Designing a Smart Watch Interface for a Notification and Communication System for Nursing Homes

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Abstract. Among the unique challenges faced by nursing homes is poor communication and notification. An analysis of the work system showed that a mobile device-based system that rely less on auditory display is promising. We proposed a smartwatch interface as part of communication and notification system for nursing homes. A user-centered design approach was adopted in the design and evaluation of the interface. The application integrates call light system, chair and bed alarms, wander guard, and calling for help functions and uses multi-modal interfaces to provide informative alarms for nursing home staff. Through a process of iterative testing and refinement with prospective users (through cognitive walkthrough, heuristic evaluation and usability testing of low-fidelity prototypes), a final design was well received by nursing experts in geriatric care and at local nursing homes. The effects of the system will be tested in the future using a high-fidelity prototype through simulation experiment.

Keywords: Nursing homes · Smartwatch · Interface

1 Introduction

The number of Americans elderly over the age of 65 is expected to increase form 40.2 million in 2010 to 88.5 million in 2050 [1]. This means there will be an increase in the need for long-term care services and facilities, such as nursing homes. Nursing home residents usually have physical or cognitive impairment, and complex health conditions, and thus are at high risk of medical errors and adverse events [2], such as falls. For example, one-in-three residents in nursing homes suffered from a medication error, infection or some other type of harm related to their treatment. A typical nursing home with 100 beds reports 100–200 fall annually [4], and about 1,800 older adults living in nursing homes die from fall-related injuries each year [5]. Nationwide, there is a growing concern about the quality and safety of residents in nursing homes [6].

One contributing factors to those events is the poor communication and notification system in nursing homes. The aim of this paper is to design a smartwatch interface for a notification and communication system for nursing homes, as a part of a multidisciplinary project "developing a fall prevention and notification system for nursing homes" [22, 23].

1.1   Mobile Devices in Healthcare

In healthcare settings, different mobile technologies have been used for communication, including mobile phones, smartphone, and hands-free devices [7]. Hands-free communication devices were proposed and implemented in healthcare settings to improve the communications efficiency and nursing workflow [8, 10]. Hands-free communication devices were introduced to the healthcare industry because of their light weight, and are intended for verbal communication through local network. Those devices allow the user to freely use his or her hands while communicating [9]. One example of such hands-free devices is Vocera. It is a simple touch device worn around the user's neck. The user can make calls by simply saying the name of the recipients [10, 11]. Despite of the promising features, literature showed negative effects of using this type of hands-free devices, such as the potential loss of control, reliability, and some technical issues, such as dropped calls, poor reception, and communication privacy and confidentiality [9, 12, 13]. Smartphones have also been used for communication in healthcare. One study found that using the smartphones can actually reduce physicians' response time compared with using pagers [14]; other studies found that using the smartphones for communication improved the perception of the users of an effective communication, increase the staff satisfaction, and made them believe the work is easier and more efficient [15, 16].

The Smartwatch is a new type of mobile and wearable devices. The primary use has been monitoring exercises and collecting biometric data, such as steps, distance, and calories consumption [17]. Smartwatch offer more convenient way of direct monitoring, and its acceptance by everyone [18]. Smartwatch have also been used as a continuous monitoring device in health care settings. For example, Samsung Gear smartwatch was used to monitor heart rate using the multi-sensors embedded in the watch and send the information to a host through a wireless networks [19]. It was used for patients with advanced Parkinson's disease, who are at high risk of falls. Those patients need a real-time gait monitoring to reduce the chance of falls. Smartwatch serve as a promising candidate of the monitoring device because it is easier to wear than other sensors placed at foot, ankle, and thigh [20]. Epic Haiku app, developed for Apple iWatch, notifies doctors about lab results and provides doctors with access to patient's information [27]. AirStrip, another app for iWatch, allows doctors to remotely monitor their patients by receiving a real-time stream of that patient's vital signs [29]. Although the application of smartwatch in healthcare industry is at its early stage, but the literature shows it is promising especially in communication, and it can improve the efficiency of workflow. Smartwatch allows staff such as nurses to use voice control while navigating the interface, send updates quickly, and receive alarms on different types of events [28]. This way nurses will always have access to up-to-date critical information about patients' conditions, without compromising any comfort as smartwatch are socially acceptable and comfortable to wear [21]. This is why we chose smartwatch as the mobile device for the proposed communication and notification system.

2 Methods

A User-Centered Design (UCD) methodology was used in consultation with healthcare professionals at local nursing homes. We began by interviewing clinical nursing professors who have extensive experience with nursing homes, and nursing home staff such as registered nurse (RNs), certified nurse aids (CNAs), unit managers and other administrative staff. We also conducted observations in local nursing homes to analyze the work system and identify human factors challenges in fall prevention. We particularly paid attention to the call light systems and how staff interacts with the system. The analysis of the work system showed that a mobile device-based system that relied less on auditory displays would be necessary for communication and notification in nursing homes. We chose smartwatch as the mobile device because of hands-free, personal, and wearable nature. The analysis also helped us define the types of tasks the smartwatch should do/provide, the action sequences, specific flow of alarming process, and level of information that should be provided with each alarm. The details of the interviews and observations can be found in [22]. In this and next section, we only provide the most relevant information.

2.1 Observations

A structural observations were conducted in four nursing homes in upstate New York. Three of the facilities were proprietary, one was public, and one was voluntary. The number of beds ranges between 150–380 beds. The authors conducted around 200 h of observations during the three shifts to collect information about (1) general information about the units such as the layout, (2) the type of call light systems each nursing home use, (3) how the system notify the staff about a call light, (3) how the staff locate the room of call light, (4) how the staff is notified about other alarms in the unit, and how they locate the alarms, (5) the call light system and other alarms in use to identify usability issues. During the observations, detailed notes were taken using a notebook, and then transformed into an electronic version immediately. Then the data were analyzed and sorted into themes.

2.2 Iterative Design

We used an iterative design and evaluation approach. Three iterations were completed. For each iteration, we used heuristic evaluation and cognitive walkthrough to evaluate the prototype. The first two prototypes were generated using PowerPoint, and the third one was made using InVision. A paper prototype was made based on the first design and was evaluated and tested by the research team using a real scenario. A brain storming session was conducted with the research team to discuss all the issues identified with the first prototype. The design was modified and improved and then tested again. The second design was tested with a nursing student who had experience working in nursing homes, and a nursing professor has extensive clinical and research experience with geriatric care particularly in nursing home care. Significant changes to the display design were made after the second iteration (see Smartwatch Interface section). For the third

iteration, we transformed our static screens into an interactive interface using InVision. The prototype was then evaluated by the team, and by the same nursing professor.

2.3 Cognitive Walkthrough

In a cognitive walkthrough, the "user" interacted with the design to explore the product and to identify factors that contribute to errors. The cognitive walkthrough consists of six steps: (1) to develop full understanding to users knowledge, (2) to identify the tasks they perform, (3) to create a detailed scenarios about the tasks, (4) To walkthrough the correct action sequence to finish the task, (5) to identify the cognitive process the users need to go through to accomplish the tasks successfully, (6) identify the learning and adaptive responses while doing the tasks [29].

Cognitive walkthrough was completed using paper prototypes and a case scenario. The scenario was done in unit with an L-shape hallway. The unit had 36 residents, 4 CNAs and 1 LPN. Each CNA was assigned 9 residents. The scenario specified the location of each one of the residents in the floor. The subject played the role of a CNA and was assigned 1 resident with a bed exit alarm, 4 with a chair exit alarm. The subjects had multiple tasks that required responding to 2 bed exit alarm, 3 chair exit alarm, and 5 call lights from the bedroom, 1 call light from the bathroom, and 1 fall incident.

3 Results

3.1 Observation Results

Nursing homes usually use many fall-prevention technologies, that send an alarm to notify the nurses about the residents conditions and if they are at risk of fall. Chair pads and bed mats are thin sheet with pressure sensors, which are able to send an alarm when the residents attempt to stand or exit bed [22]. Clip alarm, is a string clipped to the shoulder of a resident's shirt. When the residents' trunk moves forward while sitting, the string will pull the magnet off the base and trigger the alarm.

In addition to the sensors above, the call light system is another notification system extensively used in nursing homes. The call light system consists of an auditory alarm broadcast at the nurse station or loudly from speakers at different locations of nursing homes to inform the nurses of a call light, and a light with two parts (a white light to indicate call light from the bedroom, and a red light to indicate call light from the bathroom) above the door to each resident's room to help the nurse to locate the room of alarm. One of the nursing homes is using a console placed at nurse station, this console is able to display the room number to help the nurses in locating the room more easily. Another one is using pagers that displays call lights and room numbers.

Many human factors challenges are associated with those systems. Noises from the auditory systems are almost constant. This causes discomfort of the residents and the staff. Staff can also develop alarm fatigue and thus tend to ignore the alarm as they assume resident do not need. With a system that use only auditory alarms at the nurse station instead of broadcasting the alarms, the noise is less in the unit, however the response time to call light is long because the nurse station is not staffed most of the

time. Using a pager can reduce the noise and also display the room number, but nursing home staff is always busy providing service for residents, and they cannot grab the pager to see the room number. In most the nursing homes, CNAs tend to locate the room by looking at lights on the top of the doors, which is also challenging at times due to the layout. Nurses and CNAs have to walk to the middle of the hallway to see the light because of beams and door frames block some lights from being seen.

Call light systems in nursing homes also have many usability issues. All the call light system that were observed provide an auditory signal, but none of them provide any directional information for the staff [22, 23]. In addition, the auditory signal does not distinguish call light from the bedroom from call light from the bathroom, which is often represents more urgent needs. In one of the nursing homes, they use a console at the nurse station that has a display, but it can only display one room number at a time. In case of new alarm comes in, it will "cover" the pervious room number from the display and keep the newest one without any indication of the previous ones. Chair and bed mats have similar usability issues: lack of directional information, nuisance alarms and false alarms.

In summary, the staff are always busy taking care of residents thus are not hands free. They have difficulties hearing the auditory alarms, particularly from the end of the hallway. The nurse station is not always occupied, thus a central display may not work for monitoring. Smartwatches can be a creative solution for most of the problems and issues associated with call light system, and the communication breakdowns in nursing homes.

3.2 Proposed Design

We proposed a system for fall prevention and notification in nursing homes. The system uses smart sensors for predicting falls by detecting resident's intention to stand up at its early stage (see details in [23]) and includes a central display and smartwatch interfaces to present this and other alarms. The alarms include chair pads and bed mats, call lights, wander guard system, and clip alarms. They will be sent to a server in the facility then displayed based on the nature and time.

3.3 Smartwatch Interface

Design Version One. The representation of any alarms on the smartwatch (Fig. 1A) displays information about the resident, type of alarm, room number, time passed after the alarm was triggered, and the assigned CNA. The smartwatch will also present an auditory signal and a vibrotactile signal to inform the CNA of any new alarm. The CNA will be instructed to look at his/her watch to locate and identify the alarm. The display size was designed based on Samsung Gear S2 smartwatch. Three alarms can be displayed at the same time, since it is not common to have more than three alarms at the same time. CNAs can delete the alarm by swipe the alarm message to the left or to the right. After several brainstorming session with the research team/the observers at nursing homes, we added a feature that informs the CNA about her assigned residents by highlighting

the name of the CNA first (Fig. 1B). This then was changed to highlighting the entire message to become more salient (Fig. 1C).
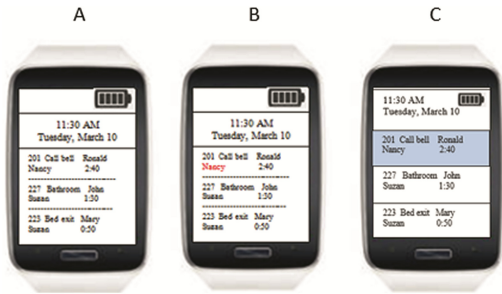

Fig. 1. Smartwatch display design. Version one, first Stage

A cognitive walkthrough was conducted to evaluate the paper prototype of the first version of the proposed design. With a case scenario, feedback was collected on the size of the smartwatch, whether the displayed information was enough and clear to be understood by the CNAs, the logic of the action sequences, and the specific flow of alarming process.

One important comment from the cognitive walkthrough was to add an icon that represents each type of the alarms to support at-a-glance monitoring. A brainstorming session with the team was conducted again, the icons were chosen and placed at the middle of the alarm message first (Fig. 2A) then they were moved to the right or to the left side of the message (Fig. 2B), and then the team decided to be consistent with the different smartphones in the market, and place the icons at the left side of the alarm message (Fig. 2C). In addition to the position of the icons, the team decided to highlight the chair exit alarm since it is very critical one and to make it more noticeable by the CNAs.
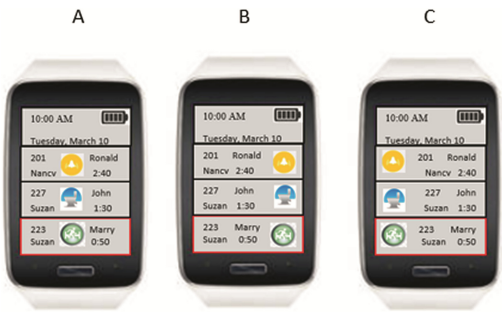

Fig. 2. Smartwatch Design. Version one, second stage

Design Version Two. The second paper prototype was prepared, and tested using a real case scenario from one of the team members based on their experience in nursing homes. Many usability issues were identified at this stage such as lack of error tolerance

if the user deleted the wrong alarm; too many highlighted alarm messages in the display (assigned residents, bed exit alarm) which might confuse the CNAs; lack of solution for more than three alarms; and what if one resident need something urgent and pushed the call light again. A few significant changes were introduced to the design. A scroll down/scroll up feature was added in case there were more than three alarms at the same time (Fig. 3A and B). In addition to adding the option of using the call light for a second time after certain wait time, a second timer was added, which would flash to be more salient (Fig. 3C). A confirmation message was added when deleting an alarm to reduce the chance of deleting another alarm by mistake. The color of the bed exist alarm icon was changed to be red because it is one of the most urgent alarms in nursing homes (Fig. 3D). Three different auditory alarms and vibro-tactile signals will also be used for notifying CNAs about different events such as bed exit alarm, chair exit alarm, and call bell alarm.
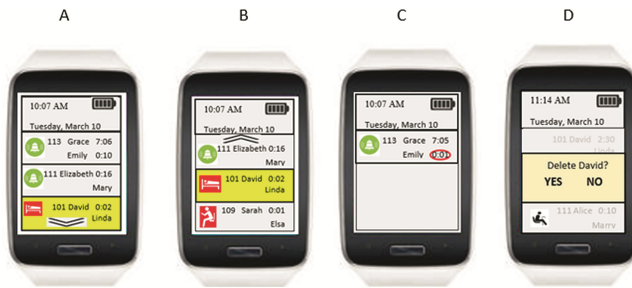

Fig. 3. Smartwatch design. Version two

The third paper prototype was created and tested by experts in nursing home care.. The prototype was tested by nursing students who already had experience working in nursing homes, and faculty members who had extensive clinical and research experience with nursing home setting. Cognitive walkthrough was conducted with the participants using specific tasks designed based on work scenarios observed in nursing homes. Participants were also asked specific questions about their understanding of the alarms and the events through the scenario. Based on the evaluation process and their own clinical experience, the participants suggested that the icons for both bed and chair exit alarm should be red and they should look the same since both indicate urgent nursing alarms (Fig. 3B).

Design Version Three. The third version of the design was well received by nursing experts in geriatric care and staff at local nursing homes. They suggested that the smartwatch be used for more communication and notification functions, such as the Wander Guard system, contacting colleagues, and calling for help. The new design shown in Fig. 4 includes a main display that consists of icons of all functions, including (1) "Assignment" that allows CNAs choose residents assigned to him/her; (2) "Alarms", for informing and notifying CNAs about different call bells and nurse alert alarms; (3) "Contacts" that contains all important phone numbers; (4) "Wander Guard" for notifying about residents who might be exiting the building; (5) "Help", with which CNAs can

send a message calling for help from other CNAs; and (6) "Emergency", for notifying the staff about any emergency in the facility such as a fall.

Fig. 4. Smartwatch design. Version three

When the staff receive their smartwatch at the beginning of the shift, the first step is to sign in to their account. They will fist click on the 'Assignment' icon to open the resident list, and choose their assigned residents by clicking on their names, and then done to exit the 'Assignment' App. Any new alarm, emergency, or any notifications will be appear at the upper left corner of the screen (Fig. 5A). The CNA then would need to swipe down to open the new notification, or she can click on the icon for App. For example, if she received an alarm about a fall, she can swipe down or she can click on the "ER" icon to see more details about the incident (Fig. 5A and B).

Fig. 5. Smartwatch. Version three

The "Alarm" App will be used to notify the staff about any alarm in their unit, such as chair/bed exit and call lights. It will display all the alarms in the unit and highlight alarms from residents assigned to the CNA who uses the App. This highlighting is customized for each user. Each staff member is supposed to respond to any alarms in the unit, no matter whether the resident was assigned to them or not. So, the same auditory sound will be used to notify the CNA about all the alarms in the unit, with only different sound for the bed or chair exit as they are considered more urgent.

The 'WG' App notifies the staff about any residents who wear an ankle band approaching exits or exiting the building. In the current system, when a resident with high risk of wander is close to an exit when the exit door is open, a very loud auditory

alarm is triggered and can be heard throughout the entire unit or floor. Sending the signal to the watch can again help reduce noise level.

The 'Contact' App will provide the speed dial for all the important contacts in the facility such as the RN on duty, unit manager, physician, or the administrators. The staff can use voice command to call in case of emergency.

'Help' App. will be used to ask for help in the same unit. It was observed in many cases CNAs looking for help from another staff member in the unit, (e.g. asking for help in using lifting machine). CNAs can use voice command after clicking on the icon to send the room number. A message will be sent to all the staff in the unit (Fig. 5C).

4   Conclusions

Poor quality of care and safety in nursing homes is an ongoing problem that is growing nationwide [6, 25, 26]. Poor communication is found to be a major contributor to errors that affect safety and quality of care. Effective staff-resident communication, sharing patient's data, and collaboration among the staff were found to be important in improving the outcomes. Smartwatch are hands-free devices that facilitate communication and notification in nursing homes. We designed a smartwatch interface as part of a communication and notification system for nursing homes. The interface presents informative visual, auditory and tactile alarms on various types of events to the user without causing too much noise for non-users (the residents or other staff members). It allows the staff to access the right information at the right time, and to be informed about the residents' conditions and any updates on their condition all the time, to be informed about any adverse events or alarms in the unit, and to communicate with their colleagues.

The effects of the system will be tested using a high-fidelity prototype through simulation experiment. Nursing home staff such as CNAs will use the smartwatch and receive alarms while performing hypothetical tasks. Their behavior, particularly response to alarm messages, will be recorded and analyzed. The system is expected to reduce response time to call lights and other alarms, and help nursing home staff to manage interruptions such as call light requests, and prioritize multiple ongoing tasks.

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