	42.4
High school graduate	141 (13)	13 (16)	21.7
Some college or technical school	483 (43)	28 (35)	24.6
College or technical degree	245 (22)	13 (16)	11.3
Region			
Midwest	320 (28)	25 (31)	21.0
Northeast	252 (22)	9 (11)	16.6
South	319 (28)	31 (39)	38.5
West	232 (21)	15 (19)	23.9
Free or reduced lunch recipient			
Yes	462 (41)	41 (52)	NA
No	657 (59)	38 (48)	NA

Abbreviations: ACS, American Community Survey; NA, not applicable.

[a] The other category includes respondents who identified as American Indian or Alaska Native, Asian, Native Hawaiian or other Pacific Islander, or self-identified as "other," with a free-text option to describe.

[b] Includes participants still in high school.

Table 2. Questions and Representative Respondent Quotes for the Most Common Themes

Theme	No. (%)[a]	Representative quote(s)
Have you heard about incentives for getting the COVID-19 vaccine (lotteries, scholarships, free stuff, etc)? If yes, what have you heard of? (n = 1106)		
Yes	871 (79)	"Yes"; "I have"
Lotteries or raffles	361 (41)	"Lotteries"; "Sweepstakes mainly"
Money or cash-equivalent	275 (32)	"I've heard that they're giving $100-1000 to people who get the vaccine."
Free items	211 (24)	"Apple products"; "marijuana cigarettes"; "discounts…at online stores or local stores in my city"
Food and drink	163 (19)	"Krispy Kreme's free donuteveryday for the rest of the year"
Scholarships	158 (18)	"University scholarships"; "free tuition and housing"
Event tickets/experiences	58 (7)	"Free lollapalooza tickets" "Tickets to sports games"
No/unsure	235 (21)	"Yes I mean now I haven't heard of those kinds of incentives." "Yes free uber rides"
Do you think incentives are a good idea? Why or why not? (n = 1092)		
Yes	759 (70)	"Yea, it may motivate people who were otherwise hesitant but needed a push"
No	172 (16)	"No it seems sketchy"
Yes and no	133 (12)	"Yes, but I think it can also send the wrong message"
Unsure/maybe	28 (3)	"Perhaps I'm not sure"
Supporting reasons		
Effective or cost-effective	459 (51)	"Yes because it encourages more people to get the vaccine" "…You pay a little to get more vaccinated and you save a lot in care costs for patients with covid-19"
Supports common good	91 (10)	"Yes because it protects everyone from spreading the virus"
Fun reward	89 (10)	"Yes, they try to get people to take the vaccine in a more fun way"
Needed for normalcy	67 (8)	"Yes, because as many people as possible need to be vaccinated in order to get through this."
Money motivates	59 (7)	"Yeah, I think they are because it motivated people who are on the fence or are reward motivated"
Opposing reasons		
Not effective or cost-effective	86 (28)	"No because ppl don't want to get the shot" "No. They waste money"
Unethical	63 (21)	"No, it is bribing people to get a vaccine that they may not want"
Wrong motivations	51 (17)	"Incentives can make people feel entitled to rewards."
Promotes mistrust	39 (13)	"They aren't, I don't trust them."
Unfair	35 (11)	"I think they are unfair to the millions of people who got vaccinated without being eligible for an incentive"
Did an incentive influence your decision about getting vaccinated? Tell us about it. (n = 1081)		
Yes	73 (7)	"Yes I did it for the incentive"
Lotteries or raffles	11 (15)	"Yes, thinking that I could be the winner of $1 million encouraged me to get vaccinated faster."
Money or cash-equivalent	10 (14)	"Yes. I was short on cash, so it really helped"
Food and drink	9 (12)	"Yes, I received a free food order for 1 month at a supermarket chain"
Free items	8 (11)	they gave discounts in the sports store to those vaccinated and I got "Really yes because I had already decided not to get vaccinated but vaccinated"
No	1008 (93)	"No, I did not consider receiving any of those incentives to get vaccinated."
Unaware or unavailable	167 (17)	"No, there are no incentives in my state" "No, I got vaccinated before most incentives started rolling out"
Motivated by safety or illness concerns	202 (20)	"The only incentive I needed was having a better chance at staying healthy and alive." "No, I got vaccinated to protect those around me."
Motivated by desire for normalcy	21 (2)	"No, I thought it was a blessing enough to be able to get the vaccine and get back to being normal afterwards"
Motivated by mandates/requirements	20 (2)	"No, but my employer at the time was starting to mandate it"
Motivated by desire to socialize	18 (2)	"Yeah, i got one so I could be able to see my friends and go out"
Motivated by parents or family	15 (1)	"No my mother had made me get the vaccine"

(continued)

Table 2. Questions and Representative Respondent Quotes for the Most Common Themes (continued)

Theme	No. (%)[a]	Representative quote(s)
If you have not gotten vaccinated against COVID-19, what would it take for you to get vaccinated? (n = 1043)		
Already vaccinated	832 (80)	"I am vaccinated because I feel like it is my duty as a member of a society, I don't want to be a part of spreading this disease"
Nothing (strong refusal)	19 (2)	"You could not get me vaccinated, it's not possible."
Unsure	16 (2)	"I don't know honestly"
Specific motivators	177 (17)	
Incentive	56 (32)	"Free money would've driven me to get vaccinated along with free college tuition for four years"
Vaccine research, safety, and/or approval	38 (21)	"At least a year or so of testing to see if there are any long term side effects"
		"Probably FDA authorization"
COVID-19 impact (self or other)	33 (19)	"A very strong reason like someone getting sick "
Mandates/requirements	15 (8)	"Stuff like having to be fully vaccinated to eat in a restaurant or go certain places"
Access	14 (8)	"It needs to be easy to get, location and time"
If someone you know has not gotten vaccinated, what would it take for them to get vaccinated? (n = 1032)		
Family/friends/peers already vaccinated	164 (16)	"Everyone I know has been vaccinated at this point"
Nothing (strong refusal)	108 (10)	"Nothing at this point, people aren't gonna do it if they haven't"
Unsure	224 (22)	"I have no idea about that."
Specific motivators	536 (52)	
Vaccine research, safety, and/or approval	115 (21)	"More proof that the vaccine is safe, like full authorization or authorization for more age groups"
Incentive	112 (21)	"Probably a money incentive. That friend…wasn't vaccinated until that $50 gift card. Then they got vaccinated."
Information or education	69 (13)	"Explaining the science behind it and why it's safe and make the community safer"
COVID-19 impact (self or other)	64 (12)	"They would get vaccinated if they had a risk to their safety"
Mandates/requirements	58 (11)	"Requirement by employer or government"
Change in mindset	55 (10)	"They must have confidence to go out to get vaccinated"
External support or pressure	37 (7)	"It would take me convincing them, because they would be able to see how important it is"

[a] Totals may not add to 100% as codes are not mutually exclusive.

Awareness of COVID-19 Vaccine Incentives and Concern About Unintended Consequences

When asked, 871 youth (79%) reported having heard of COVID-19 vaccine incentives. The most well-known incentive types among this group included lotteries and raffles (361 [41%]), cash payments and cash equivalents (275 [32%]), free items (ranging from "stickers" and "free donut[s]" to "firearms" and "weed") (211 [24%]), food and drink (163 [19%]), scholarships (158 [18%]), and event tickets and other experiential incentives (such as "free vacations") (58 [7%]). Less frequently identified incentive types included free or discounted services (such as "manicure[s]" and "free rides from Uber") (30 [3%]) and getting time off from work or school (8 [1%]).

Most respondents (892 [82%]) thought that vaccine incentives were a good idea or had positive attributes, citing beliefs that incentives were effective or cost-effective in promoting vaccine uptake (459 [51%]), beneficial for the "greater good" of society (91 [10%]), or a fun or otherwise "nice reward" for getting vaccinated (89 [10%]). There were also beliefs that vaccine incentives were necessary and would facilitate a "return to normal" or prepandemic existence (67 [8%]). A few respondents reported feeling that incentives were a preferable alternative to vaccine mandates (19 [2%]).

A total of 305 respondents (28%) had concerns about COVID-19 vaccine incentives; of these, most worried that incentives were ineffective and/or cost-ineffective tools to promote vaccination (86 [28%]), unethical or akin to "bribery" (63 [21%]), created "wrong reason[s]" or motivations to get vaccinated (51 [17%]), decreased trust in vaccines and the institutions promoting vaccination (39 [13%]), or were unfair (particularly for "the millions of people who got vaccinated without being

eligible for an incentive") (35 [11%]). Thirty respondents (3%) expressed frustration that incentives were even necessary, with a respondent stating, "[we] shouldn't have to bribe people to not die."

Participants' Experiences With Incentives

Only 73 respondents (7%) reported that an incentive influenced their decision to get a COVID-19 vaccine. Of those who were motivated by an incentive, themost commonly reported incentivetypes were lotteries and raffles (11 [15%]), cash payments and gift cards (10 [14%]), food and drink (9 [12%]), free items (8 [11%]), event tickets and other experiential incentives (5 [7%]), scholarships (4 [5%]), free or discounted services (2 [3%]), and getting time off from work or school (2 [3%]).

More youth reported not being motivated by incentives (1008 [93%]) and expressed a nonincentive-related reason for getting vaccinated. These includedto stay healthy and otherwise not "get or spread COVID" (202 [20%]), to "get back to normal," and return to a prepandemic existence (21 [2%]), to comply with a vaccine mandate (20 [2%]), to visit friends or family, or otherwise engage in social activities (18 [2%]), or because a family member asked them to or "made [them]" (15 [1%]). Of note, when asked what they thought would motivate others to get a COVID-19 vaccine, incentives were one of the most common responses for youth with an opinion (112 [21%]).

Opinions About Other Methods of Increasing COVID-19 Vaccination

When asked what it would take for an unvaccinated acquaintance to get a COVID-19 vaccine, 332 respondents (32%) reported being unsure (224 [22%]) or that "nothing" could convince these individuals (108 [10%]). Additionally, 164 respondents (16%) reported that all their acquaintances were already vaccinated. Of the 536 respondents with an opinion about how to promote vaccine uptake, the most commonly reported factors were additional COVID-19 vaccine testing or safety data (115 [21%]), incentives (112 [21%]), more general education or information-sharing about vaccines (69 [13%]), getting COVID-19, or having "someone close to them [get it]" (64 [12%]), and vaccine mandates (58 [11%]).

Fewer respondents felt that the following interventions would be effective: social support or pressure to get vaccinated (37 [7%]); improved access to vaccination (28 [5%]); a recommendation from a doctor, religious leader, politician, or other respected source (27 [5%]); more trust in government, science, and/or health care institutions (18 [3%]); permission from a family member (7 [1%]); or an alternative vaccine formulation, such as "a nasal mist option" (7 [1%]).

Discussion

Our study reported that most youth have been exposed to a variety of incentives to promote COVID-19 vaccine uptake, ranging from lotteries and cash payments to item giveaways and scholarships. Despite youths' widespread exposure to vaccine incentives, most of our respondents denied that their personal decision to get a COVID-19 vaccine was influenced by an incentive. More common was a desire to stay healthy or minimize the spread of COVID-19 to respondents' friends, family members, and the general public. However, when asked what they thought would motivate others to get a COVID-19 vaccine, about 20% of youth with an opinion reported incentives, suggesting a possible lack of youth insight into their true vaccination motivations or a disconnect between the perceived vs actual effectiveness of vaccine incentives in this demographic.

It is possible that the right type of incentive program could motivate youth vaccination. For example, a pilot program that provided $25 cash cards to North Carolinians who received or drove someone to receive their first COVID-19 vaccine dose effectively slowed a regional decline in vaccination.[13] Adolescents and young adults, whose social connections are foundational to their identity and development, may be more responsive to these types of social incentives than to others.

Although most respondents believed that vaccine incentives were a good idea, 28% expressed concerns about incentives. Beyond skepticism about the effectiveness of these programs, these youth had more fundamental concerns about the ethics of vaccine incentives and expressed worry

that incentives undermined altruistic vaccine motivations, contributed to vaccine mistrust, and decreased vaccine confidence, and were unfair to those who were vaccinated without an incentive. Some ethicists have raised similar concerns about COVID-19 vaccine incentives in recent analyses[15]; this study suggests that those concerns are shared by a segment of US youth.

As of May 2022, about one-sixth of the eligible US population has not received any COVID-19 vaccine.[23] More than half of the respondents in our study offered specific strategies to promote vaccine uptake among the unvaccinated. These included generating more vaccine-specific testing, safety data, or regulation; providing more education and information about vaccines in general; and implementing vaccine mandates. Some respondents felt that improved vaccine access, recommendations from trusted leaders, or developing noninjection vaccine formulations would be beneficial. About 6% of respondents felt that the only way to increase vaccination was through personal experience, with the unvaccinated either "getting sick" themselves or having "someone close to them... get very sick or die."

Almost all COVID-19 vaccine incentive research to-date has been focused on the adult population; this survey study is the first, that we know of, to elicit youth opinions on vaccine incentives. More research is needed to evaluate the scope and characteristics of youth COVID-19 vaccine incentives and to evaluate the effectiveness of these programs in promoting vaccine uptake. Policymakers and investigators should continue to weigh the ethical considerations of offering vaccine incentives to children who, in most states, cannot independently consent to vaccination and require their parent or guardian's consent to enroll in vaccine incentive programs.

Limitations

This study had limitations. While MyVoice recruits youth based on age, gender, race and ethnicity, and geographical benchmarks for national data, respondents are not nationally representative because there is no assurance that recruitment methods will reach all eligible participants. Certain groups of respondents (male gender, non-Hispanic White ethnicity and race, at least some college education, and Midwestern and Northeastern location) were overrepresented, which limits generalizability. Additionally, social media recruitment necessarily limits participation to those who use it, which also limits the generalizability of our results.

Another limitation stems from the vaccination status of our survey participants. While we purposefully did not ask participants if they were vaccinated against COVID-19, based on question responses, at least 80% of respondents received a COVID-19 vaccine. It is possible that unvaccinated respondents have substantively different opinions about incentives compared with their vaccinated counterparts. Relatedly, since our study provides monetary incentives for participation, it is possible the cohort is biased toward those who are motivated by incentives, however small.

Conclusions

In this qualitative study of US adolescents and young adults, COVID-19 vaccine incentives are well-known but not a significant self-reported motivator for youth vaccination; however, they are perceived to be motivating to others. Although generally viewed favorably, 28% of youth respondents expressed concerns about vaccine incentives, including but not limited to their ethical use, effectiveness, and impact on vaccine motivation and confidence. More research is needed to better characterize COVID-19 vaccineincentives targeted to youth and to evaluate the effectiveness of these programs in promoting vaccine uptake. Policymakers and investigators should consider youths' perspectives on COVID-19 vaccine incentives, along with the ethical implications of offering incentives to children who cannot independently consent to vaccination or participation in incentive programs.

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Appendix 6

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Functional Brain Network Organization and Multidomain Resilience to Neighborhood Disadvantage in Youth

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Though youth living in disadvantaged neighborhoods experience greater risk for poor behavioral and mental health outcomes, many go on to show resilience in the face of adversity. A few recent studies have identified neural markers of resilience in cognitive and affective brain networks, yet the broader network organization supporting resilience in youth remains unknown, particularly in relation to neighborhood disadvantage. Moreover, most studies have defined resilience as the absence of psychopathology, which does not consider growing evidence that resilience also includes positive outcomes across multiple domains (e.g., social, academic). We examined associations between brain network organization and multiple resilience domains in a sample of 708 twins (7–19 years old) recruited from neighborhoods with above-average poverty levels. Graph analysis on functional connectivity data from resting-state and task-based functional magnetic resonance imaging was used to characterize features of intrinsic whole-brain and network-level organization, from which we explored associations with resilience in three domains: psychological, social, and academic. Fewer connections between a brain network involved in self-referential processing (i.e., default mode network) and the subcortical system were associated with greater social resilience. Further, greater whole-brain functional integration (i.e., efficiency) was associated with better psychological resilience among youth with relatively *lower* levels of cumulative adversity exposure. Alternatively, lower whole-brain efficiency and higher whole-brain robustness to disruption (i.e., assortativity) were associated with greater psychological and social resilience among youth with relatively *higher* levels of cumulative adversity. These findings advance support for multidimensional resilience models and reveal distinct neural mechanisms supporting resilience to neighborhood disadvantage across specific domains in youth.

Public Significance Statement
The present study used brain imaging to examine how the organization of information flow throughout the brain relates to resilience to neighborhood disadvantage in youth. Results identified three domains of resilience (i.e., psychological, social, and academic), which showed unique associations with patterns of information flow across brain networks and the entire brain. This work bridges advancements in resilience theory with neuroscience to identify brain markers of resilience among youth marginalized by the socioeconomic status of their neighborhood.

Keywords: resilience, poverty, graph theory, developmental psychopathology

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continued

Jessica L. Bezek

Over 12.5 million children currently live below the federal poverty line in the United States, making poverty one of the most pervasive forms of early life adversity (Parolin et al., 2022). Childhood poverty is associated with greater risk for numerous negative outcomes, including poorer physical and mental health, lower academic achievement, and greater involvement in the criminal justice system (McLoyd, 1998). Beyond risks incurred through family-level poverty, youth are often further exposed to economic disadvantage within their neighborhood, which increases exposure to a myriad of other adversities, such as community violence, toxicants, lower quality schools, and environmental instability (Hyde et al., 2020; Leventhal & Brooks-Gunn, 2000; Trentacosta et al., 2016).

Despite the many adverse consequences of neighborhood disadvantage, a majority of youth exhibit *resilience* in the face of adversity, a process broadly defined as positive adaptation following moderate to severe stress exposure (Luthar et al., 2000; Masten, 2001). Previous work has predominantly operationalized resilience as the *absence of psychopathology*; however, this definition has come under scrutiny for several reasons. First, resilience theorists have argued that the absence of psychopathology does not intrinsically measure positive adaptation or competence (Bonanno, 2012). Second, focusing only on a lack of psychopathology restricts our understanding of resilience to a single outcome domain (e.g., psychological well-being; Infurna & Jayawickreme, 2019). In previous work, distinct resilience domains evidence only small-to-moderate correlations with one another (S. A. Burt et al., 2021), suggesting that an individual can show resilience in one domain but not another. Indeed, multidimensional models of resilience (Miller-Graff, 2022) emphasize the need for measuring not only the absence of negative outcomes but also the presence of positive outcomes across multiple functional domains. Modern resilience models also call for sensitively assessing what constitutes adversity and how exposure to single versus cumulative adversities (e.g., higher cumulative risk) may uniquely influence developmental outcomes. The present study thus characterizes resilient functioning in youth across multiple domains (i.e., psychological, social, and academic) to identify unique areas of positive adaptation and probe for potential differences in the mechanisms supporting resilience across both *distinct domains* and *varying levels* of cumulative adversity exposure.

Though neuroscience is beginning to shed light on the mechanisms underlying psychological processes (e.g., emotion, cognition) and outcomes (e.g., psychopathology), studies are only just beginning to identify the neural markers of resilience (see Eaton et al., 2022, for review). Prior research has demonstrated that resilient youth exhibit greater gray matter volume across prefrontal cortices and the hippocampus (K. B. Burt et al., 2016; Morey et al., 2016), as well as greater ventral striatum activation and attenuated amygdala reactivity to emotional stimuli (Callaghan et al., 2019; Dennison et al., 2016). These regions support processes key to resilience, including executive functioning, memory, and emotional reactivity and regulation. However, the existing neuroimaging literature has largely defined resilience as the absence of psychopathology. Moreover, while previous functional magnetic resonance imaging (fMRI) studies often focus on structural or functional differences in discrete brain regions, basic neuroscience research reveals that complex behaviors and cognitive processes are also supported by the coordination of *large-scale intrinsic brain networks* composed of several brain regions working together (Meehan & Bressler, 2012).

To date, three key cortical brain networks have been implicated in psychopathology broadly (Menon, 2011) and in the resilience literature specifically (Iadipaolo et al., 2018). These include (a) the frontoparietal network (involved in high-level cognitive control), (b) the salience network (involved in orienting and attending to salient stimuli in the environment), and (c) the default mode network (involved in self-related processing and shown to deactivate during

Promotion guidelines, syntax needed to reproduce the reported analyses is available upon request, and raw data are shared via the NIMH Data Archive. Preliminary analyses of this project were presented at the Flux Congress 2022. Jessica L. Bezek and Luke W. Hyde conceptualized this article with important input from all authors. Luke W. Hyde and S. Alexandra Burt acquired funding that supported writing and project conceptualization (as well as several published studies described within). Jessica L. Bezek and Luke W. Hyde created the initial draft with input from Scott Tillem and Gabriela L. Suarez. All authors contributed to revising the article.

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externally oriented attention). Resting-state functional connectivity analyses are often used to characterize these intrinsic networks by measuring the brain's ongoing, spontaneous activity when individuals have no task instructions. Such analyses capture baseline brain network coactivation patterns, which have been integral for characterizing trajectories of brain network development in youth and examining correlates of psychopathology (Uddin et al., 2010). However, only a handful of studies have examined associations between intrinsic connectivity and resilience in youth. To date, studies have found that stronger hippocampal–prefrontal connectivity was associated with fewer anxiety symptoms (i.e., psychological resilience) in previously institutionalized youth (Silvers et al., 2016), while reduced connectivity between cortical networks supporting self-referential processing and executive functioning was related to resilience (i.e., self-reported hardiness and persistence) in youth facing economic and threat-related adversities (Iadipaolo et al., 2018). Further, default mode network connectivity has been proposed to support more accurate error estimates and less self-doubt in the face of stereotype threat (Forbes et al., 2015). This emerging literature highlights the importance of examining both corticosubcortical connectivity as well as cortical brain networks in relation to resilience. However, existing work has only examined discrete sets of connections among specific brain regions, which does not capture the complexity of global information processing across entire networks or the brain as a whole.

Graph theoretical analyses offer a unique tool to better characterize the brain's higher order organization by delineating the overall pattern of information flow across distributed neural networks (Farahani et al., 2019). These features of information flow can be grouped into quantifiable measures of network functioning, such as the speed and effectiveness of information integration (e.g., global efficiency), and the brain's robustness against disruption (e.g., clustering and assortativity). Such properties provide unique insights into cognitive and socioemotional outcomes. For example, greater network efficiency is linked to better cognitive performance and higher IQ (van den Heuvel et al., 2009), whereas deficits in robustness and efficiency have been associated with psychopathology and neurological disorders (e.g., schizophrenia, epilepsy; Ajilore et al., 2014; Micheloyannis, 2012). To date, researchers have found that resilience in adults was associated with differences in the organization of both specific brain regions and broader networks involved in emotion regulation and salience processing (Cisler et al., 2013; Gupta et al., 2017; Ohashi et al., 2019; Teicher et al., 2020). This literature provides initial support for the utility of graph theory in understanding resilient outcomes; however, the handful of existing graph theoretical analyses have all characterized resilience as a lack of psychopathology, and no studies have examined brain network organization patterns associated with resilience in youth.

The present study addresses these gaps in the literature by examining intrinsic functional brain network organization across three levels (i.e., at the whole-brain level, the network level, and in cortical-to-subcortical regions) as it relates to resilience across three domains (i.e., psychological, social, and academic resilience). We examined these questions in a relatively large cohort of families with twins residing in neighborhoods with above-average levels of neighborhood poverty (ranging from modest to severe). First, we hypothesized that higher levels of whole-brain efficiency and robustness to disruption would predict greater psychological resilience in line with previous work (Cisler et al., 2013; Yang et al., 2021); however, our analyses of social and academic resilience outcomes were more exploratory given the lack of preexisting literature. At the specific network level, we hypothesized that (a) academic resilience would be associated with greater efficiency and robustness to disruption in the cognitive control-related *frontoparietal network* given established associations between intellectual performance and this network's organization (van den Heuvel et al., 2009); (b) social resilience would be associated with the organization of the *salience and default mode networks* given evidence for the salience network's role in evaluating social reward and default mode network contributions to self-other representations (Yeshurun et al., 2021); and (c) psychological resilience would be associated with the functional organization of all three networks of interest. Specifically, we hypothesized that the default mode and frontoparietal networks' organization may be integral for protecting against psychopathology given the two networks' role in attending to and regulating introspection (Dixon et al., 2018).

Essential to our conceptualization of resilience in the current article is the sample's exposure to adversity at the neighborhood level. That is, all youth in the sample were exposed to neighborhood adversity to some degree. At the

Gabriela L. Suarez

same time, it is possible that two children living in the same low-income neighborhood may experience different cumulative exposure to a variety of specific adversities in the home or community. The cumulative risk literature demonstrates that greater cumulative adversity exposure is associated with poorer developmental outcomes (Evans et al., 2013), which emphasizes the importance of sensitively measuring youth's *cumulative adversity* exposure when understanding the neural correlates of resilience (e.g., do the same neural processes broadly supporting resilience also support resilience in youth exposed to relatively few vs. relatively many adversities?). Thus, our second aim assessed whether youth's cumulative exposure to specific community- and family-level adversities moderated associations between functional brain network organization and multidomain resilience. We predicted that associations between intrinsic brain organization and resilience may differ by level of adversity exposure. For youth with lower levels of cumulative risk, we expected greater connectivity to be related to resilience, specifically among brain regions involved in emotional reactivity (in line with existing studies probing the neural correlates of resilience against more isolated adversities; Eaton et al., 2022). In those exposed to greater levels of risk, we hypothesized that resilience would be associated with higher robustness to disruption and lower efficiency across the entire brain, as previously found in individuals with traumatic violence exposure (Cisler et al., 2016).

Method

Participants

Participants were part of the Michigan Twin Neurogenetics Study (MTwiNS), recruited from the Twin Study of Behavioral and Emotional Development–Child (TBED-C), a project within the broader Michigan State Twin Registry (S. A. Burt & Klump, 2013). Using birth records, the study identified twin families living within 120 miles of East Lansing, Michigan, including urban (e.g., Detroit, Flint, and Lansing), suburban, and rural areas. The study included a population- based sample (528 twin families) with children aged 6–10 years and an "at-risk" sample (502 twin families) from the same geographic region recruited only from neighborhoods (as defined by census tract) with above mean levels of family poverty (>10.5% of families in the neighborhood living below the poverty line, the mean at study onset; S. A. Burt & Klump, 2019). For the present study, we recruited families from the "at-risk" sample as well as those in the broader population-based study that would have met the criteria for the at-risk sample (i.e., living in neighborhoods with above mean levels of family poverty). Participants included 708 twins in 354 families (54.7% male; 78.2% White, 12.7% Black, 1.1% Hispanic, 7.5% "other" ethnoracial identity). Youth were 7–19 years old, but most of the sample (94.2%) was 10–17 years old (M_{age} = 14.58, *SD* = 2.23). At the time of data collection, the mean neighborhood poverty level for families in the study was 20% (i.e., 20% of families' neighbors were living below the poverty line), with a range of 0%–77% (some neighborhoods had gentrified since study onset and/or families had moved since they were recruited). Participants completed all behavioral questionnaires and neuroimaging in a single lab visit. All participants who participated in the fMRI scan met fMRI eligibility criteria, such as the absence of metal in their body (see Supplemental Table S2). Participants' guardians provided informed consent, and participants provided assent in compliance with institutional review board policies and American Psychological Association ethical standards in the treatment of human participants.

Multidimensional Resilience

Consistent with our previous work in this cohort (S. A. Burt et al., 2021), the present study utilized data from multiple measures and informants to create a comprehensive measure of resilience.

Psychological Resilience

Resilience and Life Satisfaction. Youth reported on *personal and relational resilience* via the 17-item Child and Youth Resilience Measure–Revised (CYRM-R; Jefferies et al., 2019). We examined all 17 items as a single score (α = .90). Youth also reported their *satisfaction with life* via the five-item Satisfaction With Life Scale (SWLS; α = .89; Diener et al., 1985).

Lack of Psychopathology. To measure rates of psychopathology, we examined parent and youth reports on the eight psychopathology subscales from the Child Behavior Checklist (CBCL) and the Youth Self-Report (YSR): Anxious/Depressed,

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Withdrawn/Depressed, Somatic Complaints, Social Problems, Thought Problems, Attention Problems, Rule-Breaking, and Aggressive Behavior (Achenbach & Rescorla, 2000). We recoded each scale as a dichotomous variable, indicating whether the child was either above (0) or below (1) the "borderline" cutpoint for clinical significance on each subscale. The eight dichotomous variables were then summed to serve as our indicators of a lack of psychopathology, ranging from 0 to 8, where 8 indicates no psychopathology and thus higher resilience.

Social Resilience

We measured social resilience via separate parent and youth reports on both the Social Activities and Social Competency subscales of the CBCL and the YSR. These scales utilize count variables to assess the child's involvement in clubs, activities, and organizations, as well as the number of friends, contact with friends, behavior alone, and behavior with others (e.g., about how many times a week does your child do things with any friends outside of regular school hours?).

Academic Resilience

We measured academic resilience via the sum of teacher reports on the Academic Performance subscale of the Teacher Report Form (TRF; $\alpha = .94$) and parent reports on the School Competency subscale of the CBCL. These measures assess school performance across subjects, special education services received, repeated classes, and academic or other school-related problems (e.g., does your child receive special education or remedial services?). These scales are designed to measure minimum competencies (e.g., the child can be failing a class and still be considered competent overall).

Statistical Model of Multidomain Resilience

To characterize resilience multidimensionally, we conducted a confirmatory factor analysis (CFA) based on a previous exploratory factor analysis described in S. A. Burt et al. (2021). The psychological resilience factor included four indicators: youth reports of resilience and life satisfaction from the CYRM-R and SWLS and parent and youth reports of psychopathology from the CBCL and YSR. The social resilience factor included four indicators: parent and youth reports on social competency and activity engagement from the CBCL and YSR. The academic resilience factor included two indicators: parent and teacher reports of academic competence from the CBCL and TRF. We conducted a CFA in Mplus Version 1.8.7 (Muthén & Muthén, 2017) using the CLUSTER command to account for nesting within families and maximum likelihood estimation with robust standard errors to handle missing data and to protect against distortion of effects from violations of distributional assumptions (C. F. Falk, 2018). All indicators significantly loaded onto their respective factors, and the model yielded a good model fit (see Figure 1A).

Cumulative Risk Index

To characterize youth's cumulative exposure to adversities within the home and community, we derived a cumulative risk index composed of eight parent- and youth-reported indicators: (a) exposure to community violence, (b) abuse/neglect, (c) harsh parenting, (d) interpartner violence, (e) parent–child conflict, (f) stressful life events, (g) parental depression, and (h) family income. Participants received a score of zero (no exposure) or one (exposure) for each indicator based on empirically derived cut points. All measures and descriptive statistics are outlined in Supplemental Table S1, and full descriptions of cumulative risk measures as well as their reporters can be found in the Supplemental Material. To derive total cumulative risk scores, we summed each participant's score on all eight indicators. Participants with data for at least six out of eight indicators were included in final analyses (N = 698), with final scores prorated to account for missing data. Scores ranged from zero to seven (M = 1.72, SD = 1.38; Supplemental Figure S1).

fMRI Acquisition and Processing

Pseudorest Compilation

Participants completed one 7-min resting-state scan (eyes open, gazing at a fixation cross) and three behavioral task scans, including a reward task (Peckins et al., 2022), a socioemotional face processing task (Suarez et al., 2022), and a cognitive control task (Tomlinson et al., 2020). The reliability

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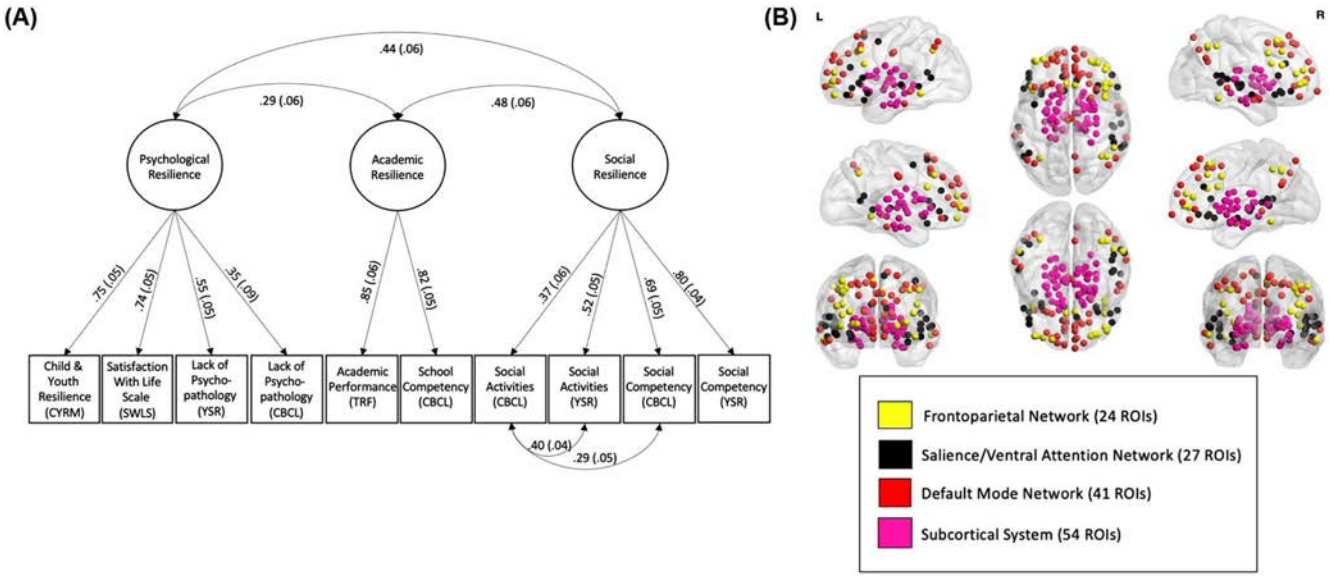
of resting-state functional connectivity data increases with greater scan length and with the concatenation of multiple shorter scans across contexts (Birn et al., 2013; Cho et al., 2021). Thus, consistent with previous work in this area (Fair et al., 2007; Kraus et al., 2021), we concatenated participants' resting-state and behavioral task scans (with task effects regressed out) to generate ~20 min of "pseudorest" scan data per participant to reliably elicit intrinsic functional connectivity networks.

Neuroimaging Procedures

As described in Suarez et al. (2022), each participant was scanned with one of two research-dedicated GE Discovery MR750 3T scanners. To enhance our magnetic resonance imaging data acquisition and harmonize our protocol with the Adolescent Brain Cognitive Development Study (Casey et al., 2018), we altered our acquisition protocol after the first 140 families. For the first 140 families, blood oxygenation level-dependent (BOLD) functional images were acquired via an 8-channel head coil and a *reverse spiral sequence* (Repetition Time/Time to Echo, TR/TE = 2,000/30 ms, flip angle = 90°, Field of View, FOV = 22 cm), which covered 43 interleaved oblique slices of 3-mm thickness. High-resolution T1-weighted Spoiled Gradient Recalled Echo images (156, 1 mm-thick slices) were aligned with the anterior commissure–posterior commissure plane and later used during normalization of the functional images. For the remaining 214 families, BOLD functional images were acquired with a 32-channel head coil

Figure 1
Neuroresilience Methods



Note. Panel A: Multidimensional resilience model. All factor loadings are from the standardized solution. Based on modification indices, the residual variances for parent and youth activities report, and parent activities report and social competency were allowed to covary. Standard errors of factor loadings are represented in parentheses. All factor loadings and covariances were significant at $p < .001$. Root-mean-square error of approximation = 0.05, comparative fit index = 0.93, standardized root mean residual = 0.05. Child-reported forms include the CYRM, SWLS, and YSR. Parent-reported forms include the CBCL. Teacher-reported forms include the TRF. A follow-up exploratory factor analysis with the two CYRM subscales (personal and relational resilience) further showed that both facets of the CYRM loaded onto the psychological resilience latent factor (loadings: $CYRM_{Personal}$ = .80, $CYRM_{Relational}$ = .81). Panel B: Brain networks of interest. Networks were parcellated using Gordon (cortical) and Tian (subcortical) functional atlases, and visualized using BrainNetViewer (Xia et al., 2013). CYRM = Child and Youth Resilience Measure; SWLS = Satisfaction With Life Scale; YSR = Youth Self-Report; CBCL = Child Behavior Checklist; TRF = Teacher Report Form; ROI = regions of interest. See the online article for the color version of this figure.

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and a gradient-echo sequence with *multiband acquisition* (TR/TE = 800/30 ms, flip angle = 52°, FOV = 21.6 cm), which covered 742 interleaved axial slices of 2.4-mm thickness. High-resolution T1-weighted Spoiled Gradient Recalled Echo images (208, 1-mm-thick slices) were aligned with the anterior commissure–posterior commissure plane and used during normalization of the functional images. Functional data were preprocessed and analyzed using Statistical Parametric Mapping Version 12 (Wellcome Trust Centre, London, the United Kingdom) via standard procedures (see Supplemental Material).

Motion and Denoising Correction Strategy

A conservative, multistep procedure was used to correct motion artifacts by combining multiple correction strategies (Parkes et al., 2018). First, data from each scanner session were motion scrubbed to identify and remove motion artifacts from the fMRI time series using a mean frame displacement cutoff value of 0.5 mm (Power et al., 2012). Sessions where >20% of the sessions were identified as motion artifact were excluded from subsequent analyses. Subjects who did not have at least two independent usable scanner sessions due to motion artifact after scrubbing were removed (see Supplemental Table S2). Second, Independent Component Analysis–based Automatic Removal of Motion Artifacts was applied to data at the subject level to remove motion-related artifacts (Pruim, Mennes, Buitelaar, & Beckmann, 2015; Pruim, Mennes, van Rooij, et al., 2015).

Graph Theoretical Analyses

Prior to completing the connectivity analysis, regions of interest (ROI) were defined using the Gordon et al. (2016) cortical atlas and the Tian et al. (2020) subcortical atlas (see Supplemental Table S3 for regions). Then, connectivity analyses were run on the preprocessed resting-state data and residualized task-based fMRI data using the CONN toolbox ROI to ROI connectivity analysis procedure (see Supplemental Material).

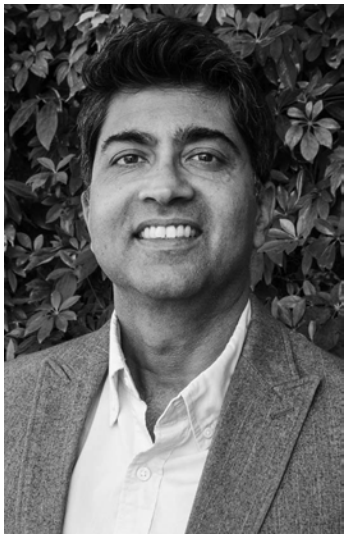
Graph Analysis

All graph analyses were completed in Matlab (Version 2018b). Using a combination of the Brain Connectivity Toolbox (Rubinov & Sporns, 2010) and native Matlab functions, we generated 40 graphs with different levels of sparsity (from proportional thresholds of .01–.40 at .01 intervals) and extracted graph metrics of interest from each graph. Next, to help ensure that graph metrics accurately reflected neural organization across different levels of sparsity, area under the curve was calculated for each graph metric across sparsity levels (Ginestet et al., 2011; Hosseini et al., 2012), producing one area under the curve value, per metric, per participant (see Supplemental Material).

Graph Metrics

Whole-Brain Organization. We extracted four measures of whole-brain organization in line with previous work (Farahani et al., 2019). First, we measured *functional integration* by extracting *global efficiency*, which measures how much time and/or neural resources are required for information to flow throughout the network. Second, we measured *robustness to disruption* by extracting two metrics. We first calculated *clustering*, which represents the degree to which nodes in the network form small computing clusters. A network with high clustering will be less impacted by a connection being interrupted because alternative paths exist for the information to flow through the cluster. Additionally, we calculated *assortativity*, which represents the extent to which nodes with a similar number of connections are connected to each other. For example, assortativity captures the extent to which highly connected points (i.e., hubs) are interconnected. We elected to study both clustering and assortativity as measures of functional robustness for two reasons. First, assortativity adds unique information about the connectivity of a network's main components, while clustering is confined to interconnections among small clusters that may not be network hubs. Second, previous work has shown an association between assortativity and resilience (Cisler et al., 2016). Last, we examined the *balance between functional integration and robustness to disruption* by calculating *sigma*. This balance is an important marker of optimal brain network organization, as it highlights the competing need for networks to have both efficient information flow and redundant interconnections supporting robustness to disruption.

Network-Level Organization. We calculated global efficiency, clustering, and sigma within our three cortical brain networks of interest: the frontoparietal, salience/ventral attention, and default mode networks (see Supplemental Methods, for network generation protocol).



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Subcortical Hubness. We extracted the number of connections (i.e., degree) between the subcortical system (e.g., amygdala, hippocampus; see Supplemental Table S3, for full list of regions) and all cortical nodes, as well as the number of connections between the subcortical system and the three cortical networks of interest (i.e., frontoparietal, salience/ventral attention, and default mode networks).

Data Analysis

A series of structural equation models were conducted in Mplus Version 1.8.7 to examine the association between functional brain network organization and the three resilience domains. We first assessed the main effects of whole-brain organization, network-level organization, and subcortical hubness on resilience. Analyses accounted for eight covariates, including age, sex, race, family income, scanner sequence (i.e., spiral vs. multiband), and motion (i.e., mean framewise displacement). To control for ethnoracial identity, we created four dummy-coded variables: White (coded as the reference variable because it was the largest group), Black, Hispanic, and Other (which included Asian, Native American, Pacific Islander, biracial, and self-identified "other" identities). We included race, a socially constructed category, as a series of covariates to account for differences in exposure to structural racism and the unequal exposures to poverty, stress, trauma, and opportunity for people of color living in the United States (Roberts & Rizzo, 2021). We controlled for family income using primary caregiver reports of monthly household gross income and any outside additional sources of income (e.g., government assistance, child support). We were not interested in using a genetically informed design in this specific study, and studies have shown that twins generally are representative of singletons in the population (Willemsen et al., 2021). As such, we used the Type = COMPLEX command to cluster twins by family ID and account for the nesting of twins within families. Additionally, we accounted for missing data using maximum likelihood estimation with robust standard errors (MLR). All 708 youth were included in the analysis, as MLR accounted for missingness on imaging and behavioral data. Follow-up analyses examining youth with and without fMRI data showed that the two groups largely did not differ on demographic or resilience variables. However, compared to those without fMRI data, the final scan sample was slightly older, included more Black youth, and reported higher rates of personal/relational resilience and activity engagement (see Supplemental Material for details). These variables were included in all models to address patterned missingness (Whitaker, 2021).

We conducted false discovery rate (FDR) corrections for multiple comparisons within whole-brain, network-level, and subcortical analyses. We corrected for 12 comparisons in whole brain and subcortical analyses (i.e., four metrics across three domains of resilience) and nine within-network comparisons (i.e., three metrics in each network for three resilience domains). To probe the potential moderating effect of cumulative risk exposure on the association between brain network organization and resilience, we ran a series of continuous interaction analyses using cumulative risk scores as a moderator. All models included the same covariates and corrected for multiple comparisons using FDR.

In accordance with the Transparency and Openness Promotion guidelines, all research materials (e.g., questionnaires) and analytic software are cited. The present study's design and analysis plan was not preregistered; however, all design and analysis decisions are presented in compliance with the American Psychological Association's reporting standards. Syntax needed to reproduce analyses is available upon request, and all raw data from this project are shared via the NIMH Data Archive.

Results

Preliminary Analyses

Zero-order correlations are reported in Supplemental Table S4. As predicted, cumulative risk was negatively associated with each resilience domain (r's = −.25 to −.45). Confirmatory factor analysis of multi-informant reports on resilience confirmed the factor structure of a previous exploratory factor analysis in this sample (S. A. Burt et al., 2021) and showed good model fit (see Figure 1A).

Aim 1: How Does Functional Brain Network Organization Relate to Multidomain Resilience?

We first examined associations with whole-brain organization. In contrast to our hypothesis that differences in functional integration (i.e., global efficiency), robustness to disruption (i.e., clustering and assortativity), and their

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balance (i.e., sigma) would predict unique resilient outcomes, there were no significant associations between functional organization and the three resilience domains (see Table 1). At the network level, we observed associations between all three networks and multiple resilience domains while controlling for covariates (i.e., age, sex, race, parent-reported family income, scanner sequence, fMRI head motion). However, these associations became trends when correcting for multiple comparisons. Consistent with our hypotheses, frontoparietal network robustness to disruption (i.e., clustering) was associated with academic functioning, such that greater clustering was associated with higher academic resilience (b^* = .10, p = .023, p_{FDR} = .069). Similarly, salience network clustering showed a positive association with academic resilience (b^* = .10, p = .044, p_{FDR} = .132), and default mode network clustering showed a positive association with psychological resilience (b^* = .11, p = .026, p_{FDR} = .078). Last, lower functional integration (i.e., global efficiency) in the frontoparietal network was associated with higher levels of social resilience (b^* = −.12, p = .028, p_{FDR} = .084). No direct associations between resilience and any other network or graph metric were significant (see Table 2).

At the subcortical level, we observed that fewer connections between the subcortical system and the default mode network were associated with higher social resilience, consistent with studies linking default mode network connectivity to the social understanding of others (Li et al., 2014; Yeshurun et al., 2021; b^* = −.13, p = .013, p_{FDR} = .049, R^2 = .219; see Supplemental Figure S2). In contrast, the number of corticosubcortical connections for the frontoparietal and salience networks was not significantly related to the three resilience domains (see Table 3). Last, there were no significant associations between the total number of corticosubcortical connections across the whole brain with any resilience domain.

Aim 2: Do the Neural Correlates of Resilience to Neighborhood Disadvantage Differ for Youth With Higher Versus Lower Cumulative Adversity Exposure?

At the whole-brain level, we observed a significant interaction between a measure of functional integration (i.e., global efficiency) and cumulative risk predicting

Table 1
Whole-Brain Associations With Multidomain Resilience

		Main effect regression		Interaction regression						
		Graph metric main effect		Graph metric main effect		Cumulative risk main effect		Interaction effect		
Graph metric	Resilience domain	b^*	p	b^*	p	b^*	p	b^*	p	p_{FDR}
Global efficiency	Psychological	−0.015	.769	−0.033	.498	−0.593	<.001***	−0.132	.006**	.031*
	Social	0.049	.440	0.043	.473	−0.189	.001**	−0.046	.355	
	Academic	−0.025	.645	−0.040	.478	−0.131	.020*	−0.090	.051	
Assortativity	Psychological	0.043	.346	0.073	.082	−0.613	<.001***	0.144	.001**	.007**
	Social	0.048	.383	0.069	.207	−0.214	<.001***	0.148	.001**	.007**
	Academic	−0.070	.156	−0.061	.217	−0.133	.023*	0.052	.288	
Clustering	Psychological	0.000	.995	0.019	.707	−0.589	<.001***	0.102	.064	
	Social	−0.052	.437	−0.049	.439	−0.188	.001**	0.017	.755	
	Academic	0.021	.705	0.034	.547	−0.129	.022*	0.070	.166	
Sigma	Psychological	−0.069	.186	−0.023	.638	−0.595	<.001***	−0.067	.274	
	Social	0.007	.906	0.005	.939	−0.214	<.001***	−0.101	.034*	.114
	Academic	0.033	.590	0.050	.417	−0.129	.029*	0.027	.676	

Note. Nonshaded columns include results from regression analyses conducted for Aim 1 (i.e., main effect regression), which explored the main effect of whole-brain topology on multidomain resilience. Shaded columns include results from regression analyses for Aim 2 (i.e., interaction regression), which explored the main effect of whole-brain topology on multidomain resilience as moderated by cumulative risk. All analyses controlled for age, sex, race, family income, scanner sequence, and functional magnetic resonance imaging head motion. N = 708 participants total; n = 559 participants with imaging data. FDR correction was completed for 12 tests across all graph metrics and resilience domains. Standardized β values are reported as b^*. FDR = false discovery rate. Bolded items reflect statistically significant effects.
* p < .05. ** p < .01. *** p < .001.

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psychological resilience ($b^* = -.13$, $p = .006$, $p_{FDR} = .031$, $R^2 = .354$; see Table 1). We utilized a validated online utility (Preacher et al., 2006) to calculate the levels of the moderator variable at which this interaction was significant. We found that greater global efficiency (i.e., efficiency >21.19) predicted *less* resilience in youth with relatively *higher* levels of cumulative risk (i.e., those with risk scores >2.91, $n = 159$; 22.5% of the sample). In contrast, we found that greater global efficiency predicted *higher* psychological resilience in youth with relatively *lower* cumulative risk scores (i.e., those with risk scores <0.43; $n = 140$; 19.8% of the sample), though the simple slope for the association in youth with lower risk scores was a trend (see Figure 2A).

We also observed significant interaction effects between network robustness against disruption (i.e., assortativity) and multiple resilience domains, which is consistent with work defining assortativity as a "resilient" neural architecture (Farahani et al., 2019; Table 1). First, we found a significant interaction between assortativity and cumulative risk in predicting greater psychological resilience ($b^* = 0.14$, $p = .001$, $p_{FDR} = .007$, $R^2 = .362$; Figure 2B). Simple slope analyses indicated that higher assortativity was associated with higher psychological resilience, but only in youth with above mean cumulative risk scores (i.e., risk scores above 1.95; $n = 344$; 48.6% of the sample). Similarly, we found a significant interaction between assortativity and cumulative risk in predicting greater social resilience ($b^* = 0.15$, $p = .001$, $p_{FDR} = .007$, $R^2 = .255$; Figure 2C), but once again only in youth with relatively higher cumulative risk scores (i.e., youth with scores above 2.00; $n = 208$; 29.4% of the sample). All assortativity interaction effects remained significant after correcting for multiple comparisons.

At the network level, we observed interactions between the organization of two brain networks and academic resilience (Table 2), though these associations were only statistical trends when corrected for multiple comparisons. First, functional integration (i.e., global efficiency) in the frontoparietal network interacted with cumulative risk to predict academic resilience ($b^* = -.13$, $p = .021$, $p_{FDR} = .063$). Second, we observed an interaction between a measure of robustness to disruption (i.e., clustering) in the salience/ventral attention network and academic resilience ($b^* = .10$, $p = .035$, $p_{FDR} = .105$).

At the subcortical level, we observed an interaction between subcortical hubness and psychological resilience that again became a trend when correcting for multiple comparisons ($b^* = -0.12$, $p = .033$, $p_{FDR} = .116$; Table 3). Given the low statistical significance of these findings after correcting for multiple comparisons, we did not interpret these trend results further.

Discussion

In the present study, we used graph theory to characterize functional brain network organization and explore associations with multidomain resilience to neighborhood disadvantage in a relatively large sample of youth living in low-income neighborhoods. We found that fewer connections between the default mode network and the subcortical system were associated with greater social resilience. Additionally, we found that associations between whole-brain organization and multidomain resilience differed by youth's level of cumulative adversity exposure. In youth exposed to higher levels of cumulative adversity, greater robustness to disruption was associated with social resilience, while lower global efficiency and higher robustness to disruption were related to greater psychological resilience. For youth experiencing less cumulative adversity, greater efficiency of whole-brain information flow was associated with greater psychological resilience. These results indicate that properties of information flow both between networks and throughout the entire brain may be a mechanism supporting youth's psychological and social functioning in the face of neighborhood disadvantage, while also highlighting that the specific neural signatures of resilience may differ by youth's overall level of adversity exposure.

First, we found that fewer connections between the subcortical system (e.g., amygdala, hippocampus, striatum, thalamus) and the default mode network were associated with higher levels of social resilience. Broadly, the subcortical system is associated with memory and affective processing (e.g., threat and reward responsivity), while the default mode network has been linked to self-referential thinking and understanding other's mental states (Yeshurun et al., 2021). Our finding in these systems appears to align with the emerging neuroimaging resilience literature. For example, within the subcortical system, greater activation in the ventral striatum (a region associated with reward sensitivity and

Table 2
Network-Level Associations With Multidomain Resilience

			Main effect regression			Interaction regression						
			Graph metric main effect			Graph metric main effect		Cumulative risk main effect		Interaction effect		
Network	Graph metric	Resilience domain	b^*	p	p_{FDR}	b^*	p	b^*	p	b^*	p	p_{FDR}
FPN	Global efficiency	Psychological	−0.046	.438		−0.044	.323	−0.579	<.001***	−0.056	.200	
		Social	−0.116	.028*	.084	−0.107	.042*	−0.185	.001**	−0.006	.910	
		Academic	−0.054	.297		−0.048	.418	−0.111	.036*	−0.129	.021*	.063
FPN	Clustering	Psychological	0.034	.533		0.034	.492	−0.592	<.001***	−0.059	.201	
		Social	0.014	.788		0.004	.935	−0.197	<.001***	−0.068	.092	
		Academic	0.101	.023*	.069	0.112	.013*	−0.124	.022*	0.066	.095	
FPN	Sigma	Psychological	0.084	.089		0.057	.217	−0.586	<.001***	−0.051	.323	
		Social	0.005	.927		−0.006	.905	−0.190	.001**	−0.026	.639	
		Academic	0.026	.642		0.019	.740	−0.129	.026*	−0.025	.650	
SAL	Global efficiency	Psychological	0.024	.682		−0.034	.492	−0.585	<.001***	0.074	.252	
		Social	−0.099	.075		−0.121	.029*	−0.205	<.001***	0.012	.803	
		Academic	0.023	.658		0.010	.850	−0.119	.027*	0.074	.221	
SAL	Clustering	Psychological	−0.002	.969		0.025	.581	−0.588	<.001***	0.045	.428	
		Social	0.069	.186		0.074	.157	−0.194	.001**	0.005	.928	
		Academic	0.104	.044*	.132	0.108	.032*	−0.126	.018*	0.103	.035*	.105
SAL	Sigma	Psychological	0.033	.532		0.027	.564	−0.586	<.001***	0.038	.513	
		Social	−0.099	.080		−0.109	.054	−0.192	.001**	−0.023	.670	
		Academic	0.062	.197		0.064	.184	−0.123	.022*	0.065	.198	
DMN	Global efficiency	Psychological	−0.053	.323		−0.094	.046*	−0.601	<.001***	−0.042	.396	
		Social	0.065	.213		0.055	.279	−0.187	.001**	−0.037	.395	
		Academic	0.020	.723		0.008	.888	−0.134	.025*	−0.066	.158	
DMN	Clustering	Psychological	0.110	.026*	.078	0.126	.007**	−0.589	<.001***	0.027	.647	
		Social	−0.023	.697		−0.022	.702	−0.188	.001**	0.008	.870	
		Academic	0.008	.884		0.017	.755	−0.124	.027*	0.048	.367	
DMN	Sigma	Psychological	0.010	.871		0.009	.865	−0.585	<.001***	0.024	.693	
		Social	0.055	.354		0.051	.399	−0.193	.001**	−0.023	.684	
		Academic	0.010	.861		0.008	.889	−0.137	.022*	−0.042	.442	

Note. Nonshaded columns include results from regression analyses conducted for Aim 1 (i.e., main effect regression), which explored the main effect of network-level topology on multidomain resilience. Shaded columns include results from regression analyses for Aim 2 (i.e., interaction regression), which explored the main effect of network-level topology on multidomain resilience as moderated by cumulative risk. Analyses controlled for age, sex, race, family income, scanner sequence, and functional magnetic resonance imaging head motion. N = 708 participants total; n = 559 participants with imaging data. FDR correction was completed for nine tests within each brain network. FPN = frontoparietal network; SAL = salience/ventral attention network; DMN = default mode network; FDR = false discovery rate. Standardized β values are reported as b^*. Bolded items reflect statistically significant effects.
* $p < .05$. ** $p < .01$. *** $p < .001$.

learning) was linked to fewer depression symptoms in youth following early life adversity (Dennison et al., 2016). Additionally, a graph theory analysis in adults found that reduced functional integration (i.e., efficiency) of the amygdala was associated with a lack of psychopathology following childhood maltreatment (Ohashi et al., 2019). At the broader network level, a study examining dynamic resting-state connectivity found that reduced connectivity between the default mode network and a salience emotion network was related to resilience against poverty among youth (Iadipaolo et al., 2018). Taken together, the existing literature suggests that reduced connectivity of certain subcortical structures (e.g., amygdala) and the default mode network may support more resilient outcomes.

The present study adds to this literature by suggesting that fewer connections *between* these two systems may also be advantageous. Given the default mode network's role in self-referential thinking, it has been hypothesized that fewer connections between this network and subcortical structures serve to reduce self-focused rumination (Schilbach et al., 2014), which may be a mechanism underlying greater openness to engaging with peers and higher levels of social resilience observed in the present study. Additionally, cortical networks with fewer subcortical connections characterize an organizational pattern with less integrated information flow (Ohashi et al., 2019). In turn, less integration may reduce the ability for threat-related information from subcortical regions to propagate throughout the brain, which may also support resilience in youth facing neighborhood disadvantage.

As a second aim, the present study explored whether associations between functional brain network organization and multidomain resilience persisted at relatively higher versus lower levels of cumulative adversity exposure, offering insight into whether different processes may be needed to support resilience across the continuum of cumulative adversity exposure. We found that whole-brain functional integration and robustness to disruption were uniquely related to psychological and social resilience depending upon youth's level of exposure to additional adversities. In youth with higher levels of cumulative

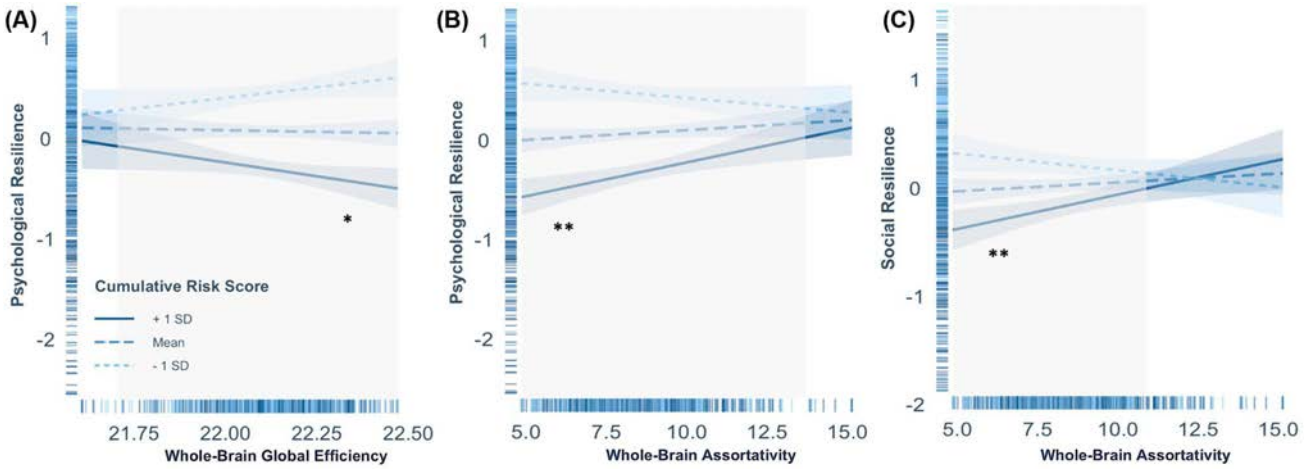
Table 3
Subcortical Associations With Multidomain Resilience

		Main effect regression			Interaction regression						
		Graph metric main effect			Graph metric main effect		Cumulative risk main effect		Interaction effect		
Degree	Resilience domain	b^*	p	p_{FDR}	b^*	p	b^*	p	b^*	p	p_{FDR}
Subcortical to FPN	Psychological	0.023	.638		0.037	.455	−0.592	<.001***	−0.020	.767	
	Social	0.008	.898		0.008	.890	−0.191	.001**	−0.014	.801	
	Academic	0.025	.630		0.023	.648	−0.133	.021*	−0.043	.425	
Subcortical to SAL	Psychological	−0.019	.717		−0.004	.927	−0.592	<.001***	−0.024	.686	
	Social	−0.105	.077		−0.104	.070	−0.201	.001**	−0.052	.306	
	Academic	−0.048	.393		−0.045	.425	−0.135	.019*	−0.043	.451	
Subcortical to DMN	Psychological	0.094	.080		0.084	.082	−0.583	<.001***	0.073	.202	
	Social	−0.133	.013*	.049*	−0.141	.008**	−0.197	.001**	0.003	.952	
	Academic	−0.046	.423		−0.043	.464	−0.126	.026*	0.066	.237	
Subcortical to cortical	Psychological	0.039	.439		−0.004	.932	−0.602	<.001***	−0.117	.033*	.116
	Social	0.029	.584		0.012	.823	−0.199	.001**	−0.078	.098	
	Academic	−0.020	.695		−0.030	.566	−0.133	.021*	−0.024	.638	

Note. Nonshaded columns include results from regression analyses conducted for Aim 1 (i.e., main effect regression), which explored the main effect of subcortical hubness on multidomain resilience. Shaded columns include results from regression analyses for Aim 2 (i.e., interaction regression), which explored the main effect of subcortical hubness on multidomain resilience as moderated by cumulative risk. Analyses controlled for age, sex, race, family income, scanner sequence, and functional magnetic resonance imaging head motion. N = 708 participants total, n = 559 participants with imaging data. FDR correction was completed for 12 tests across all graph metrics and resilience domains. FPN = frontoparietal network; SAL = salience/ventral attention network; DMN = default mode network; FDR = false discovery rate. Bolded items reflect statistically significant effects.
* $p < .05$. ** $p < .01$. *** $p < .001$.

adversity exposure, lower functional integration (i.e., global efficiency) was related to better psychological resilience. Alternatively, in youth experiencing lower levels of cumulative risk, higher global efficiency was associated with higher psychological resilience. Greater whole-brain efficiency has been linked to better psychological outcomes across multiple age groups and psychopathologies, in line with our finding in the lower cumulative adversity exposure

Figure 2
Cumulative Risk Exposure Moderates the Association Between Whole-Brain Organization and Multiple Resilience Domains



Note. Panel A: Higher whole-brain global efficiency is associated with greater psychological resilience in youth experiencing less cumulative risk, while lower global efficiency is associated with greater psychological resilience in youth experiencing more cumulative risk (b^* = −0.132, p_{FDR} = .031; simple slopes: p_{-1SD} = .053, p_{+1SD} = .035). Panel B: Higher whole-brain robustness to disruption (i.e., assortativity) is associated with higher psychological resilience in youth with greater cumulative risk exposure (b^* = 0.144, p_{FDR} = .007; simple slopes: p_{+1SD} = .001). Panel C: Higher whole-brain robustness to disruption (i.e., assortativity) is associated with higher social resilience in youth with greater cumulative risk exposure (b^* = 0.148, p_{FDR} = .007; simple slopes: p_{+1SD} = .008). Simple slope significance values are positioned near their respective group. Interaction effects are significant within regions shaded in gray. For visualization purposes, plots were generated using the *interactions* package in R, which does not adjust standard errors for family clustering and depicts only participants with functional magnetic resonance imaging scan data (n = 559). FDR = false discovery rate. See the online article for the color version of this figure.
* $p < .05$. ** $p < .01$.

group (Ajilore et al., 2014; Micheloyannis, 2012). However, some evidence suggests that reduced efficiency may support more adaptive psychological outcomes in the face of certain adversities. For example, lower whole-brain efficiency has been associated with larger and faster symptom reduction in youth seeking treatment for posttraumatic stress disorder following assault (Cisler et al., 2016). Further, reduced nodal efficiency in specific regions (e.g., amygdala) has been associated with adult resilience to psychopathology following childhood maltreatment (Ohashi et al., 2019). In light of these disparate accounts on the role of global efficiency in psychological functioning, the present study suggests that identifying the type and quantity of risk exposure may be integral to parsing the role of whole-brain functional integration in psychological outcomes. For example, our findings suggest that greater whole-brain efficiency may support better psychological functioning, but only in the context of certain "doses" of adversity exposure.

In resilient youth exposed to more cumulative adversity, we observed an association between greater whole-brain robustness to disruption (i.e., assortativity) and higher resilience in both social and psychological domains. Assortativity captures the level of connectivity between brain network hubs (i.e., central, well-connected brain areas), which can serve as a protective factor for neural communication. In a network with high assortativity, damage to one main, well-connected component is less detrimental because other components remain well-connected themselves. In line with this framework, higher levels of assortativity have been associated with a faster reduction in youth's posttraumatic stress disorder symptoms during treatment (Cisler et al., 2016). Further, a study in adults found that resilience to depressive symptoms in those with a history of early life stress was associated with greater clustering (another measure of robustness to disruption) in a prefrontal region implicated in inhibitory control and emotion regulation (Cisler et al., 2013). Given that our findings highlight a role for assortativity rather than clustering, it could be that connectivity among brain network "hubs" is especially protective in younger populations exposed to adversity, a hypothesis that would benefit from further research. Additionally, it is interesting that robustness to disruption is significantly related to resilience only in youth exposed to higher levels of cumulative risk. One hypothesis may be that greater adversity introduces greater threat for network damage or overload, as different early life adversities are associated with different impacts on network structure (Gupta et al., 2017). In the face of many adversities, youth may be exposed to the varied and compounding impacts of adversity on network architecture, such that greater network robustness against disruption is especially important for resilient outcomes.

Though our study includes several notable strengths, we acknowledge existing limitations and areas for future research. First, our analyses are cross-sectional, which precludes the ability to identify whether these are preexisting neural correlates or mechanisms that emerged to help youth adapt to challenging environmental demands. Future studies exploring longitudinal measures of neural and behavioral functioning will be helpful for tracking the development of resilience across the lifespan. Second, some studies report discrepancies between census tract boundaries and residents' perceptions of their neighborhood (Coulton et al., 2013). Future work probing the relationship between resilience and youth *perceptions* of neighborhood disadvantage may offer new insights into studies of resilience at the neighborhood level. Additionally, the present study made specific analytic decisions that should be considered in the future measurement of resilience more broadly. For example, we conceptualized resilience as a lack of negative outcomes (i.e., psychopathology, dichotomized) and the presence/extent of positive outcomes (e.g., dimensional measure of satisfaction with life) in three domains. As such, our findings may not generalize to other ways of measuring resilience or other resilience domains. Further, several measures in the cumulative risk index (i.e., Conflict Tactics Scale, Adult Child Relationship Scale, Adolescent Life Events Scale) do not have published norms, nor is there a clear way to characterize which collection of items would characterize "adversity." Given our focus on youth living in low-income neighborhoods, we may be undercounting the amount of adversity youth have been exposed to. Our index used a standard deviation above the sample mean for these measures and binarized adversity exposure to be consistent with standards for categorizing cumulative risk, yet our approach leaves room for examining how the frequency or severity of such exposures may uniquely relate to domain-specific resilience mechanisms. Last, we identified several findings that were statistical trends after correcting for multiple comparisons. We did not discuss these findings to be conservative with our interpretations, but further information about these findings is reported in the Supplemental Material to bolster future research.

Constraints on Generality

A strength of the present study is the strong sampling frame (i.e., birth records), which increases generalizability and is relatively unique among neuroimaging studies (E. B. Falk et al., 2013). However, these findings can only be generalized to families within this midwestern region, or potentially to families in other locations with similar sociodemographic trends. Additional work with strong sampling frames is needed in national and international samples to identify if these findings are similar across different contexts. Further, studies of racial minorities have revealed that resilience can also be associated with biological costs to the individual. For example, resilience in psychological and academic domains has been associated with accelerated biological aging in

African American youth and adults (Brody et al., 2016). Our study offers novel insight into resilience mechanisms in individuals marginalized by economic disadvantage at the neighborhood level, but more research is needed to identify the neural mechanisms supporting resilience in individuals from other marginalized identities and contexts.

Conclusions and Implications

Despite these future research directions, the present study offers a novel contribution to the resilience literature through a developmental neuroscience examination of multidomain resilience in individuals typically underrepresented in the neuroimaging literature. This work is the first to reveal how unique forms of resilience in youth experiencing neighborhood disadvantage may be supported by distinct properties of brain networks and global information flow. In particular, our findings illuminate functional integration, robustness to disruption, and cortical–subcortical connectivity as network features with relevance to multiple resilience domains. In tandem with growing research revealing the impact of adversity on brain development, research linking mechanistic neural signatures to multidomain resilience offers a new avenue for developmental neuroscience to inform the type and timing of interventions supporting positive development. Future work exploring the intersection between systemic adversities, neurobiological mechanisms, and resilience will be crucial for further uncovering targets for reform and boosting pathways toward resilience amongst broader communities of youth.

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