Michael Merrill – Research Statement

My interests lie in designing and building population-scale systems which make the internal processes of human cognition and behavior machine-readable, particularly in the contexts of mental health and digital interventions. *In situ* human behavior represents a largely untapped trove of unstructured data, and by learning more about the link between these behaviors and mental illness we can build new tools to combat the growing mental health crisis we face in this country and abroad. I am particularly interested in measuring circadian disruptions and their relevance to mental health and wellbeing, large-scale population sensing, and developing tools for digitally augmented care in clinical contexts.

At Cornell I worked in the People Aware Computing Lab under the supervision of Dr. Tanzeem Choudhury. While I contributed to several projects in the two years between then and graduation, my primary focus was on CrossCheck: a passive mobile monitoring system for the prediction of relapse in patients with schizophrenia. At the time of publication, CrossCheck was the longest longitudinal smartphone-based study of patients with severe mental illness. Schizophrenic relapse is not a binary event. Patients and caregivers alike report lengthy declines, in which a variety of symptoms may manifest, including sleep disruptions, polar swings in sociability, and trouble organizing thoughts. Accordingly, the project's greatest challenge was adapting the analysis to account for variations in participant behavior. We found that models which were trained on the union of population data and just 20% of a participant's data performed 60% better at predicting patients' moods than models trained on population data alone. Due in part to the significance of my contributions to PAC Lab and CrossCheck, I was able to attend UbiComp 2016 in Heidelberg, Germany. Reflecting on this experience gave me insight into what excites me professionally and personally: we found results that not only confirmed clinical expectations but also delivered insights into private and subtle signals that may have been impossible to measure before the proliferation of mobile sensing.

During the summer before my senior year I interned with Dr. Anind Dey in the Ubicomp Lab at Carnegie Mellon. While at CMU I recognized that although there were several open-source mobile sensing platforms (AWARE, Purple Robot, Funf) there was no unifying standard for the analysis and visualization of smartphone data. My vision was to engineer a data pipeline which could load smartphone sensor data and self-reports from an arbitrary source and then perform visualization and feature extraction. Given my skill set at the time it was ambitious to think the project could be finished within one summer. I was able to complete the feature processing library and deliver early analysis on a cohort of CMU students, but the single core SQL and Pandas pipeline ran too slowly to be useful in the long term. However, since entering industry, I have successfully built a similar system for internal use.

Following my summer at CMU I built upon my work with one of Dr. Dey's students by recruiting 66 of 79 members of a Cornell social fraternity for a cohort analysis study on the feasibility of predicting friendship through smartphone sensor data. We found some promising results, and are working to develop our findings for future publication. The study and the dataset have left me wondering if it is possible to measure the propagation of negative affect through an insular network and whether there is a measurable community component to depression. If we observe negative affect in one member of a network of digital traces, what does this tell us about another member who shares social or physical ties? If one member of

the cohort receives help in the form of therapy, medication, or a digital intervention, could positive outcomes propagate to their peers?

At the start of my senior year I began working part-time for Dr. Choudhury's mobile sensing startup, HealthRhythms, and following graduation I joined the company as its second full-time employee. It was difficult to attach myself to the company rather than apply directly to graduate school, but I wanted to take time to refine my technical skills and see to the research threads that started in PAC Lab and led into the startup. Currently my research focuses on discovering links between smartphone sensor data and self-reported symptoms in patients with bipolar disorder, depression, and chronic anxiety. My publicly available work has produced two posters, and we are currently engaged with an intellectual property law firm to file my first patent on behalf of the company. A key tenet of HealthRhythms' mission is understanding the role that circadian disruptions play in the perpetuation of mental health disorders. For one project, I designed and implemented a proprietary sleep detection algorithm that performs on-par with existing state-of-the-art classifiers but with significantly lower computational overhead. I have also prototyped novel methods for measuring deviations from daily routine which may be linked to downturns in mental health. Additionally, as part of my day-to-day work at HealthRhythms I've been involved with the planning, management, and analysis of a dozen studies of varying size through our academic and pharmaceutical partners.

My work at HealthRhythms has generated new curiosities about how smartphone data can be fused with other modalities. We have found that the larger the scale of a clinical study, the harder it becomes to practically collect detailed data. While it is possible to capture behavioral data from massive cohorts with mobile sensing, studies that employ ground truth measurements like sleep actigraphy are often limited in scale due to budgetary constraints and logistic practicality. These challenges ignited my interest, leading me to wonder how we could employ a technique like transfer learning to combine broad information from large datasets with higher-resolution and high accuracy data from smaller deployments. Moreover, how do we leverage population-level data to the improved measurement of mental illness with personalized models?

Most recently my interests have expanded beyond mobile interventions. The gold standard for treatment of depression and anxiety is a combination of medication and, crucially, a strong clinician-patient relationship. I have become interested in employing natural language processing methods to study the ways in which patients with depression and anxiety use language to express their symptoms in clinical settings. Standard clinical assessments like the HAM-D rely on the subjective translation of patient interviews into ordinal scales. Perhaps if we can better measure the latent patterns that link words and mental state we will be able to build new assessments that better augment existing therapeutic practices. Furthermore, the prospect of healing after a mental health diagnosis can be daunting for patients, particularly without a constructive vocabulary with which to discuss trauma. Could a digital therapeutic assistant leveraging conversations with previous patients find an answer to the vocabulary problem?

As we march closer to accurate and passive measurement of behavioral health at a global scale, these powerful tools will inspire even greater questions. As the earth's climate changes, I believe it will become a social imperative to consider behavioral health in the contexts of mass migration and extreme weather

events. Could digital biomarkers allow us to measure the effects of climate on human mobility and behavior? The American Public Health Association reports that 54% of adults and 45% of children experience some form of depression following a natural disaster. Might we be able to measure and respond to this effect though smartphone sensor data?

To me, a PhD would mean the opportunity to develop the cognitive tools I need to answer these questions and branch out in new directions. I have tried tackling some of these problems on my my own, but with every success I find myself looking at another layer of depth. It's easy enough to read a paper on a new technique or model and implement it, but it's another thing entirely to build on ideas from the community and contribute my own answers. When I look forward and wonder about the rest of my career, I simply can't imagine floating on superficial understanding while the most interesting problems flow beneath. My two years in industry have rewarded me with hands-on experience and grown my understanding of my existing limitations, but above all they have helped me realize that if I stay on this path it's unlikely I'll have the chance to tackle long-shot problems and take my conceptual masteries of math, mental health, machine learning, and human-computer interaction to this next level. Only a research-based education can properly do that.