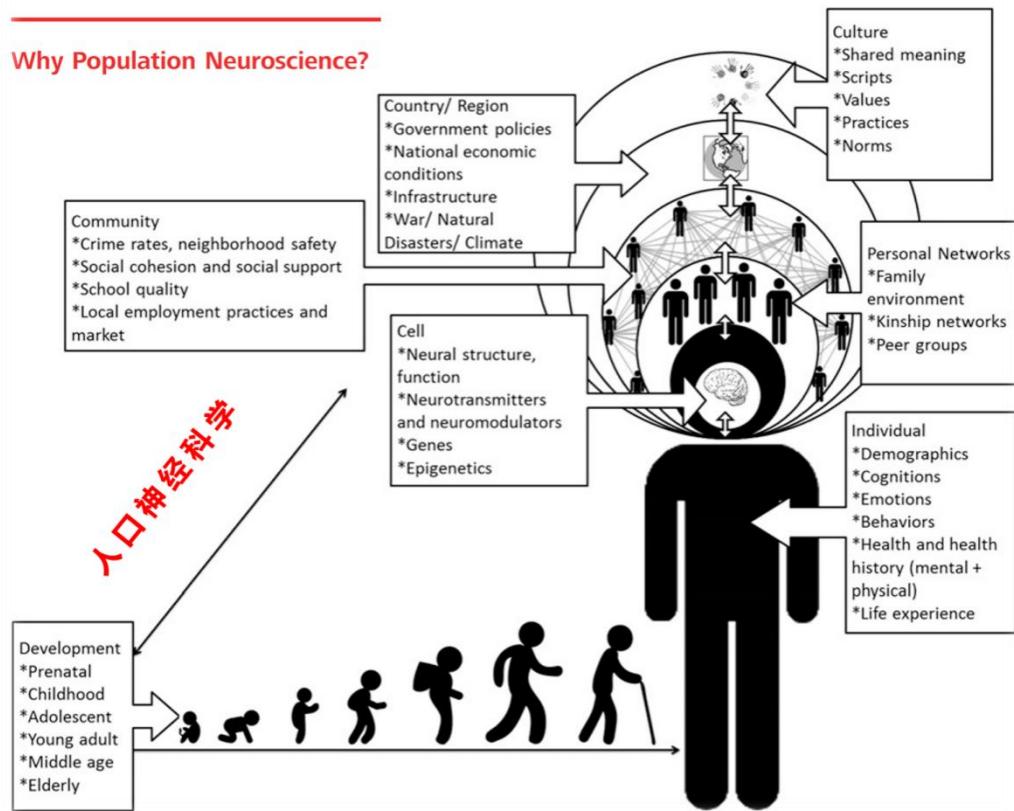


## What is a representative brain? Neuroscience meets population science

Emily B. Falk<sup>a,b,c,1</sup>, Luke W. Hyde<sup>d,e,f,1</sup>, Colter Mitchell<sup>e,g,i,2</sup>, Jessica Faul<sup>e,3</sup>, Richard Gonzalez<sup>b,d,h,3</sup>, Mary M. Heitzeg<sup>i,3</sup>, Daniel P. Keating<sup>d,e,i,j,3</sup>, Kenneth M. Langa<sup>a,k,l,3</sup>, Meghan E. Martz<sup>d,3</sup>, Julie Maslowsky<sup>m,3</sup>, Frederick J. Morrison<sup>d,3</sup>, Douglas C. Noll<sup>n,3</sup>, Megan E. Patrick<sup>k,3</sup>, Fabian T. Pfeffer<sup>e,g,3</sup>, Patricia A. Reuter-Lorenz<sup>d,e,o,3</sup>, Moriah E. Thomason<sup>p,q,r,3</sup>, Pamela Davis-Kean<sup>b,d,e,f,4</sup>, Christopher S. Monk<sup>d,e,f,i,o,4</sup>, and John Schulenberg<sup>d,e,f,4</sup>

### Why Population Neuroscience?



北京师范大学 心理学部

## Developmental Population Neuroscience

发展人口神经科学（文献阅读示范课）

左西年 (Xi-Nian Zuo)

Beijing Normal University  
State Key Lab of Cognitive Neuroscience & Learning

National Basic Science Data Center  
Chinese Data-sharing Warehouse for In-vivo Imaging Brain

# What is a representative brain? Neuroscience meets population science

Emily B. Falk, Luke W. Hyde, Colter Mitchell , Jessica Faul, Richard Gonzalez, Mary M. Heitzeg, Daniel P. Keating, Kenneth M. Langa, Meghan E. Martz, Julie Maslowsky, Frederick J. Morrison, Douglas C. Noll, Megan E. Patrick, Fabian T. Pfeffer, Patricia A. Reuter-Lorenz, Moriah E. Thomason, Pamela Davis-Kean, Christopher S. Monk, and John Schulenberg   
[Authors Info & Affiliations](#)

Edited by Mary C. Waters, Harvard University, Cambridge, MA, and approved September 11, 2013 (received for review May 31, 2013)

October 22, 2013 | 110 (44) 17615-17622 | <https://doi.org/10.1073/pnas.1310134110>

 13,323  115

**PNAS**



As we advocate cross-disciplinary collaboration, we describe how (i) our group has come together representing many disciplines and (ii) how this paper was written as an example of the potential of this type of group. (i) In 2010, the University of Michigan challenged social science researchers to cross the traditional bounds of their disciplines to think of emerging cross-disciplinary work that would inform the science in the future. P.D.-K. and F.J.M. received a grant from this initiative centered on documenting important changes in the brain related to socioeconomic differences of children and families. This research, however, was based on small sample sizes and a fairly basic understanding of indicators of socioeconomic differences. Thus, a conference was assembled to bring together researchers across the social sciences and neuroscience to discuss the state of this research and ways to improve and validate findings. One outcome of this conference was that investigators across the University began to meet and identify important synergies across broad areas of social and neural sciences. With support from the Institute for Social Research, the senior authors began hosting monthly meetings for these discussions. The group continues to grow and represent multiple disciplines and career stages, often with junior members contributing "cutting edge" new approaches. (ii) This manuscript was the result of discussions that the group has had from 2012–2013 and emerged as a way to organize our collective vision. Key to the production of the paper was that the three first authors were junior investigators with three very different backgrounds (e.g., demography, social neuroscience, and developmental neurogenetics) interested in collaborating and synthesizing interests from across our fields. As the three first authors were somewhat representative of the larger group, we were able to structure a paper and receive feedback from the larger group, especially in parts of the manuscript core to each member's expertise. We also received excellent feedback from two reviewers: their thoughtful input significantly strengthened the manuscript.



People / Faculty / **Emily Falk, Ph.D.**

## Emily Falk, Ph.D.

**Professor of Communication, Psychology, and Marketing**

**Associate Dean for Research**

### Colter Mitchell

Faculty Associate, Population Studies Center.  
Research Associate Professor, Family Demography, Survey Research Center.

Ph.D., Sociology, University of Michigan

### Moriah E. Thomason, PhD

Barakett Associate Professor of Child and Adolescent Psychiatry, Department of Child and Adolescent Psychiatry  
Associate Professor, Department of Population Health



← **John Schulenberg**



Ann Arbor | Dearborn | Flint

© 2022 The Regents of the University of Michigan 500 S. State Street, Ann Arbor, MI 48109 USA  
 Privacy Notice  
 +1 (734) 764-1817  
 Contact us

Careers

Portal en Español

Português

密西根大学



Campus Safety



Information & Resources

# Toward discovery science of human brain function

Bharat B. Biswal<sup>a</sup>, Maarten Mennes<sup>b</sup>, Xi-Nian Zuo<sup>b</sup>, Suril Gohel<sup>a</sup>, Clare Kelly<sup>b</sup>, Steve M. Smith<sup>c</sup>, Christian F. Beckmann<sup>c</sup>, Jonathan S. Adelstein<sup>b</sup>, Randy L. Buckner<sup>d</sup>, Stan Colcombe<sup>e</sup>, Anne-Marie Dogonowski<sup>f</sup>, Monique Ernst<sup>g</sup>, Damien Fair<sup>h</sup>, Michelle Hampson<sup>i</sup>, Matthew J. Hoptman<sup>j</sup>, James S. Hyde<sup>k</sup>, Vesa J. Kiviniemi<sup>l</sup>, Rolf Kötter<sup>m</sup>, Shi-Jiang Li<sup>n</sup>, Ching-Po Lin<sup>o</sup>, Mark J. Lowe<sup>p</sup>, Clare Mackay<sup>c</sup>, David J. Madden<sup>q</sup>, Kristoffer H. Madsen<sup>f</sup>, Daniel S. Margulies<sup>r</sup>, Helen S. Mayberg<sup>s</sup>, Katie McMahon<sup>t</sup>, Christopher S. Monk<sup>u</sup>, Stewart H. Mostofsky<sup>v</sup>, Bonnie J. Nagel<sup>w</sup>, James J. Pekar<sup>x</sup>, Scott J. Peltier<sup>y</sup>, Steven E. Petersen<sup>z</sup>, Valentin Riedl<sup>aa</sup>, Serge A. R. B. Rombouts<sup>bb</sup>, Bart Rypma<sup>cc</sup>, Bradley L. Schlaggar<sup>dd</sup>, Sein Schmidt<sup>ee</sup>, Rachael D. Seidler<sup>ff</sup>, Greg J. Siegle<sup>gg</sup>, Christian Sorg<sup>hh</sup>, Gao-Jun Teng<sup>ii</sup>, Juha Veijola<sup>jj</sup>, Arno Villringer<sup>ee, kk</sup>, Martin Walter<sup>ll</sup>, Lihong Wang<sup>q</sup>, Xu-Chu Weng<sup>mm</sup>, Susan Whitfield-Gabrieli<sup>nn</sup>, Peter Williamson<sup>oo</sup>, Christian Windischberger<sup>pp</sup>, Yu-Feng Zang<sup>qq</sup>, Hong-Ying Zhang<sup>ii</sup>, F. Xavier Castellanos<sup>b,j</sup>, and Michael P. Milham<sup>b,1</sup>

\*This Direct Submission article had a prearranged editor.

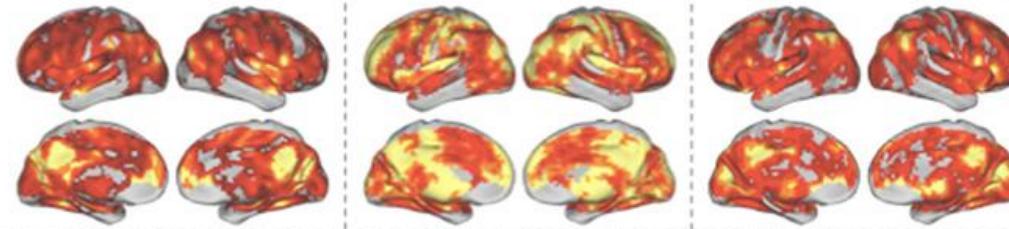
Edited\* by Marcus E. Raichle, Washington University, St. Louis, MO, and approved January 20, 2010 (received for review October 14, 2009)

Although it is being successfully implemented for exploration of the genome, discovery science has eluded the functional neuroimaging community. The core challenge remains the development of common paradigms for interrogating the myriad functional systems in the brain without the constraints of *a priori* hypoth-

pathological processes in the brain. To initiate discovery science of brain function, the 1000 Functional Connectomes Project dataset is freely accessible at [www.nitrc.org/projects/fcon\\_1000/](http://www.nitrc.org/projects/fcon_1000/).

database | neuroimaging | open access | reproducibility | resting state

CENTER  
2.3 >8



AGE

Younger  
Older

SEX

Female  
Male

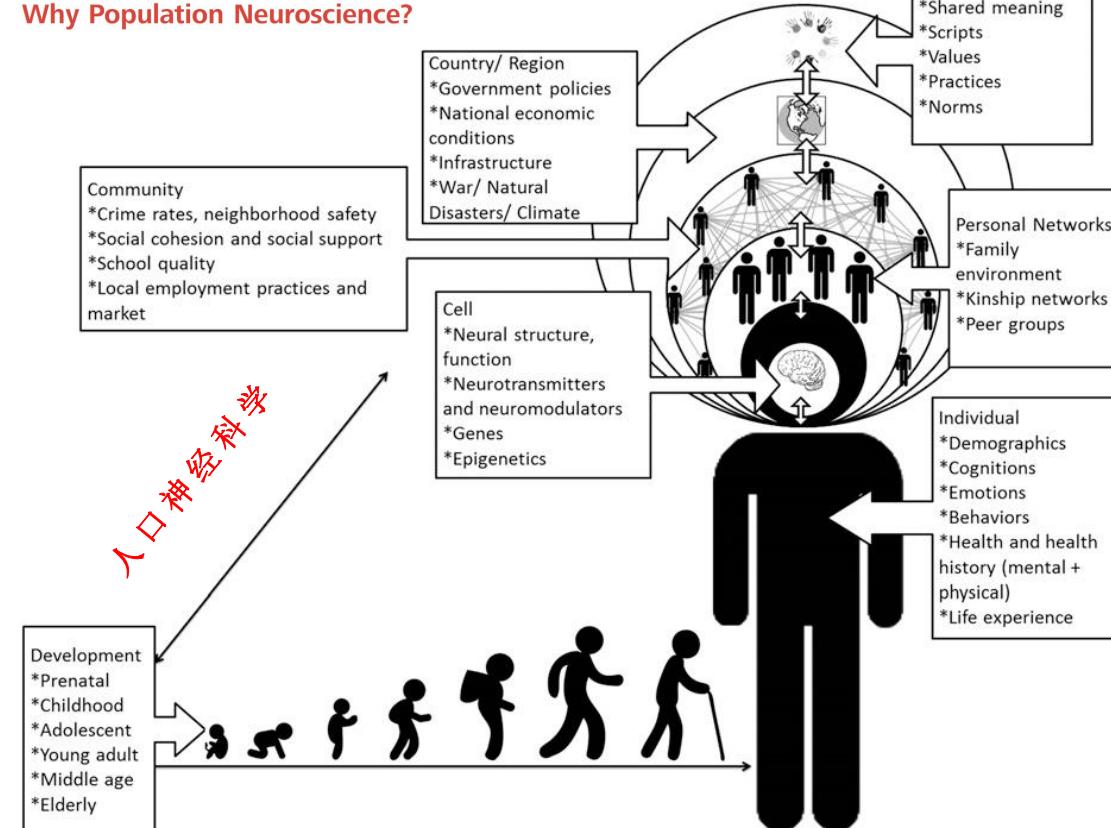
neuroimaging | life course | statistics | survey methodology | physics

PERSPECTIVE

## What is a representative brain? Neuroscience meets population science

Emily B. Falk<sup>a,b,c,1</sup>, Luke W. Hyde<sup>d,e,f,1</sup>, Colter Mitchell<sup>e,g,1,2</sup>, Jessica Faul<sup>e,3</sup>, Richard Gonzalez<sup>b,d,h,3</sup>, Mary M. Heitzeg<sup>i,3</sup>, Daniel P. Keating<sup>d,e,i,j,3</sup>, Kenneth M. Langa<sup>e,k,l,3</sup>, Meghan E. Martz<sup>g,3</sup>, Julie Maslowsky<sup>m,3</sup>, Frederick J. Morrison<sup>d,3</sup>, Douglas C. Noll<sup>n,3</sup>, Megan E. Patrick<sup>e,3</sup>, Fabian T. Pfeffer<sup>e,g,3</sup>, Patricia A. Reuter-Lorenz<sup>d,e,o,3</sup>, Moriah E. Thomason<sup>p,q,r,3</sup>, Pamela Davis-Kean<sup>b,d,e,f,4</sup>, Christopher S. Monk<sup>d,e,f,i,o,4</sup>, and John Schulenberg<sup>d,f,4</sup>

### Why Population Neuroscience?



PERSPECTIVE



PERSPECTIVE

Representative group of brains

↑  
brain norm

population neuroscience

代表脑？常模脑？

# What is a representative brain? Neuroscience meets population science 《什么才是代表性的大脑？神经科学与人口科学的碰撞》

Emily B. Falk<sup>a,b,c,1</sup>, Luke W. Hyde<sup>d,e,f,1</sup>, Colter Mitchell<sup>e,g,1,2</sup>, Jessica Faul<sup>e,3</sup>, Richard Gonzalez<sup>b,d,h,3</sup>, Mary M. Heitzeg<sup>i,3</sup>, Daniel P. Keating<sup>d,e,i,j,3</sup>, Kenneth M. Langa<sup>e,k,l,3</sup>, Meghan E. Martz<sup>d,3</sup>, Julie Maslowsky<sup>m,3</sup>, Frederick J. Morrison<sup>d,3</sup>, Douglas C. Noll<sup>n,3</sup>, Megan E. Patrick<sup>e,3</sup>, Fabian T. Pfeffer<sup>e,g,3</sup>, Patricia A. Reuter-Lorenz<sup>d,e,o,3</sup>, Moriah E. Thomason<sup>p,q,r,3</sup>, Pamela Davis-Kean<sup>b,d,e,f,4</sup>, Christopher S. Monk<sup>d,e,f,i,o,4</sup>, and John Schulenberg<sup>d,e,f,4</sup>

Departments of <sup>a</sup>Communication Studies, <sup>d</sup>Psychology, <sup>h</sup>Statistics, <sup>i</sup>Psychiatry, <sup>j</sup>Pediatrics and Communicable Diseases, <sup>k</sup>Internal Medicine, <sup>n</sup>Biomedical Engineering; <sup>o</sup>Neuroscience Graduate Program; <sup>b</sup>Research Center for Group Dynamics, <sup>e</sup>Survey Research Center, and <sup>g</sup>Population Studies Center of the Institute for Social Research; and <sup>f</sup>Center for Human Growth and Development, University of Michigan, Ann Arbor, MI 48109; <sup>c</sup>Annenberg School for Communication, University of Pennsylvania, Philadelphia, PA, 19104; <sup>l</sup>Veterans Affairs Center for Clinical Management Research, Ann Arbor, MI 48105, <sup>m</sup>Robert Wood Johnson Foundation Health and Society Scholars Program, Population Health Sciences, School of Medicine and Public Health, University of Wisconsin–Madison, Madison, WI 53706; <sup>p</sup>School of Medicine Pediatrics and <sup>q</sup>Merrill Palmer Skillman Institute for Child and Family Development, Wayne State University, Detroit, MI 48202; and <sup>r</sup>Perinatology Research Branch, National Institutes of Health, Detroit, MI 48202

4月快译 (一)

© 2013 The Authors. Journal compilation © 2013 Association for Child and Family Development, Cambridge, MA, and approved September 11, 2013 (received for review May 31, 2013)

## Abstract

Why Population Neuroscience?

Current Practices in Neuroimaging...

Getting Inside the Black Box: Adding...

Integrative Framework

Benefits to Neuroscience,...

Conclusion

Acknowledgments

References

The last decades of neuroscience research have produced immense progress in the methods available to understand brain structure and function. Social, cognitive, clinical, affective, economic, communication, and developmental neurosciences have begun to map the relationships between neuro-psychological processes and behavioral outcomes, yielding a new understanding of human behavior and promising interventions. However, a limitation of this fast moving research is that most findings are based on small samples of convenience. Furthermore, our understanding of individual differences may be distorted by unrepresentative samples, undermining findings regarding brain-behavior mechanisms. These limitations are issues that social demographers, epidemiologists, and other population scientists have tackled, with solutions that can be applied to neuroscience. By contrast, nearly all social science disciplines, including social demography, sociology, political science, economics, communication science, and psychology, make assumptions about processes that involve the brain, but have incorporated neural measures to differing, and often limited, degrees; many still treat the brain as a black box. In this article, we describe and promote a perspective—population neuroscience—that leverages interdisciplinary expertise to (i) emphasize the importance of sampling to more clearly define the relevant populations and sampling strategies needed when using neuroscience methods to address such questions; and (ii) deepen understanding of mechanisms within population science by providing insight regarding underlying neural mechanisms. Doing so will increase our confidence in the generalizability of the findings. We provide examples to illustrate the population neuroscience approach for specific types of research questions and discuss the potential for theoretical and applied advances from this approach across areas.

3月17日 (heynd reproducibility)

neuroimaging | life course | statistics | survey methodology | physics

生命周期

调查方法学

物理

## Abstract

### Why Population Neuroscience?

Current Practices in Neuroimaging...

Getting Inside the Black Box: Adding...

Integrative Framework

Benefits to Neuroscience,...

Conclusion

Acknowledgments

References

Downloaded from https://www.pnas.org by Beijing Normal University on September 20, 2013

### Why Population Neuroscience?

How do biology, social situations, and the broader environmental context interact to guide behavior, health, and development? This question is fundamental to most, if not all, social and behavioral sciences. We argue that to effectively address the many topics that stem from this larger question across disciplines, it is necessary to (i) bring a “population perspective” to neuroscience and (ii) leverage neuroscience tools within population sciences, which are subdisciplines of many fields, areas, and departments focused on documenting and understanding the dynamics of human populations, including outcomes such as health, well-being, behavior, etc.

Although recent advances in neuroscience research, and neuroimaging in particular, speak to how social, cognitive, and emotional processes unfold (1–5), the extent to which existing knowledge in human neuroscience

applies to broader, theoretically relevant populations, and the ways that macrolevel structures (e.g., social structure, neighborhood safety, school quality, media exposure) influence neural processes is often unknown (6). Thus, in parallel with a broader social science focus on the limitations of nonrepresentative samples (7, 8), we are now at a critical juncture for social and biological science. What would a “representative group of brains” tell us about the generalizability of current samples and current findings regarding brain-behavior mechanisms? How do individual differences in brain structure and function affect cognitive, affective, and behavioral outcomes and how do social situations and broader environmental contexts interact with these processes? Current methods in much of neuroscience research and the absence of neural measures in most population-based research limit our ability to answer these questions (9).

2013

At the same time, most social scientists are interested in thoughts and behaviors (e.g., decision making, empathy, attitudes), which must have some relationship to the brain. As such, neural measures, especially neuroimaging, have become widely used in several specific social science disciplines (e.g., psychology, decision science) (1–5, 10–12).

Author contributions: P.D.-K., C.S.M., and J.S. formed and led group; E.B.F., L.W.H., and C.M. wrote paper and E.B.F., L.W.H., C.M., J.F., R.G., M.M.H., D.P.K., K.M.L., M.E.M., J.M., F.J.M., D.C.N., M.E.P., F.T.P., P.A.R.-L., M.E.T., P.D.-K., C.S.M., and J.S. designed and edited manuscript.

The authors declare no conflict of interest.

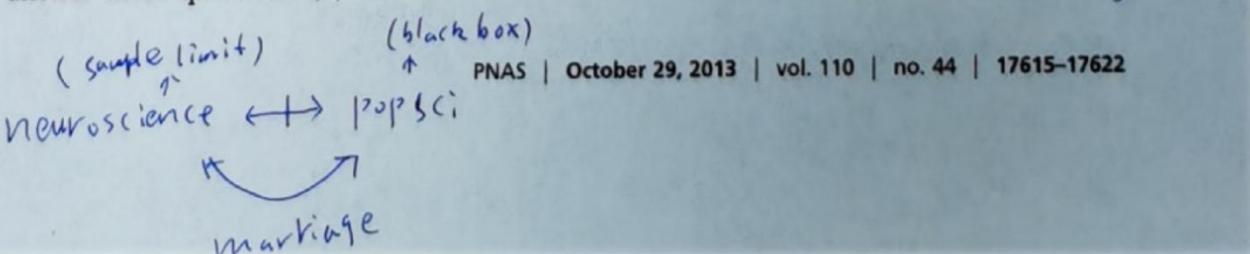
This article is a PNAS Direct Submission. *bio*

<sup>1</sup>E.B.F., L.W.H., and C.M. contributed equally to this work. *#31-54*

<sup>2</sup>To whom correspondence should be addressed. E-mail: cmsm@umich.edu.

<sup>3</sup>J.F., R.G., M.M.H., D.P.K., K.M.L., M.E.M., J.M., F.J.M., D.C.N., M.E.P., F.T.P., P.A.R.-L., and M.E.T. contributed equally to this work.

<sup>4</sup>P.D.-K., C.S.M., and J.S. contributed equally to this work.



## Abstract

### Why Population Neuroscience?

### Current Practices in Neuroimaging...

### Getting Inside the Black Box: Adding...

### Integrative Framework

### Benefits to Neuroscience,...

### Conclusion

### Acknowledgments

### References

PNAS

However, this trend toward brain science has not been as true for social sciences that deal in large and representative samples (e.g., social demography) or long-term development (e.g., the life course), leading to a view of the brain as a black box in those disciplines. A more recent focus within population sciences on how the broader environment “gets under the skin” suggests that this may be a key moment to look to the brain. Health psychologists have demonstrated that the broader environment becomes biologically embedded in the brain over the course of development (5, 13–17), but how does this yield observed variations within populations? Therefore, we argue that the critical juncture described for neuroscience research also poses an opportunity for population science research more broadly. Taken together, how can neuroscience research usefully inform broader understanding in the population sciences and how can these sciences be brought to bear on neuroscience research?

In the present article, we point to building momentum of a new subfield—population neuroscience (6, 18)—and the opportunities it affords. A population neuroscience perspective emphasizes an understanding of human behavior across multiple levels of influence (e.g., from culture to social structure, to experience, to behavior, to genes, to neural connectivity and function guided by a multilevel ecological model (12, 19–21) (Fig. 1). We encourage readers to read Paus’s initial treatment of population neuroscience cited above. Although our thesis focuses on the interchange between population sciences and neuroscience, we believe that this thesis fits within the larger and emerging field Paus has described as population neuroscience and thus we use his term to characterize our goals for this emerging discipline.

Below, we highlight work on predictors, outcomes, moderators, and mediators of the brain-behavior relationship in studies that

inform our understanding of broader populations (22). We place specific emphasis on integrating perspectives on sampling methodology from demography and survey research (23, 24) into a population neuroscience approach (6). We provide more concrete examples to illustrate the necessity of a population neuroscience approach for certain types of research questions and the benefits it can afford to both neuroscientists and population scientists. We then outline specific goals to make population neuroscience a reality and discuss the need for theoretical and applied advances from this approach. #RJ

2024.2.1

4月8日 13:45

脑与行为关系

71

## Abstract

## Why Population Neuroscience?

## Current Practices in Neuroimaging...

## Getting Inside the Black Box: Adding...

## Integrative Framework

## Benefits to Neuroscience,...

## Conclusion

## Acknowledgments

## References

## Current Practices in Neuroimaging

**Research: How Universal Is What We Know?** 我们到底知道什么？

Researchers in both social and biological sciences have pointed to the negative consequences of extrapolating from small, nonrepresentative samples based on the systematic biases these samples can introduce (9). For example, for years, research suggested that IQ was highly heritable, but more recent research using more representative samples found that genetic heritability was decidedly lower for the whole population (25). Previous researchers had used samples primarily consisting of high socioeconomic status (SES) participants. SES, however, was shown to moderate the genetic heritability such that for high SES genetic heritability was above 70%, but for low SES participants genetic heritability was closer to 10% (7, 25). Similarly there are many examples across other domains of research where early nonrepresentative convenience samples and/or small sample sizes led to incorrect or inconsistent estimates of outcomes, including errors such as misconceptions of age patterns on morbidity and cognition (26, 27), the assumption that basic tenets in social psychology (e.g., the fundamental attribution error) generalize to all people (7, 28, 29), and relationships between socioeconomic position, neuropathology, and dementia (30). Beyond these consequences, social scientists have long noted the constraints and problems imposed by reliance on student subject pools (8, 29) and Western, Educated, Industrialized, Rich, and Democratic (WEIRD) populations more broadly (7). These samples differ in many concrete ways from broader populations of interest, which has led to a greater emphasis by the National Institutes of Health on including women and minorities in studies (31, 32). Additionally, even within medical clinical trials there has been a call for greater use of practical clinical trials to improve the external validity of the results (33, 34).

Learning from these examples, the need for population neuroscience for certain types of

中国脑科学与技术  
神经通路图

research questions is clear. Population neuroscience leverages well-known sampling techniques that are routinely used in other fields such as demography, epidemiology, and survey research (11, 12) to strengthen the link between sample and target population and enhance the generalizability of results. The extent to which neuroscience findings can inform and be informed by disciplines that focus on macro level structures (e.g., demography, sociology) rests on our ability to maximize generalizability to relevant populations. It should be noted that what constitutes a relevant population is often subjective and project specific. Researchers may target different populations (e.g., by disease status/risk, age, geographic region, or SES level) based on their research goals and substantive theoretical questions, but a key aspect of moving research forward is identifying and describing the relevant population the research is intended to characterize or address. Not explicating the population could lead to problems of comparability, replication, and inference.

## Getting Inside the Black Box: Adding Neuroimaging and Other Neuroscience Methods to Broader Population Science

Over the last several years, there has been a rapid expansion of social and population researchers using biomarkers (e.g., cortisol response, cholesterol levels, epigenetics) to examine how the social environment gets under the skin (17, 35). Examining these biological mechanisms of social environment and health has produced important justifications for funding of continued work in the social and population sciences (5, 36). However, very little current population-focused work has examined the brain, which may be an optimal biomarker to examine the wide variety of variables typically found in population-based studies (e.g., health decision-making, educational achievement, acceptance of new ideas). Thus, the current practice of many population researchers using large, omnibus studies is well suited to allow even a small group of population neuroscience experts to make immediate impacts on a wide variety of research areas.

With the help of neuroscientists, population scientists can begin to open the black box of the brain that has long been assumed, but rarely examined, in most population-based models.

For example, one set of topics of interest to population scientists includes the effects of neighborhood and family poverty and social inequality on later outcomes such as family instability, educational attainment, health, employment, crime, and psychiatric disorders.

Although population research has established robust effects of poverty and inequality on these outcomes (37–42), neural mechanisms of these effects have not been a primary focus in population approaches. However, within neuroscience and health psychology, research has begun to show that early life experiences such as parenting and SES have effects on brain areas such as the amygdala and prefrontal cortex (43–47), areas that have also been linked to a variety of relevant outcomes such as crime and violence (48, 49), depression (50), social cognition (51, 52), drug use (53, 54), and cognitive control (55).

For example, a recent study demonstrated that early life stress predicted stress responses in the hypothalamic-pituitary-adrenal axis, which in turn predicted connectivity between the amygdala and prefrontal cortex and later risk for depression (56).

## 神经通路图

因此，新兴的研究显示，早期经验可以影响功能、结构和连接性，从而解释为什么某些大脑区域的体验（如贫困）会导致有害的健康和行为结果，以及为什么一些个体更容易受到这些体验的影响。

尽管这项研究开始阐明经验在神经水平上的生物学嵌入，但它尚未解决一个第二相关的关键问题：文化如何在开发认知地图中起作用，这些地图允许我们理解并导航世界（57）。例如，我们的大脑帮助我们获得信息，并通过复杂的特定于文化的信息来解释它们。这可能有助于通过神经成像揭示跨文化差异，从而促进跨学科伙伴关系（58–60）。此外，将此类过程与宏观层面的变量（例如，社会网络结构）和生物变量（例如，对认知任务的神经反应）结合起来，也有助于推进人口和神经科学理论。

总的来说，通过与神经科学家合作，人口科学家可以指定新的生物过程，如大脑结构和功能，这将塑造认知和感知经验，从而影响行为。这个过程导致了经验与生物学之间相互影响的交互作用（61, 62）。尽管神经科学无法捕捉所有级别的经验，但它可以帮助说明经验如何生物学地嵌入，并随着时间的推移如何经验与生物学相互作用以解释对人口科学家感兴趣的问题。

## Integrative Framework

那么这些目标如何成为现实呢？如何能够将多个分析水平（即，从突触到细胞再到个体再到群体或国家）联系起来？以下，我们将概述六步方法论，以实现这一宏伟目标：促进神经科学和健康心理学研究，使人口神经科学能够改善社会和健康结果。

**Goal 1: Integrate Brain Imaging into Existing Representative (Sub)samples.** 通过使用诸如样本分层、集群采样、子采样和“计划缺失”等技术，神经科学方法可以与正在进行的大型人群水平研究相结合，而无需收集每个样本的神经数据。

## Abstract

### Why Population Neuroscience?

### Current Practices in Neuroimaging...

#### Getting Inside the Black Box: Adding...

#### Integrative Framework

#### Benefits to Neuroscience,...

#### Conclusion

#### Acknowledgments

#### References

population studies). It also requires multidisciplinary communication and collaboration (e.g., development of methodology and common language shared across areas), so that critical methods and findings across the disciplines that study these phenomena can inform each other.

#### Getting Inside the Black Box: Adding Neuroimaging and Other Neuroscience Methods to Broader Population Science

Over the last several years, there has been a rapid expansion of social and population researchers using biomarkers (e.g., cortisol response, cholesterol levels, epigenetics) to examine how the social environment gets under the skin (17, 35). Examining these biological mechanisms of social environment and health has produced important justifications for funding of continued work in the social and population sciences (5, 36). However, very little current population-focused work has examined the brain, which may be an optimal biomarker to examine the wide variety of variables typically found in population-based studies (e.g., health, decision-making, educational achievement, acceptance of new ideas). Thus, the current practice of many population researchers using large, omnibus studies is well suited to allow even a small group of population neuroscience experts to make immediate impacts on a wide variety of research areas.

With the help of neuroscientists, population scientists can begin to open the black box of the brain that has long been assumed, but rarely examined, in most population-based models.

is  
经验的黑匣子

前述研究机制制

Therefore, emerging research showing that early experience can affect the function, structure, and connections within and between key brain areas may help explain why experiences such as poverty lead to deleterious health and behavioral outcomes and also why some individuals are more susceptible to these experiences.

Although this research is beginning to elucidate biological embedding of experience at the neural level, it has not yet addressed a second related key process linking experience and behavior: the effect of culture in developing cognitive maps that allow us to understand and navigate the world (57). For example, our brains help us to acquire and then use complex information specific to our culture(s), such as knowing the difference between breakfast and snack foods, how to respond to authority, whether smoking is bad, etc., but the content of these cognitive maps is not currently accessible through neuroimaging, suggesting the importance of interdisciplinary partnerships (58–60). Furthermore, additional work linking such processes with macrolevel variables (e.g., social network structure) and biological variables (e.g., neural responses to cognitive tasks) also stands to advance both population and neuroscientific theory.

Overall, by partnering with neuroscientists, population scientists can specify new biological processes such as brain structure and function, which would shape cognition and perception of experiences thereby influencing behavior. This process leads to an interaction through which experience and biology shape each other

PERSPECTIVE

For example, one set of topics of interest to population scientists includes the effects of neighborhood and family poverty and social inequality on later outcomes such as family instability, educational attainment, health, employment, crime, and psychiatric disorders. Although population research has established robust effects of poverty and inequality on these outcomes (37–42), neural mechanisms of these effects have not been a primary focus in population approaches. However, within neuroscience and health psychology, research has begun to show that early life experiences such as parenting and SES have effects on brain areas such as the amygdala and prefrontal cortex (43–47), areas that have also been linked to a variety of relevant outcomes such as crime and violence (48, 49), depression (50), social cognition (51, 52), drug use (53, 54), and cognitive control (55). For example, a recent study demonstrated that early life stress predicted stress responses in the hypothalamic-pituitary-adrenal axis, which in turn predicted connectivity between the amygdala and prefrontal cortex and later risk for depression (56).

cannot capture experience at all levels, it can help to specify how some experience is biologically embedded and how experience and biology interact over time to explain questions of interest to population scientists.

#### Integrative Framework

How can these goals become reality? How can we link multiple levels of analysis (i.e., move from synapse to cell to brain to individual to groups to regions to nations)? Below, we outline six concrete steps toward the big picture goal of promoting generalizability in neuroscience investigations and harnessing neuroscience tools to understand processes of interest to population scientists.

(2)(3)

across scales  
R&D

(1) 将其转化为  
样本来  
全进阶

**Goal 1: Integrate Brain Imaging into Existing Representative (Sub)samples.** By using techniques such as sample stratification, cluster sampling, subsampling, and “planned missingness” (63), neuroscience methods can be integrated with ongoing and large-scale population-level studies without needing to collect neural data on every sample

## Abstract

Why Population Neuroscience?

Current Practices in Neuroimaging...

Getting Inside the Black Box: Adding...

## Integrative Framework

Benefits to Neuroscience,...

## Conclusion

## Acknowledgments

## References

## Integrative Framework

How can these goals become reality? How can we link multiple levels of analysis (i.e., move from synapse to cell to brain to individual to groups to regions to nations)? Below, we outline six concrete steps toward the big picture goal of promoting generalizability in neuroscience investigations and harnessing neuroscience tools to understand processes of interest to population scientists.

**Goal 1: Integrate Brain Imaging into Existing Representative (Sub)samples.** By using techniques such as sample stratification, cluster sampling, subsampling, and “planned missingness” (63), neuroscience methods can be integrated with ongoing and large-scale population-level studies without needing to collect neural data on every sample

across scales  
3S  
LJ  
RK

(1) 将现有代表+  
样本来  
促进共享

PNAS | October 29, 2013 | vol. 110 | no. 44 | 17617

行为学123456789

neuroscience methods have lagged in terms of addressing the use of multiple scanners (69, 80, 81), standardizing tasks used for functional (and resting-state; ref. 82) MRI studies, understanding the effect of different pulse sequences on findings (83, 84), standardization of single data processing streams (85, 86), and statistical approaches for issues such as multiple comparisons (68). Understanding the extent to which different laboratories, scanners, and methods can reliably collect data (80) is also vital to population-based studies, because most large studies rely on cluster sampling, which is conducive to using multiple laboratories for imaging. Cross-team data sharing also highlights the need for better methods for secure data sharing and computation across sites. Moreover, research is needed to examine factors that affect MRI results (e.g., head motion, ability to attend to a task) that covary with health factors and behaviors (e.g., chronic hypertension, smoking), which may be linked to environmental factors being studied (e.g., SES, geography). We also need designs and analytic tools that allow us to combine variables and processes at different time scales and levels of analysis. Finally, research that examines translation from neuroimaging to neural methods or proxies including self-report measures that are cost-effective and can be implemented at a population level are also critical in the translation of this research from smaller samples to larger samples and to wide-scale clinical relevance.

Ultimately, methodological advances (including sampling approaches) will be inherently intertwined with theory and the hypotheses being tested in these studies. Although sampling for large-scale representativeness may not be appropriate for all research questions, goal 2 emphasizes the need for methods in cases where the scientific question calls for this type of generalizability and/or where theoretical questions cannot be adequately addressed using data from one level of analysis alone.

**Goal 4: Explore Moderators of Brain-Behavior Links and Neural Predictors of Relevant Outcomes.** A growing body of research has demonstrated that environmental factors influence brain development. For example, childhood SES predicts brain structure (46) and function (45). Likewise, the size of our social networks relates to brain structure (93, 94). Given that the social environment is known to affect a wide array of biological responses (5, 17, 19, 95), a next important goal for neuroscience will be to further understand how experience at multiple levels (e.g., culture, family, social networks, SES) affects neural structure and function (46, 96–101). In parallel, it is certain that social and environmental variables moderate the link between brain and behavior (12), but further research is needed to examine such interactions. For example a recent study has demonstrated that level of perceived social support moderates the previously much replicated relationship between

17618 | www.pnas.org/cgi/doi/10.1073/pnas.1310134110

行为学123456789  
社会环境的神经机制  
社会支持与脑功能

## Abstract

### Why Population Neuroscience?

### Current Practices in Neuroimaging...

### Getting Inside the Black Box: Adding...

### Integrative Framework

### Benefits to Neuroscience,...

### Conclusion

### Acknowledgments

### References

杏仁核活动与焦虑  
amygdala reactivity and trait anxiety, indicating that many brain-behavior relationships may vary by environment and experience (102). However, if research does not explore these moderators, then these relationships may be assumed to be invariant across people and environments.

To fully leverage the fruits of the methodological goals outlined above, neuroscientists and population scientists might also reconsider the ways that neural variables are conceptualized (103). Traditional neuroimaging research has focused on the brain as a dependent measure (e.g., Where do certain processes take place in the brain? What structures support those processes?). Decades of neuroimaging literature have now characterized several processes that may be able to predict outcomes of interest to population scientists (e.g., neural activity in response to health communications predicts large-scale effects of media campaigns (104)). With this in mind, neural variables (e.g., structure, function, connectivity) can be hypothesized in advance and treated as predictor variables of relevant population level outcomes (103). This

methods may contribute to a shift from the assumption that is not readily available and may be a source of identifying the best methods (105). Moreover, increasing shift from the assumption that a dependent or independent variable can be a moderator and experience to behavior

### 角色的视角转换

amygdala reactivity and trait anxiety, indicating that many brain-behavior relationships may vary by environment and experience (102). However, if research does not explore these moderators, then these relationships may be assumed to be invariant across people and environments.

### Goal 5: Changing of the Cultures in Neuroscience and Population Research.

As population research has recently begun to acknowledge the usefulness and importance of including genetic and other biomarker data (108–113), scholars note a lack of brain research in the examination of the influence of macrolevel processes on health and behavior (111, 114). Moreover, we argue that even though most population researchers may not use MRI data, a better general understanding of the behaviorally relevant elements of basic brain research will be important for the progress of the field, especially as cross-discipline studies are becoming the norm rather than exception.

Likewise, for many neuroscience questions,

smaller targeted samples make

sense, and many findings within the social,

affective, and cognitive neurosciences have

replicated well across laboratories, across geo-

developed by Poldrack and colleagues (115), we propose the addition of some basic sampling strategy information, as well as the facts that would typically be included in a Consolidated Standards of Reporting Trials (CONSORT) flow diagram ([www.consort-statement.org/consort-statement/](http://www.consort-statement.org/consort-statement/)) to the checklist (Table 1).

Funding for interdisciplinary training and interaction, support for interdisciplinary working groups, and consultation across disciplines will promote true cross-pollination. For example, conferences that bring together scientists across these disciplines can lead to more explicit collaboration and a better understanding of methods and the benefits of each discipline's area of expertise. Funding that focuses explicitly on these specific aims may yield studies that have big impacts, not only on the study's specific question but more broadly on how we interpret and understand neuroimaging and population science. Although these studies may seem risky to funding agencies, these are the types of studies that can have big rewards.

*Just to keep it simple, we can focus on population neuroscience areas of emphasis*

#### Advantages of reporting this information regularly

Specific subject and recruitment details to report	Advantages of reporting this information regularly
Target population: Author note about who the sample may generalize to in the larger population	Draws attention to the author specified relevant population and draws attention to when samples may be limited in generalizing to other populations
Sample design: Sampling strategy used to select potential participants from a larger population pool	Allows readers to understand the strengths of the strategy used, as well as possible sampling error and bias within the study, and what methods will be needed to appropriately account for the strategy
Recruitment strategy and response rate: Techniques used to find, contact and encourage study participation	Allows for assessment of selectivity of sample by learning the extent to which nonresponse bias may influence the findings
Analysis exclusion criteria: Measures used to distinguish analysis sample	Delimits the sample and population of who and who is not included
Attrition bias: (longitudinal studies) Rates of continued participation	Allows for the assessment of selectivity of a longitudinal sample due various types of attrition
Demographics: age, race, and ethnicity, SES at each step from recruitment to scanning to those with usable data	Draws attention to the diversity of characteristics of the sample and potential bias in who is retained at any step along the way
Efforts to standardize across multiple scanners if the study includes such data: If multiple scanners or scan sites were used in data collection, what specific steps were taken to standardize pulse sequences, protocols, and other factors that might affect the imaging data? What steps were taken to adjust for scanner variability without removing variability that is due to differing demographics or participant characteristics across sites?	Draws attention to portions of the protocol that are standard across sites, and elements that may introduce variability

A complement to the guidelines suggested by Poldrack et al. (115), which include suggestions for reporting design specification, task specification, planned comparisons, details of the subject sample (e.g., inclusions/exclusion criteria), ethics approval, behavioral performance, image properties, preprocessing, first level modeling, group level modeling, inferences related to statistical images, ROI analysis, and figures/tables.

organization of population neuroscience through their emphasis on the multiple layers of influence on behavior and cognition. Life course and development frameworks imply that the relationships between social context and the brain may not be constant across an individual's life, may vary as a function of the context in which individuals operate, and may not be constant over cohorts or historical periods (116). Developmental theory has as its primary focus the interaction of person, process, and context, as studied with regard to age and age-graded transitions in processes and relationships (20, 62, 117). Life course theories focus on context as well (cohort, period, and historical contexts) and will be relevant here. Thus, these theories highlight the (individual, societal, and historical) timing of transitions and adaptation to various transitions, which are likely to influence and qualify brain-behavior relationships in powerful ways that are yet to be examined. Beyond thinking of these contexts as predictors and moderators of brain processes, ecological models emphasize that brain processes are nested and embedded within larger social contexts at multiple levels and are likely to be influenced by and influence these contexts (Fig. 1). Thus, partnerships across these disciplines may bring a more complex and interactional framework to our understanding of neuroscience (20, 61, 62).

## Abstract

Why Population  
Neuroscience?

Current Practices in  
Neuroimaging...

Getting Inside the  
Black Box: Adding...

Integrative  
Framework

Benefits to  
Neuroscience,...

Conclusion

Acknowledgments

References

*Benefits to Neuroscience, Population Science, and Broader Social Sciences*

Implementation of the six steps outlined above would promote advances in the integration of

helping to formulate the possible chronic (regional). Likewise, in human genetics, genetic influences on brain structure and function, such as discrimination, poverty, SES, and social support (5, 17, 43, 44). As well, these influences are used as a predictor of behavior and moderator of the social environment. As illustrated by imaging genetics approaches, one

方法

实践层面建议

对社会/民族 影响途径

Table 2. Areas of emphasis within a population neuroscience framework

Areas of emphasis	Why?	How?
Increase the representativeness of samples using neuroimaging approaches	<ul style="list-style-type: none"> <li>• Neuroimaging studies based on convenience samples may not optimally address target research questions or may come to erroneous conclusions</li> <li>• All brains are not the same</li> </ul>	<ul style="list-style-type: none"> <li>• Increased emphasis on sampling approaches (goal 5) <i>✓ reliable measures</i></li> <li>• Use of sophisticated sampling and analytic techniques to decrease <math>N</math> needed in samples (goal 3)</li> </ul>
Increased collection of larger, well-characterized neuroimaging samples at multiple points across the life span	<ul style="list-style-type: none"> <li>• Understand developmental trajectories of brain development</li> <li>• Increase replicability and generalizability of results</li> </ul>	<ul style="list-style-type: none"> <li>• Merging existing data sets and meta-analysis (goal 2)</li> <li>• Large-scale collaborative studies</li> <li>• Piggybacking neuroimaging on existing behavioral studies</li> <li>• Increased work on cross-site imaging and standardization of protocols to allow for combining samples (goal 1)</li> <li>• Longitudinal imaging (goal 6)</li> </ul>
Increase the emphasis on larger social context and experience as a predictor and moderator of brain-behavior links	<ul style="list-style-type: none"> <li>• Evidence in social sciences emphasizes the importance of broader context and culture on behavior</li> <li>• Ignoring these variables assumes uniform brain-behavior relationships which is unlikely</li> </ul>	<ul style="list-style-type: none"> <li>• Examination of moderators and collection of data from diverse groups (both cross- and within-culture) (goal 4)</li> <li>• Examination of ecological and interactional models (goal 6)</li> </ul>
Increased training and collaboration between neural and social scientists	<ul style="list-style-type: none"> <li>• Neural science can gain from increased focus on samples and on contextual effects</li> <li>• Population science can gain from increased understanding of the brain as a mediator of context-behavior links</li> </ul>	<ul style="list-style-type: none"> <li>• Funding focused on this "high-risk, high-reward," large-scale collaboration</li> <li>• Conferences and national meetings for collaboration and learning</li> <li>• Emphasis on making each discipline's methods accessible (goal 5)</li> </ul>

## Abstract

Why Population Neuroscience?

Current Practices in Neuroimaging...

Getting Inside the Black Box: Adding...

Integrative Framework

Benefits to Neuroscience,...

Conclusion

Acknowledgments

References

## Conclusion → 摘除了一个部分

We outlined a framework to better understand influences and mechanisms of behavior from culture to experience to brain structure and function, which would also improve confidence in the generalizability of neuroimaging findings. To take action on this framework, collaboration is needed between neuroscientists, survey methodologists, biophysicists, biostatisticians, and representatives from across social sciences, and population-based sciences in particular. These stakeholders include members of multiple social and behavioral sciences (psychology, sociology, economics, epidemiology, medicine, education, communication). Research across each of these disciplines will benefit from the resulting knowledge. However, our point is not simply that researchers should collaborate in

99.27

Journal University on September 21, 2022 from IP address 219.

across disciplines, rather it is more pressing: social and neural sciences are building huge literatures that could be more efficient and informative; however, at the present, “we don’t know what we don’t know”: human neuroimaging studies are limited in the extent to which results might generalize based on relatively less sophisticated sampling methods, whereas social science disciplines that focus on brain science may be missing a critical piece of understanding behavior phenomena even at macro levels. Thus, this is a critical moment for these disciplines. Collaboration can and should happen through funding opportunities, summer institutes, cross-disciplinary training of future scientists, graduate and postdoctoral training opportunities across areas, and each area making their methods accessible to others. This framework is meant to be dynamic and will be refined as members of each of these groups agree on principles for the collection and analysis of representative brain imaging data. Although this goal is ambitious, the groundwork is in place, and several large-scale neuroimaging studies and existing nationally representative surveys with interest in adding neuroscience data provide jumping off points (6). Accomplishment of this overarching goal will provide deeper insights about how biology, social situations, and broader environmental context interact to guide behavior and development. In turn, this will advance basic science and provide concrete insight for the design of better interventions and policies.

Downloaded from https://www.pnas.org by Beijing

Falk et al.

## Abstract

Why Population  
Neuroscience?

Current Practices in  
Neuroimaging...

Getting Inside the  
Black Box: Adding...

Integrative  
Framework

Benefits to  
Neuroscience,...

Conclusion

Acknowledgments

References

SEND 2014

社會環境神經發育

**ACKNOWLEDGMENTS.** This paper was made possible by the collective efforts of the Social Environment and Neural Development (SEND) working group within the Survey Research Center (SRC) at the University of Michigan. We gratefully acknowledge the SRC for support of this group, as well as funding supporting group members: National Institutes of Health (NIH)-1 Grants DP2 DA035156-01 (to E.B.F.), U01AG009740 (to J.F.), R01 DA027261 (to M.M.H.), R01 AA12217 (to M.M.H.), and U01 AG09740 (to K.L.), and the Robert Wood Johnson Foundation Health and Society Scholars program (J.M.). As we advocate cross-disciplinary collaboration, we describe how (*i*) our group has come together representing many disciplines and (*ii*) how this paper was written as an example of the potential of this type of group. (*i*) In 2010, the University of Michigan challenged social science researchers to cross the traditional bounds of their disciplines to think of emerging cross-disciplinary work that would inform the science in the future. P.D.-K. and F.J.M. received a grant from this initiative centered on documenting important changes in the brain related to socioeconomic differences of children and families. This research, however, was based on small sample sizes and a fairly basic understanding of indicators of socio-economic differences. Thus, a conference was assembled

to bring together researchers across the social sciences and neuroscience to discuss the state of this research and ways to improve and validate findings. One outcome of this conference was that investigators across the University began to meet and identify important synergies across broad areas of social and neural sciences. With support from the Institute for Social Research, the senior authors began hosting monthly meetings for these discussions. The group continues to grow and represent multiple disciplines and career stages, often with junior members contributing “cutting edge” new approaches. (*ii*) This manuscript was the result of discussions that the group has had from 2012–2013 and emerged as a way to organize our collective vision. Key to the production of the paper was that the three first authors were junior investigators with three very different backgrounds (e.g., demography, social neuroscience, and developmental neurogenetics) interested in collaborating and synthesizing interests from across our fields. As the three first authors were somewhat representative of the larger group, we were able to structure a paper and receive feedback from the larger group, especially in parts of the manuscript core to each member’s expertise. We also received excellent feedback from two reviewers: their thoughtful input significantly strengthened the manuscript.

• 括弧內註明方式

(2月) 2  
iti會

ney  
社會  
經濟  
差異  
研究  
方法

## Abstract

## Why Population Neuroscience?

## Current Practices in Neuroimaging...

## Getting Inside the Black Box: Adding...

## Integrative Framework

## Benefits to Neuroscience,...

## Conclusion

## Acknowledgments

## References

- 1** Cabeza R, Nyberg L (2000) Imaging cognition II: An empirical review of 275 PET and fMRI studies. *J Cogn Neurosci* 12(1):1–47.
- 2** Cacioppo JT, Berntson GG, Sheridan JF, McClintock MK (2000) Multilevel integrative analyses of human behavior: Social neuroscience and the complementing nature of social and biological approaches. *Psychol Bull* 126(6):829–843.
- 3** Lieberman MD (2010) Social cognitive neuroscience. *Handbook of Social Psychology*, eds Fiske S, Gilbert D, Lindzey G (McGraw-Hill, New York), 5th Ed, pp 143–193.
- 4** Sanfey AG, Loewenstein G, McClure SM, Cohen JD (2006) Neuroeconomics: Cross-currents in research on decision-making. *Trends Cogn Sci* 10(3):108–116.
- 5** Eisenberger NI, Cole SW (2012) Social neuroscience and health: Neurophysiological mechanisms linking social ties with physical health. *Nat Neurosci* 15(5):669–674.
- 6** Paus T (2010) Population neuroscience: Why and how. *Hum Brain Mapp* 31(6):891–903.
- 7** Henrich J, Heine SJ, Norenzayan A (2010) The weirdest people in the world? *Behav Brain Sci* 33(2–3):61–83, discussion 83–135.
- 8** Sears DO (1986) College sophomores in the laboratory: Influences of a narrow data base on social psychology's view of human nature. *Pers Soc Psychol* 15(3):515–530.
- 9** Button KS, et al. (2013) Power failure: Why small sample size undermines the reliability of neuroscience. *Nat Rev Neurosci* 14(5):365–376.
- 10** Stiles J (2009) On genes, brains, and behavior: Why should developmental psychologists care about brain development? *Child Dev Perspect* 3(3):196–202.
- 11** Zelazo PD, Paus T (2010) Developmental social neuroscience: An introduction. *Soc Neurosci* 5(5–6):417–421.
- 12** Crone EA, Dahl RE (2012) Understanding adolescence as a period of social-affective engagement and goal flexibility. *Nat Rev Neurosci* 13(9):636–650.
- 13** Keating DP (2010) *Nature and Nurture in Early Child Development* (Cambridge Univ Press, New York).
- 14** Hertzman C, Boyce T (2010) How experience gets under the skin to create gradients in developmental health. *Annu Rev Public Health* 31:329–347.
- 15** Boyce WT, Sokolowski MB, Robinson GE (2012) Toward a new biology of social adversity. *Proc Natl Acad Sci USA* 109(Suppl 2):7143–7148.
- 16** Meany MJ (2010) Epigenetics and the biological definition of gene x environment interactions. *Child Dev* 81(1):41–79.
- 17** Taylor SE (2010) Mechanisms linking early life stress to adult health outcomes. *Proc Natl Acad Sci USA* 107(19):8507–8512.
- 18** Paus T (2012) Some thoughts on the relationship of developmental science and population neuroscience. *Int J Develop* 36(1):9–11.
- 19** Bronfenbrenner U (1979) *The Ecology of Human Development: Experiments by Nature and Design* (Harvard Univ Press, Cambridge, MA).
- 20** Cicchetti D, Toth SL (1997) Transactional ecological systems in developmental psychopathology. *Developmental Psychopathology: Perspectives on Adjustment, Risk, and Disorder*, eds Luthar SS, Burack JA, Cicchetti D, Weisz JR (Cambridge Univ Press, Cambridge, UK), p 317.
- 21** Li S-C (2009) Brain in macro experiential context: Biocultural co-construction of lifespan neurocognitive development. *Prog Brain Res* 178:17–29.
- 22** Chiao JY, Cheon BK (2010) The weirdest brains in the world. *Behav Brain Sci* 33(2–3):88–90.
- 23** Groves RM, et al. (2009) *Survey Methodology* (Wiley, Hoboken, NJ).
- 24** Kish L (1995) *Survey Sampling* (Wiley, Hoboken, NJ).
- 25** Turkheimer E, Haley A, Waldron M, D'Onofrio B, Gottesman II (2003) Socioeconomic status modifies heritability of IQ in young children. *Psychol Sci* 14(6):623–628.
- 26** Camp CJ, West RL, Poon LW (1989) Recruitment practices of psychology research in gerontology. *Special Research Methods for Gerontology*, eds Lawton MP, Herzog AR (Baywood, Amityville, NY), pp 163–189.
- 27** Ransohoff DF, Feinstein AR (1978) Problems of spectrum and bias in evaluating the efficacy of diagnostic tests. *N Engl J Med* 299(17):926–930.
- 28** Miller JG (1984) Culture and development of everyday social explanation. *J Pers Soc Psychol* 45(5):961–978.
- 29** Peterson RA (2001) On the use of college students in social science research: Insights from a second-order meta-analysis. *J Consum Res* 28(3):450–461.
- 30** Brayne C, et al.; ECLIPSE Collaborative Members (2010) Education, the brain and dementia: neuroprotection or compensation? *Brain* 133(Pt 8):2210–2216.
- 31** Beahar MC (2003) Public health context of women's mental health research. *Psychiatr Clin North Am* 26(3):781–799.
- 32** Brawley OW, Freeman HP (1999) Race and outcomes: Is this the end of the beginning for minority health research? *J Natl Cancer Inst* 91(22):1908–1909.
- 33** Tunis SR, Stryer DB, Clancy CM (2003) Practical clinical trials: Increasing the value of clinical research for decision making in clinical and health policy. *JAMA* 290(12):1624–1632.
- 34** Glasgow RE, et al. (2006) External validity: We need to do more. *Ann Behav Med* 31(2):105–108.
- 35** Wolfe B, Evans W, Seeman TE (2012) *The Biological Consequences of Socioeconomic Inequalities* (Russell Sage Foundation Publications, New York).
- 36** Muscatell KA, Eisenberger NI (2012) A social neuroscience perspective on stress and health. *Social and Personality Psychological Compass* 6(12):890–904.
- 37** Brooks-Gunn J, Duncan GJ (1997) The effects of poverty on children. *Future Child* 7(2):55–71.
- 38** Xue Y, Leventhal B, Brooks-Gunn J, Earls F (2005) Neighborhood residence and mental health problems of 5- to 11-year-olds. *Arch Gen Psychiatry* 62(5):554–563.
- 39** Sirin SR (2005) Socioeconomic status and academic achievement: A meta-analytic review of research. *Rev Educ Res* 75(3):417–453.
- 40** Appleyard K, Egeland B, van Dulmen MH, Sroufe LA (2005) When more is not better: The role of cumulative risk in child behavior outcomes. *J Child Psychol Psychiatry* 46(3):235–245.
- 41** Wilkinson RG, Pickett KE (2006) Income inequality and population health: A review and explanation of the evidence. *Soc Sci Med* 62(7):1768–1784.
- 42** McLanahan S (2009) Fragile families and the reproduction of poverty. *Ann Am Acad Pol Soc Sci* 621(1):111–131.

- 43** Giannaris PI, et al. (2007) Parietal anterior cingulate morphology covaries with perceived social standing. *Soc Cogn Affect Neurosci* 2(3):161–173.
- 44** Giannaris PI, et al. (2007) Prospective reports of chronic life stress did decreased matter volume in the hippocampus. *Neuroimage* 35(2):795–803.
- 45** Giannaris PI, et al. (2011) Parental education predicts corticothalamic connectivity in adulthood. *Cereb Cortex* 21(6):896–910.
- 46** Hanson JL, et al. (2013) Brain development and poverty: A first look. *The Biological Consequences of Socioeconomic Inequalities*, Wolfe B, Evans W, Seeman TE (Russell Sage Foundation, New York).
- 47** Hackman DA, Farah MJ, Meany MJ (2010) Socioeconomic status and the brain. Mechanistic insights from human and animal research. *Nat Rev Neurosci* 11(9):651–659.
- 48** Hyde LW, Shaw DS, Hariri AR (2013) Neuroscience, developmental psychopathology, and youth antisocial behavior: Review, integration, directions for research. *Dev Rev* 33:168–223.
- 49** Crowe SL, Hyde RW (2008) The development of antisocial behavior: What can we learn from functional neuroimaging studies? *Psychiatry* 70(6):1145–1159.
- 50** Price JL, Drevets WC (2010) Neurocircuitry of mood disorders. *Psychopharmacology* 35(1):192–216.
- 51** Hyde LW, Shaw DS, Hariri AR (2013) Neuroscience, developmental psychopathology, and youth antisocial behavior: Review, integration, directions for research. *Dev Rev* 33:168–223.
- 52** Crowe SL, Hyde RW (2008) The development of antisocial behavior: What can we learn from functional neuroimaging studies? *Psychiatry* 70(6):1145–1159.
- 53** Price JL, Drevets WC (2010) Neurocircuitry of mood disorders. *Psychopharmacology* 35(1):192–216.
- 54** Hyde LW, Shaw DS, Hariri AR (2013) Neuroscience, developmental psychopathology, and youth antisocial behavior: Review, integration, directions for research. *Dev Rev* 33:168–223.
- 55** Crowe SL, Hyde RW (2008) The development of antisocial behavior: What can we learn from functional neuroimaging studies? *Psychiatry* 70(6):1145–1159.
- 56** Price JL, Drevets WC (2010) Neurocircuitry of mood disorders. *Psychopharmacology* 35(1):192–216.
- 57** Hyde LW, Shaw DS, Hariri AR (2013) Neuroscience, developmental psychopathology, and youth antisocial behavior: Review, integration, directions for research. *Dev Rev* 33:168–223.
- 58** Crowe SL, Hyde RW (2008) The development of antisocial behavior: What can we learn from functional neuroimaging studies? *Psychiatry* 70(6):1145–1159.
- 59** Price JL, Drevets WC (2010) Neurocircuitry of mood disorders. *Psychopharmacology* 35(1):192–216.
- 60** Hyde LW, Shaw DS, Hariri AR (2013) Neuroscience, developmental psychopathology, and youth antisocial behavior: Review, integration, directions for research. *Dev Rev* 33:168–223.
- 61** Price JL, Drevets WC (2010) Neurocircuitry of mood disorders. *Psychopharmacology* 35(1):192–216.
- 62** Hyde LW, Shaw DS, Hariri AR (2013) Neuroscience, developmental psychopathology, and youth antisocial behavior: Review, integration, directions for research. *Dev Rev* 33:168–223.
- 63** Price JL, Drevets WC (2010) Neurocircuitry of mood disorders. *Psychopharmacology* 35(1):192–216.
- 64** Hyde LW, Shaw DS, Hariri AR (2013) Neuroscience, developmental psychopathology, and youth antisocial behavior: Review, integration, directions for research. *Dev Rev* 33:168–223.
- 65** Price JL, Drevets WC (2010) Neurocircuitry of mood disorders. *Psychopharmacology* 35(1):192–216.
- 66** Hyde LW, Shaw DS, Hariri AR (2013) Neuroscience, developmental psychopathology, and youth antisocial behavior: Review, integration, directions for research. *Dev Rev* 33:168–223.
- 67** Price JL, Drevets WC (2010) Neurocircuitry of mood disorders. *Psychopharmacology* 35(1):192–216.
- 68** Hyde LW, Shaw DS, Hariri AR (2013) Neuroscience, developmental psychopathology, and youth antisocial behavior: Review, integration, directions for research. *Dev Rev* 33:168–223.
- 69** Price JL, Drevets WC (2010) Neurocircuitry of mood disorders. *Psychopharmacology* 35(1):192–216.
- 70** Hyde LW, Shaw DS, Hariri AR (2013) Neuroscience, developmental psychopathology, and youth antisocial behavior: Review, integration, directions for research. *Dev Rev* 33:168–223.
- 71** Price JL, Drevets WC (2010) Neurocircuitry of mood disorders. *Psychopharmacology* 35(1):192–216.
- 72** Marcus DS, et al. (2007) Open access series of imaging studies (OASIS): Cross-sectional MRI data in young, middle-aged, non-demented, and demented older adults. *J Cogn Neurosci* 19(8):1498–1507.
- 73** Jack CR, Jr., et al. (2008) The Alzheimer's disease neuroimaging initiative (ADNI): MRI methods. *J Magn Reson Imaging* 27(4):685–691.
- 74** Potkin SG, Ford JM (2009) Widespread cortical dysfunction in schizophrenia. *The FBRN imaging consortium*. *Schizophr Bull* 35(1):15–18.
- 75** Thyreus B, et al.; IMAGEN Consortium (2012) Very large fMRI study using the IMAGEN database: Sensitivity-specificity and population effect modeling in relation to the underlying anatomy. *Neuroimage* 61(3):723–728.
- 76** Marcus DS, et al. (2007) Open access series of imaging studies (OASIS): Cross-sectional MRI data in young, middle-aged, non-demented, and demented older adults. *J Cogn Neurosci* 19(8):1498–1507.
- 77** Jack CR, Jr., et al. (2008) The Alzheimer's disease neuroimaging initiative (ADNI): MRI methods. *J Magn Reson Imaging* 27(4):685–691.
- 78** Hyde LW, Gorka A, Manuck SB, Hariri AR (2011) Perceived social support moderates the link between threat-related amygdala reactivity and trait anxiety. *Neuropsychology* 24(6):541–556.
- 79** Berkman ET, Falk EB (2013) Beyond brain mapping: Using the brain to predict real-world outcomes. *Curr Dir Psychol Sci* 22(1):45–53.
- 80** Falk EB, Berkman ET, Lieberman MD (2012) From neural responses to population behavior: Neural group predicts population-level media effects. *Psychol Sci* 23(5):439–445.
- 81** Falk EB, Berkman ET, Marin T, Mann H, Hariri AR (2010) Predicting personality-induced behavior change from the brain. *J Neurosci* 30(25):8421–8424.
- 82** Yeshenko I, Puelz M (2009) Beyond diastolic stress: Differential susceptibility to environmental influences. *Psychol Biol* 135(6):885–898.
- 83** Zhao J, et al. (2010) Theory and methods in cultural neuroscience. *Soc Cogn Affect Neurosci* 5(2):356–361.
- 84** Satyri N, McGonagle K, Schoen RF (2009) Introduction to the special issue on the scientific assessment of biomarkers in the panel study of income dynamics. *Biomethodology and Social Biology* 55(2):113–117.
- 85** Freese J, Shostak S (2009) Genetics and social inquiry. *Annu Rev Social* 35(1):107–128.
- 86** McDade TW, Williams S, Snodgrass JJ (2007) What a drop can do: Dried blood spots as a minimally invasive method for integrating biomarkers into population-based research. *Demography* 44(4):899–925.
- 87** Freese J, U-JCA, Wade LD (2009) The potential influences of biology to social inquiry. *Annu Rev Social* 29(1):233–256.
- 88** Boardman JD, et al. (2011) Population composition, public policy, and the risk of smoking. *Demography* 48(4):1517–1533.
- 89** Mitchell C, et al. (2013) Differential sensitivity to social environments: Implications for research. *Am J Public Health* 103(5):510–510.
- 90** Maynard DS (2002) A brief history of human society: The origin and fate of prehistoric racial groups. *Am Soc Rev* 67(1):1–29.
- 91** Podrack RA, et al. (2008) Guidelines for reporting an fMRI study. *Neuroimage* 40(2):409–414.
- 92** Ben-Shlomo Y, Kuh D (2000) A life course approach to chronic disease epidemiology: Conceptual models, empirical challenges and interdisciplinary perspectives. *Int J Epidemiol* 31(2):285–293.
- 93** Lerner RM (2008) *Developmental Science, Developmental Systems, and Contingent Theories of human development*, eds Damon W, Lerner RM, (Wiley, Hoboken, NJ), 6th Ed, Vol. 1.
- 94** Ben-Shlomo Y, et al. (2010) Towards a unified science of human brain function. *Proc Natl Acad Sci USA* 107(10):4734–4739.
- 95** Korn EL, Graubard BE (1995) Analysis of large health surveys: Accounting for the sampling design. *J R Stat Soc Ser A Stat* 158(2):233–295.
- 96** Xie Y (2000) Demography: Past, present, and future. *J Am Stat Assoc* 95(449):17–34.
- 97** Sameroff AJ, Cook TD, Campbell DT (2002) Experimental and Quasi-Experimental Designs for Generalized Causal Inference (Houghton-Mifflin, Boston), 2nd Ed.
- 98** Lavigne LM, Koch GG, Schwartz TA (2011) Applying sample survey methods to clinical trials data. *Stat Med* 2017(18):2690–2653.
- 99** Korn EL, Graubard BE (1995) Analysis of large health surveys: Accounting for the sampling design. *J R Stat Soc Ser A Stat* 158(2):233–295.
- 100** Giannaris PI, et al. (2007) Health psychology: what is it and what is it about? *Arch Gen Psychiatry* 66(1):89–94.
- 101** Hariri AR (2009) Socioeconomic status and the neurobiology of resilience. *Am J Public Health* 99(1):1674–1680.
- 102** Hyde LW, Gorka A, Manuck SB, Hariri AR (2011) Perceived social support moderates the link between threat-related amygdala reactivity and trait anxiety. *Neuropsychology* 24(6):541–556.
- 103** Berkman ET, Falk EB (2013) Beyond brain mapping: Using the brain to predict real-world outcomes. *Curr Opin Psychol* 22(1):45–53.
- 104** Falk EB, Berkman ET, Lieberman MD (2012) From neural responses to population behavior: Neural group predicts population-level media effects. *Psychol Sci* 23(5):439–445.
- 105** Falk EB, Berkman ET, Marin T, Mann H, Hariri AR (2010) Predicting personality-induced behavior change from the brain. *J Neurosci* 30(25):8421–8424.
- 106** Yeshenko I, Puelz M (2009) Beyond diastolic stress: Differential susceptibility to environmental influences. *Psychol Biol* 135(6):885–898.
- 107** Hyde LW, Gorka A, Manuck SB, Hariri AR (2011) Perceived social support moderates the link between threat-related amygdala reactivity and trait anxiety. *Neuropsychology* 24(6):541–556.
- 108** Satyri N, McGonagle K, Schoen RF (2009) Introduction to the special issue on the scientific assessment of biomarkers in the panel study of income dynamics. *Biomethodology and Social Biology* 55(2):113–117.
- 109** Freese J, Shostak S (2009) Genetics and social inquiry. *Annu Rev Social* 35(1):107–128.
- 110** McDade TW, Williams S, Snodgrass JJ (2007) What a drop can do: Dried blood spots as a minimally invasive method for integrating biomarkers into population-based research. *Demography* 44(4):899–925.
- 111** Freese J, et al. (2010) Theory and methods in cultural neuroscience. *Soc Cogn Affect Neurosci* 5(2):356–361.
- 112** Giedd JN, et al. (1996) Quantitative magnetic resonance imaging of human brain development: Ages 4–18. *Cereb Cortex* 6(4):551–560.
- 113** Falk EB (2013) Can neuroscience advance our understanding of core questions in Communication Studies? An overview of Communication Neuroscience. *Communication @ the Center*, ed Jones S (Hampton Press, New York), pp 77–94.
- 114** Hariri AR (2009) The neurobiology of individual differences in complex behavioral traits. *Annu Rev Neurosci* 32:225–247.
- 115** Hariri K, et al. (2011) Toward a developmental conceptualization of contributors to overweight and obesity in childhood: the sIc model. *Child Development Perspectives* 5(1):50–58.
- 116** Antonucci TC, et al. (2012) The right to move: A multidisciplinary lifespan conceptual framework. *Current Gerontology and Geriatrics Research* 873937.