

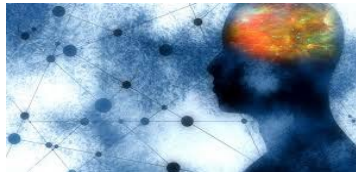


Members of the ILHBN that attended the 2022 Annual Conference held at the University of Southern California.

2022 Intensive Longitudinal Health Behavior Network Annual Conference, University of Southern California

Background: The Intensive Longitudinal Health Behavior Network (ILHBN), supported under RFA-OD-17-004 and RFA-OD-17-005, was established in October 2018 as part of the National Institutes of Health’s Longitudinal Health Behaviors initiative to encourage research projects that explain underlying mechanisms and predict health behaviors within individuals over time utilizing intensive longitudinal, within-person protocols that leverage recent advances in mobile and wireless sensor technologies and big data analytics.

The ILHBN research sites study such diverse health behavior changes as prevention of suicidal thoughts and behaviors, smoking, drug use, alcohol use, and sedentary behavior, and the promotion of mental health, sleep, and physical activities. The establishment of the ILHBN enables consolidation and building of a network of resources to enhance current and future theorizing, measurement, analysis, and implementation of sustainable health behavioral change mechanisms.



Mission and Goals: The overarching mission of the ILHBN is to develop an infrastructure to pursue well-designed collaborative projects and complementary site-specific studies that, collectively, accomplish the goals of:

1. Introducing innovations into longstanding health behavioral theories;
2. Advancing the field of theory-driven behavior change interventions; and

3. Providing a framework to guide future intensive longitudinal studies of health behaviors.

The Network members have been successful in developing numerous resources including tools and publications that further advance the field. Many of the tools can be found

<https://ilhbn.ssri.psu.edu/resources/tools>. An array of

publications can be found

<https://ilhbn.ssri.psu.edu/resources/publications>.

Reflecting on the ILHBN Annual Meetings: The ILHBN Network has met annually since its inception in 2018. The kickoff meeting was held in Bethesda, MD in the October 2018. The second meeting was held in Boston, MA at Harvard University in October 2019. The third and fourth meetings were held virtually because of COVID-19. The fifth and final meeting was held in October 2022, both in-person and virtually, at USC in Los Angeles.

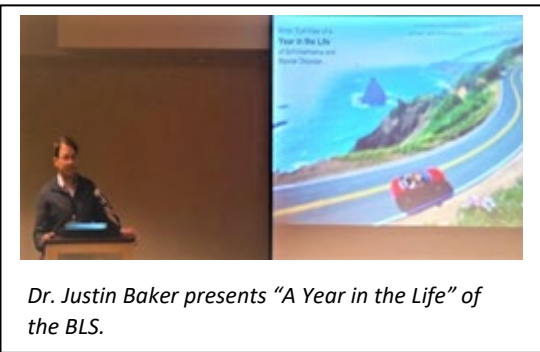
Welcome and Opening Remarks: Dr. Donna Spruijt-Metz of USC and this year’s ILHBN Chair, welcomed the group, both in-person and virtually. Attendees participated from various Universities across the country.



Dr. Donna Spruijt-Metz welcomes the ILHBN Network members to the 2022 Annual Meeting.

Bipolar Longitudinal Study (BLS) The Robust Predictors of Mania and Psychosis (RPMP) study led by Drs. Justin Baker and Scott Rauch at the McLean Hospital serves to identify early biological, environmental, and social factors that trigger mania and psychosis in individuals known to be at risk for these mental health conditions using smartphone, wearable, GPS, and audio-video data. Use of such passive and active markers helps lay the groundwork for tailored intervention strategies that account for the multifaceted nature and etiologies of psychosis and bipolar disorders so as to maximize intervention efficacy at the individual level.

Dr. Justin Baker, Harvard University, discussed progress



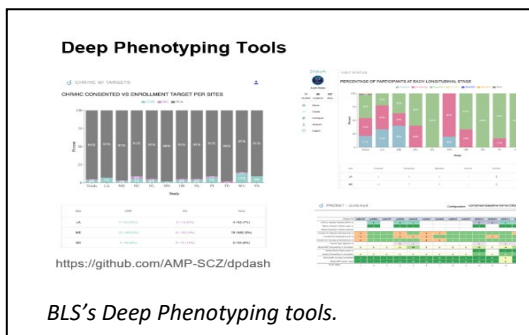
Dr. Justin Baker presents "A Year in the Life" of the BLS.

made during the previous year. Topics included the notion of using

Latent Construct Models to "sense" mental health conditions and behaviors, modeling continuous "energy", robust predictors of mania and psychosis, continuous assessment of sleep/wake activity with raw triaxial accelerometry, and deep phenotyping tools.

Publications written by the BLS team include "Case Report of

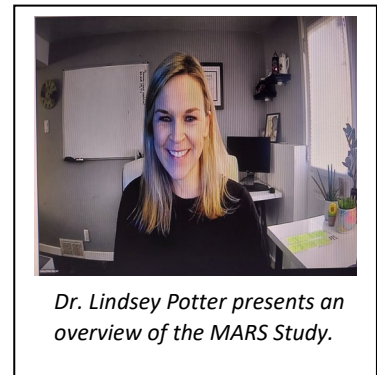
Dual-Site Neuro-stimulation and Chronic Recording of Cortico-Striatal Circuitry in a Patient with Treatment Refractory"¹ and "Determining sample size and length of follow-up for smartphone-based digital phenotyping studies"².



Mobile Assistance for Regulating Smoking (MARS)

The novel use of mHealth Data to Identify States of Vulnerability and Receptivity to Just-in-Time Adaptive Interventions (JITAIS) – denoted herein as the Mobile Application for Regulating Smoking or MARS study -- is led by Drs. Inbal Nahum-Shani and David Wetter at the University of Michigan at Ann Arbor and University of Utah. The project seeks to advance the field of theory-driven behavior change interventions by investigating the dynamic role of emotions, self-regulation, and context in detecting vulnerability to lapse, and receptivity to self-regulatory activities in adult smokers (19 years or older) attempting to quit, as well as ascertaining the utility of these states in triggering real-time self-regulatory recommendations. ILD are critical for identifying states of vulnerability and receptivity as close as possible to real time and in real world settings.

Dr. Lindsey Potter of Utah University discusses the MARS study where she identifies the problem and solution for smoking, review the aims, study and app design, challenges, and solutions. She also



Dr. Lindsey Potter presents an overview of the MARS Study.

provided a review of Grafana, the tool they use to monitor compliance and software integrity. Jamie Yap



Jamie Yap discusses publications drawn from the MARS Study.

of the University of Michigan discusses laying the groundwork for investigating the U01's aims, the findings, and publications they've developed. Some publications include "The use of ambulatory assessment in smoking

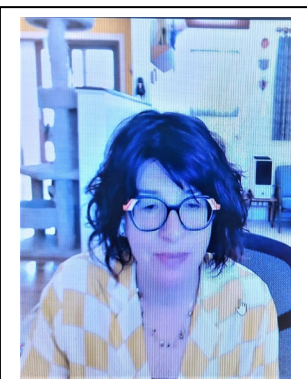
¹ Olsen, Sarah T; Basu, Ishita; Bilge, Mustafa Taha; et al. <https://www.ncbi.nlm.nih.gov/pubmed?otool=nihlib&term=33192400>

² Barnett, Ian; Torous, John; Reeder, Harrison T; Baker, Justin; Onnela, Jukka-Pekka <https://www.ncbi.nlm.nih.gov/pubmed?otool=nihlib&term=33043370>

cessation”³ and “Developments in Mobile Health Just-in-Time Adaptive Interventions for Addiction Science.”⁴

Colorado Online Twins Study (CoTwins)

Substance use behaviors are difficult to test in traditional longitudinal studies with infrequent (e.g., annual) assessments, particularly during vulnerable or critical transitional periods, such as around the transition from adolescence to adulthood, and following participation in intervention studies. CoTwins: A Twin Study of Adolescent Alcohol and Drug Use Development Leveraging Intensive Longitudinal Assessments – denoted herein as the CoTwins Study – led by Drs. Naomi Friedman and Scott Vrieze at the Universities of Colorado and Minnesota, respectively, uses smartphone sensors and weekly surveys to assess substance use, executive function, disinhibition, risk-taking, and social context on a quasi-continuous basis multiple years during the transition from adolescence to young adulthood (with participants ages from 14 to 21 years old). Intensive longitudinal measures derived from the smartphone's GPS, camera, and microphone, combined with all the quasi-experimental strengths of an adolescent twin study design, provide rigorous tests of whether and how environmental and social context disrupts normative developmental trends.



Dr. Naomi Friedman discusses the CoTwins study.

Dr. Naomi Friedman of Colorado University reviewed AIMs, the app that they have developed to ensure compliance, reviewed lab appointments and survey dates per person as well as in-lab and online and phone assessments. She discussed some of the publications their group has been focusing on, including “Association studies of up

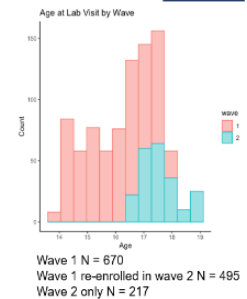
³ Vinci, Christine; Haslam, Aaron; Lam, Cho Y; Kumar, Santosh; Wetter, David W; <https://www.ncbi.nlm.nih.gov/pubmed?otool=nihlib&term=29398067>

⁴ Carpenter, Stephanie M; Menictas, Marianne; Nahum-Shani, Inbal; Wetter, David W; Murphy, Susan A <https://www.ncbi.nlm.nih.gov/pubmed?otool=nihlib&term=33747711>

CoTwins: Colorado Online Twin Study



- 887 adolescent twins
 - 167 MZ & 277 DZ (88 OS) pairs
- Aged 13.98-19.05 at lab visit
 - M age 16.41, SD = 1.22
- Lab visits ran from 2015-2022
- 53.8% female
- Main areas of research:
 - Traditional health and psychological assessments
 - Real-world environment
 - Repeated assessments



Findings from the CoTwins Study.

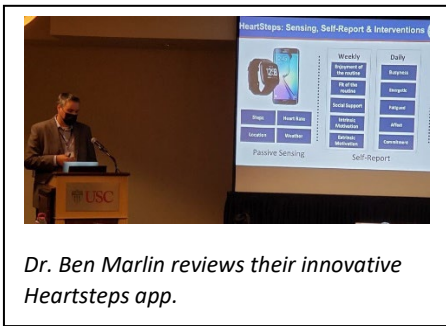
to 1.2 million individuals yield new insights into the genetic etiology of tobacco and alcohol use”⁵ and “A prospective study of alcohol involvement and the dual-systems model of adolescent risk-taking during late adolescence and emerging”⁶ as well as other current projects. Dr. Friedman closed by identifying some of challenges they have encountered since the project’s inception.

Dynamic Models of Behavior (DMB) The Operationalizing Behavioral Theory for mHealth: Dynamics, Context and Personalization (denoted herein as the Model of Behavior - MOB) Study led jointly by Drs. Donna Spruijt-Metz, Benjamin Marlin, and Pedja Klasnja at the University of Southern California, University of Massachusetts, Amherst, and University of Michigan, respectively, is a micro randomized trial (MRT). An MRT is an experimental study design aimed at optimizing just-in-time adaptive interventions. The study seeks to produce convenient, economical, scalable, and effective JITAI solutions to sustain healthy physical activity and limit sedentary time for adults aged above 18 years old. Through the use of a computational modeling framework that integrates dynamic behavior theories and continuous sensing of individuals' activities and context, the project designs and evaluate ways to adapt to individuals’ ongoing dynamical changes to

⁵ Liu, Mengzhen; Jiang, Yu; Wedow, Robbee; et al., <https://www.ncbi.nlm.nih.gov/pubmed?otool=nihlib&term=30643251>

⁶ Ellingson, Jarrod M; Corley, Robin; Hewitt, John K; Friedman, Naomi P; <https://www.ncbi.nlm.nih.gov/pubmed?otool=nihlib&term=30398695>

intervene “just-in-time.” To optimize a mobile intervention that is meant to be woven into the participant’s daily lives in order to continue to be helpful in developing and maintaining healthy physical activity habits, a myriad of considerations must be taken into account that fluctuate between as well as within participants over time. These include environmental considerations such as weather, but also time of day, mood, social environment. To examine these juxtapositions as they fluctuate in real time, ILDM are essential.



Dr. Ben Marlin reviews their innovative Heartsteps app.

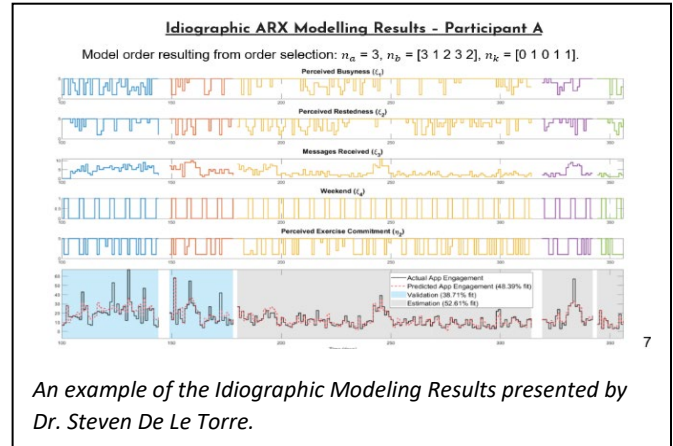
Dr. Ben Marlin, University of Massachusetts Amherst, discusses the Heartsteps app their site developed, and how it identifies

passive sensing, self-reporting data, and interventions. He further reports incomplete data and additional methodology goals they’ve identified. Dr. Marlin also introduces the BayesLDM Toolbox and its functionalities.

Dr. Steven De Le Torre, University of Southern California, further discusses intensive longitudinal data collection and dynamic modeling inspired by the fluid analogy approach and evaluated as variations of the autoregressive model with exogenous input (ARX). “Black Box” modeling and assessing model fits. He continues his discussion by asking the audience if missing data is an obstacle, or an opportunity. He closes his session by talking through the Bayesian approach to handling missing data and provides an example of step responses. Publications



Dr. Steven De Le Torre reviews and example of Idiographic Modeling Results.



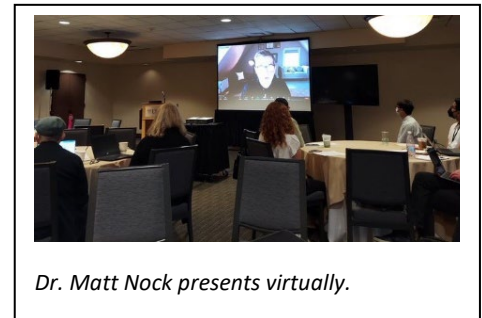
An example of the Idiographic Modeling Results presented by Dr. Steven De Le Torre.

include “Advancing Behavioral Intervention and Theory Development for Mobile Health: The Heart Steps II Protocol”⁷ and “BayesLDM: A Domain-Specific Language for Probabilistic Modeling of Longitudinal Data”⁸.

Sensing and Mobile Assessment in Real Time (SMART)

the Intensive Longitudinal Study of Suicidal Behaviors and Related Health Outcomes (SBRHO), led by Dr. Matthew Nock at Harvard University, capitalizes on recent advancements in mobile technologies to integrate passive (e.g., GPS, accelerometer, physiological measures) and active (e.g., self-reports) markers of risk along with advanced computational modeling (e.g., machine learning) approaches to identify which people with suicidal thoughts are at greatest risk for suicidal behavior, or when and why they are at elevated risk.

Dr. Matt Nock, Harvard University, opens by relaying to the audience the background and rationale for the SMART



Dr. Matt Nock presents virtually.

study. He continues by identifying some of the foundational methodology work done. Dr. Nock talks through their study design, recruitment strategies, and outcome measures. Finally, he tells the audience about the study progress to date that includes numerous

⁷ Donna Spruijt-Metz, Benjamin M. Marlin, Misha Pavel, Daniel E. Rivera, Eric Hekler, Steven De La Torre; et al.; <https://doi.org/10.3390/ijerph19042267>

⁸ Karine Tung, Steven De La Torre, Mohamed El Mistiri, et. al. <https://dblp.uni-trier.de/db/journals/corr/corr2209.html#abs-2209-05581>

Background and rationale for our study

- We can identify meaningful subgroups from EMA data.



Nickman et al. (2015) Depression and Anxiety

Background for the SMART study, discussed by Dr. Matt Nock.

papers published or in progress including “Negative affect is more strongly associated with suicidal thinking among suicidal patients with borderline personality disorder than those without”⁹

and “Advancing the Understanding of Suicide: The Need for Formal Theory and Rigorous Descriptive Research”¹⁰.

Mobile Assessment for the Prediction of Suicide

(MAPS) the Mobile Assessment for the Prediction of Suicide (MAPS) study led by Drs. Nicholas Allen and Randy Auerbach at the University of Oregon and Columbia University, respectively, also leverages mobile technologies, specifically, adolescents' naturalistic use of smartphone technology and phone usage data (e.g., text messages, music choices, ambient light, screen-on time, video and audio diaries) to identify promising

short-term predictors of suicide among high-risk adolescents, thereby improving the understanding, prediction, and prevention of suicidal behaviors – the second leading cause of death among adolescents – and associated health outcomes.



Dr. Nick Allen reviews an epidemiological perspective on suicidal behaviors.

⁹ Mou, David; Kleiman, Evan M; Fedor, Szymon; Beck, Stuart; Huffman, Jeff C; Nock, Matthew K; <https://www.ncbi.nlm.nih.gov/pubmed?otool=nihlib&term=30103067>

¹⁰ Millner, Alexander J; Robinaugh, Donald J; Nock, Matthew K; <https://www.ncbi.nlm.nih.gov/pubmed?otool=nihlib&term=32680678>

Digital Phenotyping

- Transition from thinking to acting may occur in minutes to hours (Millner et al., 2016).
- Capturing dynamic affective change requires intensive longitudinal assessment (Allen et al., 2019)
- Recent advances in smartphone technology allow:
 - Active assessment (e.g., EMA)
 - Mobile sensor monitoring (e.g., accelerometry, geolocation)



Dr. Nick Allen reviews details of SMART Digital Phenotyping.

Dr. Nick Allen, Oregon University, opens with an epidemiological perspective on suicidal behaviors, digital phenotyping, as well as an overview of the MAPS study design. Dr. Allen continues with an in-depth review of recruitment and retention and provides a snapshot of the data they've been collecting. He discusses some of the findings on suicidal phenomenon they've identified in a recent publication. Publications include “Short-term prediction of suicidal thoughts and behaviors in adolescents: Can recent developments in technology and computational science provide a breakthrough?”¹¹ and “The Elusive Phenotype of Preadolescent Suicidal Thoughts and Behaviors: Can Neuroimaging Deliver on Its Promise?”¹² Finally, he reviews data related to adolescent smartphone social communication and app usage, as well as home-stay data identified through GPS collection.

Temporal Influences of Movement and Exercise (TIME)

Weight gain increases dramatically in early adulthood, increasing risk of cancer and chronic disease later in life. The Temporal Influences of Movement and Exercise (TIME) Study led jointly by Drs. Genevieve Dunton and Stephen Intille at the University of Southern California and Northeastern University, respectively, uses mobile technologies to collect ILD from young adults (18 to 24 years old) to elucidate the micro-temporal mechanisms underlying the adoption and maintenance of physical activity, limited sedentary time, and sufficient sleep

¹¹ Allen, Nicholas B; Nelson, Benjamin W; Brent, David; Auerbach, Randy P; <https://www.ncbi.nlm.nih.gov/pubmed?otool=nihlib&term=30856493>

¹² Auerbach, Randy P; Chase, Henry W; Brent, David A; <https://www.ncbi.nlm.nih.gov/pubmed?otool=nihlib&term=33789457>

duration in emerging adults. Results emerging from this study can help build more predictive health behavior theories and inform personalized behavior interventions to reduce obesity and improve public health.



Dr. Genevieve Dunton introduces the TIME study.

Dr. Dunton provides an overview, progress, and accomplishments of the study. Dr. Dunton further provided an overview of the papers their site has published that include “Early effects of the COVID-19 pandemic on physical activity and sedentary behavior in children living in the U.S.”¹³ and “Ambulatory Assessment for Physical Activity Research: State of the Science, Best Practices and Future Directions”¹⁴.



Dr. Stephen Intille provides examples of their findings.

Dr. Stephen Intille, Northeastern University, discusses the challenges related to missing data and provides

several examples. He briefly provides an overview of a cases study where their team identified a shift in the data collected.

EMA Workgroup Shirlene Wang, PhD Candidate, University of Southern California, began by reviewing the Project Aims and used the TIME study to provide an example of demographics. Shirlene and Dr. Genevieve Dunton, University of Southern California, prompted the network projects to pool data to collectively address questions such as “Is there a minimum amount of data we need?” and “are there predictive factors that we should prioritize in studying individuals’ affect?”.

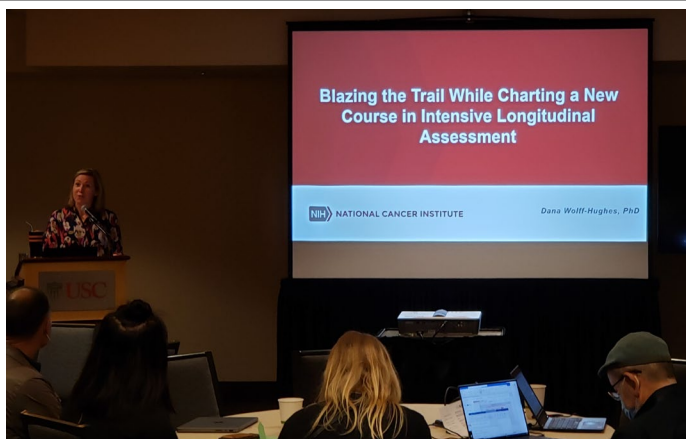
GPS Workgroup Jordan Alexander, Colorado State University, presented on Affect and Mobility during the COVID-19 Pandemic. He provided sample demographics, affect & mobility sample characteristics, discussed the data they’ve collected thus far, and finally talked through the conclusions they have made. Drs. Scott Vrieze and Sy-Miin Chow led the group in a question/answer/comment session related to GPS data. Yosef Bodovski, The Pennsylvania State University, presented COVID-19 measures and data sources, including HealthData.gov, CDC, and CoronaNet.

Missing Data Workgroup Drs. Sy-Miin Chow, Linying Ji, and Young Won Cho, Pennsylvania State University, led discussions on cross-project collaborations on cross-study project collaborations on missing data handling approaches. Dr. Ji solicits input from the audience on common missing data challenges encountered in the ILHBN studies. Young Won Cho presents ideas on how to leverage study/data examples to formulate a framework to help facilitate modeling of missing data for practitioners.

Engagement Workgroup Dr. Billie Nahum-Shani, University of Michigan, presents the goals, definition, and how to use novel data analytic methods to identify and characterize barriers and facilitators to engagement in intensive longitudinal studies. Dr. Donna Spruijt-Metz, University of Southern California shares her thoughts and coordinates discussions on ways to study

changes in engagement in studies implementing just-in-time interventions.

Keynote: Blazing the Trail While Charting a New Course in Intensive Longitudinal Assessment

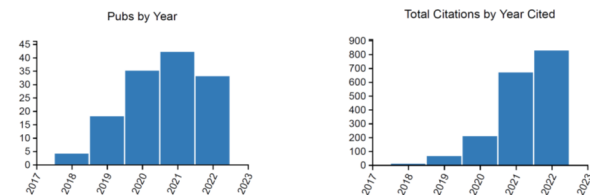


Dr. Dana Wolff-Hughes, the Keynote speaker, identifies the accomplishments from the ILHBN project.

Dr. Dana Wolff-Hughes, National Institute of Health, provided an inciteful keynote where she provided an historical perspective, identified what the Network has accomplished thus far as well as what is still needed moving forward. Dr. Wolff-Hughes noted that there have been:

- Over 1,700 citations drawn from the ILHBN publications.
- All of the ILHBN publications on PubMed to date have Relative Citation Ratio (RCR) values

Impact of the ILHBN



Dr. Dana Wolff-Hughes provides an overview of the impact of the ILHBN.

well above 3.0.¹⁵ These include work on Engagement, developing and tailoring approaches for new and existing digital biomarkers, harmonization standards, and more.

Future Directions

Developing New Tools

- Home-based technologies
- Accurate real-time & JITAs
- Software for data integration and interoperability

Digital Biomarkers

- SDoH
- Symptoms & Risk Factors
 - Fatigue
 - Stress

Training & Resources

- Evaluating technology
- Conducting ILD studies
- Methods (e.g., micro-EMA)
- Regulatory and Policy Issues

Workforce Development

- Building collaborations
- Lifecourse approach

Recruitment and Retention

- Remote and hybrid designs
- Micro-EMA
- Conversational agents and chatbots
- Define & assess engagement

Equity in Digital Health

- Ensuring access to technology
- The role of digital navigators
- Addressing ELSI-related issues

Novel data sources

- HER and claims data
- IoT data

Modeling & Methods

- Digital Phenotypes
- Heterogeneity of Risk Factors
- Digital Twins
- Quantum

She closes out her Keynote by identifying “What’s Next”. Some of these future directions include the development of new tools and digital biomarkers, room to improve recruitment and retention designs, enhancing training resources and workforce development approaches, and developing novel data sources, models, and methods.

Link to more ILHBN member Publications:

<https://ilhbn.ssri.psu.edu/resources/publications>

¹⁵ RCR is a measure of the scientific influence of each paper by field-and time-adjusting the citations it has received, and benchmarking to the median for NIH publications, the value of which is set at 1.0.