Leveraging Rarely-Investigated Populations for Research on Behavioral and Social Processes in an Aging Context Expert Meeting

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Table of Contents

Meeting Summary

Introduction

Much of the evidence base for understanding emotion, cognition, and sociality is from studies in Western, educated, industrialized, rich, and democratic (WEIRD) societies, and even within WEIRD populations, most participants in behavioral research on determinants of healthy aging are non-poor. On July 2-3, 2018, the National Academies of Sciences, Engineering, and Medicine's Committee on Population and the National Institute on Aging of the National Institutes of Health convened an expert meeting in Washington, DC, to discuss the potential value of examining individual variation and age-related changes in behavioral, affective, cognitive, and social processes across WEIRD and non-WEIRD populations and at multiple levels of socioeconomic status (SES). Expanding aging research to non-WEIRD societies and less frequently studied sub-populations in our own society, such as those low on the socioeconomic ladder, may aid discovery of both universal and environmentally dependent mechanisms that underlie aging processes across the life course.

The central issue that meeting participants were asked to address is how to identify the causal pathways through which different social and environmental exposures interact with behavior and biology to shape development, and, ultimately, psychological function and behavior in aging. The presentations and discussions focused on a variety of different themes, including evolutionary perspectives, cultural differences in psychological functioning, the impact of SES and resource scarcity on psychological functioning, approaches for learning from non-WEIRD and other under-investigated populations, prospective study designs, and future directions. Insights from this meeting can inform future research priorities. The full agenda is provided in Appendix A, and the participants list is provided in Appendix B.

Setting the Stage for the Meeting

Martha Farah, University of Pennsylvania
Michael Gurven, University of California, Santa Barbara

Since the 1980s, the field of cognitive neuroscience has steadily expanded to investigate brain functioning at many levels, from the psychological to the molecular. Studies initially focused on cognition in healthy young individuals but eventually broadened to include social and emotional processes and brain aging, as well as individual differences between people based on genetics and environment. More recently, investigators have focused on high-level influences, such as SES and culture, and have found that aging processes are influenced at all of these levels. Farah and Gurven encouraged participants to explore further possible interactions among developmental, psychological, and environmental influences on aging.

Session I: Evolutionary Perspectives

Insights Using Evolutionary Perspectives Among Non-WEIRD Populations

Michael Gurven, University of California, Santa Barbara

Humans did not evolve in modern conditions. Although universal human aging characteristics continue to exist in modern environments, research on WEIRD populations alone is not sufficient for demonstrating their universality. One human universal characteristic is prosociality. Prosocial behavior likely persisted in humans because members of a social network can serve as insurance policies (e.g., by helping to ensure access to food in impoverished conditions) and because individuals benefit more from coordinating and sharing with others than they can by acting alone. However, even a universal characteristic such as prosociality can manifest differently in different contexts. An environment that threatens starvation will reward different behaviors than one that threatens obesity. Thus, researchers can study non-WEIRD populations and understudied subgroups within WEIRD societies to investigate how biological and environmental factors interact to influence aging.

Several explanatory frameworks have been proposed to unify aging trajectories across cultural and environmental contexts. One such framework is Life History Theory (LHT), which applies evolutionary logic to individual lifespans. In an environment that presents daily mortality hazards, it may be adaptive for people to behave in ways that would be dangerously risky in safe contexts. This insight may help explain why health-related behaviors vary in frequency in different environments (e.g., more risk-taking behavior in high-mortality environments). An important concept for studying environmental influences on aging is the *reaction norm*, which refers to the range of phenotypic variations that organisms with identical genotypes manifest across different environments. Particularly in combination with LHT, researchers can employ this concept to explain variations in cognitive aging patterns as adaptations to environmental pressures, including those at the cultural, behavioral, and psychological levels. For example, the Tsimané of Bolivia, who live in a high-mortality environment, tend to have an external locus of control, which is connected to attitudes of low self-efficacy and decreased likelihood to seek treatment for health problems. Understood as a reaction norm, this attitude could be interpreted as an adaptive method of selecting practical goals given the constraints of a dangerous environment that disincentivizes an emphasis on longer-term health goals.

Grandmothering and Human Evolution: Why Separate Nuclear Families Can Make Things Hard on Everyone

Kristen Hawkes, University of Utah

While female fertility ends at about the same age in humans as in other extant hominid species (the great apes), human longevity is substantially greater. Researchers have wondered what evolutionary benefit these postmenopausal years provide. Because genes pass from one generation to the next, the grandmother hypothesis suggests that as ancestral populations shifted to savanna resources that were difficult for small juveniles to acquire, the foraging productivity of older females enabled mothers to wean youngsters well before they could feed

themselves. As longer-lived grandmothers subsidized more descendants, lifespans increased in subsequent generations. Across the mammals, greater longevity is linked to later maturity and increased brain size. So not only are humans weaned early, but also while they still depend on others for food and their larger brains remain notably underdeveloped.[1] The social challenges this entails may account for our distinctive appetites for social engagement.[2]

The grandmother hypothesis has been evaluated with mathematical simulations. When simulations with hominid parameters are run without grandmothering, no postmenopausal longevity evolves, as is the case in nonhuman hominids. However, when simulations allow for grandmothering subsidies, longevity increases to the typical human level, but the end of female fertility remains below 50 years.[3]

The situation is further complicated by differences between male and female reproductive strategies. As overall longevity increases for both sexes and menopause occurs at the usual time, the ratio of fertile males to fertile females shifts. That ratio is female biased in most mammals, but, mammalian males, unlike females, continue to produce viable gametes throughout the life course. The increased number of older males compete for access to younger females. Because more male competitors make mate-guarding an advantageous strategy, this may account for our distinctive habit of pair bonding. The same evolutionary logic that drives biological and social changes across species on an evolutionary timescale may also help to explain reaction norms, for example changing ecological and social dynamics alter the apparent value of the future, which in turn influences behavioral choices. Living in dangerous neighborhoods and harsh environments may incentivize earlier maturity and reproduction, which could help to explain different life history patterns across cultures and social environments.

Tracking Biocultural Dynamics in Differential Human Well-Being: Applications to Aging

Carol Worthman, Emory University

Approaches to studying aging must treat biology and psychobehavioral characteristics as intimately associated. LHT provides a framework for explaining how evolution designs organisms to achieve reproductive success. Natural selection is the process by which organisms that are best adapted to their environment tend to survive and reproduce. For humans, this process is heavily influenced by cultural beliefs, values, and practices. Significant work has been

[1] K. Hawkes and B.L. Finlay, "Mammalian brain development and our grandmothering life history," *Physiol. Behav.* 193(A), 55-68 (2018).

[2] S.B. Hrdy, *Mothers and Others: The Evolutionary Origins of Mutual Understanding* (Boston, MA: Harvard University Press, 2011); K. Hawkes, "Primate sociality to human cooperation: Why us and not them?" *Hum. Nat.* 25, 28-48 (2014); M. Tomasello and I. Gonzales-Cabrera, "The role of ontogeny in human cooperation" *Hum. Nat.* 28, 274-288 (2017).

[3] P.S. Kim, et al., "Grandmothering drives the evolution of longevity in a probabilistic model," *J. Theor. Biol.* 353(21) (2014); P.S. Kim et al. "Why isn't menopause later? Grandmothering & age at last birth." *J. Theor. Biol.* 461. 84-91. (2019).

done to understand how culturally informed behaviors shape the conditions under which child development occurs, and the subsequent effects on adult outcomes.

Aging results from a series of tradeoffs that organisms face, starting before conception, between allocating time and energy among somatic, reproductive, and survival functions, in ways that maximize their fitness across the life course. In doing so, the life course is a product of tradeoffs of conditions under which people age and the balance of present actions with future actions. It is important to think about the intersection of biological and psychocultural tradeoffs, which do not always operate in the same way.

Research has elucidated three contextual factors important to aging. The first is structural violence—a concept developed by Paul Farmer that refers to structural inequality that is baked into society. Gender differences in terms of workloads and opportunities, social hierarchies based on caste, ethnicity, and religion, and maldistribution (i.e., unequal sharing of resources) contribute to inequality across settings. A second contextual factor is environmental instability due to natural disasters and human conflict and displacement. Such instability forces people to make tradeoffs on a daily basis in terms of the resources that are available to them. Worthman and colleagues are interested in understanding how structural factors, such as gender and caste, interact with environmental factors. To this end, they are focusing on Nepal, which experienced a devastating earthquake in 2015 that affected every societal group, as a potential model to predict resilience. The third contextual factor is cultural models, which drive definitions and expectations about the life course, wellbeing, physical and mental health, and relationships.

The study of pathways can improve understanding of global variations in aging. For example, *immune function and HPA activity* mobilize many resources. It will be important to understand how the ecologies under which people age shape reactivity and restraint in different contexts, and how the timing and chronicity of exposures shape the ontogeny of immune function and HPA activity. *Sleep* occupies one-third of our lives and is extremely important for cognitive function. Yet, sleep practices and budgets may differ across populations (e.g., WEIRD versus non-WEIRD). The physiology of sleep and how it affects aging is an intriguing research topic. Finally, evidence is accumulating about the influence of *gut microbiota*—which themselves are influenced by behavior—on the immune system, risk for obesity and diabetes, and cardiovascular health, metabolic function, and kidney function in the long term.

Researchers should capitalize on natural experiments to study the intersecting contextual factors that affect aging. For example, Worthman and colleagues are conducting field work in Nepal, where structural violence (e.g., inequality based on caste for Hindus), environmental instability (due to the earthquake), and local variation in cultural models related to health and wellbeing are all at play.

Discussion

Moderator: Martha Farah, University of Pennsylvania

Although sampling diverse populations produces valuable data, some theoretical analysis must precede empirical data collection. For instance, although the theoretical split between WEIRD and non-WEIRD societies is useful for clarifying gaps in current research, it is also somewhat simplistic. Each environment contains unique material and sociological factors that determine what is adaptive for individuals living there. To systematically probe unique environments, investigators need to approach sample selection with specific theoretical questions and hypotheses. Those hypotheses provide a roadmap for data collection, making it possible to test explanatory theories, without which interventions will be ineffective.

To judge an environment as harmful or to identify certain aims as desirable within an environment also involves theoretical considerations. Human physiological, behavioral, and cognitive plasticity suggests that modifying environments to produce desired effects is possible. However, which effects are desired remains an open question. As aging research expands to study non-WEIRD populations, investigators are challenged to interpret similar outcomes across different environments. Classical notions about positive and negative outcomes may be undermined when new environments are investigated. Some classically negative conditions can cause stress-adaptive outcomes that are linked to better health. For example, clean environments in WEIRD societies can have negative effects on human microbiota, which benefit from some exposure to dirt. In comparing WEIRD and non-WEIRD populations, another interpretive difficulty emerges from differences in formal education. Formal education introduces specific cultural and often psychological criteria to assess flourishing (e.g., exam performance or obedience). These criteria will often impact the way individuals think about and set goals for their future. Attempts to translate those criteria to non-WEIRD contexts, particularly when the researchers have themselves been formally educated in WEIRD settings, raise important theoretical questions about human flourishing that must be addressed.

Session II: Cultural Differences in Psychological Functioning

Cross-Cultural Differences in Memory

Angela Gutchess, Brandeis University

Memory is a constructive cognitive process that changes over the life course. It involves selecting information for attention and reconstructing mental representations. Because these processes are active and error-prone, researchers have questioned to what extent they are influenced by culture in addition to age. Memory experiments comparing Americans and Turks found evidence of cultural differences in information recall. Americans tended to make more category mistakes,[4] which could be related to the fact that categorical thinking (which is more

[4] A.J. Schwartz, et al., "Cross-cultural differences in categorical memory errors," *Cogn. Sci.* 38(5), 1-11 (2014).

prominent among Westerners[5]) is connected to false memories. Further work compared Westerners' and East Asians' ability to recall visual stimuli in detail.[6] Westerners encoded more detailed information, and brain scans indicated that the differences between the two groups were reflected in low-level perceptual brain processes, which could indicate that culture influences how the brain constructs memories. Investigators also looked at how aging-related cognitive diminishment may interact with cultural differences and found that cultural differences were unaffected by age, pointing to culture as an independent influence.

This work raises several experimental and interpretive challenges. Existing cognitive aging research is not based on representative samples and tends to be focused on non-poor WEIRD populations. This limitation has implications for developing interventions to improve cognitive aging trajectories and suggests that one intervention may cause varied outcomes in different cultural contexts. However, conducting cross-cultural research tends to further complicate interpretation. When investigators discover a cultural difference, they must decide whether to interpret it as an advantage in one group or an impairment in the other. The choice between those interpretations suggest two very different approaches to intervention. Even within WEIRD populations, rapid cultural changes mean that investigators need longitudinal data to disentangle cohort and age differences.

Culture and Aging East and West

Richard Nisbett, University of Michigan

Researchers have discovered differences in cognitive styles across Eastern and Western cultures. Westerners tend toward analytic reasoning, which focuses on details and internal working parts of an object or a situation. Easterners tend toward holistic reasoning, which refers to a heightened sensitivity to context and to high-level relationships between objects and situations. In addition, Westerners are generally better at using formal logical rules to reach a conclusion, whereas Easterners excel at postformal reasoning, which involves flexibility in dealing with novel problems.

To further investigate these differences, researchers tested cross-cultural samples for a factor they called wisdom, which relates to how one approaches social conflict. Participants were presented with community- and personal-level conflict situations and asked to describe what would happen next and to explain why they thought it would happen. Responses were coded for different approaches to conflict and showed that, according to the criteria developed by the investigators, older Americans are wiser than younger Americans, but older Japanese are not wiser than younger Japanese.

Cultural differences may explain the disjunction. Japanese culture emphasizes harmony and conflict avoidance, so Japanese children are taught wise social strategies during early

[5] L.J. Ji, et al., "Is it culture or is it language? Examination of language effects in cross-cultural research on categorization," *J. Pers. Soc. Psychol.* 87(1), 57-65 (2004).
[6] L.E. Paige, et al., "Cross-cultural differences in the neural correlates of specific and general recognition," *Cortex* 91, 250-261 (2017).

education, whereas Americans may require life experience to learn what Japanese are taught as children. Culture could also account for differences across American and Japanese populations along the Big Five personality traits (openness, conscientiousness, extraversion, agreeableness, and neuroticism). Japanese show greater fluctuation in these traits over the life course, and some research suggests that personality in Japanese individuals is more context sensitive. However, it could be that American culture encourages more self-analysis, leading individuals to develop more stable self-concepts that inhibit fluctuations.

Aging in Consumer Contexts

Carolyn Yoon, University of Michigan

Past research on age differences in consumer decision-making has adopted the person-context fit framework, which refers to the degree to which a consumer has the necessary resources to act on a decision to pursue a marketed opportunity. A consumer who has the necessary resources to make an independent decision is said to have a high degree of fit in that context. Analyses that use this framework look at interactions between task and contextual factors and individual characteristics to determine fit. Dependent variables commonly include consumer attention, attitudes, preferences, memory, and willingness to pay, and less commonly factors such as consumer disposition of goods and creativity.

Several studies have investigated how age affects persuasion within a person-context fit framework looking specifically at the illusion of truth phenomenon. This phenomenon occurs when repeated exposure to a statement leads a person to believe that the statement is true. Compared to younger adults, older adults tend to have worse memory for context (e.g., source of the information), although they tend to perform similarly in memory tasks focused on simple familiarity of the statements. Research has shown that familiarity and memory of context can dissociate and that the illusion of truth effect can intensify with repeated exposure to a product or health claim. Thus, warnings about false claims can backfire upon repeated exposure, leading the statement's context to be forgotten and the false claim to be remembered as true. If repeat exposure occurs after even a delay of 30 minutes, the effect is exaggerated in older adults compared to younger adults. However, after a longer delay of several days, younger and older adults forget the statement's context at similar levels, and both age groups are more likely to remember the false claim as true. Further research on this effect suggests that stating facts as positive statements rather than stating falsehoods as warnings may mitigate the illusion of truth effect.

To the extent that neurobiological decline in memory that occurs with aging is a cognitive universal, the illusion of truth effect is expected to be similarly pronounced among older consumers across different cultures. However, it is possible that the level of trust in different cultures moderates this effect. For instance, in countries that are characterized by high trust (e.g., Norway, Denmark), the illusion of truth effect may be magnified, while in countries with low trust (e.g., countries such as Columbia, Brazil), the effect is reduced.

Aging Against the Odds: Mental and Cognitive Health Among Mature Adults in Malawi

Hans-Peter Kohler, University of Pennsylvania

Aging research conducted in non-WEIRD populations can help fill knowledge gaps not addressed by existing research. Investigators have conducted longitudinal field work in Malawi to probe how adverse environments affect aging and mental health. The AIDS epidemic in Malawi drastically altered 10-year survival probabilities (especially for males) between 1970 and 2020. Middle-aged Malawians who survived the AIDS epidemic constitute a cohort that has survived adverse conditions, which can be compared to findings from WEIRD populations. The longitudinal data, which includes mental health, cognitive function, and hypertension, was expanded by linkages to socioeconomic information and early-life events.

These investigations yielded surprising results. As individuals in the Malawi cohort age, their anxiety and depression rates increase, which is the opposite of the pattern found in WEIRD cohorts. Socioeconomic stressors were not found to be explanatory factors for the rising depression and anxiety rates, but stressors related to physical health do appear to play a role. Grip strength tends to decline with age and serves as a reliable mortality predictor, and the cohort has high hypertension levels despite lacking traditional risk factors. Although the rise in Malawian depression rates exceeds that of WEIRD cohorts, the experience of depression is less severe in the Malawian cohort. Researchers have begun to suspect that the measurement criteria developed for WEIRD contexts may be measuring different underlying constructs when administered in a non-WEIRD context.

Baseline cognitive health measures do not predict cognitive aging in the Malawian cohort, though they do predict mortality. Healthy older Malawians tend to remain productive and participate in intergenerational transfers, but once their health begins to decline they become dependent on younger generations. As the Malawians age, investigators found that their cognitive aging accelerates and that this acceleration varies according to gender and SES. In sum, these cross-cultural results suggest that patterns of noncommunicable diseases and other physical and mental health measures vary in different populations.

Culture, Environmental/Social Stress, and Human Well-Being: A Cognitive and Biocultural Anthropological Perspective

Jeffrey Snodgrass, Colorado State University

Environmental and social stressors can interact with specific cultural contexts to affect subjective well-being through both cognitive and biocultural pathways. Investigators have conducted field work in two similar Indian villages located within or nearby the same wildlife sanctuary. One village was displaced outside its ancestral home in the core of this sanctuary, while the other was left in its original location in the sanctuary's buffer zone. Researchers sought to identify various mental and cognitive health predictors between each village's residents and found that village affiliation, as indicated by a subjective self-identification with one village or the other, was the most robust predictor of subjective well-being, as measured by the researchers' locally developed Positive and Negative Affect Schedule. Individuals who were

affiliated with the displaced village consistently reported lower subjective well-being. Affiliation with the displaced village even predicted aging-related biomarkers such as shorter telomeres and less healthy cortisol profiles.[7] Researchers have postulated that the meaning derived from emotional connection to a physical place, as the basis of social identity, may connect subjective well-being to physical and mental health.[8]

Further research in WEIRD settings has helped to corroborate the broader hypothesis that physical and mental health are mediated by cultural factors such as how meaning is sought through social relationships. One study, which examined Internet Gaming Disorder (IGD), now a clinically recognized addiction, revealed surprising patterns. The study showed that lonely individuals who engage in highly involved gaming can develop a support community on line that can buffer the potential negative health effects of loneliness.[9] Dry bloodspot analyses revealed a link between an aggregate measure of self-reported "positive" versus "negative" game-playing experiences and a suite of immune function biomarkers, referred to as CTRA (the "conserved transcriptome response to adversity"), such that players with a higher balance of positive compared to negative experiences had lower levels of this immune function adversity profile. This result suggests that certain factors at the psychological and cultural levels may be driving biological processes.[10] IGD comparisons across Europe, China, and the United States reveal strong similarities in addiction patterns, which suggests that an underlying neurobiological "addiction" profile may manifest similarly across cultures.

Discussion

Moderator: Michael Gurven, University of California, Santa Barbara

Research on cultural differences raises two related questions: (1) what is culture? and (2) how can it be isolated experimentally? Different research strands (e.g., neuroscience and anthropology) often conceptualize culture differently, which can confound efforts to integrate insights from multiple fields. There was broad consensus that attempts to agree on a universal definition of "culture" do not appear to be fruitful; rather, researchers should clearly define such concepts within the framework of their specific research question to make interpreting study results as unambiguous as possible. For example, investigators who study the cultural impacts of international trade might define "culture" in partially economic terms, whereas those who study traditions of religious worship might focus more on identity issues rather than on economics. Such definitions must be tailored to investigators' specific research interests and

[7] S. Zahran, et al., "Stress and telomere shortening among central Indian conservation refugees," *Proc. Natl. Acad. Sci. U.S.A.* 112(9), (2015).

[8] J.G. Snodgrass, et al., "Religious ritual is good medicine for indigenous Indian conservation refugees: implications for global mental health," *Curr. Anthropol.* 58(2), 257-284 (2017).

[9] J.G. Snodgrass, et al., "Online gaming involvement and its positive and negative consequences: a cognitive anthropological 'cultural consensus' approach to psychiatric measurement and assessment," *Comput. Hum. Behav.* 66(C), 291-302 (2017).

[10] J.G. Snodgrass, et al. "Social Genomics of Healthy and Disordered Internet Gaming." *Am. J. Hum. Biol.* e23146 (2018).

made as explicit as possible. Doing so can encourage rigor, reproducibility, and transparency of research and will facilitate understanding across fields.

When general concepts such as culture are not operationalized and controlled for, unintended confounds may remain hidden within an experimental design. For instance, studies that measure stimulus response across two social groups should ensure that the stimulus itself does not introduce a cultural bias. Only a small subset of conceptual categories seems to be culture invariant (i.e., universal), which means that practices such as stimulus normalization and research resources such as the Human Relations Area Files (a joint ethnographic database that investigators use to perform cross-cultural comparisons) can be leveraged to avoid cultural bias confounds.

Investigators use various approaches to isolate cultural influences in a study design, but each involves significant tradeoffs. Some researchers choose to develop their own metric tailored to the specific cultural comparison that their study will probe. This approach allows for detailed comparison of specific groups that differ on a specific dimension or set of dimensions, but custom metrics may not be generalizable. In addition, investigators may control for factors that would have revealed unexpected cross-cultural differences.

Overall, investigators should not take culture for granted as a concept. Rather, they should regard culture as a broad category containing many dimensions that can be described at many levels of analysis and should seek to discover specific distinctions using clear operationalization of relevant dimensions or features. In doing so, a larger range of potential explanatory factors will become available for investigation.

Session III: The Impact of Socioeconomic Status and Resource Scarcity on Psychological Functioning—Life-Span Development Perspectives

Early-Life Nutrition in the Poor Resource Setting of Guatemala and Life-Span Development

Jere Behrman, University of Pennsylvania

Childhood stunting, which is especially common in developing countries, often serves as a proxy measurement for chronic malnutrition. Growing children have high nutrition needs, and developing countries tend to lack nutrient- and energy-rich food sources. Children with immature immune systems in these environments are susceptible to infections and sicknesses from contaminated foods. Research shows that during the first 1,000 days after conception many health factors can affect physical and cognitive development throughout the life cycle. For instance, investigators have discovered associations between early-life nutrition and later-life outcomes such as height and income, as well as neurological outcomes such as reduced nerve myelination and decreased dendritic lengths in certain parts of the cortex. Thus, nutritional interventions that target development during the first 1,000 days after conception can lead to positive outcomes in later life.

For example, from 1969 to 1977 the Institute of Nutrition of Central America and Panama conducted a longitudinal early-life nutrition study. Investigators provided everyone, but particularly pregnant mothers and young children, in four Guatemalan villages with one of two nutrition supplements: one rich in protein and energy and the other less nutritious. The cohort has since undergone rounds of follow-up data collection to investigate the links between early-life nutrition and later-life outcomes.[11] The protein-rich supplement was associated with reduced stunting, but also with improved wage-earning in men,[12] schooling in women, and reading levels and cognitive skills in both sexes later in life.[13] The strongest effects were linked to exposure in the first 1,000 days after conception.[14] However, exposure to the higher-protein supplement was also linked to higher adiposity, blood pressure, and blood lipids in later life. In addition, some benefits that persist through young adulthood fade as individuals enter mature adulthood, and nutritional supplementation is not uniformly effective at preventing adult cardiometabolic disease. Thus, although nutritional supplementation is associated with various health benefits, especially in countries with high chronic malnutrition and stunting levels, understanding how supplementation might provide lasting cognitive and other benefits without exacerbating other health risks requires further investigation.

Socioeconomic Status, the Brain, and Well-Being Over the Life-Span

Martha Farah, University of Pennsylvania

SES affects both physical and mental health and is associated with many aging-related outcomes including cognitive ability and life expectancy. It includes objective measures (e.g., occupation and income) as well as subjective perceptions such as self-identified social status, all of which can affect physical and mental health. Many such effects are mediated by the brain, which integrates genetic and environmental factors to affect an individual's overall physical and mental health. For instance, the brain not only controls the cognitive and emotional processes vital to mental health, but also orchestrates the stress responses that trigger hormones and inflammatory cascades implicated in physical diseases from heart disease to arthritis. Considering these connections, research has recently begun to investigate how SES affects the brain.

Investigators have found that childhood SES can predict cortical surface area in certain brain regions as well as the structure of the prefrontal cortex and the hippocampus, which are involved in learning, cognition, and emotional processing. Investigators have also shown that lower SES individuals tend to show higher amygdala activation in response to threatening stimuli and to be more alert to potential dangers in their environment. Conversely, their reward systems tend to be less reactive than those of higher SES individuals. Researchers speculate

[11] R. Grajeda, et al., "The Human Capital Study 2002-04: tracking, data collection, coverage and attrition," *Food Nutr. Bull.* 26(S2), S15-S24 (2005).
[12] J. Hoddinott, et al., "Effect of a nutrition intervention during early childhood on economic productivity in Guatemalan adults," *Lancet* 371(9610), 411-6 (2008).
[13] J. Maluccio, et al., "The impact of improving nutrition during early childhood on education among Guatemalan adults," *Econ. J.* 119(537), 734-763 (2009).
[14] N.D. Ford, et al., "Exposure to improved nutrition from conception to age 2 years and adult cardiometabolic disease risk: a modelling study," *Lancet* 6(8), e875-e884 (2018).

that these differences are adaptations—to adverse or even hostile environments—that reflect the brain's developmental plasticity as a function of environmental exposures. Differences across brain regions may provide ways to test hypotheses regarding SES-related causal mechanisms.

Investigators are interested in understanding how SES affects physical and mental health across the lifespan and in developing beneficial interventions. However, the possible factors involved, from neurological factors to stress exposure and parenting practices, and all their potential synergistic interactions, make understanding these processes exceedingly challenging. Some factors, which include some genetic traits, remain fixed across the life course, while others, such as culture, are not fixed but often remain relatively stable. However, some factors that link SES with physical and mental health, such as immediate and urgent needs for food or shelter, may function more as states rather than traits. Understanding how long-term, cumulative effects of SES on cognition and short-term situational reductions of cognitive bandwidth shape behaviors such as future discounting will have implications for aging. Longitudinal data can help to untangle these complexities, but investigators need better ways to use such data to test causal hypotheses, which will depend upon their ability to collaborate across disciplines and develop problem-driven (as opposed to discipline-driven) theoretical frameworks.

The Developmental Origins of Disparities in Mental Disorders

Stephen Gilman, National Institutes of Health

Longitudinal data are required to study how later-life mental health outcomes are influenced by early life. However, within longitudinal datasets, differences between historical periods and the present day can introduce confounds; context-dependence can determine whether an intervention translates across time and place. Nevertheless, proposing and testing theories using longitudinal data will strengthen efforts to develop effective interventions. Investigators have conducted several studies searching for links between developmental factors in early life and mental health disorders in adults.

During Finland's wars with the Soviet Union from 1935 to 1944, thousands of Finnish children were evacuated to Sweden to enter foster case and escape the danger. One study investigated mental health disorders among the cohort of Finnish adults who had been evacuated to Sweden as children. These adults were compared to their siblings who had remained in Finland during the same period. The former evacuees were more likely to be hospitalized for mood and anxiety disorders.[15] Investigators also followed up with the evacuees' children and their cousins and found that evacuees' children were also more likely to be hospitalized for mental health disorders, suggesting an intergenerational effect, whereby early exposure to parental separation resulted in patterns of poor mental health that were transferred across generations. Further research is needed to elucidate the pathways that link adverse exposure in parents to poor outcomes in their offspring.

[15] T. Santavirta, et al., "Long term mental health outcomes of Finnish children evacuated to Swedish families during the second world war and their non-evacuated siblings: cohort study," *BMJ* 350, g7753 (2015).

Another study conducted during the 1950s followed a cohort of children from gestation to age 7 to investigate the connections between SES and neurodevelopment and mental health. Longitudinal follow-up studies have revealed strong associations between social disadvantage and neurodevelopment. A corresponding causal pathway appears to be linked to decreased concentrations of interleukin 8 (which is involved in synaptogenesis and in the development of the fetal hypothalamic-pituitary-adrenal axis) in maternal serum at mid-gestation.[16] SES has also been linked to reduced frontal gray matter[17] and deficits in language ability, with lower SES associated with worse outcomes longitudinally.[18] More recently, investigators followed up with the same cohort of children from the 1950s (now in mid-adulthood) and found that those born into severe social disadvantage were more likely to suffer from mental health disorders including major depressive disorder[19] and attention deficit hyperactivity disorder. Researchers hypothesize that maternal stress induces inflammation and causes cascading effects that cross the placenta, affecting homeostatic systems across the life course and leading to a range of physiological effects such as shorter telomere length, blunted cortisol responses to social stress, and increased interaction between peripheral inflammation and neural circuitries involved in threat, reward, and executive control. These adverse effects may intensify during adolescence and persist into adulthood.

Early Embedding of Different Dimensions of Adversity Exposure

Margaret Sheridan, University of North Carolina at Chapel Hill

Evidence suggests that early-life adversity has lasting consequences for cognitive functioning. Cumulative risk models emphasize the role that stress and inflammation play during childhood; however, recent work focuses on brain plasticity. During early development, continuous neurogenesis and synaptic pruning allow adverse environmental influences to influence physical brain structures that persist across the life course. Investigators have developed a two-category taxonomy for childhood adversity called the Dimensional Model of Adversity and Psychopathology (DMAP), which includes two dimensions of distinct adverse environmental influences: deprivation and threat (i.e., neglect and abuse).[20]

Deprivation and threat tend to co-occur, but investigators have used existing datasets to show the independent contributions of each.[21] Imaging studies show that adolescents with abuse

[16] S.E. Gilman, M. Hornig, A. Ghassabian, J. Hahn, S. Cherkerzian, P.S. Albert, S.L. Buka, J.M. Goldstein. "Socioeconomic disadvantage, gestational immune activity, and neurodevelopment in early childhood." *PNAS*. 114(26), 6728-33 (2017). PMID: 28607066.
[17] J.L. Hanson, et al., "Family poverty affects the rate of infant brain growth," *PLoS One* 10(12), e80954 (2013).
[18] D.A. Hackman and M.J. Farah, "Socioeconomic status and the developing brain," *Trends Cogn. Sci.* 13(2), 65-73 (2009).
[19] G.C.L. Hung, et al., "Cognitive ability in childhood and the chronicity and suicidality of depression," *Br. J. Psychiatry* 208(2), 120-127 (2016).
[20] M.A. Sheridan and K.A. McLaughlin, "Dimensions of early experience and neural development: deprivation and threat," *Trends Cogn. Sci.* 18(11), 580-585 (2014).
[21] K.A. McLaughlin, et al., "Childhood adversity and neural development: deprivation and threat as distinct dimensions of early experience," *Neurosci. Biobehav. Rev.* 47, 578-91 (2014).

histories tend to interpret neutral faces as more threatening and to have heightened activation in brain regions associated with fear processing.[22] In contrast, results from magnetic resonance imaging link childhood deprivation with sparser dendritic connections and a thinner cerebral cortex.[23] These two brain features are also associated with low SES, but this link is mediated by language complexity in the family home. SES and neglect together also predict executive function and associated neural function, which is consistent with the idea that harsher exposure produces more severe effects (a core DMAP concept). Cluster analyses performed on existing data have tested some DMAP predictions, but results are not entirely consistent, suggesting the need for further work.

The DMAP framework has also been applied in non-WEIRD settings such as Liberia, Peru, Jordan, Syria, and Ghana. Long-term memory (LTM) tasks were developed to test cognitive function across time. After linkage to other data such as lifetime trauma, food consumption, and maternal education, researchers found that maternal education in the Liberian cohort and that perceived insecurity levels in the Jordan cohort predicted LTM performance. Moreover, social interventions designed to relieve stress through peer bonding and mutual support, administered to 12- to 18-year-old Syrian Refugees in Jordan, did not impact cognitive functioning, which is consistent with the notion that these differences originate in early-life development.

Discussion

Moderator: Michael Gurven, University of California, Santa Barbara

Several interpretive challenges arise when searching for predictive factors that connect early-life experience with later-life outcomes. For example, the SES concept, which is widely used in population studies, includes both objective measures such as income and occupation, and subjective self-assessments. Differentiating the SES concept can provide new opportunities for investigation that could challenge and deepen existing theoretical frameworks.

Likewise, investigators have found that schooling level in early life is often strongly associated with many later-life outcomes, including cognitive and physical functioning measures. However, researchers must ask whether schooling predicts these outcomes, or whether schooling and later-life outcomes are both influenced by an intervening variable.

Another marker that raises interpretive challenges is birthweight. Birthweight has been associated with many later-life outcomes, but identical twin measurements have indicated that the gestational environment (e.g., differences between rates of nutritional absorption through the placenta for identical twin fetuses) has a marked influence. Thus, birthweight may be a derivative measure, and environmental exposures during gestation, such as inflammation resulting in immune dysregulation, may explain some outcomes that are often assumed to be

[22] K.A. McLaughlin, et al., "Child maltreatment and neural systems underlying emotion regulation," *J. Am. Acad. Child Adolesc. Psychiatry* 54(9), 753-62 (2015).
[23] K.A. McLaughlin, et al., "Neglect as a violation of species-expectant experience: neurodevelopmental consequences," *Biol. Psychiatry* 82(7), 462-471 (2017).

more directly connected to birthweight. Investigators are currently exploring serial biomarker measurements across the course of gestation to identify more specific causal pathways that link the gestational environment to various later-life outcomes.

The tendency to view WEIRD societies as standard or typical is a concern. WEIRD societies are atypical from both a geographical and a temporal standpoint. Most human social environments throughout history were unlike modern WEIRD societies, just as most societies today are non-WEIRD. However, investigators who regard WEIRD societies as "normal" might tend to view non-WEIRD societies as suffering from deficiencies, whereas the obverse interpretation—that WEIRD societies are unusually enriched, for example in terms of average life span and access to food, shelter, and formal education—may be more accurate.

Roundtable Discussion: Approaches for Learning from non-WEIRD and Other Under-Investigated Populations

Moderator: Michael Gurven, University of California, Santa Barbara

Investigators must take a problem-driven approach to their research. However, most problems contain multiple levels, and multiple methods exist for investigating them. Some studies aim to test a specific hypothesis. Other studies analyze existing data or adopt an exploratory approach to gathering new data. Asking investigators in the field to reflect on what they think they know about aging and then designing methods to test those theories might be a promising approach. Under-studied populations provide a valuable opportunity to conduct such tests. Refuting conventional wisdom could expand the field in new and exciting ways.

Focusing on comparisons between WEIRD and non-WEIRD societies in research on aging can be useful, but analysis must move beyond a simplistic dichotomy. It is important to remember that there is diversity within every culture and similarities across cultures. For example, cell phones are now common in non-WEIRD contexts, which creates substantial cultural overlap. Whereas within WEIRD populations, SES is associated with differences often observed across cultures, such as the tendency to be independent versus interdependent.

Breakout Group Summaries

Participants were divided into smaller groups to design a prospective study that addresses a key knowledge gap discussed during the meeting.

Group 1: Farah, Gutchess, Snodgrass, Worthman

This group discussed strategies for investigating the role that social relationships play in the aging process across cultures. Cultures have different norms and traditions that establish social relationship patterns. However, within these cultural constraints individuals actively form their own social ties. Social institutions such as marriage could provide a focal point for investigators to study the role that social customs and relationships play within and across cultural contexts.

However, maintaining a cross-cultural level of analysis may conceal differences *within* a culture. For example, although marriage customs may differ among castes in one society, such differences may be obscured if the whole caste society is compared with marriage customs in a

WEIRD society. Existing research has linked social relationships to health, for example, by showing that co-sleeping promotes physical health by tending to regulate sleep patterns. This suggests the potential value in cross-cultural research that focuses on connections between social relationships and various physical and cognitive health factors.

Group 2: Gilman, Hawkes, Nisbett

This group focused on ways to measure SES differences across time and place. SES as a construct can refer to objective structural factors such as social safety nets, or subjective measures such as one's self-perceived social position. Developing reliable measurement methods that capture objective and subjective SES-related indicators could help to differentiate the concept and test proposed mechanisms that may underly aging disparities. Investigators should also consider whether seemingly negative characteristics, for instance those associated with low-SES environments, may be reactive adaptations to adverse conditions that confer an advantage within those contexts.

Group 3: Behrman, Gurven, Kohler, Sheridan, Yoon

This group proposed a study design to investigate early precursors to cognitive aging and dementia in four non-WEIRD populations for which longitudinal data covering at least two decades already exists: Bolivia, Chile, Guatemala, and Malawi. The study would adapt available instruments to collect data on cognition, social connectiveness, and subjective well-being in mature adulthood. Researchers would use existing longitudinal datasets from these countries to investigate possible predictors such as schooling attainment, prior health, work history, and marital/fertility history. Specific aims would include investigating how intergenerational transfers and gender differences operate across these four societies. An overall aim would be to compare the measures with those from high-income countries.

Discussion

The breakout session structure provided a valuable opportunity to think practically about how to extend aging research to new contexts and to collaborate across specializations. Assembling investigators with different expertise helped the participants see opportunities for collaboration on problems they would not have thought to approach directly on their own.

However, the WEIRD versus non-WEIRD conceptual framework obscures many details that are crucial for thinking about potential study designs. For example, it conceals important differences between hunter-gatherer societies and village-dwelling communities and ignores diverse conditions that are found within WEIRD societies. Future research should seek to address contextual differences at each of these levels.

Synthesis

Stephen Gilman, Eunice Kennedy Shriver *National Institute of Child Health and Human Development*

Aging research in the past has focused on populations in WEIRD settings. However, WEIRD populations do not capture risk factor distributions for developmental potential and aging on a

global scale. Thus, the search for invariant and modifiable risk factors, with the aim to develop interventions to improve outcomes, entails studying non-WEIRD populations.

However, this approach raises several measurement problems. Regarding the level of granularity, at one extreme, every individual has unique developmental and aging risk factors, while, at the other extreme, any particular measure will have a single worldwide average value. To effectively test hypotheses across the wide distance between these extremes, investigators must begin with explicit theoretical hypotheses that can (1) inform sampling strategies and (2) help to operationalize constructs such as "population," such that measurements can be meaningfully interpreted and compared across diverse contexts. They must also develop the measurements themselves (which includes measurement theories and technologies) that can reliably capture relevant risk factors across populations for comparison.

The overarching goal of investigators studying aging trajectories, both globally and within specific contexts, is to uncover patterns and to test explanatory hypotheses that seek to account for developmental and aging risk factors within and across populations that contain extreme heterogeneity. The search for invariant and modifiable risk factors and processes in aging is challenged by research indicating that cultural influences can underly physiological outcomes. For example, one study found that, although the shape of the statistical distributions for systolic blood pressure among Kenyan nomads and among civil servants in London are very similar, the entire distributions *themselves* are shifted with respect to each other.[24]

When research is narrowly constrained to certain types of culture or context (e.g., to WEIRD populations), it may seem natural to misinterpret parochial features of a specific cultural context as universal, invariant characteristics of human aging. Future research must (1) rely on improved measures of population heterogeneity, (2) employ constructs of health and well-bring that are validated across populations, and (3) broaden the scope of contexts explored, such that invariant risk factors, as they exist, can be separated from contextual risk factors. If this goal is achieved, it could facilitate the development of effective interventions that, where necessary, are context-specific.

Concluding Remarks on General Themes

Angela Gutchess, Brandeis University
Margaret Sheridan, University of North Carolina at Chapel Hill

Meeting presentations and discussion made clear that concepts such as aging and high-mortality can have different meanings in non-WEIRD populations, and that the relationship between health and aging can vary between and within societies in unexpected ways. For example, while a WEIRD culture may think of aging as the simple progression of years of life, a high-mortality population with short average lifespans may think of aging in terms of social status or responsibility. In addition, investigators who study elderly individuals, particularly those in high-mortality populations, must account for the fact that elderly samples are nonrepresentative. That is, individuals who survive into old age in high-mortality environments

[24] G. Rose, "Sick individuals and sick populations," *Int. J. Epidemiol.* 30(3), 427-432 (2001).

are likely to be unusually resilient, perhaps both physically and psychologically. Thus, in WEIRD and non-WEIRD populations alike, investigators must consciously adopt a life course perspective.

One such approach, which was highlighted by many presenters, uses the LHT, which addresses topics such as risk accumulation and parental life experience, and how those factors interact with childhood development. By widening the study of aging to encompass all stages of life, new possibilities for explanatory pathways linking early life factors (e.g., nutrition) with later life outcomes (e.g., cognitive ability) become feasible. Moreover, this wider perspective allows differences between WEIRD and non-WEIRD contexts to be probed in novel ways that account for cultural and contextual differences at all life stages.

In addition, participants emphasized the need for aging research to be driven by specific problems of explanation, and therefore also to be guided by attempts to test specific hypotheses by seeking refutations of theoretical predictions. This point provoked discussion regarding challenges to achieving conceptual clarity in theories, particularly those that cross-disciplinary boundaries. Several participants stressed the importance of developing and validating constructs within specified theoretical frameworks. This emphasis reflects the need to ensure that constructs are valid and meaningful in the context in which they are deployed, which contrasts with the futile effort to establish a single “universal” or “essential” definition of a concept that is expected to hold in every situation.

The overall aim that is shared by all meeting participants is to identify the causal pathways through which different social and environmental exposures interact with behavior and biology to shape development, and, ultimately, psychological function and behavior in aging. This aim requires investigators to think mechanistically and to develop ways to test hypotheses that make predictions across WEIRD and non-WEIRD settings, leading to better understanding of environmental and genetic factors that underlie variant aging patterns. Although the WEIRD/non-WEIRD dichotomy is a useful shorthand, each context is specific, and investigators should resist the temptation to place too much emphasis on these simplistic categories.

Appendix A: Agenda

Day 1: July 2, 2018

8:30 a.m. **Sign-in and Badge Pick-up**

9:00 ***Welcome to the National Academies***
Barbara Wanchisen, Director, BBCSS

9:05 ***Introductory Remarks from the National Institute on Aging***
Lis Nielsen, Division of Behavioral and Social Research
Melissa Gerald, Division of Behavioral and Social Research

9:15 ***Setting the Stage for the Meeting***
Martha Farah, University of Pennsylvania
Michael Gurven, University of California, Santa Barbara

9:30 ***Session I: Evolutionary Perspectives***
From an evolutionary perspective, differences between human populations are largely thought to represent adaptations in response to different conditions in the environment. Although behavioral plasticity is thought to be one of the hallmarks of human populations, it is widely debated to what extent genetic, environmental, and cultural factors independently and jointly contribute to population-based differences in psychological and social processes, and variability in aging experiences and outcomes. Examining a broad set of measures across a broad range of environmental conditions at different time points might shed light on the full extent to which behavior at older ages is flexible and modifiable and under what conditions. Participants in this session will consider the following questions:

- To what extent and how might research with rarely-investigated populations lead to a better understanding of age-related behavioral and social processes in ways which might inform the conceptualization of "healthy aging?"
- How can research with rarely-investigated populations help to define reasonable expectations in achievement and functional performance measures or set for boundaries of limitations in intervention outcomes for older adults?

Michael Gurven, University of California, Santa Barbara
Kristen Hawkes, University of Utah
Carol Worthman, Emory University

10:15 **BREAK**

10:30 ***Session I, continued***
Open discussion between presenters and other invited participants
Moderator: Martha Farah, University of Pennsylvania

11:30 ***Session II: Cultural Differences in Psychological Functioning***
This session will focus on the respective roles of the social and physical environment on cognitive and socioemotional functioning and decision making and their links to health. Participants in this session will consider the following questions:

- How does the social environment, including cultural norms, impact age-related changes in psychological function in midlife and older age?
- How do different social norms and physical environmental constraints impact the association between social connectedness and health?
- What general assumptions should be avoided in such studies?

Angela Gutchess, Brandeis University
Hans-Peter Kohler, University of Pennsylvania
Richard Nisbett, University of Michigan
Jeffrey Snodgrass, Colorado State University
Carolyn Yoon, University of Michigan

1:00 p.m. **BREAK TO PURCHASE LUNCH (Available for sale in 3rd floor refectory)**

1:45 ***Session II, continued***
Open discussion between presenters and other invited participants
Moderator: Michael Gurven, University of California, Santa Barbara

2:45 p.m. ***Session III: The Impact of Socioeconomic Status and Resource Scarcity on Psychological Functioning - Life-Span Developmental Perspectives***
There is a growing interest in research on populations faced with resource constraints, such as those living in poverty, and in understanding the effects of exposure on cognitive and socioemotional functioning and decision making and their links to health. That the role of lifelong poverty in cognitive processes and behaviors might compromise cognitive or social function is an open question. Questions to be addressed in this session include:

- How do socioeconomic status and resource scarcity and uncertainty impact social cognition, social behavior, decision making and cognitive aging?
- How do social norms and practices alter aspects of decision-making across the life-span?

Jere Behrman, University of Pennsylvania
Martha Farah, University of Pennsylvania
Stephen Gilman, National Institutes of Health
Margaret Sheridan, University of North Carolina at Chapel Hill

3:45 **BREAK**

4:00 ***Session III, continued***
Open discussion between presenters and other invited participants
Moderator: Michael Gurven, University of California, Santa Barbara

5:00 ***Summary of Day One***
TBD

5:15 **Adjourn Day One**

Day 2: July 3, 2018

8:30 a.m. ***Overview of Day Two***
Martha Farah, University of Pennsylvania
Michael Gurven, University of California, Santa Barbara

8:40 ***Reflections on Day One***

9:10 ***Roundtable Discussion: Approaches for Learning from non-WEIRD and Other Under-Investigated Populations***

Beyond a strictly life-span developmental approach, how can cultural, psychological, evolutionary, sociological, and anthropological perspectives help refine questions for future research? How can we leverage studies of non-WEIRD populations to (1) identify the causal pathways through which different environmental exposures interact with behavior and biology to shape psychological and social processes, and – ultimately – health outcomes, and (2) leverage this knowledge to enhance our understanding of successful aging and identify population-appropriate modifiable targets for intervention. What are the ideal populations for such studies? What are proposed solutions for overcoming methodological challenges that hinder scientific advances?

Moderator: Michael Gurven, University of California Santa Barbara

10:00 ***Setting the Stage for Breakout Session***

Martha Farah, University of Pennsylvania
Michael Gurven, University of California, Santa Barbara

10:15 **BREAK and move to Breakout Session**

10:30 ***Breakout Session: Prospective Study Design***

Participants will be divided into smaller groups to design a prospective study that addresses a key knowledge gap discussed during the meeting.

11:30 ***Report-out from Breakout Groups***

12:30 p.m. **BREAK TO PURCHASE LUNCH (Available for sale in 3rd floor refectory)**

1:15 ***Insights and Future Directions***

Participants will be asked in turn to offer their reflections on the meeting, identifying one new insight gained as a result of the discussions and/or a recommendation for future research.
Moderator: Martha Farah, University of Pennsylvania

2:15 ***Synthesis and Next Steps***

TBD

2:30 ***Closing Remarks from the National Institute on Aging***

Lis Nielsen
Melissa Gerald
Amelia Karraker
Dana Plude

2:45 ***Adjourn***

Appendix B: Participants List

National Institute on Aging
Melissa Gerald, Division of Behavioral and Social Research
Amelia Karraker, Division of Behavioral and Social Research
Lisbeth Nielsen, Division of Behavioral and Social Research
Dana Plude, Division of Behavioral and Social Research

National Academies of Sciences, Engineering, and Medicine
Adrienne Stith Butler, Board on Behavioral, Cognitive, and Sensory Sciences
Garrett Tyson, Board on Behavioral, Cognitive, and Sensory Sciences
Barbara Wanchisen, Board on Behavioral, Cognitive, and Sensory Sciences
Tina Waters, Board on Behavioral, Cognitive, and Sensory Sciences

Invited Experts
Jere Behrman, University of Pennsylvania
Martha Farah, University of Pennsylvania
Stephen Gilman, *Eunice Kennedy Shriver* National Institute of Child Health and Human Development
Michael Gurven, University of California, Santa Barbara
Angela Gutchess, Brandeis University
Kristen Hawkes, University of Utah
Hans-Peter Kohler, University of Pennsylvania
Richard Nisbett, University of Michigan
Margaret Sheridan, UNC Chapel Hill
Jeffrey Snodgrass, Colorado State University
Carol Worthman, Emory University
Carolyn Yoon, University of Michigan