Social Computation

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I am a **Human-computer interaction researcher**. My areas of interest include digital health, social computing, and accessibility. I design, build, and evaluate social computing systems and end-user tools that support communities in performing complex knowledge work like experimentation. My research draws on the knowledge and needs of experts (microbiologists and neurologists) and communities (fermenters and people with neurological disorders).

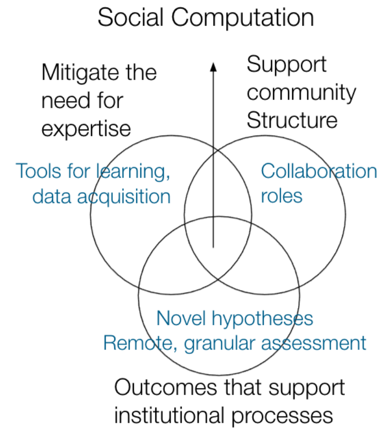

Figure 1: Social computation provides tools for deeper individual contributions, platforms that support community structures, and outcomes that are relevant for institutional processes.

2005 Machines struggled to label images, translate phrases, and fold protein structures. As access to the internet expanded, Luis von Ahn [1] saw an opportunity: people could do what machines failed at. Under the hood, such *human computation* approaches also curated massive labeled datasets that have bootstrapped important technological successes.

2021 People cannot match the scale and latency at which machines label images, fold proteins, and translate phrases. Meanwhile, social computing has exploded. People globally collectively spend millions of hours every minute online. I see a massive opportunity for *Social Computation*.

[1] L. von Ahn. *Human Computation*. PhD thesis, Carnegie Mello University, 2005

I propose **Social Computation as a class of computational and social computing techniques that enable community-led complex knowledge work**. Social Computation techniques build on communities' contextual knowledge, social structures, and lived experience. To support motivated communities, tools and platforms embed techniques that provide conceptual and procedural guidance [2], collaboration roles [3], and designs for institutional impact [4] [5]. Online spaces are typically designed by drawing on the presuppositions and relationships that mark offline systems[6]. Social Computation provides an alternate vision where communities need not just donate data to answer experts' questions. Rather, they can perform complex knowledge work themselves.

Widely considered hot-spots of misinformation and hoax, internet platforms demonstrate the challenging, complex relationship between science and society. My research seeks to improve this situation. In my doctoral and postdoctoral work at UC San Diego and Harvard University, I have built systems for Social Computation for science and telemedicine. **Contributing principles to social computing, accessibility, and digital phenotyping tools, my research demonstrates several firsts**. First, 344 volunteers from 27 countries converted their lived experience to hypotheses about the microbiome; experts rated 19% of such hypotheses as novel. Second, communities ran controlled experiments with global participation to test such hypotheses. In particular, A fermentation community tested whether drinking kombucha helps maintain normal stool consistency with a between-subjects experiment. Third, people with neurological disorders provide accurate and reliable estimates of motor impairments with a few minutes of at-home use of a tool. This work provides the first *in-the-wild* empirical evaluation of multiple motor impairment measures from accessibility literature.

My research has received multiple accolades and interest beyond my immediate research area of Human-Computer Interaction. My doctoral research was awarded the **School of Engineering Exemplary Ethical Engineering Award** at

[2] **Vineet Pandey**, J. Debelius, E. R. Hyde, T. Kosciolek, R. Knight, and S. Klemmer. Docent: Transforming personal intuitions to scientific hypotheses through content learning and process training. In *Proceedings of the Fifth Annual ACM Conference on Learning at Scale*, pages 1–10, 2018

[3] **Vineet Pandey**, T. Koul, C. Yang, D. McDonald, M. Price Ball, B. Greshake Tzovaras, R. Knight, and S. Klemmer. Galileo: Citizen-led experimentation using a social computing system. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, pages 1–14, 2021

[4] **Vineet Pandey**, N. C. Khan, K. Z. Gajos, and A. S. Gupta. At-home use of a computer-based pointing task accurately and reliably estimates motor impairments. In *Submission*, 2022

[5] N. C. Khan, **Vineet Pandey**, K. Z. Gajos, and A. S. Gupta. Free-living motor activity monitoring in ataxia-telangiectasia. *The Cerebellum*, pages 1–12, 2021

[6] Jim Hollan and Scott Stornetta. Beyond being there. In Proceedings of the SIGCHI conference on Human factors in computing systems, pages 119–125,1992

my PhD institution. I have been invited to present research at multiple venues including **American Society of Microbiology**; **Precision Medicine Initiative**; and **MIT Innovation Lab**. I am grateful that multiple classes have including my research in their curriculum.

Future research directions include 1) online platforms that prototype different community-expert configurations; 2) computational tools for deeper knowledge mechanistic insights; and 3) techniques for better scientific work and discourse online. My goal is to make Social Computation systematic for a broad range of communities and experts to draw benefits from. and any researcher to use and broaden to more domains.

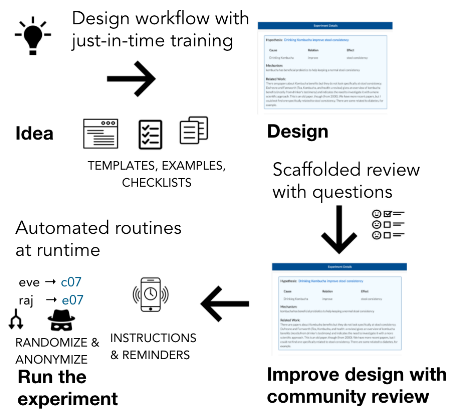

Figure 2: GALILEO supports communities in designing and running between-subjects experiments to test intuitions

Social Computation for science and medicine

> "Science and technology—when applied with vision and *optimism*, with wisdom and *humility*, with rigor and *integrity*, and with a commitment to engage and ***serve everyone***—are among the most powerful forces ever devised to better the human condition." [7]

Clinical trials for COVID-19 vaccines demonstrated to the public what scientists already know: the difficulty of creating new knowledge is a fundamental intellectual barrier to societal progress. I believe that **the current approach of relying solely on institutional experts to create knowledge is insufficient to meet the scale, diversity, and novelty of people's needs**. Consider the role of Randomized Controlled Trials (RCTs) in science and medicine. Funded generously by agencies, RCTs provide a rigorous design to evaluate treatments, tools, and other interventions. Despite their successes, scientific processes like randomized experiments suffer from two critical concerns.

1. **Trained professionals** design experiments, navigate the logistics, and track outcomes. Most people lack the know-how and skills to run scientific investigations. Consequently, they are limited to participating in the scientific process as data donors regardless of their motivation to contribute more. Additionally, many trials rely on expert assessment of change in condition severity. This is sub-optimal for two reasons. First, relying on the perceptual and experiential knowledge of professionals/experts provides narrow, coarse-grained assessments. Such assessments might not track subtle changes in the condition. Second, to improve assessment quality, some research employs specialized measures in specialized settings. Participating in such studies is not possible for most people around the world.

2. **Long latency** in enrolling participants and tracking outcomes. Coarse-grained expert assessments provide a scale with likely poor sensitivity. Consequently, more people are needed to evaluate an intervention. Better quantitative, objective, granular scales can support evaluation of treatments with fewer participants. In turn, such tools can increase the number of interventions tested over a fixed number of participants. Rare disorders (also called orphan disorders) could benefit from such approaches. While any one rare disease affects a small number of individuals, nearly 25-30 million people in the United States are affected by some rare disease. A lack of *sufficiently-large markets* can suppress investment in potential treatments and make it difficult to find participants for trials: one clinical trial

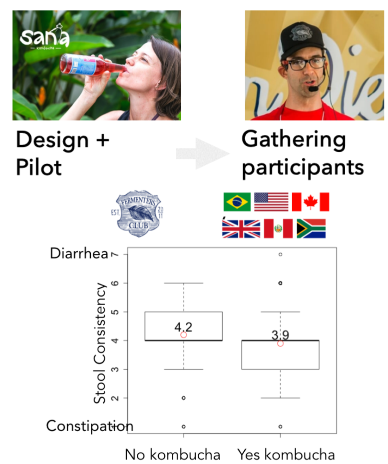

Figure 3: A global fermentation community used GALILEO to design, review, and run a week-long experiment testing the effect of kombucha on stool consistency. The flags represent participants' nationality.

[7] Eric Lander, POTUS' Science Advisor and Director of the Office of Science and Technology Policy. 2021. (*highlights* mine)

with a rare disorder recruited 39 people over 10 years. Meanwhile, online communities for such disorders run into hundreds and more.

As a result, **scientific work is synonymous with institutional research**. To evaluate the feasibility of *Social Computation* in science and medicine, I have contributed the design, deployment, and evaluation of four novel systems: GUT INSTINCT, DOCENT, GALILEO, HEVELIUS AT HOME). Results with online communities suggests that there's a massive opportunity to accelerate knowledge creation using tools that mitigate the need for expertise and provide online platforms for finding ready volunteers.

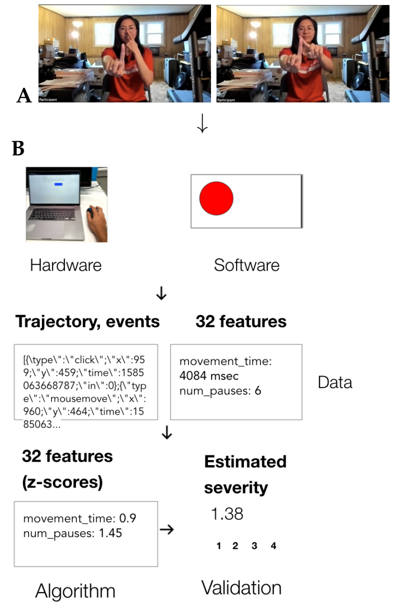

Figure 4: A) A demonstration of Finger-Nose task over video conferencing. B) HEVELIUS AT HOME tracks features. Families with neurological access Hevelius at home using a mouse and a browser on a personal computer. Activities comprise pointing tasks and reports from participant and caregivers.

Achieving Social Computation: Tools, Platforms, Institutions

> "Part of what distinguishes science from cognition more broadly is the **cultural accumulation of tools and knowledge** that can support information gain in ways that go well beyond naive exploration." [8]

[8] Schulz, L. E. (2012). Finding new facts; thinking new thoughts.

Synthesizing existing literature and my research suggests that technological efforts for complex knowledge production succeed when they intervene at three levels: individual, community, and institutional.

1. **Deepen individual contributions** with tools that mitigate the need for expertise. People need to know the genre of work and implement it correctly. While learning resources are distributed across the internet, they are rarely integrated with the task. People lack knowledge for *what* to do and *how*. Tools for designing experiments or collecting appropriate data can either provide such learning resources or change the representation the activity to a domain that mitigates the need for training.

2. **Support existing community structures**, motivation, and participation levels. Complex work can overwhelm people with the number and variety of tasks. To succeed at collaboration, technological interventions need to be directed towards some–e.g. progressive–forces over others [9]. Communities that accomplish impressive feats exhibit resilience, self-organization, and hierarchy [10]. Such communities demonstrate dynamic, contextual decision-making; they *act*; and they possess an organizational structure. While many online communities are massive, few support complex work with appropriate roles and support contribution mechanisms. My research suggests supporting motivated communities with explicit roles that reuse prior knowledge and provide scaffolds for micro-expertise.

[9] K. Toyama. *Geek heresy: Rescuing social change from the cult of technology*. PublicAffairs, 2015

[10] D. H. Meadows. *Thinking in systems: A primer*. Chelsea Green Publishing, 2008

3. **Produce outcomes that support institutional processes**. My postdoctoral research has taught me a key lesson: long-term success and value of community-led work relies on its success in leveraging existing institutional expertise and meeting existing needs. Many novel research tools and processes are not designed with the final beneficiaries needs in minds; others have noted it too [11]. To leverage communities' strengths and make their outputs useful, my research focuses on domains where communities can complement institutional work. The human microbiome offers an area with a lot of popular excitement, many opportunities for simple experiments, and a literature with more questions than answers. The science is *nascent*, *personally motivating*, and *contextual*. Experts know little, people care, and individual differences are important. While everyone has a gut full of microbes, its

[11] M. Roberts, D. Driggs, M. Thorpe, J. Gilbey, M. Yeung, S. Ursprung, A. I.Aviles-Rivero, C. Etmann, C. McCague, L. Beer, et al. Common pitfalls and recommendations for using machine learning to detect and prognosticate forcovid-19using chest radiographs and ct scans.Nature Machine Intelligence,3(3):199–217,2021

causal influences remain largely unknown. The world could benefit greatly from a more comprehensive understanding of the microbiome, what influences its composition, and the impact our gut has on our health. Neurological disorders provide another area of enquiry. Clinical assessments evaluate progression but tracking early and subtle changes is difficult. Interpretable, granular, quantitative measures that support institutional needs can be useful.

Tools that mitigate the need for expertise

To mitigate the need for professional expertise in scientific work, my research suggest two ways. First, for tasks that follow known templates, provide just in time support that includes conceptual and procedural knowledge. Second, for tasks that require difficult-to-teach tacit expertise, represent them in domains that can be computationally analyzed **??**.

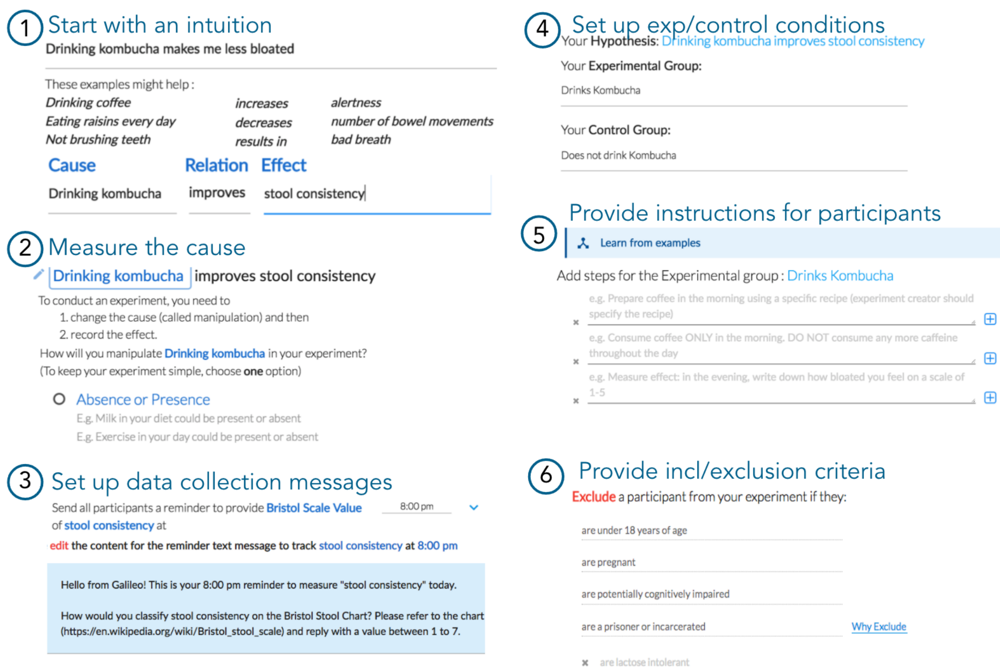

Figure 5: GALILEO's design module helps people transform intuitions into experiment designs

Designing experiments without prior expertise

To perform a complex activity, people need to have a good working model of both the concepts and procedures My research introduces procedural guidance to build just-in-time expertise for difficult tasks. Procedural guidance has multiple advantages: it is minimal, leverages teachable moments, and can be ability-specific. Because learning complex activities overwhelms working memory, the Galileo experimentation system chunks related elements and embeds procedural training with examples, checklists, and templates. Chunked presentation reduces cognitive load and offers a just-in-time plug for holes in knowledge. Galileo's design workflow 5 demonstrates the efficacy of reifying the genre of between-subjects experimentation in the software itself.

Motor impairment assessment with few minutes' tool use at home

Obtaining valid, reliable, and low-burden quantitative assessment of motor impairments is a key challenge in the longitudinal care of people with motor impairments. My Postdoctoral research demonstrates how tools can support communities in creating valid and reliable assessments of motor impairments **without using expert time**. A recent computer-based system, called HEVELIUS [12], quantifies motor impairments in the dominant arm when used under researcher supervision. While promising in the lab setting, the utility of such tools is unknown in the wild. People might not comply with the instructions, come across interruptions, or use devices in settings that don't yield useful data. Hevelius' key insight is quantifying people's motor performance by analyzing a user's performance on *pointing tasks* where people move the cursor to indicate a particular target. Trajectories and events from such mouse-based pointing task are converted to features; such features are then compared across people with motor impairments and age-matched healthy controls. Hevelius mitigates the necessity of finding healthy controls by using a normative dataset based on existing corpus. Such characterization efforts meet experts' objectives as well: they improve researchers' understanding of motor impairments in natural settings.

Platforms for participation at different levels

My dissertation research contributed the GUT INSTINCT platform that enabled community-led novel scientific work [13]. The key contribution of GUT INSTINCT is providing appropriate learning sources at the time of action [14]. Multiple evaluations—controlled experiments and field deployments with online communities including American Gut participants—demonstrate that communities can transform intuitions to hypotheses and structurally-sound experiments.

Collaborative hypotheses generation

DOCENT explicitly teaches people to create hypotheses by combining personal insights and online learning with task-specific scaffolding. Novices contribute hypotheses as the system introduces conceptual learning embedded in short lectures, and software-guided procedural learning. DOCENT's Learn-Train-Ask workflow substantially improved quality of hypotheses in a 2x2 between-subjects experiment with 344 online volunteers including American Gut participants. Prompting participants to explicitly connect personal observations with existing knowledge increased the overall quality and novelty score of questions. **Participants generated 399 hypotheses; 19% were rated novel by microbiome experts.** Further, an analysis of 68 participants (in one condition)– who added at least one question– demonstrated that the leader formed 1% of participants but contributed 19% of the answers and 49% of all collaborative activity (adding follow-ups, editing others' question, adding options).

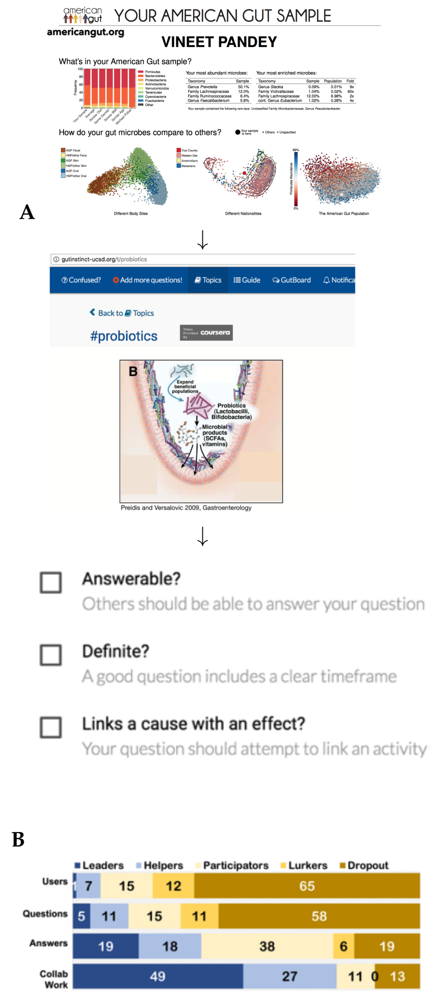

Figure 6: From data donors to hypotheses generators. A) DOCENT integrates conceptual and procedural learning. B) People voluntarily showcased different contribution levels.

[12] K. Z. Gajos, K. Reinecke, M. Donovan, C. D. Stephen, A. Y. Hung, J. D. Schmahmann, and A. S. Gupta. Computer mouse use captures ataxia and parkinsonism, enabling accurate measurement and detection. *Movement Disorders*, 35(2): 354–358, 2020

[13] **Vineet Pandey**. *Citizen-led Work using Social Computing and Procedural Guidance*. University of California, San Diego, 2019.
School of Engineering Exemplary Ethical Engineering Award

[14] **Vineet Pandey**, A. Amir, J. Debelius, E. R. Hyde, T. Kosciolek, R. Knight, and S. Klemmer. Gut Instinct: Creating scientific theories with online learners. In *Proceedings of the 2017 CHI conference on human factors in computing systems*, pages 6825–6836, 2017

Community-led experiments

GALILEO reifies experimentation in the software, provides multiple roles for contribution, and automatically manages interdependencies. Galileo social computing system that instantiates procedural support using three techniques: experimental design workfow that provides just-in-time training, review with scafolded questions, and automated routines for data collection (Figure 2. Experiment creators can invite others to review and participate in the experiment. Participants from around the world join experiments, follow instructions, and provide data in response to automated data collection reminders. A deployment across 16 countries found that people generated structurally-sound experiments on personally meaningful topics. **Fermenters and Open Humans communities–with members across 8 countries–designed, iterated on, and ran weeklong experiments**.

Figure 7: Platforms for asynchronous telemedicine. **Potential collaboration with digital health researchers and clinicians**.

Research Directions

My research is inspired by the goal of democratizing expertise of complex domains and–in the process–creating ways to meaningfully embed computation in society. Low-effort capacity-building tools and platforms can scale up scientific work by people outside institutional settings. This section outlines future research ideas that open up multiple directions for designing new systems and for contributing novel theory.

Computational tools for deeper knowledge: characterizing disorders and drawing mechanistic insights

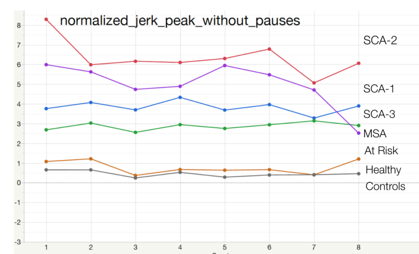

Figure 8: Limited research on many disorders leads to them being clustered together. Sensitive measures from digital phenotyping tools can support better characterization of such disorders and spur clinical research. **Potential collaboration with Machine learning, Accessibility, and Clinical researchers**

My converstions with clinical researchers suggests that experts seek representations that support their existing knowledge while adding complementary, interpretable, personalized information. **Better characterizing similar conditions with natural usage data and mechanistic information can bootstrap a broader class of digital health tools**. My current cross-sectional analysis of HEVELIUS-AT-HOME usage across five neurological disorders—Amyotrophic Lateral Sclerosis (ALS), Spinocerebellar ataxia (SCA), Ataxia-telangiectasia (A-T), Myasthenia Gravis (A-T), and Delirium—suggests that participants across disorders produce unique profiles for reliability, median performance, and correlation with ground truth. This is a promising avenue of enquiry: many disorders are poorly characterized due to limited research efforts.

Similar motor performance might have differing underlying mechanisms and causes. Beyond existing behavioral biomarkers, I am also interested in building prototypes that go one level deeper by tracking **mechanistic markers**.

Online platforms that prototype different community-expert configurations

My conversations with clinical practitioners, clinical researchers, and conference attendees have convinced me that Social Computation has immediate applications for clinical work. **I intend to build the first examples of double bottom line systems in clinical work that explicitly use people and clinicians' complementary knowledge and needs to provide benefits to both groups**. Such prototypes could take the form of sociotechnical workflows that includes platforms for synchronous activities (e.g. initial meeting; feedback messages) and tools for asynchronous use (e.g. online self-experimentation workflow that divides experimentation into participant-led and clinician-supported phases). Online platforms can integrate this workflow with a motor performance impairment tool (like HEVELIUS-AT-HOME) for generating validated outcome measures alongside Patient-reported outcomes. Such self-experimentation platforms open the way of valid single control designs (SCDS) that might support communities with rare disorders in creating personally- and clinically-relevant knowledge [15].

[15] H. Studd, K. Z. Gajos, A. Gupta, **Vineet Pandey**, and M. Jacobs. Understanding clinician perspectives to identify opportunities for telemedicine beyond covid-19. In *Submission*, 2022

Such a setup is one possibility among many for potential collaboration between clinicians (including complex care teams), people with disorders, and caregivers. **Building and deploying prototypes to explore these possibilities will inform potentially better ways to distribute clinical and scientific work among experts and communities.**

Creating ~~Mis~~Information on Social Platforms: HELPING HANDS

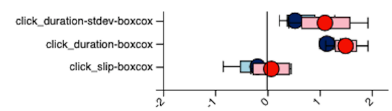

Figure 9: One need: Feedback and collaboration tools for people with disorders, caregivers, and clinicians.

The quality of knowledge from community experiments can be improved with better contextual support for catching/correcting human biases. For instance, experiment length, potential confounds and lack of double-blind processes can be tricky to implement for a novice experimenter. The choice of such details can vary immensely across the scientific domain, the topic, and questions of interest. Different collaboration tools and approaches–e.g. low-cost multimodal interfaces and audio chatrooms–can likely provide richer interactions.

I want to transform tools like HEVELIUS-AT-HOME into platforms that supports collaborative work among patient communities, experts, and volunteers. Such community work can be assisted by appropriate, interactive visualization of physiological data. While massively multivariate data–like microbiome information– are extremely difficult to interpret, smaller deadline can help communities develop and understanding of their performance.

My prior work demonstrates that small interfaces have big effects [16]. Evaluating the effect of online platform design on access, use, and dropouts will continue to be a focus of my research.

[16] C. M. Hicks, **Vineet Pandey**, C. A. Fraser, and S. Klemmer. Framing feedback: Choosing review environment features that support high quality peer assessment. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, pages 458–469, 2016

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