Passive Monitoring for Significant Health Events

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What is “Passive” Monitoring? - There is no such thing as (entirely) passive sensing

Differing conceptions of what is “passive”

...do not require any additional response or action from the patient within the mHealth app

... require patients to provide a response or modify the content in real time

Value of More Passive, Inobtrusive Monitoring


50% of the cohorts ceased engagement after 12 days

https://www.moonlightsonatadoc.com/
Use Case Dictates Assessment Approach – ORCATECH/CART platform

Multi-domain Home Assessment

**Data**
- Clinical
- Imaging
- Fluids

**Clinical Trials**
- Beattie et al. 2020
- Lyons et al., 2015
- Kaye et al., 2018

**Clinical Practice**
- Population Health
- Clinical Operations

**Clinical Environment**
- Indoor Environment
- Physiology

**New sensors or methods**
- Mobility
- Socialization
- Sleep
- Cognition

**Safety**
- Mobility
- Socialization
- Sleep
- Cognition

**Tech Data (aging, fluids)**
- EHR / External Data

**ORCATECH Sensing Life Kinetics**

Thomas et al. 2021; Beattie et al. 2020; Lyons et al., 2015; Kaye et al., 2018
**EVERYDAY COGNITION**


**MOBILITY**


**SOCIAL ENGAGEMENT**

Peterson, et al. PloS One, 2015; Thomas, et al. AAN, 2018

**SLEEP**

Normal  NA-MCI  A-MCI

Miller et al. GSA, 2019; Hayes et al. ADAD, 2014

Passive, Multi-Domain, Remotely & Longitudinally Acquired, Digital Biomarkers
Passive Sensing Requires CONTEXT

### Web-based Weekly Questionnaire

<table>
<thead>
<tr>
<th>No.</th>
<th>Question</th>
<th>Yes/No</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>In the past week, is someone newly assisting you with medication management, bathing, dressing or grooming?</td>
<td></td>
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<tr>
<td>2</td>
<td>Have you felt downhearted or blue for three or more days in the past week?</td>
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<tr>
<td>3</td>
<td>In the past week I felt lonely.</td>
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<tr>
<td>4</td>
<td>AWAY FROM HOME</td>
<td></td>
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<tr>
<td>5</td>
<td>VISITORS</td>
<td></td>
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<td>6</td>
<td>MEDICATION CHANGE</td>
<td></td>
<td></td>
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<tr>
<td>7</td>
<td>FALLS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>ACCIDENTS/INJURIES</td>
<td></td>
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<tr>
<td>9</td>
<td>HOSPITALIZATION/ER</td>
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<tr>
<td>10</td>
<td>HEALTH CHANGE/ILLNESS</td>
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<tr>
<td>11</td>
<td>LIFE SPACE CHANGE</td>
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<tr>
<td>12</td>
<td>ASSISTANCE</td>
<td></td>
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<tr>
<td>13</td>
<td>MOOD - BLUE</td>
<td></td>
<td></td>
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<tr>
<td>14</td>
<td>MOOD - LONELY</td>
<td></td>
<td></td>
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<tr>
<td>15</td>
<td>PAIN LEVEL (1-10)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>PAIN INTERFERENCE</td>
<td></td>
<td></td>
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</tbody>
</table>

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Life Space & Event Monitoring During a Norovirus Epidemic - 2011


Note the 2 weeks when the resident stayed mostly in their apartment weathering the norovirus quarantine that was going on in their community and how this changed their usual pattern – sleeping in and starting computer session later.
A remote-monitoring sensing platform deployed in homes detects population-based changes 1-year before and after a cancer diagnosis.

Wu et al. *Journal of Clinical Oncology* 39, no. 15_suppl (May 20, 2021) 1569.
Mobility changes before and after PD diagnosis – Tx Effects

Long-term Change + Venue Change

Mobility Two Ways + ↑ Granularity

Walking Speed (cm/sec)

Time of Day (Hour)

Mobility Two Ways + ↑ Granularity

Personal home
Continuing Care Retirement Communities (CCRC)

Walking speed (cm/sec)

Weeks before and after a PD diagnosis

Carbidopa TID

Carbidopa TID

Walking Speed (cm/sec)

Time of Day (Hour)

Days prior to and since PD prescription
Monitoring Late-Stage Dementia in LTC: Treatment efficacy for agitation

115 night shifts (10 pm-6 am); 15 occasions when the person with Alzheimer’s disease received PRN medication for treatment of agitation.

Area of Activity Key
- **BED**
- **FUTON**
- **FRONT DOOR**
- **BATHROOM**

A Culturally Relevant Multi-modal Brain Health Program - SHARP
Sharing History through Active Reminiscence and Photo-imagery

PI: Raina Croff
NIA: P30AG008017, P30AG024978, Alzheimer’s Association
The Future – Bridging Gaps with Opportunities for Research

More evidence is needed across the board…

SPECIAL TOPICS

- Understanding effects of context on unsupervised data
- Improving outcome measures: (Re-)defining ‘gold’ standards to be ecologically valid and more meaningful (e.g., sleep lab vs home; cognitive test vs everyday cognition; room transitions vs timed walks)
- Multi-domain digital outcomes (efficient, confirmatory, mechanism validating)
- Taking advantage of high-dimensional data (valid N-of-one analyses)

OVERARCHING AREAS

- User issues (diversity, clinicians, researchers, lawyers)
- Technical issues (hardware, software, data): device/sensor churn, acceptable error/precision of measures, algorithms, etc.
- Privacy / Agency / Autonomy
- Infrastructure, Infrastructure, Infrastructure
- Collaboration, Collaboration, Collaboration
In 1963: “It would be nice if all of the data which sociologists require could be enumerated because then we could run them through IBM machines and draw charts as the economists do. However, not everything that can be counted counts, and not everything that counts can be counted.

Making Sense of Environment Sensing Over Time: Air Quality

Correlation indoor air monitors and the estimates of air quality at closest outdoor locations = 0.418 (range= 0.0610-0.585)

Time Out of Home as Predictor of Functional Decline / Death