# Monitoring Everyday Functioning in Normal Aging and Mild Cognitive Impairment in a Smart Environment: An Evaluation of Direct Observation And Data Mining Techniques

Carolyn Parsey[1], Prafulla Dawadi[2], Maureen Schmitter-Edgecombe[1], Diane Cook[2]
[1]Washington State University, Department of Psychology
[2]Washington State University, School of Electrical Engineering and Computer Science

## Introduction

• Americans want to age-in-place. However, to live independently individuals must be able to perform instrumental activities of daily living (IADL), such as meal preparation and managing medications.

• Interdisciplinary efforts of psychologists, computer scientists, and engineers in the Integrative Training in Health-Assistive Smart Environments IGERT program, as well as other research groups, have resulted in the development of "smart environments" that can recognize and track everyday activities.

• Smart homes may also prove to be a useful assessment tool for monitoring everyday functional abilities, detecting changes in IADLs that may signify health concerns, and implementing interventions to extend duration of independent living. These research questions are currently being explored by the cross-disciplinary efforts of the Integrative Training in Health-Assistive Smart Environments IGERT program.

• In this study we evaluated the ability of sensor data (obtained from a smart home) to provide a measure of performance of IADLs for an older adult population. We compared the data obtained from the sensors to both direct observation of IADL performance and a laboratory test that served as proxy for everyday functioning.

• We hypothesized that if the sensor data can be used to accurately derive a measure of everyday functioning it should also correlate with other measures of everyday abilities, such as direct observation and laboratory measures.

## Participants and Smart Home Testbed

### Participants

• Participants were 28 older adults (20 females, 8 males), ranging from 59 to 85 years of age (mean age = 72.64) and 12 to 18 years of education (mean education = 15.70 years).

• To increase variability within the sample, participants included both cognitively healthy older adults and individuals with mild cognitive impairment (MCI), a transitional stage between normal aging and dementia.

### The WSU Smart Home Testbed (CASAS)

• CASAS is a two-story townhouse with a living room, dining room, and kitchen on the first floor, and three bedrooms and one bathroom on the second floor. Only the first floor was used for data analysis in the current study.

• Different types of sensors are located throughout the apartment, including 51 motion sensors on the ceiling (Figure 1), magnetic door sensors on the refrigerator, microwave door, and on the cabinets, and item vibration sensors on various objects such as a medication dispenser.

*Figure 1.* Motion sensors detected movement from positions on ceiling

• The smart home also has power sensors and temperature sensors to monitor power usage and the temperature of the rooms (see Figure 2 for the sensor layout and floor plan of CASAS).

## Method

### Measures of Everyday Functioning

Three measures were used to assess everyday functioning:

***Direct Observation Measure***: Participants completed eight IADLs in the CASAS smart home testbed:

1. Sweeping the kitchen and dusting the dining/living room
2. Filling a 7-day medication dispenser with medications
3. Writing a message in a birthday card, completing an appropriate monetary check, and addressing an envelope
4. Operating a DVD player to watch a 5-minute news clip on TV
5. Watering three indoor plants
6. Talking on the phone about the news clip they watched
7. Cooking a microwaveable meal of noodle soup
8. Selecting an outfit appropriate for a job interview

• Experimenters observed and coded the participant's performance for overall quality and completion of necessary steps, as well as for six types of errors for each IADL, including critical errors (failure to carry out the task completely), and non-critical errors (problems with efficiently completing the task).

• An overall score for each IADL was derived based on the number of critical and non-critical errors committed, ranging from 1 (task completed without any errors) to 5 (less than 50% of the task completed). These eight scores were summed to derive the direct observation score.

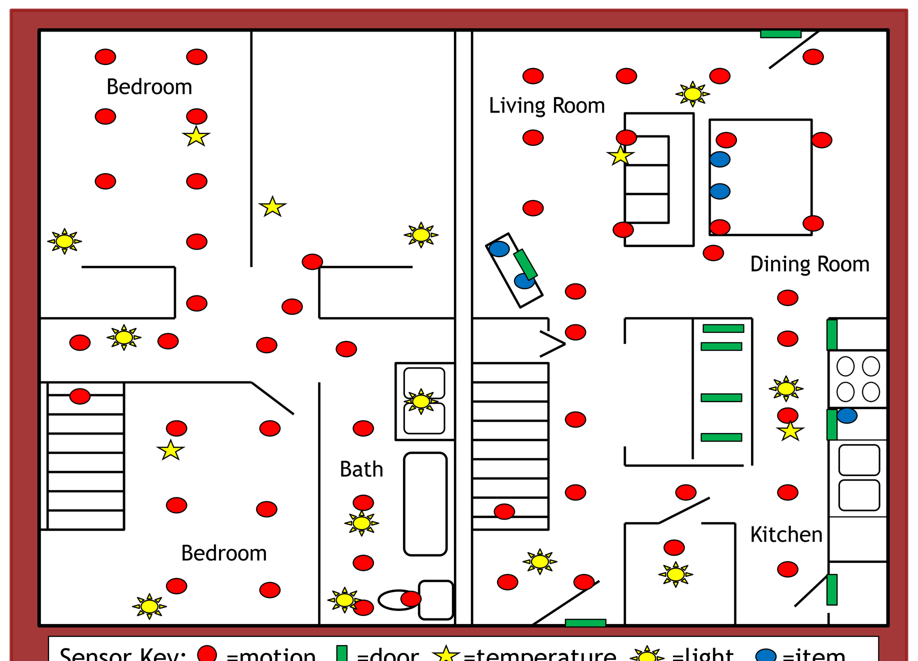


*Figure 2.* Sensor layout and floor plan of CASAS testbed

***Data Mining Method with Sensor Data:*** As the participant completed the IADLs in the CASAS testbed, different sensors were triggered in the home and recorded into a database.

• Because the sensor events lack context, researchers then annotated these events to attribute patterns of sensor events to particular activities (e.g., motion sensors in the kitchen at the same time as activity with opening kitchen cupboards, using the sink, and operating the stove suggests cooking noodle soup).

• From the annotated data we extracted various features that represent how well the participant performed the activity. These features include measures of time elapsed (duration) to complete the activity, the number of target sensor events triggered, and the number of unrelated sensor events.

• Using a neural network machine learning algorithm we derived overall scores for each of the eight IADLs, which were then averaged to obtain an overall functional score for the participant.

***Laboratory Measure:*** Participants completed the Everyday Problems Test (EPT), a paper and pencil-based measure of everyday problem-solving. The EPT requires solving simulated "real world" tasks involving various IADL domains (e.g., travel, meal preparation).

## Results

• Pearson correlations were used to analyze relationships between the data obtained through direct observation, laboratory testing and the sensors in the CASAS smart home testbed.

• Controlling for age, the functional score calculated from the motion sensor data correlated significantly with the direct observation score ($r$ = -.605, $p$ = .005; see Figure 3) and the EPT ($r$ = .583, $p$ = .007; see Figure 4). The EPT also strongly correlated with the direct observation score ($r$ = -.624, $p$ = .003).

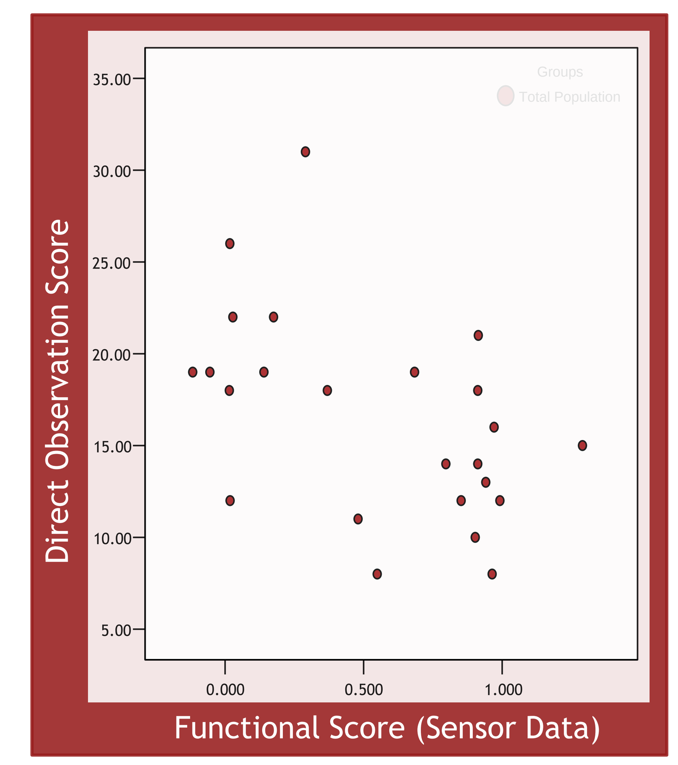


*Figure 3.* Correlations of Direct Observation and Functional Scores

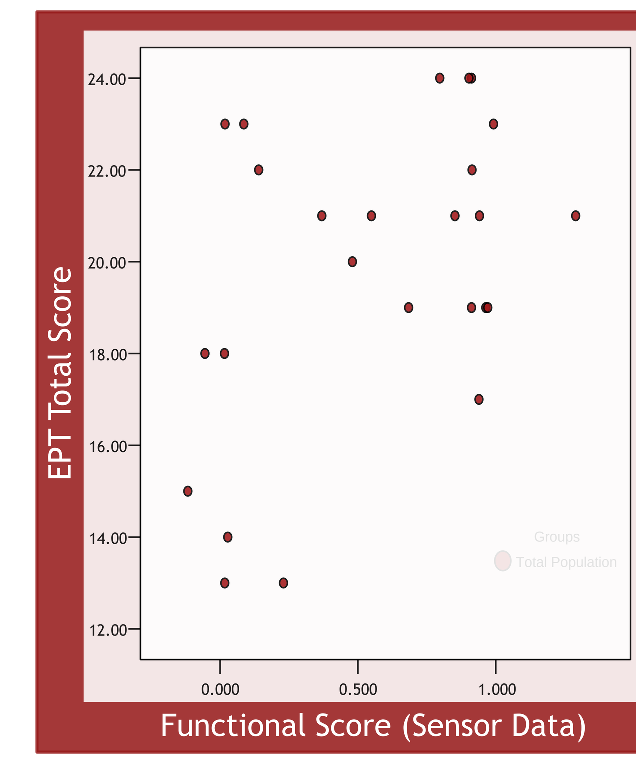


*Figure 4.* Correlations of EPT Total Scores and Functional Scores

## Discussion

• Strong correlations between the functional score derived from the sensor data and the direct observation score suggests agreement between these measures, indicating that data mining procedures of sensor data are capable of capturing similar information about everyday functioning as direct observation of these activities.

• Findings from this study suggest that monitoring daily activities through sensor systems in the home can provide valuable information about everyday functioning. Such monitoring could also be used to observed changes in activities suggestive of health concerns.

• Collaborative efforts between social science, computer science, and engineering allow for development of such in-home monitoring systems that both cater to the needs of older adults and provide accurate assessment of everyday functioning using technology. These smart home systems could be used to promote independent living for the elderly and delay the need for placement in care facilities.

• Additional research is necessary to determine whether information derived from sensor data collected within a smart home can provide accurate and ongoing information regarding an individual's everyday functional status. Such information would allow for the functional status of individuals to be assessed on a daily basis within their home environment and earlier interventions to be initiated.

## Acknowledgments

This research is based upon work supported by the National Science Foundation under Grant No. DGE-0900781, and the Life Sciences Discovery Fund of Washington State.