# Assessing Professional Caregiver Needs in Assistive Smart Homes

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**Abstract**

With the elderly population on the rise, assistive smart technology is positioned to help the elderly living community take on the upcoming age wave. The promise of this technology is focused on providing high-quality data to caregivers. While the research community has published many successes gathering and modeling medical data, there is little work on how to effectively deliver data to caregivers. This study attempts to inform researchers and engineers building smart technologies how to better understand the needs of nurses assisting the elderly. Interviews suggest nutrition, sleep length and quality, cleanliness of the individual,

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safety, and elopement by cognitively impaired individuals are of central concern. It is also important for programmers to make graphs and charts with axis have a real-world relationship. Sensor "events" are not relevant to nursing staff, and should not be presented in their raw form. Time increments are more appropriate for this population than quantity of sensor events. During the design of user-facing tools, a little extra care to the needs of caregivers can ensure assistive smart homes are helpful technologies.

**Keywords**
Smart homes • Elder care • Nursing needs • User experience • Interviews

## Introduction

With the population of those over the age of 65 on the rise around the world, and especially in the developed world, care for these individuals becomes a costly prospect (Fisk et al. 2009). The elder care facilities available simply will not be enough to take care of the projected 17–29% of the population who need them in the coming years. Technology holds promise as part of the solution to this looming issue as a means to assist older adults in remaining independent and at home, while reducing the work load on nursing care practitioners.

Smart Homes are an implementation of the ubiquitous computing concept, where technology is embedded in the environment around us. These technologies are designed to be low profile, second nature to use, and support our conscious and unconscious needs. Inexpensive and low-power modern computers and wireless functionality are rapidly bringing the ubiquitous computing ideals within reach.

The Center for Advanced Studies in Adaptive Systems' (CASAS) smart home implementations use sensors and computers to observe, model, and interact with people living at home (Crandall et al. 2013). These smart homes are designed to monitor the whole living space and preserve privacy, while placing minimal requirements on the residents that could adversely affect their daily behavior. The goals of the system are to build accurate models of how people are living, to measure their physical and cognitive health, and provide tools giving a comprehensive view of the resident to their care providers.

A smart home platform generates data in the form of sensor events, activity models, and quality of activities, such as sleep or medication compliance. However, it is relatively unexplored how to best deliver this information to the caregivers who need it. Nursing staff, physicians, children of the clients, and spouses are all important caregivers who may utilize smart home data to better help those in need. Little formal work has been done with these groups to understand their needs. Currently, the majority of user testing has been to design for the aging adult themselves. Engineering and nursing researchers at University of Missouri's TigerPlace smart elder care facility have performed a series of focus group studies with elderly participants to better understand the needs of those in the home (Demiris et al. 2004, 2008; Arsand and Demiris 2008). This was an important step to

understand which activities are key for the individuals residing in the homes, and to establish information about privacy and obtrusiveness concerns. However, it does not tell us what the caregivers need.

Researchers at TigerPlace have collaborated with nursing staff for years, and always stressed the importance of this partnership (Skubic et al. 2009). Their publications often hint at the feedback they have received from such a partnership, but have not formally explored what nurses need from smart home technologies.

Other work has explored the needs of informal caregivers, or those family members who look in on older adults while they are still living in their homes (Hwang et al. 2012). This research included caregivers in a participatory design process using established user-centered design techniques. Researchers brought in future users, showed them various designs, assessed the users' needs, and asked caregivers to run through usability tests in order to effectively design a prompting system interface that would help them do their day-to-day tasks.

To date, the only research assessing professional caregiver needs from smart home technology was a questionnaire with only 18 participants (Chernbumroong et al. 2010). These results are exploratory at best, so further assessments need to be performed.

Historically, visualizations of smart home data are driven by researcher needs. TigerPlace in Missouri published some of their visualization tools, consisting of a simple black and white chart of room occupancy over time (Rantz et al. 2008). The visualization plotted the sensor events occurring over several days. The result was a visible means to see room occupancy density by showing darker or lighter shades of grey.

CASAS has taken this idea a step further (Zulas et al. 2012). The concept of the original occupancy density chart was expanded into a colorized Activities of Daily Living (ADLs) chart (see Fig. 1). The colorized version uses different colors to show the ADLs being performed by the resident, and for how long. In Fig. 1, each row of data (three columns, from left to right) indicates the intensity of activity, the activity taking place, and a layout of the home to help people put the activities and their order in context. However, to better understand what each color means, the user must click the blue link above the graph and then remember the scales from a separate page before returning to the ADLs chart.

This improved ADLs chart was augmented with various plots to include types of activities occurring in the home and a prototype health trend of the resident. The health trend tries to give a global sense of the resident's sleep, activity, and social life in a single plot (see Fig. 2). The six boxes provide information about the home and resident as follows (moving from upper left to upper right, then lower left to lower right): the volume of sensor data gathered at any time, gauges of core daily needs, a socialization over time tool, the total number of events per activity, a pie showing the proportion of time the resident spent in each room, and a "health trend" to try and demonstrate a mechanism capable of showing health behavior over time.

Delivering efficient, clear, and concise information to nursing caregivers is important for the deployment of effective smart home technologies. To move toward this goal of a useful smart home platform, the CASAS researchers interviewed a

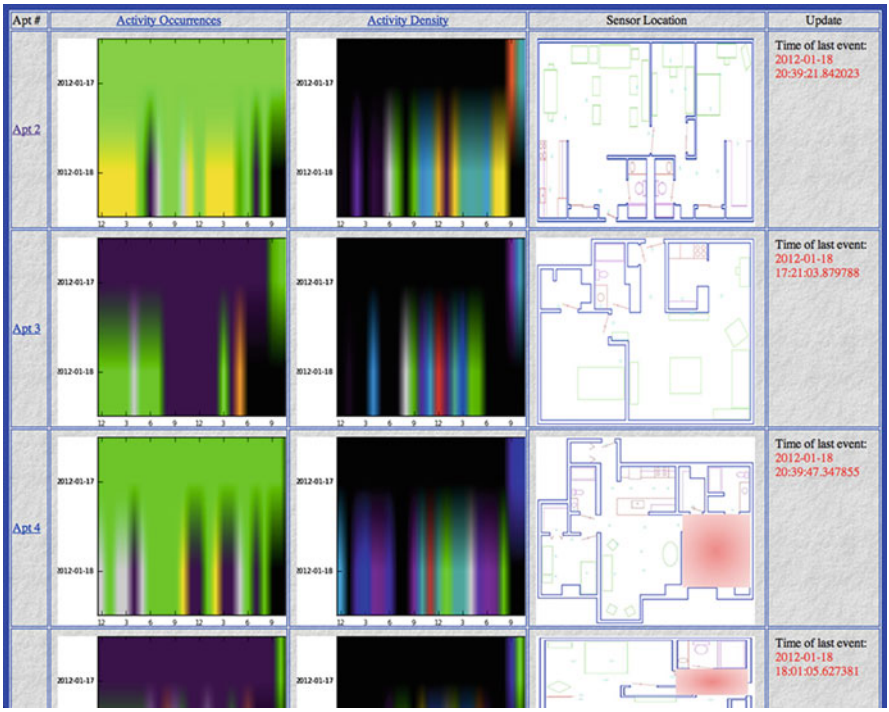


**Fig. 1** CASAS dashboard, visualization of smart home data sensor activities. Colors on the *left* indicate number of sensor firings over time with day on the y-axis and time of day on the x-axis. Colors on the *right* indicate activity taking part. Far *right* is a map of the living quarters

series of professional nurses in the gerontology field. While this is not a complete process, the results have already begun to change how the CASAS user interfaces are designed and deployed. This work describes these interviews and summarizes the results.

## Methods

### Participants

To gather desires, perspective, and feedback on the CASAS tools, a total of nine nurses were interviewed from three different types of nursing care facilities. Three were from a continuing care retirement center with a strong aging in place philosophy, housing high-income residents set in a large metropolitan area, three were from an adult daytime care facility, while the last three were from a nursing care facility, where both of the last facilities reside in a rural city. The university Institutional Review Board approved the study, and informed consent was obtained from each participant. Participants were all female with an average age of 44 years of

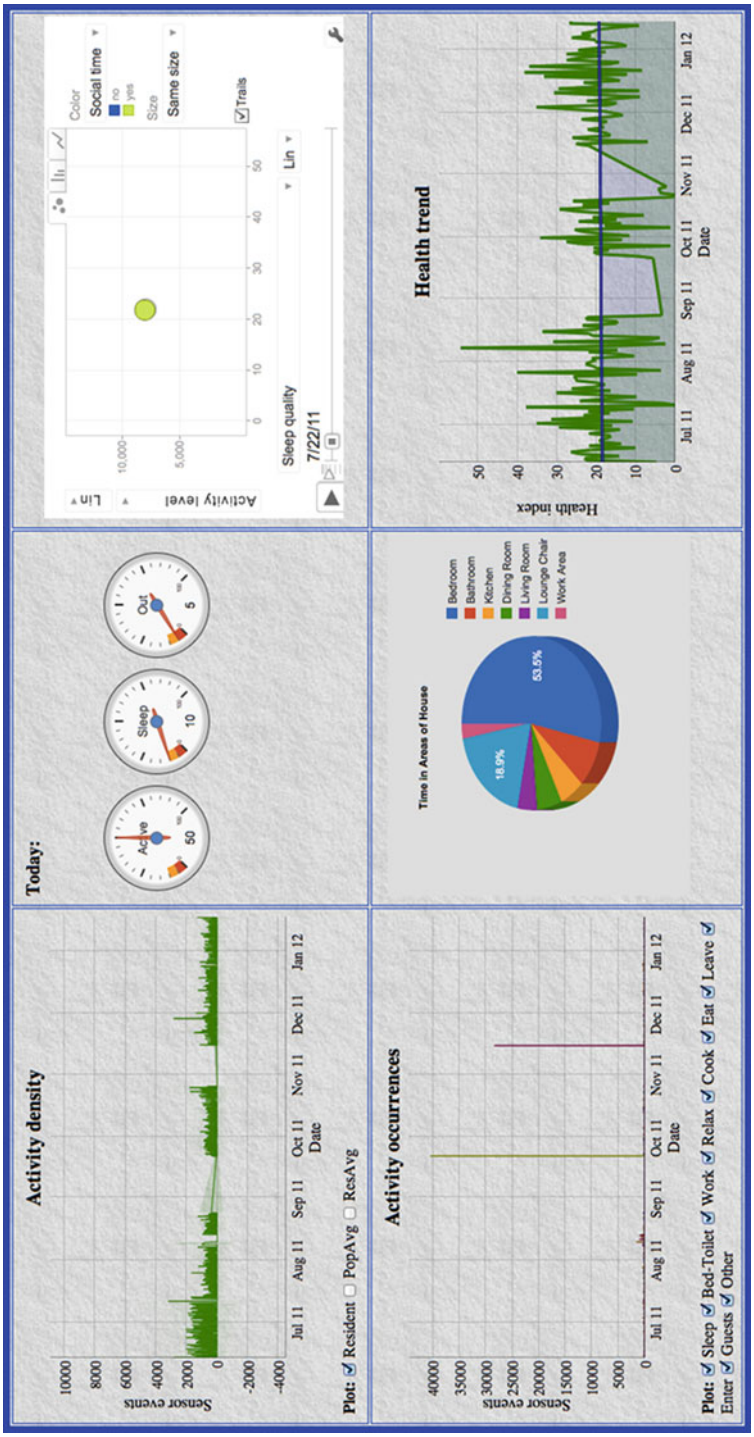


**Fig. 2** CASAS profile, visualization of smart home data expanded to include graphs. Graphs include (from *left* to *right*, *top* to *bottom*) overall sensor firings, amount of time spent on specific activities, socialization, sensor firings by activity type, percent time spent in locations around the residence, and a calculated health trend

age and a range from 26 to 68. They had professional nursing experience ranging from two and a half months to 46 years and experience with elderly clients from 1 to 46 years. All participants were at least certified nursing assistants.

## Materials

Interviews took place at each nursing facility in an available private office space. Each was recorded using a voice memo application on a smartphone. Viewing of the current smart home visualization tools was made available on a laptop screen with an attached USB mouse.

Apart from the interviews, the System Usability Scale (SUS) was applied. The SUS is a 10-item questionnaire with a five-point Likert-like scale assessing the ease of use and understandability of a system (Brooke 1986). Scores are modified for reversal questions, then totaled and multiplied by 2.5 to give a score out of 100.

## Procedures

Participants were led through a directed interview with questions on demographics, computer experience, willingness to learn new technology, and general needs from technology. They were then shown the CASAS smart home visualization of assistive smart home data and allowed to explore this for several minutes. A walk through of the interface by the interviewer was given upon request. Next, the SUS was administered and feedback about the website was obtained. Finally, the participant's needs for the system were obtained, along with any final thoughts.

A secondary observer was present for the proceedings, and 96% inter-rater reliability was achieved on the records kept by both observers.

## Results

Interviews proceeded very well, and the system was generally well received. Nurses stated the system was "cool," "savvy," and "fantastic." Some went so far as to want it for all of their clients.

Nurses' computer experience on a 1 to 10 scale was an average of 6.1, with a range from 3 to 10. Their comfort with technology on a 1 to 10 scale was an average of 7.4, with a range from 2 to 10. Lastly, their willingness to learn a simple new technology on a 1 to 10 scale was an average of 8.7, with a range from 3 to 10.

The results of the SUS varied greatly with a score as low as 10/100 and as high as 77.5/100, with an average score of 47.8. Higher scores did not necessarily correlate with greater experience or comfort with technology.

Several themes began to emerge from the interviews to help in describing the overall needs of the nursing staff. These themes centered about important activities of daily living (ADLs), safety of the patient, and delivery of the data.

## Activities of Daily Living

*Nutrition*. Perhaps one of the most talked about ADLs nurses would like to know more about was nutrition. Regardless of location, nurses often wanted to know whether their clients were eating, what kinds of food they were consuming, and how their weight was trending. While current implementations of the CASAS smart home can distinguish when a person is eating or not, it does not determine what was eaten or the quality of their diet.

*Sleep*. Many aspects of sleep were important to nursing staff. These include how often a person is sleeping during the day time, how long they sleep uninterrupted at night, how many times they got up in the night, overall quality of sleep, and whether the individual has sleep apnea. Much of this is currently modeled in the smart home, but appropriate details about sleep apnea may be difficult to ascertain.

*Hygiene*. Hygiene of the elderly client was a common theme as well, such as cleanliness of the home, cleanliness of the individual, ability to dress themselves, and cleanliness of cooking or eating areas. Many of these are difficult to detect with general purpose sensors. Showering is easily covered, but cleanliness of the home and ability to dress was out of the scope of the CASAS tools.

*Socialization*. Socialization may be defined as the individual leaving the house to interact with the community, having visitors in the home, or even accepting help or care to help them with their everyday living. These things are currently being assessed by the assistive smart technologies.

*Routine*. It was very important to some nurses, and indicated indirectly by others, that a healthy older adult would take part in routines. As stated by one nurse, if an individual often goes to bed at 3am and wakes at noon, this may not be an unhealthy sleep cycle, but simply a person's normal routine. A break from routine is often a solid indicator of a change in the individual's health or well-being. Using the data gathered by the smart home sensors, the CASAS lab has made algorithms to attempt to gauge routines. Further, the question becomes which activities are most important to track.

*Activity*. Activity can be described by either overall mobility around the home, the amount a person goes out of the home, or amount an individual takes part in facility activities. For differing levels of care, activity was described differently. For independent living, this was activity in the home or leaving the home. For adult day health this was taking part in activities while in their care. For nursing care this was taking part in activities around the ward. All agree that activity is better than sedentary behavior. Activity is central to what the smart home attempts to gather.

*Emotional well-being*. Perhaps one of the most difficult things to gather information about using technology, is emotional well-being including people's depression, loneliness, and happiness levels. Nursing staff often gathered this data themselves and believed technology maybe should not attempt to gauge this key part of an individual's health.

*Quality of ADLs*. Nursing staff often indicated if a person's health is declining, the quality of their ADLs might also decline. One nurse described it as a person with a cognitive impairment might go into the kitchen and take twice as long with cooking

a meal as usual because they would often forget where they were in the process. There were also worries the system could not detect how well ADLs were being performed. Several researchers from the CASAS lab have been attempting to respond to this need, however, research on the quality of ADL performance is difficult and is still in early stages.

## Safety

*Medication*. Medication may be the second most important thing nursing staff wished to be addressed. It was important to them not only to ensure their clients take their medication on time, and take everything prescribed to them, but also that they do not take too much or take someone else's medication. Doing so might cause serious health concerns. It is often difficult for nursing staff to keep track of when patients are in independent living and adult daycare programs. Several research labs have been attempting to gather medication compliance, however, this is a very involved activity and there is as of yet no perfect solution.

*Fall detection*. Falls are of major concern for any elderly individual, because they can easily mean hospitalization, rehabilitation, and have serious potential to be fatal, especially if an immobilized individual goes undetected for an extended period of time (Simpson 1993). Effective fall detection with monitoring technology has proven to be difficult. There is no evidence of a real-world deployable solution effectively solving the falls issue at this time.

*Fall risk*. There are many things nursing staff indicated were risk factors for falls that might be able to be detected more easily than falls themselves. Nursing staff also indicated that often it was better to prevent falls than to deal with a fall once it occurred. Risk factors for falls included clutter in the homes, mobility issues for the individual, transferring problems (i.e., problems getting out of chairs/bed or into chairs/bed), and whether the individual was receiving help with the activities they were no longer able to safely do. Creating technology capable of assessing these risks and warn caregivers could be an important component to better care.

*Cognitive health*. Another difficult concept to ascertain from a smart home system is an individual's cognitive health. Cognitive problems can lead to wandering or elopement and create a myriad of problems for an individual's ADL performance. Assessing a person's cognitive capabilities is an important part of the smart homes assessment. For this reason, the CASAS lab has several clinical psychologists on staff working closely with cognitive decline in older adults and attempt to learn how to best detect the signs of a change in cognitive health through in-home sensing tools.

*Medical information*. Many nursing staff participants suggested they would like to know some sort of medical information about their patients including blood pressure, heart rate, and whether they were incontinent or not. These problems would most likely require some sort of wearable device and quality "smart toilet" devices capable of close physiological and chemical analysis of the patients throughout their day. Wearable devices have proven to be problematic, as older participants

often forget to wear them. Until a better solution is found, this data may still be left to the nurses and physicians to collect.

*Safety equipment*. To help prevent falls, increase the quality of mobility, and help patients with transferring, safety equipment is often available. However, nursing staff indicated it is not always used. The capability of a monitoring system to report safety equipment use may help caregivers determine when such devices are not employed. Smart homes currently do not track this information on a large scale. This might be an easy next step to aid in elder safety.

*Elopement*. For patients with cognitive impairments, elopement, or leaving the home or facility without reason or help, is a problem. This is especially dangerous in winter months in cold locations. It is a major concern for nursing staff, who then need to call local authorities and search the area to find a wandering patient. Detection of elopement for elderly clients with dementia or Alzheimer's would save time, money, and lives. This behavior is difficult to follow outside of the home without a wearable device. The smart home can detect when the door is opened to warn caregivers, however, this may capture times someone is leaving the house for a good reason. Further investigation to address elopement is needed.

## Delivery of Data

*Overall understanding*. Many things that make sense to researchers when displaying data do not work in real-world applications. For instance, the CASAS visualization was often criticized for lacking adequate labeling of graphs and features, using numbers making sense only to the researchers and for having axis labels that did not make sense to the caregivers. This was especially noted when using "sensor events" as a unit of measure. Nursing staff would have much preferred the use of units of time, duration of the activity, number of times an activity occurred, or percent of time in a day spent doing an activity.

*Quick visualization*. Nurses suggested because they are busy people, a quick visualization of the data they can look at and draw information from was very important. This was reinforced by the pie chart of room utilization on the CASAS visualization being the most liked source of information.

*No graphs assuming knowledge*. Many graphs created by researchers assume special knowledge. For the CASAS visualization, this was the health trend, a mathematically derived graph utilizing times out of the house, overall activity, and sleep quality. Nursing staff often disliked this graph because they did not know how the trend was derived and wanted more control over any assumptions made in its creation.

*Do not trust data*. Many times nursing staff did not trust the data to be accurate. They were not sure a computer system could correctly determine what a person was doing through sensor events and computer models. As more than one nurse put it, "What if this person is in the kitchen but they are just wandering and not doing anything in there?"

*Too much/not enough information*. For some data there was too much information, such as the health trend, where nurses did not know how to use the data.

For others there was not enough information, especially information about what things meant, how to use them, and pure numbers such as, how many times in a single night someone got out of bed or how many times a person left the house in a day. Nursing staff often suggests that they would like an access to the raw numbers without graphs.

*Alerts*. Perhaps one of the most asked for features of the current system was an alert system. Nurses described a system where they could set a threshold of behavior change and then generate an alert when criteria were met. Nurses would also like alert systems for elopement, falls, and medication changes or compliance.

*Communication with other health professionals*. A request made outside of the scope of smart home technology was a central clearinghouse for health records for their elderly clients. Some of the biggest problems for most facilities were rooted in not knowing information from all of the many doctors their patients would see, all of the medications their patients would take, and what kind of health records the individual had before they started with the local nurse's program. Effective digital patient records systems are still in development and could eventually be integrated with smart home technologies.

## Conclusion

This assessment provided a variety of areas nursing staff care about when attending to older adults. Many of these areas have been addressed by smart home development to date, are being worked on, or could be improved given this feedback. However, some areas, like detecting clutter in the home, were things that have not been addressed yet and might be new opportunities for improving smart homes in the future.

Visualization interfaces for most smart homes need to be clearer for non-researchers. They need to have metrics suited for to the job being by the end user, and aligned with the user's ability to incorporate information into their work. Sensor activities are useful for the researcher and meaningless to the nurse. There are years of research on properly depicting data for quick and accurate retrieval to be taken into account when creating such applications (Tufte 2001; Cleaveland 1985). Participatory design with the nursing staff should be used to include them in the engineering process. Nurses from a variety of locations (i.e., low income vs. high income, assistive care vs. independent care, day care vs. full time care) should be polled to ensure the best generalized design.

Assistive smart homes can be of great use to all who are involved in the care of an elderly individual. It can help to assess decline in abilities and alert caregivers to potential problems. Understanding how to make this data available and understandable for all who need it is an integral step in that process, and the users can truly help researchers to better understand how to make these tools a reality.

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