Mobile and Sensor Technology as a Tool for Health Measurement, Management, and Research with Aging Populations

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Today’s talk

- Background and motivation
- The data pipeline of mHealth technology
- Data collection techniques & trade-offs
- Translating data to insight, informatics, and interventions
- Concluding remarks & group discussion
Background & motivation
Personal background & research focus

My research *designs, engineers, and studies the impact of* human-centered *technologies* that empower people in managing various aspects of their daily lives and *wellbeing*
By 2050, number of adults 65+ expected to double and account for 1/5 of the global population.
While a huge achievement, aging societies also present novel challenges to healthcare.

As the lifespan grows, so do rates for noninfectious diseases, mental health problems, and age-related declines:

- 70% of global burden of disease
- 3/4 of deaths worldwide
- $47 trillion in spending by 2030

Sources: Centers for Disease Control and Prevention, World Health Organization, World Economic Forum
For older adults, the occurrence of these conditions is even higher and estimated to continue growing

Of people 65 years and above:

- 80% have 1 or more chronic illness
- 75% have 2 or more chronic illnesses
- 2/3 don’t receive the care they need

Sources: American Association of Retired Persons, National Council on Aging, National Institute of Mental Health
Behavior contributes the most to disease development, progression, and outcome.

Factors Influencing Health

- Genetics: 30%
- Social Circumstances: 20%
- Medical Care: 10%
- Behavioral Patterns: 40%

The top risk factors for premature death all relate to lifestyle choices.

High BMI, excessive alcohol, inactivity, poor diet, smoking

Sources: Centers for Disease Control and Prevention, World Health Organization
“the single greatest opportunity to improve health and reduce premature deaths lies in personal behavior.”

Prof. Steven Schroeder, MD, former RWJ President

and promote flourishing throughout the lifespan, including its later stages
A paradigm shift in how we approach heath research and care

The age of behavior change & prevention

The person as the nexus of health management
The power of mobile technology...

... to enable health care that is

- low cost
- continuous
- personalized
- scalable
Access and attitudes

- Stereotypes that older adults are unable and unwilling to try new technologies is a **misconception**
- Studies find older adults exhibit open-minded **receptivity** and willingness towards the use of mHealth technologies
- But also perceive that tools aren’t designed to **suit their abilities**
- Low adoption may be due to **design failures**, not people’s disinterest

The data pipeline of mHealth technology

Collection | Analytics | Informatics

Automated & manual capture | User modeling & assessment | Insight & action
Data collection techniques & trade-offs
Manual & passive strategies

Subjective self-report

Automated sensing
Manual & passive strategies

Subjective self-report

Automated sensing
Traditional approaches to health reporting face limitations related to recall, accuracy, and adherence.

During doctor visits

Daily diaries

Paper instruments
Supporting momentary assessment (EMA) and experience sampling (ESM) with technology

Initially, reminders to track were delivered on devices such as pagers or through cellphone text messages, though the recording itself was still made on paper.
Large focus today on smartphone-based reporting given its ubiquity and support for rich interactions

Brief design dive: pain self-assessment

1. Empathize
2. Define
3. Ideate
4. Prototype
5. Test
Design requirements

(Derived from the self-report and usability literatures, consultations with clinicians and target users, and our experience working with older adults and developing EMA systems)

- Low-burden and high-accessibility interactions
- Smartphone medium
- Repeated use
- Cognitive translation
- Eliciting potentially distressing experiences
Since last check-in, I feel:

Better!

Save

Worse

On a scale of 1-5 fingers, how are you feeling today?

Trace here
1. Please touch and hold the screen to report your current pain level from empty circle (no pain) to the full circle (worst pain possible).
   - Reset
   - Submit

2. Please report your current pain level (0 = no pain, 10 = worst pain possible) by tapping the screen.
   - Submit

3. Please touch the screen with 1 to 5 fingers to report your current pain intensity level (5 = worst pain ever).
   - Submit

4. Please tap on the image that best represents your current pain level:
   - Worst pain imaginable
   - No pain at all
   - Submit

5. Please tap on the image that best represents your current pain level:
   - Worst pain imaginable
   - No pain at all
   - Submit

6. Please indicate your current pain level with the following seek bar:
   - Worst pain imaginable
   - No pain at all
   - Submit

7. Please indicate your current pain level by moving this bar:
   - Worst pain imaginable
   - No pain at all
   - Submit

8. Please indicate your current pain level with the following NHS:
   - Worst pain imaginable
   - 10
   - 9
   - 8
   - 7
   - 6
   - 5
   - 4
   - 3
   - 2
   - 1
   - 0
   - No pain at all
   - Submit

9. Please tap or swipe up/down to change the face such that it best represents your current pain level.
   - Submit
Deployment surfaces new constraints!

- Impractical or socially inappropriate to use a phone
- Time consuming to make a self-report
- **Age-specific** accessibility barriers
  - Low digital skills
  - Cognitive impairments
  - Functional limitations (vision, motor skills)
From screen to squeeze

Tangible user interfaces to support natural, intuitive, discreet reporting
Manual & passive strategies

Subjective self-report

Automated sensing
Manual & passive strategies

Subjective self-report

Automated sensing
“Passive sensing” captures behavioral and physiological data through sensors embedded in personal devices.
Deriving digital biomarkers for aging use cases

<table>
<thead>
<tr>
<th>Sensors</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accelerometer, GPS</td>
<td>Mobility and frailty</td>
</tr>
<tr>
<td>Inertial sensors</td>
<td>Standing and balance</td>
</tr>
<tr>
<td>Microphone</td>
<td>Neurodegeneration</td>
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<tr>
<td>App usage logs</td>
<td>Cognitive declines</td>
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</tbody>
</table>

Wearables and on-body sensing

Cardiac vital signs

Motion impairments

Attacks and falls


ECG, heart rate, respiration, motion

Heart & respiration rates, nap posture

Whereabouts and safety
Contactless sensing and Internet of Things (IoT)

Gait velocity and stride

Insomnia and sleep

Acute incidents (fever, immobility) and routine monitoring (eating, sleeping)

Sources: Hsu 2017, Hsu 2017, Luo 2017, Luo 2018
### Benefits, disadvantages, and trade-offs among data collection approaches

<table>
<thead>
<tr>
<th>Manual tracking</th>
<th>Passive Sensing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sense of agency</td>
<td>Relieves tracking overhead</td>
</tr>
<tr>
<td>Mindful self-awareness</td>
<td>Can capture data imperceptible to people and with more granularity</td>
</tr>
<tr>
<td>Direct data control</td>
<td>“Objective” measurement</td>
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<tr>
<td>Tracking can be burdensome</td>
<td>Reduces personal awareness</td>
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<tr>
<td>Limits on granularity of data a human can record</td>
<td>Can’t capture subjective experiences</td>
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<tr>
<td>Biases &amp; inaccuracies of self-assessing status</td>
<td>Inaccurate for some types of data</td>
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<tr>
<td>Negative reactivity</td>
<td>Privacy invasive</td>
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<tr>
<td></td>
<td>Security &amp; storage of large volumes</td>
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<tr>
<td></td>
<td>Uncomfortable to wear</td>
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<tr>
<td></td>
<td>Data loss still an issue due to battery and forgetfulness to charge or wear</td>
</tr>
</tbody>
</table>
Hybrid data collection strategies

Sleep tracking examples according to Choe et al.’s (2017) semi-automated tracking framework:

Kim et al.’s (2017) OmniTrack implements an architecture based on such principles:
Beyond supporting care, mHealth can also drive basic science

- Studying diverse & large samples, in naturalistic settings, over longitudinal periods
- Academic efforts to develop general use, reusable, and extensible open mHealth platforms for research
  - AWARE, MyExperience, ohmage, Open mHealth Platform, Purple Robot
- But more research necessary to investigate and take steps to extend these platforms’ accuracy, coverage, and appropriateness for older adult populations and adaptive aging applications
Translating data to insight, informatics, and interventions
Common informatics and intervention targets for aging applications

- Ambient awareness for care networks and remote family
- Reminders or nudges (medication, activity)
- Intergenerational connectedness
- Future visions

Sources: Consolvo 2004, Mynatt 2001, Cornejo 2013, Micallef 2016, Zarate 2016, IBM/Pepper
Concluding remarks & discussion
Design constraints and goals for adaptive aging mHealth tools

(requirements that research finds most mHealth tools are not designed to satisfy)

- Implementing **usability** features to make interfaces more accessible to older adults facing cognitive, motivational, or physical limitations
  - E.g., large touch-targets, readable fonts & sizes, high-contrast, simple interactions, low manipulability, enhanced and adaptive volume control
- Utilizing **interaction modalities** that are more intuitive and natural
  - E.g., older adults now account for over 1/3 of voice assistant users
- Minimizing info overload and delivering cognitively legible feedback
  - E.g., moving from heavily quantitative and text-based reporting to more **qualitative representations** of personal data
Conceptualizing design dimensions

(abstracted data pipeline)

System-driven

- Automated
- Prescriptive

User-driven

- Manual
- Reflective

Agency

Lifelong use

- Recurrent tests
- Chronic management

Timeframe

Temporary use

- One-time diagnostic
- Behavior change
Smartphone UIs

Assessment

Long-term use

Temporary use

Assistance
Ethical considerations for mHealth

• Responsible management of (potentially sensitive, stigmatic, and exploitable) collected data

• Older adults have raised general privacy concerns about health technology
  • Necessary to directly investigate older adults’ privacy understanding & comfort levels
  • Develop usable mechanisms for communicating data preferences and controlling collected data (viewing, deleting, managing access)
  • Privacy-preserving sensing methods

• Regulation & policy
  • E.g., to guard against insurance companies setting rates based on a person’s historical or predicted mHealth data
  • Formalized standards and approval procedures for new tools
Other future directions

• Need more common-format, interoperable, and reusable mHealth platforms vs. one-off applications

• Developing mHealth experiences and infrastructures to support the social ecologies of the aging process

• mHealth as a way to not only bridge inequities but uncover and understand them in the first place

• Designs that challenge ageist stereotypes and promote a framing of flourishing in later life
Thanks! Questions?

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- Developing mHealth experiences and infrastructures to support the social ecologies of the aging process
- mHealth as a way to not only bridge inequities but uncover and understand them in the first place
- Designs that challenge ageist stereotypes and promote a framing of flourishing in later life