Informed Decision Making for In-home Use of Motion Sensor-based Monitoring Technologies

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Motion sensor–based monitoring technologies are designed to maintain independence and safety of older individuals living alone. These technologies use motion sensors that are placed throughout older individuals’ homes in order to derive information about eating, sleeping, and leaving/returning home habits. Deviations from normal behavioral patterns are detected using statistical analysis of activities of daily living. Sensors are linked to mobile devices and secure Web pages in order to transmit information to designated caregivers who live outside the home. It is difficult to make informed decisions about purchasing new technologies. This article describes elements for making informed decisions about purchasing motion sensor–based monitoring technologies and factors that could be used to evaluate these technologies. Case managers, physicians, nurses, and social workers may be asked to help older individuals and their families make informed purchasing decisions. Recommendations and practical tools are provided to best support these professionals in their dialog with older individuals and their families.

Key Words: Monitoring technologies, Family caregivers, Quality of life

Background

Smart homes are residences equipped with technology designed to enhance older residents’ safety and monitor their health conditions in their homes (Courtney, Demiris, & Hensel, 2007; Gentry, 2009). “Connected homes” are a class of smart home that uses monitor–response systems to enable information exchanges between end users (older individuals) who live at home and observers (caregivers or response services) who are outside of the home. There are variations of connected homes described more fully below, but there is one type, called motion sensor–based monitoring technologies, that has received significant media and consumer attention (Marsa, 2007; Olson, 2008).

Motion sensor–based monitoring technologies provide data about older individuals’ time spent in a particular area of the home (e.g., bathroom). This information can then be compared with residents’ baseline activities (e.g., number of nocturnal trips to the bathroom) to look for pattern changes and thus extrapolate health information (e.g., possible urinary tract infection). Data about residents’ mobility, toilet use, sleeping, leaving/returning,
and eating habits are transferred to designated caregivers via E-mails and text messages (Courtney, Demiris, Rantz, & Skubic, 2008). Connected homes generally do not transmit data to users’ health care providers (Courtney et al., 2008; Gentry, 2009). Motion sensor–based monitoring technologies are designed to improve the quality of life, safety, and independence of older individuals in their homes (Cook & Schmitter-Edgecombe, 2009; Courtney et al., 2007; Gentry, 2009). These laudable purposes, coupled with powerful testimonials and glowing newspaper articles, make the technology appealing (Marsa, 2007; Olson, 2008). However, it is difficult to make an informed decision about purchasing an intervention that is new, especially when the technological limitations and benefits are uncertain. The purpose of this article is twofold (a) to describe the elements necessary to make an informed decision about purchasing motion sensor–based monitoring technologies and (b) to enumerate factors that could be used to evaluate the technology in making an informed decision.

Physicians, social workers, nurses, and case managers are often asked to help individuals and their families make decisions about community-based or in-home support services. These professionals often facilitate decision making with patients or clients and families by discussing the financial implications, the appropriateness of an intervention for a particular person, and the benefits and limitations of the intervention. This article should support these professionals in helping older individuals and their families make informed decisions about purchasing motion sensor–based monitoring technologies.

### Types of Monitoring Technologies

Connected homes, also referred to as monitoring technologies, have existed since the 1990s, but consumer use has dramatically expanded only as recently as 2007 with the widespread use and availability of home-based Internet (Gentry, 2009, p. 211; Stout, 2010). The number of users is not known, but many connected home projects are under way (Erikson, Karlsson, Soderstrom, & Tham, 2004; Gentry, 2009, p. 211). Several private companies in the United States provide monitor–response systems for a monthly fee ($30–$75), although the initial purchasing fee could be as much as $8,000 (Stout, 2010, Costs section, para. 11). In addition, large private companies have recently begun developing monitoring technologies (Gentry, 2009; Stout, 2010). As seen below, the types of monitoring technologies vary considerably, ranging from video monitoring to motion sensor–based monitoring technologies (Table 1):

1. The first type of monitoring technology is a video monitoring system. Video cameras are installed in older individuals’ homes. Caregivers are able to monitor residents from off-site locations through interactive Web-based systems. If unsafe behaviors are observed, residents are contacted through home-installed loudspeakers (Gentry, 2009; Table 1).

2. Another type of connected home eliminates video cameras by using home-based sensors (smoke alarms, temperature detection, and door security switches). The sensors are linked to a central dispatcher who contacts the older person and/or sends a responder to the home if problems are detected (Gentry, 2009; Table 1).

3. There is a third type of connected home called motion sensor–based monitoring technology. This eliminates human observation altogether to maintain privacy for older residents (Courtney et al., 2007; Hensel, Demiris, & Courtney, 2006). This type of connected home relies on motion sensors linked to a computer system that collects data. Motion sensors are strategically

<table>
<thead>
<tr>
<th>Are older individuals observed?</th>
<th>Video monitoring technologies</th>
<th>Home-based sensor technologies</th>
<th>Motion sensor–based technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Generally no</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Are sensors used?</td>
<td>No</td>
<td>Generally no</td>
<td>Yes</td>
</tr>
<tr>
<td>Are deviations detected using statistical algorithms?</td>
<td>No</td>
<td>Yes</td>
<td>Generally no</td>
</tr>
<tr>
<td>Are emergency responders notified automatically?</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Are health care providers notified automatically?</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Are designated caregivers notified automatically?</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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</tbody>
</table>

The Gerontologist
placed inside cabinets, refrigerators, front doors, bedrooms, and bathrooms to derive information about eating, sleeping, and leaving/returning home habits. Deviations from normal behavioral patterns are detected using statistical analysis of activities of daily living (Barger, Brown, & Alwan, 2005; Cook & Schmitter-Edgecombe, 2009; Courtney et al., 2007; Virone et al., 2008).

These sensors are linked to mobile devices and secure Web pages in order to transmit the information to designated caregivers. Sometimes, there are interactive features, such as communication centers that enable caregivers to send messages and pictures to older individuals on a television or touchscreen. News, weather, and cognitive exercises can also be displayed on the screen, whereas health care information, including weight, blood pressure, and temperature, is collected through a server and transmitted to caregivers (Gentry, 2009). Motion sensor–based monitoring technologies can exist in assisted living facilities and skilled nursing facilities, but the primary focus for company Web advertising is the in-home setting.

### Elements to Make Informed Decisions

A fundamental tenet of informed decision making is that individuals should be able to participate in decisions about their own lives and voluntarily accept or decline the offered intervention. This would include decisions about whether to permit motion sensor–based monitoring technologies in one’s home (Jonsen, Siegler, & Winslade, 2006). Voluntariness, along with information and comprehension, are three requisites for making informed decisions about accepting or declining an intervention. Information, comprehension, and voluntariness are well understood and commonly practiced in the health care setting, but the application of these three requisites to motion sensor–based monitoring technologies is unique.

**Table 2** provides these elements and key points for discussion that could be used by health care professionals in facilitating informed decision making. This table could be used by physicians, social workers, nurses, and case managers, as these are the professionals most likely to be asked by older individuals and their families to assist in making informed decisions about motion sensor–based monitoring technologies.

### Information

This first element to making an informed decision is information. Adequate information should be available to decision makers. Although motion sensor–based monitoring technologies’ Web sites contain useful information, such as testimonials

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**Table 2. Elements for Informed Decision Making**

<table>
<thead>
<tr>
<th>Element 1: providing information</th>
<th>Practical recommendations for discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Encourage older individuals and family members to do independent research, including calling organizations, talking to friends, and talking to device representatives.</td>
<td></td>
</tr>
<tr>
<td>2. Discuss the information available on company Web sites (diagrams and testimonials) and unavailable information (costs, user-friendliness, and data sharing limitations).</td>
<td></td>
</tr>
<tr>
<td>3. Reinforce that data gathered by motion sensor–based technologies are not automatically sent to health care professionals.</td>
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</table>

**Element 2: ensuring comprehension**

Have a family meeting so that you can:

1. Assess
   - (a) Ability of older individuals to live alone with only motion sensor–based monitoring technologies;
   - (b) Ability of older individuals to participate in decision making;
2. Simplify information for older individuals;
3. Emphasize the decision is ultimately the older individual’s decision;
4. Clarify misperceptions;
5. Elucidate goals, values, and bases of decision making.

**Element 3: ensuring voluntariness**

1. Encourage family and older individuals to select a device with override settings for opting out of utilization;
2. Discuss alternatives with family and older individuals.
and diagrams, some information is not discussed that may be necessary to make an informed decision. For instance, costs or additional expenses for customizable features, assessments, training, and follow-up are not discussed on their Web sites. Furthermore, most insurance companies require a test of “medical necessity” for reimbursement of assistive technologies, so monitoring technologies are typically paid for out-of-pocket (Gentry, 2009), a point not mentioned on company Web sites.

Data output limitations and confidentiality considerations are rarely discussed on company Web sites. Although data gathered could be used to extrapolate protected health information that could be ethically and legally abused by monitoring personnel or device representatives, confidentiality assurances are generally provided only in the context of third parties who are not family or company personnel. Furthermore, such personal information could conceivably be used for criminal means, such as knowledge about older individuals’ leaving/returning behaviors, but safety protections are rarely discussed.

Physicians, social workers, nurses, case managers, and families could supplement information provided on the Web with information gained through their own research conducted by calling company representatives, talking to someone who owns the device, consulting organizations or societies, or searching independent reliable Web sites (Table 2). Community senior centers and organizations may have members who are current users of sensor-based monitoring technologies.

Comprehension

The second element for informed decision making is comprehension. To make an informed decision about accepting or declining an offered intervention, one must be able to comprehend the information provided. This would include the ability to synthesize information about an intervention’s purpose, benefits, limitations, and alternatives, as well as the ability to apply the information to one’s values and goals and articulate the basis for and consequences of the decision (Jonsen et al., 2006).

Override settings, available at a higher cost, may be used so that older individuals can disconnect monitoring technologies if they no longer voluntarily wish to have them in their homes (Courtney et al., 2007). By encouraging older individuals to make decisions that are genuinely their own, social workers, physicians, nurses, and case managers could facilitate making an informed decision about purchasing motion sensor–based monitoring technologies.

Factors for Evaluating Motion Sensor–Based Monitoring Technologies

Assuming voluntariness, information, and comprehension are present to make an informed decision,
it is important to consider the bases to make an informed decision. Three factors (motion sensor–based monitoring technology’s effectiveness, its ability to improve quality of life, and its obtrusiveness) can be evaluated and weighed in selecting a system that is most appropriate for the older individual. These factors are based on the individual’s subjective evaluation of the factors.

If a cognitively intact person voluntarily decides to accept or decline monitoring technologies after receiving full information and evaluating the three factors, then this decision should be respected, even if others do not agree with the decision. If the older person is unable or unwilling to evaluate these factors, then a close family member acting as a surrogate decision maker on behalf of the older individual could help reach a conclusion in keeping with the person’s values, goals, and preferences (Figure 1).

**Effectiveness**

One major factor that should be evaluated in selecting a system is their mechanical effectiveness. The effectiveness of motion sensor–based monitoring technologies is debatable. On the one hand, several academic projects in Japan, Europe, and the United States have sought to maximize motion sensor–based monitoring technologies’ mechanical effectiveness with promising results (Chan, Campo, 2012).
Esteve, & Fourniols, 2009). Previously, movements of professional caregivers, pets, roommates, or visitors were mistakenly attributed to behavioral patterns of older individuals (Virone et al., 2008). Although such compromises in data integrity still occur, glitches have become rare as a result of technological improvements (Table 3).

On the other hand, a significant, but often unacknowledged, functional limitation is that motion sensor–based technologies can only identify the amount of time older individuals spend at a particular location, not their specific activities (Gentry, 2009). As a result, caregivers may become unnecessarily worried or take false comfort in their assumptions about older individuals’ activities. For example, a caregiver might believe that an older resident ate lunch when transmitted information indicates that the refrigerator door was opened for several minutes when, in actuality, the older person opened the door, found nothing appealing, and chose not to eat lunch (Table 3).

It is important for social workers, physicians, nurses, and case managers to be familiar with current limitations and promising developments and able to discuss them when assisting older individuals and families in selecting a system. If, in weighing these considerations, the older person, or surrogate decision maker, determines that the monitoring technology is ineffective, it probably should not be used. This is because technologies were designed to promote safety and self-efficacy in the home. If it cannot do that for which it was designed, then its use cannot easily be justified. If, on the other hand, it is judged to be effective without a corresponding decrease in quality of life or significant increase in obtrusiveness (discussed below), it could be used (Figure 1).

**Obtrusiveness**

An additional factor to be used in evaluating motion sensor–based monitoring technologies is obtrusiveness. Obtrusiveness has been defined as something that is both undesirable and physically or psychologically prominent according to a user’s subjective perception, including: (a) physical dimensions, which encompasses characteristics such as physical discomfort, dependence, and movement impediment; (b) usability, including lack of user-friendliness or demand on time/effort; (c) privacy dimensions, which refers to a perceived invasion of personal information or perceived violations of physical self; and (d) functional dimensions, demonstrated by perceptions of malfunctions or lack of usefulness (Courtney et al., 2007).

The obtrusiveness of the device should be no greater than is necessary to account for the needs of the older individual (Figure 1). An assistive technology that is not narrowly tailored to the needs of the individual may be considered excessively obtrusive, burdensome, and perhaps inappropriate.

Social workers, physicians, nurses, and case managers could learn about older individuals’ and families’ evaluations of obtrusiveness by discussing particular technological features: (a) Is the device removable? (b) Does the device have override settings that allow users to opt out of the monitoring? (c) Can the device be customized for individual preferences? (d) Is the device as minimally intrusive as possible? (Gentry, 2009; Wild et al., 2008).

Motion sensor–based monitoring systems are, by their very design, at least minimally obtrusive because they are monitoring devices. The question of whether monitoring technologies are appropriate for a specific person is not whether there is obtrusiveness, but rather, how much obtrusiveness is involved (Figure 1). The more obtrusive the device is, the greater the technological effectiveness and improvement in quality of life should be. Because sensor–based monitoring technologies provide the most privacy of all of related monitoring technologies, obtrusiveness should not be a significant issue (Table 3).

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<th>Benefits</th>
<th>Limitations</th>
</tr>
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<tbody>
<tr>
<td>Factor 1: effectiveness</td>
<td>- Compromises in data integrity are rare</td>
<td>- Can only detect the amount of time an older person spends in a room, not the person’s activity.</td>
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<td>Factor 2: quality of life</td>
<td>- Users’ testimonials note improvement in quality of life</td>
<td>- In studies involving older individuals (prospective purchasers), participants cite lack of usefulness.</td>
</tr>
<tr>
<td>Factor 3: obtrusiveness</td>
<td>- Offers more privacy than related monitoring technologies</td>
<td>- Typically, data are not sent to health care providers or emergency personnel.</td>
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Quality of Life

A third factor that should be evaluated in selecting an appropriate system is the impact the technology will have on the older person’s quality of life. Monitoring technologies’ effectiveness and obtrusiveness are components of a quality of life assessment. For instance, significantly obtrusive monitoring technologies will not, on average, improve quality of life and, therefore, should not be used in most circumstances (Figure 1). But quality of life is a broad concept and can include considerations other than just effectiveness and obtrusiveness, such as the impact the monitoring technology has on someone’s independence, self-esteem, or daily tasks. Quality of life assessments are driven by considerations most important to the individual and should be in keeping with one’s values, goals, and preferences.

Glowing testimonials on company Web sites suggest that many current users and their caregivers perceive an improvement in quality of life. However, because data sharing is limited to family, the need for a pragmatic justification is often desired by research participants who are prospective users of the technology (Botsis, Demiris, Pedersen, & Hartvigsen, 2008; Courtney et al., 2008; Demiris, Hensel, Skubic, & Rantz, 2008; Mihailidis, Cockburn, Longley, & Boger, 2008, Wild et al., 2008; Table 3).

Given that current users and prospective users disagree about the impact motion sensor–based monitoring technologies have on quality of life, case managers, physicians, nurses, or social workers might suggest that older individuals try out the technology for a short time before making a final decision. If the older person or surrogate decision maker determines that the monitoring technology decreases quality of life, it probably should not be used. This is because a perceived decrease in quality of life would violate the technology’s intended supportive function. Just as with effectiveness, if the technology cannot do that for which it was designed, it seems impractical to use it (Figure 1).

Implications for Future Research

Existing literature on smart homes focuses on the benefits of the technology but pays little attention to users’ concerns, perceptions, or needs (Courtney et al., 2008). Data regarding the number of current users and the environments in which they live are also critical and timely in order to mitigate potential abuse. One environment in which potential abuse might occur is the assisting living facility setting. For instance, management of assisted living facilities might install motion sensor–based monitoring technologies in their residents’ rooms without seeking the agreement of residents. If assisted living facilities’ residents do not voluntarily agree to have the technology in their rooms, it would likely be inappropriate to use the technology for reasons enumerated above. Without some sense of the number of users or their environments, potential abuse may be unrecognized or underestimated.

One way to determine whether potential abuse exists is to develop empirical studies that would assess whether and how surrogate decision makers make informed purchasing decisions about motion sensor–based monitoring technologies. Do surrogate decision makers assess whether older individuals are able to fully comprehend and process information about the technology? A related project might assess how surrogate decision makers evaluate effectiveness, obtrusiveness, and quality of life and determine whether this coincides with health care professionals’ evaluations of the technology.

Conclusions

Monitoring technologies have undergone significant design improvements as a result of research studies conducted at academic facilities in Europe, Japan, and the United States (Chan et al., 2009). With increasing design improvements, large private companies have either launched or are in the process of developing motion sensor–based monitoring technologies for consumer use.

However, as with any new intervention, it may be difficult to make an informed decision about whether to purchase the technology. Case managers, physicians, nurses, and social workers may be called upon by older individuals and their families to help them think through the implications of purchasing motion sensor–based monitoring technologies. Toward the goal of familiarizing health care professionals with motion sensor–based monitoring technologies and supporting them in facilitating informed decision making, this article discussed purposes, limitations, and benefits of the technology. It also underscored three elements to making an informed decision and three bases that could be used to evaluate monitoring technologies. To this end, this article provided recommendations and practical tools...
for these professionals to best support them in their dialog with older individuals and their families about purchasing motion sensor–based monitoring technologies.

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References


