CURRENT MEASUREMENT GAPS AND OPPORTUNITIES AFFORDED BY MOBILE TECHNOLOGY

Harnessing Mobile Technology to Predict, Diagnose, Monitor, and Develop Treatments for Nervous System Disorders—A Workshop

National Academies of Sciences, Engineering, and Medicine
Forum on Neuroscience and Nervous System Disorders

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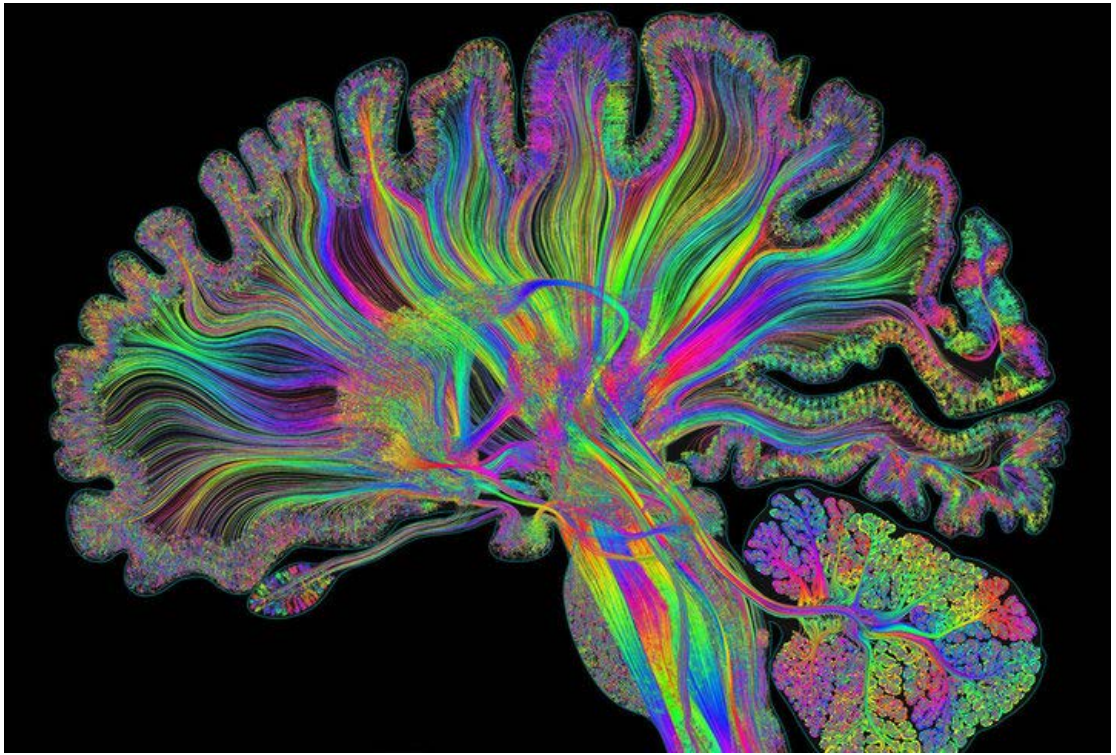
Disclosures

- **Salary and equity, Verily Life Sciences**

CURRENT MEASUREMENT GAPS AND OPPORTUNITIES AFFORDED BY MOBILE TECHNOLOGY

Present State of Understanding the Brain…



Exquisite

Present State of Assessing Neurological Disorders…

Exquisitely crude

Current Approaches

Neurological exam, patient report, disease-specific scoring schemes (UPDRS, MSFC, ADAS-COG, etc.) are…

- **Subjective and pseudo-quantitative**
- **Limited in scope**
- **Limited to occasional cross-sectional assessment—and usually in artificial settings**
- **Don’t take into account what is of greatest importance to the patient and their family**

You Can’t Manage What You Can’t Measure

There is a large unmet need for better measures of “disease burden”

- Disease onset
- Symptom severity
- Impact on daily life
- Progression
- Stabilization
- Regression
- Response to symptomatic treatment
- Response to disease-modifying therapy

…that are

- **Objective**
- **Quantitative**
- **More frequently measured—and in the context of normal life**
- **Of greater relevance to patients and their families**


OPPORTUNITIES
Research + Clinical Care

The Promise of Digital Tools: Research

To more deeply understand health and disease and to speed therapy development

- Phenotyping diseases in new ways: new techniques & new phenomena
- Documenting disease status (especially early manifestation) and progression
- Serving as endpoints of symptomatic or disease response in interventional trials
- Bringing more relevant, “real-world” evidence of treatment effects—beneficial and adverse
- Enhancing efficiency of study conduct and statistical power
- Improving access to relevant populations
- Increasing diversity of participation in clinical studies
- Enabling the conduct of virtual studies

The Promise of Digital Tools: Clinical Care

To improve efficiency and efficacy of disease management

- Providing earlier and more definitive diagnoses
- Delivering more useful clinical phenotyping for prognostication
- Enabling greater precision and more personalization of treatment
- Being a treatment in and of itself
- Monitoring response to treatment and disease trajectory to optimize outcomes
- Motivating and engaging patients in their care
- Improving access to expert care
- Facilitating population health management

Approaches

Multiple approaches may be complementary

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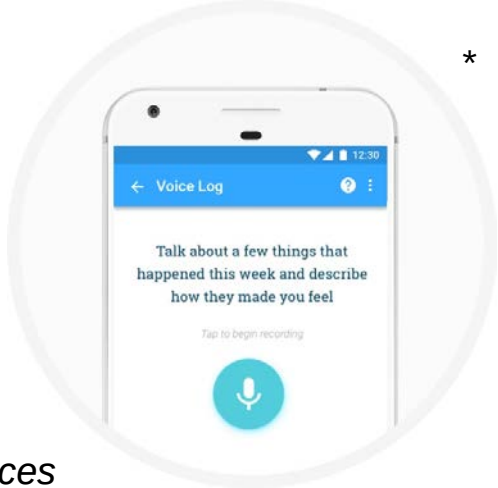
- **Body wearables** (wrist, leg, torso) to measure movement, activity, pulse, other physiological signals, environmental factors, and patient inputs
- **Environmental sensors** (e.g., bed sensor to measure sleep, other in-home devices) to measure physiological signals and provide environmental context
- **Computer- or mobile device-based applications** to measure movement, test cognition, evaluate mood, administer surveys, allow patient ratings, gauge social interactivity, etc.
- **Others**



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** Investigational devices*

Domains to Consider

Many neurological and psychiatric disorders are multi-system in their manifestations

- **Movement**
  - Overall activity level per unit of time
  - Types and proportion of activity
  - Geospatial attributes
  - Gait parameters
  - Dexterity
  - Balance
  - Disease-specific features (e.g., tremor)
  - Abnormal movements
  - Falls
  - Use of assistive devices
- **Sleep**
- **Cognition**
- **Speech**
- **Vision**
- **Mood**
- **Behavior**
- **Cardiovascular features**
- **Autonomic function**
- **Social interactivity**
- **Quality of life**

Settings & Contexts to Consider

Opportunities for a comprehensive picture of function

- In-clinic
- At home / during normal daily life
- Episodic—targeted (e.g., to discern treatment response) or ongoing (on a schedule)
- Continuous / near-continuous
- Structured tasks versus free-living activity versus combination
- Labeled by patient or not

Validation

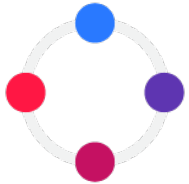
Must occur at multiple levels

- **Sensor really senses desired function:** accelerometer measures movement in that plane, PPG senses pulse
- **Basic feature extraction is accurate:** IMU data results in accurate step count, PPG analysis provides accurate pulse rate
- **Activity classifiers portray reality:** at rest vs. walking vs. running vs. sleeping
- **Individual or aggregated features correlate with clinically meaningful concepts** (neurological exam, clinical scores, functional capacity, patient-reported outcomes, disease severity, imaging, molecular endotype, etc.)
- **Features usefully measure change over time for use as clinical study end points or clinical decision support**

But the tools and data are not enough…

Our approach at Verily

Collect



Organize

Activate

Challenges

- Extracting maximal information from the fewest numbers/locations of devices and those that fit into natural daily life
- Identifying measures that have clinical relevance and meaning to patients
- Validating outputs against existing, often imperfect, standards and “ground truth”
- Expanding the concept of reliability beyond domains that are obvious (i.e., believing from “learned machines”)
- Integrating data from disparate sources, platforms, and operating systems
- Trending data over time in useful ways
- Synthesizing data for ease of use
- Presenting data in meaningful ways for different audiences
- Engaging patients, researchers, and clinicians to use
- Obtaining acceptance from regulatory bodies
- Ensuring privacy, security, and trust

Conclusions

- The convergence of multiple factors (better technology, ubiquity of smartphones and other devices, cloud computing, advances in data science) presents exciting opportunities to develop new methods and measures for characterizing transition from health to disease, measuring disease burden, and tracking disease progression/regression.
- These new methods will complement and likely improve upon the present state of our limited, subjective, and crude measures of neurological function.
- Thoughtful collection, organization, and activation of data will be required for full potential to be realized.
- ***With these approaches, we have immense opportunity to advance clinical neuroscience research, accelerate therapy development, and improve clinical care and outcomes for those with nervous system disorders.***

Thank You!