# Taking the Time to Care: Empowering Low Health Literacy Hospital Patients with Virtual Nurse Agents

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**ABSTRACT**
Ninety million Americans have inadequate health literacy, resulting in a reduced ability to read and follow directions in the healthcare environment. We describe an animated, empathic virtual nurse interface for educating and counseling hospital patients with inadequate health literacy in their hospital beds at the time of discharge. The development methodology, design rationale, and two iterations of user testing are described. Results indicate that hospital patients with low health literacy found the system easy to use, reported high levels of satisfaction, and most said they preferred receiving the discharge information from the agent over their doctor or nurse. Patients also expressed appreciation for the time and attention provided by the virtual nurse, and felt that it provided an additional authoritative source for their medical information.

**Author Keywords**
Universal Access, Relational Agent, Embodied Conversational Agent, Health Literacy, Patient Education, Patient Safety, Hospital Discharge

**ACM Classification Keywords**
H5.2 [Information Interfaces and Presentation]: User Interfaces—Evaluation/methodology, Graphical user interfaces, Interaction styles, Natural language, Theory and methods, Voice I/O. J.3 [Computer Applications] Life and Medical Sciences – Health.

**INTRODUCTION**
Being a hospital patient is one of the most dis-empowering situations one can experience in modern society, and very little research has been done to date on systems to provide information to patients while they are in their hospital beds. Hospital discharge represents a significant transition that, while typically only lasting less than 8 minutes, is intended to transform patients from completely passive recipients of care to being completely responsible for all aspects of their health care. Post-hospital discharge self-care regimens are typically complex, with the average patient being discharged with ten medications and multiple follow up appointments. The discharge is even more hazardous for patients who have difficulty reading and following basic written medical instructions; a condition referred to as inadequate health literacy.

In collaboration with a medical research team at Boston Medical Center, we have developed an automated system that teaches patients about their post-discharge self-care regimen while they are still in their hospital beds. In order to make the system as acceptable and effective as possible, we designed the interface to incorporate an animated virtual nurse (VN) who embodies best practices in health communication for patients with inadequate health literacy. The VN is deployed on a wheeled kiosk with a touch screen display attached to an articulated arm that can be positioned in front of patients while they are in bed (Figure 1). The VN spends approximately half an hour with each patient, reviewing the layout and contents of an "After Hospital Care Plan" (AHCP) booklet that is produced for them and contains their personal medical information. The paper booklet is given to patients before their conversation with the VN, and the VN reviews a digital version of the booklet in the interface, so that patients can follow along with the agent's explanation in their paper booklets.

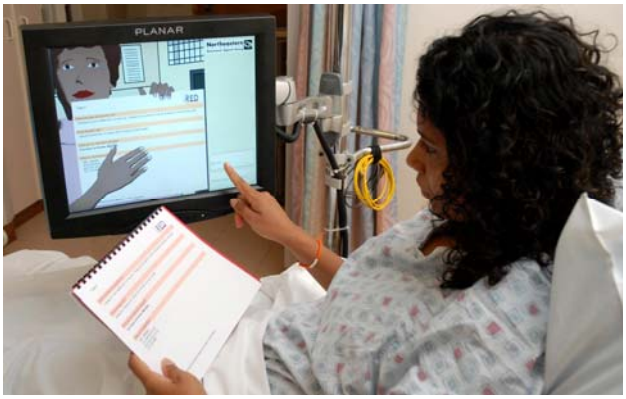


**Figure 1. Patient Interacting with Virtual Nurse**


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### Health Literacy

Health literacy is the ability to perform the basic reading and numerical tasks required to function in the healthcare environment [1]. Health literacy is not simply the ability to read; it also requires a complex set of analytical and decision-making skills, and the ability to apply these skills to health situations. Fully 36% of American adults have limited health literacy skills, with even greater prevalence among patients with chronic diseases, those who are older, and those who have lower levels of education [25]. Among indigent and minority patients in urban areas this number rises to over 80% [34].

Although our system is designed to address the particular needs of patients with inadequate health literacy, we anticipate that, as with many advances in universal access, it will prove beneficial for all patients, regardless of health literacy level. At least one study has shown that when medical instructions are designed for patients with inadequate health literacy, all patients benefit from the improved clarity.

### Hospital Discharge

The hospital discharge process is the source of many medical errors and, until recently, had no national standards or guidelines in the U.S. Approximately 20% of patients discharged from hospitals in the U.S. suffer adverse events and are re-hospitalized within 90 days, and approximately one third of these complications are preventable [14]. Among the leading reasons cited for these preventable complications are inadequate patient health literacy [2], patient lack of understanding of how to take their medications or of medication side effects, and low patient adherence to treatment regimens. The poor preparation of patients for hospital discharge is highlighted by studies showing that less than half of discharged patients know their diagnosis or the purpose of their medications [21].

Beginning in 2004, a team at Boston Medical Center developed a "re-engineered" hospital discharge process" that was the basis for a new national standard. This process has been specially designed for patients with inadequate health literacy, and includes extensive patient education about their diagnosis, medications, follow-up appointments, pending lab tests, and other self-care procedures, through both face-to-face consultation with a nurse and the development of the AHCP booklet. In a clinical trial involving 749 patients, this new process was found to decrease hospital and emergency room re-admissions by 30% [20]. However, one roadblock to disseminating this process to other hospitals is that it takes up to one additional hour of a nurse's time to thoroughly review all required information with each patient at the time of discharge, so development was begun in 2005 to design an in-hospital, automated patient education system.

### Embodied Conversational Agents for Patient Education

Evidence suggests that face-to-face encounters with a health provider—in conjunction with written instructions—remains one of the best methods for communicating health information to patients in general, but especially those with inadequate health literacy [24]. Face-to-face consultation is effective because it requires that the provider focus on the most salient information and that the information be delivered in a simple, conversational speaking style. Protocols for grounding in face-to-face conversation allow providers to dynamically assess a patient's level of understanding and repeat or elaborate information as necessary [10]. Face-to-face conversation also allows providers to explicitly ask patients to do, write, say, or show something that demonstrates their understanding [13]. Finally, face-to-face interaction allows providers to use verbal and nonverbal behaviors, such as empathy [15] and immediacy [27], to elicit patient trust, enabling better communication and satisfaction. Clinicians also make extensive use of pointing gestures when explaining written materials to patients in order to clarify references and describe the structure and layout of the text [6].

Given the affordances of face-to-face consultation, one technology that shows particular promise for conveying health information to patients with inadequate health literacy is the use of an embodied conversational agent (ECA) that simulates face-to-face conversation with a nurse. In addition to the use of the communicative behaviors listed above, they can adapt their messages to the particular needs of patients and to the immediate context of the conversation. This interactivity and tailoring to each patient's unique medical information and needs makes ECAs far more effective than simply playing recorded video clips. ECAs can also provide health information in a consistent manner and in a low-pressure environment in which patients are free to take as much time as they need to thoroughly understand it and to ask as many questions as they like. ECAs can also consistently evaluate patient comprehension of the material presented. Physicians infrequently evaluate patients' understanding, and when they do it is mostly to simply to ask "do you understand?" without waiting for a reply [29].

## RELATED WORK

In recent years, the HCI community has produced many technologies to promote health and wellness for non-hospitalized individuals, including diet and exercise tracking and promotion (e.g., [4]), and tracking of physiological measures for chronic disease self-care management. Many technologies have also been developed for both home-based and institutional eldercare (e.g., [28]). Within the hospital environment, most HCI research has been clinician-centric (e.g., [33]). One exception is a series of systems by Bers, *et al.* that provided immersive multi-user collaborative support environments for pediatric patients with renal and cardiac diseases [3], and other conditions. However, none of these in-hospital interfaces were designed for post-discharge self-care education, and none of the health or wellness interfaces were designed specifically for patients with inadequate health literacy.

Within the medical community there are many in-hospital patient interfaces developed for medical interventions, such as VR-based analgesia [19]. Medical researchers have also developed several health education kiosks for placement in public spaces or clinic waiting rooms. Of particular relevance is a waiting room touch screen kiosk for diabetes education, designed to accommodate patients with inadequate health literacy [17]. The system featured simplified navigation buttons and multimedia educational content and testimonials tailored to users' prior computer experience, learning styles and ethnicity. While this system was found to be fairly easy to use (65.0% for inadequate health literacy users vs. 87.5% for adequate health literacy participants), its use did not lead to any significant differences in diabetes outcomes, compared to a control group, and the authors did not describe what design features they specifically included to address health literacy issues.

Since users of our system have to be able to read their AHCP booklets, they are required to have a minimal level of English reading literacy ("ability to read a newspaper"). However, design guidelines and lessons learned from interfaces for illiterate and semi-literate users are relevant. Medhi, *et al.* suggest using semiabstract graphics (cartoons), voice feedback, and greatly simplified navigation [22], and Ghosh, *et al.* suggest keeping digital representations of paper forms as close in appearance to the real artifacts as possible [18], all of which we have incorporated into our design.

### Embodied Conversational Agents (ECAs)

There is now a significant body of literature on the design and evaluation of ECAs (for overviews, see [9,31]). The effect of simply adding a character or face to an interface seems to provide stronger subjective than objective results, and both of these effects are fairly weak [35]. However, the use of particular verbal and nonverbal behavior by an ECA to achieve specific outcomes while maintaining intuitive appeal and rapid interface learnability continues to motivate the use of ECAs for many applications.

Pedagogical ECAs have been used as instructors for a wide range of topics, including plant biology [23], physics, and computer literacy [26]. Some researchers have shown positive learning outcomes when students interact with a pedagogical ECA compared to students who learn without an ECA [23,26].

Bickmore, *et al.* have explored the use of ECAs in health behavior change interventions for exercise [4,7] and medication adherence [5], both of which had significant patient education components. One of these systems is particularly relevant to the current effort because it involved a subject population comprised of older adults (63-85) who had low levels of reading and computer literacy [4]. Participants randomized into the intervention condition interacted with an animated exercise advisor agent daily on a touch screen home computer for two months. Results showed that all intervention users found the interface easy to use, reported high levels of trust in and liking of the agent, and walked significantly more than those randomized to a control condition.

## DESIGN METHODOLOGY

Our multi-disciplinary design team comprised HCI researchers, doctors and nurses, a health literacy expert, and programmers and animators. The design process, from project start to completion of the user studies, lasted three years.

We used a multi-faceted approach to designing a system that would effectively teach patients, including those with inadequate health literacy, about their hospital discharge instructions. We began our design process with an ethnographic study of the re-engineered hospital discharge intervention that was currently underway in the hospital. Members of the design team visited hospital rooms, attended rounds with the medical team, observed discharge sessions in which nurses taught patients about their AHCP booklets, and interviewed the nurses who were performing this task. From these activities we learned about the stakeholders and basic workflow requirements of the system.

In addition to these "big picture" activities, we investigated the micro-behavior of expert nurses during discharge consultations with patients. We videotaped several mock discharge interactions in which one of the nurses explained an AHCP booklet either to a member of the research staff or a layperson recruited from a population that matched the hospital's demographic. We conducted discourse analyses of the videotaped interactions to characterize the verbal and nonverbal behavior used by the nurses while explaining a booklet to a patient. We also conducted two rounds of user testing of a VN explaining discharge instructions to users in our HCI lab [6].

### Context of Use

The deployment site for the system is Boston Medical Center, a 547 bed safety net hospital that serves an urban, 84% minority, traditionally underserved population. Approximately 58% of this population has inadequate health literacy.

The minimal discharge process involves a physician "reconciling" a patient's medications (ensuring there are no drug interactions, etc.) and electronically signing off on the final medication list in the electronic medical record. The process is a tedious one for the patient. Typically, the patient will hear in the morning that they may go home later that day, but the decision is often not finalized until the afternoon. After hours of waiting, patients are anxious to leave the hospital and are often the last to find out if and when they will be discharged. If the patient does go home, the time interval between medication reconciliation and the patient leaving the hospital can vary between a few minutes to several hours. Since the AHCP booklet cannot be created

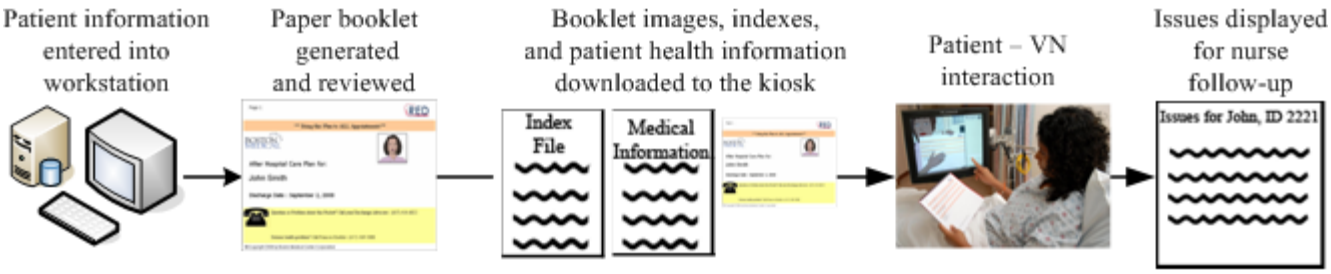


**Figure 2. Workflow for Virtual Nurse System**

until the medications have been finalized, the time window in which the VN must operate can be very short.

### *Explanation of Health Documents*

From our micro-analyses of nurses explaining AHCP booklets we found that one kind of nonverbal behavior was nearly ubiquitous: the use of pointing gestures by the nurse towards the booklet being explained. We compiled a model of the occurrence and form of referential hand gestures and other nonverbal behavior used by the nurses that could be used to drive the nonverbal behavior of an ECA explaining a health document to a patient. We also observed that the nurses omitted a significant amount of detail and used more scaffolding (description of document structure) when describing the booklet to listeners with inadequate health literacy, compared to listeners with adequate health literacy [6].

### Patient Safety Requirements

Following a user-centered design strategy, we always sought to keep the patient's experience in mind when designing the interface and interaction. Even this, however, took second priority relative to patient safety. The physicians on the project sought to identify those teaching points that were the most safety critical, and we made every effort to ensure that patients finished the interaction understanding them. These points included certain medication warnings and the overall medication regimen (schedule and dosing of each medication).

For safety reasons we also developed tools and procedures to support validation of the dialogue content used by the VN. We developed a visual scripting tool that let non-technical members of the project team contribute and review dialogue content for the VN. We also developed tools to generate sample descriptions for each medication in both text and audio recording for review by physicians, as well as tools to support fine tuning the pronunciation of medical terms by the speech synthesizer.

## DESIGN OF A VIRTUAL DISCHARGE NURSE

An overview of the workflow for the VN system is shown in Figure 2. A nurse first enters all of a patient's post-discharge self-care information into a workstation backed by a relational database, after which the AHCP booklet is automatically generated, its digital page images are saved to the database, and the paper booklet is printed. While the booklet is being generated, the system also produces a machine-readable index file, specifying the spatial location within the booklet of each piece of information the VN will discuss, as well as a machine readable file of teaching points the VN will cover. These two files, and the booklet images, are then downloaded to a mobile kiosk that is then wheeled into the patient's room (Figure 1). After the patient is given their paper booklet and provided with a brief training session on how to use the touch-screen interface, they are left to conduct their conversation with the VN. At the end of this interaction, any unresolved patient questions or issues are displayed for a human nurse to follow up with the patient, and results of the session are uploaded to the database.

### Designing for Patients with Inadequate Health Literacy

In addition to the use of the conversational behaviors described above, the literature indicates that it is best to communicate using multiple, redundant modalities when communicating with patients with inadequate health literacy [24]. Given this, and our micro-analysis of nurse explanation behavior, we gave the VN the ability to hold and point at an image of the patient's AHCP booklet while explaining it, rather than simply reviewing the discharge information verbally (Figure 3). In addition, the VN instructs the patient to follow along in their paper copy of the AHCP booklet during the explanation, with explicit directions to the patient to turn to the page being discussed.

The VN is also designed to talk with patients once a day, every day they are in the hospital, communicating all of the information that is known at that time about their diagnosis and post-discharge self-care regimen, in order to reinforce the information as much as possible.

We also used short "open book" comprehension tests during the interaction to test patient understanding of key points with a few multiple-choice questions. If a patient fails these tests, the VN provides "scaffolding" to help them locate the information in their booklet. Following our observations of nurse behavior, the location of the information in the booklet, as well as the structure of the booklet layout, is reviewed. If they failed a subsequent comprehension test, an alert was posted for a human nurse to follow up with them before they went home.


**Figure 3. Virtual Nurse Interface**

Finally, while some level of English reading literacy is required to use the system (since patients had to be able to read the AHCP booklet), patients with relatively low *reading* literacy were accommodated by keeping their utterance inputs as simple as possible (e.g., most consisted of "OK.", "Yes.", "No.", and "What?").

### Touch Screen Interface

The VN was developed using an existing framework for ECA-based health counseling [8], extended with a computational model for the explanation of documents [6]. In this interface, the agent speaks, using a synthetic voice, and displays animated nonverbal behavior (hand gestures, posture shifts, facial expressions, etc.) in synchrony with the speech. User contributions to the conversation are made by touching utterance option buttons on a touch screen display that are dynamically updated for each user speaking turn (Figure 1). We considered using speech recognition as the input modality rather than the touch screen, but the hospital room can be a very noisy environment, and a significant portion of the patient population speaks English as a second language with many accents that would be problematic for commercial speech recognizers.

The 17" touch screen is deployed on a mobile kiosk that allows for bedside patient-education (Figure 1). The kiosk consists of a wheeled base, a 4' tall handled stand and an articulated arm. The arm allows the screen to be positioned and tilted in front of the patient accommodating their mobility whether they are lying or sitting up in bed, or sitting in a chair. The Boston Medical Center patient population has great diversity in race and ethnicity, education, linguistic ability, physical and mental abilities, and, of course, health status. We made many modifications to the touch screen interface based on our user testing to accommodate as many patients as possible. These included: allowing the touch screen buttons to be placed on either side of the interface to accommodate the handedness of patients; moving the touch screen buttons as low on the screen as possible to accommodate individuals who had difficulty reaching the screen due to motor impairments; minimizing the number of touch screen inputs required to conduct an interaction to minimize patient fatigue; and the optional use of headphones for patients who wanted privacy or had hearing impairments.

### Dialogue Content

Dialogues are scripted, using a custom hierarchical transition network-based scripting language, and a visual dialogue design tool. The final system contains 550 dialogue states including 322 unique medication scripts covering 2254 medicines, along with 48 scripts for diagnoses.

VN utterances that reference parts of the document are annotated with a logical ID (e.g., "medication-3-dose"). At runtime, the model of nurse pointing behavior is used to determine whether the VN should point at the document, and, if so, the hand shape to use. The index file created when the AHCP booklet was produced maps the logical ID to an AHCP page number and coordinates.

### Nurse Character Design

Two female nurse characters were designed—one middle-aged Caucasian and one middle-aged African American—to better match the patient demographic and improve acceptability of the VN (Figure 4). We originally designed eight character models and conducted a survey of 32 hospital patients to select the two most acceptable characters. We also conducted surveys to select the synthetic voice that patients felt best matched each character from among a set of available commercial voices, and to determine given names for the characters. The characters were also drawn with Boston Medical Center badges, and placed in front of a background scene matching the hospital environment. Finally, a picture of the VN was printed on the cover of the AHCP booklet, next to a picture of the patient's primary care provider (Figure 3).

### Caring and Bedside Manner

The importance of caring, empathy and good "bedside manner" is widely recognized in healthcare as a key factor in improving not only patient satisfaction, but treatment outcomes across a wide range of health care disciplines [16], but particularly in nursing [30]. Given this, prior successful implementations of empathic computer agents [7], and the need for the VN to maintain patients' attention

**Figure 4. VN Characters: Louise (L) and Elizabeth (R)**

for the hour it may take to relate all of the information in their discharge plans, we augmented the VN's informational dialogue with relational dialogue. Following earlier work on "relational agents", we integrated a range of relational behavior into the VN dialogue, including appropriate forms of address (calling the patient by name), social chat at the beginning of every interaction, meta-relational communication, appropriate humor, appropriate feedback at every empathic opportunity, and reminding of information discussed in past interactions to give a sense of continuity. The VN also offers patients the opportunity to take breaks at several points during the interaction in order to sustain attention and engagement.

### A Typical Session with the Virtual Nurse

Once the mobile kiosk is wheeled into a patient's room and the touch screen positioned in front of them, patients are given a very brief training session in which they are told that the character will talk to them and they just need to touch what they want to say from the options provided on the screen.

A fragment of a typical conversation is shown in Figure 5. The VN proceeds through the AHCP booklet linearly, describing each section before moving on to the next. The booklet includes information on a patient's care team, diagnosis, medications, follow-up appointments, pending tests, and recommended diet and exercise regimens.

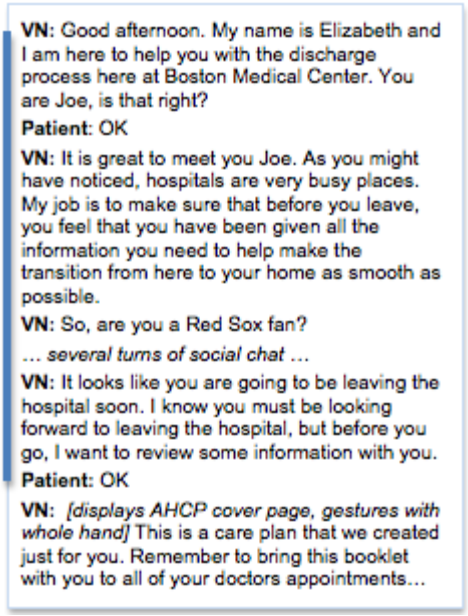


**Figure 5. Sample dialogue - relational aspects highlighted**

We wanted to ensure that patients did not leave with any unresolved issues or questions that the system could not address, and developed a reporting mechanism that displayed a list of unresolved issues for a human nurse to follow up with after the patient's interaction with the VN.

## PRELIMINARY USER STUDY

For safety reasons, we conducted a user study with non-hospitalized participants before testing the VN system on actual hospital patients. The experiment was conducted in a conference room in the hospital and representative examples of AHCP booklets were used that did not contain actual medical information about the test users. To account for the varying complexity of discharge instructions among patients, three example versions of the booklet were created and systematically varied across users.

### Measures

In addition to basic demographics and computer literacy, health literacy was assessed using the Rapid Estimate of Adult Literacy in Medicine (REALM) [12]. The REALM questionnaire asks participants to read aloud a list of 66 health-related words and ranks the participant into one of four brackets (1=3rd grade or below, 2=4th to 6th grade, 3=7th to 8th grade, 4=high school). We further categorized participants as having either adequate (bracket 4) or inadequate (brackets 1-3) health literacy, as other researchers in health literacy have done. Following their session with the VN, participants were asked several questions to assess their satisfaction with and attitude towards the system (Table 1), and then conducted a semi-structured interview to reflect on their feelings, perceptions, and acceptance of the VN.

### Participants

A total of 30 non-hospitalized people (70% female, aged 20-60, 77% minority) participated in the first evaluation of the VN. Most participants were not frequent computer users with 7% having never used a computer before, 47% having used one a few times, 40% having used one regularly and one participant self-identified as a computer expert. Sixty-three percent (n=19) were classified as having adequate health literacy and 37% (n=11) were classified as having inadequate health literacy.

### Procedure

Following administration of demographic and health literacy measures, participants were asked to role-play that they had been admitted to the hospital and were about to go home. They were given a paper copy of the AHCP booklet and a brief introduction to using the touch screen interface (from a seated position), and told that the VN would explain the document to them, preparing them to leave the hospital. Participants were randomized to interact with either Elizabeth or Louise, and whether or not the VN used relational behavior (empathy, etc.) or not.

### Results

All participants completed the interaction without any difficulty, with sessions lasting 18 to 47 minutes. Participants indicated that they were satisfied with the VN, found the system natural and easy to use, and thought that the VN was informative and useful (Table 1). Participants who interacted with a VN that used relational behavior

rated the VN as being more friendly than the non-relational VNs, $t(28) = 2.25$, $p < .05$. In addition, participants with adequate health literacy felt that the VN cared about them more than participants with inadequate health literacy, $t(28) = 2.17$, $p < .05$.

*"She kept asking if I was tired, if I wanted to take a break. she cared about me, you know."*

During qualitative interviews, 92 % (n=23) of participants asked said that they were comfortable receiving health information from a computer. When asked if they would prefer to hear the information from a doctor or nurse, 26% (n=8) said yes, 33% (n=9) were indifferent, and 37% (n=10) said that they would prefer the VN.

As participants reflected on their experience with the VN, several themes began to emerge. The first was that participants seemed to appreciate the amount of *information* given to them by the VN, and the amount of *time* that the VN spent with them. They liked that the VN took as much time as was needed to go through all the details of the AHCP booklet, and that the VN checked to make sure the patient understood what was being described. Two-thirds of the participants chose not to take the shortest path through the dialogue, asked the VN questions and requested more information when given the opportunity through the VN's dialogue.

*"It's more helpful than talking to a person; it's just like the nurse, but she explained everything to the 'T'."*

*"Sometimes doctors just talk and assume you understand what they're saying. With a computer you can go slow, go over things again and she checks that you understand."*

A second theme was that participants felt the system would be useful in an actual hospital setting. For six participants, interacting with the system evoked strong emotions about the lack of attention given to them in the past by medical providers in a hospital. They told detailed stories about their past experiences with hospital discharge; how they felt passed over or talked down to, and indicated that the information from the VN would be useful in preparing actual patients to leave the hospital.

*"It was just like a nurse, actually better, because sometimes a nurse just gives you the paper and says 'Here you go.' Elizabeth explains everything."*

*"I think that's great. Because when I was hospitalized and they discharged me, they gave me a lot of medicines, but they didn't really go over them. They were just like 'here are your prescriptions.' If someone came in like that [pointing to the computer] and talked to me I would have felt like 'Yes, I'm ready to go home.'"*

*"I've had problems with, not this hospital, but other hospitals. I wasn't given the quality time that this lady gave me."*

Participants also felt that interacting with the system may help patients become more actively involved in managing their health. Although they were role playing, for a few the interaction seemed to invoke empowering thoughts, indicating that it may help to improve communication with their doctor.

*"I would like that. When you're waiting to get discharged you need something to do anyway. I like the ideas to write things down because when I get to the doctor I always forget what I'm going to ask."*

*"It was useful. A lot of people don't know the side effects of their medications, they just take what their doctor tells them."*

### Lessons Learned

We made several design changes following the first round of user testing. One of the major changes was in the way the VN responded to patients failing the medication comprehension test. In the first version of the system, the VN would review *all* of a patient's medications again if they made any mistake on the test. While this seemed to be effective (most patients would pay more attention the second time through) it required that the longest part of the interaction (typically 19 minutes long) be repeated, and most users were visibly upset when they discovered that they had to listen to everything again. In the revised version, the VN reminds patients who make mistakes that they can look the information up in their paper booklet, points out where they can find the correct answer to the question, and provides a quick review of the booklet layout, rather than repeating the details of all the medications in their list.

## HOSPITAL PATIENT USER STUDY

Following our successful pilot test with non-hospitalized participants, we conducted a user study to determine the usability and acceptance of the VN by actual hospital patients, using their actual medical data, with the patients using the system from their hospital beds. Although the final VN system will talk to patients every day they are in the hospital, this study evaluated a single interaction at the time of discharge. Each patient received a personalized AHCP booklet, containing information specific to his or her own medications, diagnosis and appointments, and the VN reviewed this patient-specific information with them.

### Measures

The same scale measures from the first user study were used, along with three additional questions relating patient experience with the VN to their hospital experience (Table 1).

| QUESTION | Rating Scale | | Study | |
|---|---|---|---|---|
| | 1 | 7 | First | Second |
| How *satisfied* were you with Louise | not at all | very | 6.1 (1.2) | 6.7 (0.7) |
| How *helpful* was Louise? | not at all | very | 6.7 (0.7) | 6.5 (0.7) |
| Was the information *useful*? | not at all | very | 6.5 (0.8) | 6.6 (0.8) |
| How *friendly* was Louise? | not at all | very | 6.6 (0.7) | 6.7 (0.7) |
| How *natural* was talking to Louise? | artificial | natural | 5.4 (1.7) | 5.8 (1.7) |
| How *informative* was Louise? | not at all | very | 6.8 (0.6) | 6.8 (0.5) |
| How *easy* was talking to Louise? | difficult | easy | 6.4 (1.4) | 6.8 (0.7) |
| How much do you *trust* Louise? | not at all | very | 5.6 (1.4) | 6.7 (0.8) |
| How much do you feel that Louise *cares* about you? | not at all | very | 5.4 (1.8) | 5.8 (1.8) |
| How did you feel about a computer character giving you health information? | not at all comfortable | completely comfortable | | 6.3 (1.1) |
| Would you rather have heard the information from a doctor or nurse? | definitely prefer doctor or nurse | definitely prefer Elizabeth/Louise | | 5.4 (1.9) |
| How much did you feel that your talk with Louise helped you get ready to leave the hospital? | not at all | very | | 6.5 (0.8) |

**Table 1. Self-report Ratings of the Virtual Nurse (mean (SD))**

### Participants

Nineteen patients interacted with the VN prior to hospital discharge. Participants were 53% female, aged 25-75 (M=55.42), 53% minority, 42% inadequate health literacy, and had similar levels of prior computer experience to those in the first study.

### Procedure

The study took place on three inpatient floors of Boston Medical Center. Each morning, a list of patients being discharged within a few days was created, and those patients were approached about participating in the study. To qualify, patients had to be over 18, and indicate that they were able to read a newspaper. Patients who consented to participate had background and REALM measures administered, and were randomized to interact with Elizabeth or Louise and whether or not the VN used relational behavior or not within the dialogue. Prior to discharge, the mobile kiosk was brought to their hospital room and participants received a brief introduction to using the touch screen. They were given a paper copy of their AHCP booklet and began their conversation with the VN.

### Results

Participants were discharged with 13 unique diagnoses, and an average of 10 medications (range 3 to 22), and between 1 and 3 follow-up appointments. Patients interacted with the system from a variety of positions; lying down in bed, sitting up in bed, and sitting up in a chair. As in the first study, all participants completed the interaction without any problems, with sessions lasting 7 to 79 minutes (average 39.9). An average of 2.4 (range 0 to 7) issues were generated for nurse follow up for each patient.

Patients reported high levels of satisfaction with the VN, thought the information was useful and helpful and 94% indicated the system was easy to use (as one patient put it: *"I don't like computers but that was easy."*). They also reported that interacting with the VN helped prepare them to leave the hospital, that they felt comfortable receiving health information from a computer character, and that they would not have rather heard the information from their doctor or nurse. Full results for scaled items are shown in Table 1.

As each interaction was specific to the patient's particular medical information, no two interactions were the same. Depending on the content, there were times when patients were given the opportunity to ask questions, or request that the VN give more information about a particular medication or diagnosis. Of those patients who were given opportunities through the VN's dialogue to request more information 60% (n=15) chose to hear additional details, with an average of 4.9 requests per interaction. These included items such as: "What if I miss a dose?", "Why is it important to treat this condition?", and choosing to hear more details about medication side-effects.

Patients who interacted with the VN programmed to use relational behavior reported feeling that the VN cared more about them than the patients who interacted with the VN that did not use relational behavior, $t(17) = 1.9$, $p=.07$. They also felt that the information was more useful, $t(17) = 2.21$, $p<.05$, than those who interacted with the non-relational VN.

*"She treated me like a real person! She's not like a computer. This is awesome work! This is really excellent."*

Similar to our preliminary user study, patients indicated during qualitative interviews that they appreciated the amount of information and time given to them by the VN. This was most often the reason given for preferring the VN over their doctor or nurse, as shown in Table 1. As these patients described it:

*"I prefer Louise, she's better than a doctor, she explains more, and doctors are always in a hurry."*

*"She tells me more than my doctor does."*

Also, as in the previous user study, the interaction seemed to invoke reports of empowerment from the patients. For example, during one interaction Louise described muscle pain as a potential medication side effect, and afterwards the patient commented, *"That's one of my symptoms! I need to tell my doctor to take me off that."* Another patient indicated that after interacting with the VN and hearing the full details about his medications, he may follow his medication regimen more closely. *"There are times when I would take meds and I would stop after awhile. With this advice it is better."*

## GENERAL DISCUSSION

We designed a virtual nurse that could teach hospital patients with inadequate health literacy about their discharge instructions. Design features for this population included the use of an intuitive conversational agent interface, redundant modalities for the medical information (screen image, printed text, and synthetic speech), and integrated comprehension checks.

Collectively, our user studies involved 49 participants aged 20 to 75, with 47% categorized as having inadequate health literacy. In both studies, participants found the virtual nurse very easy to use with less than a minute of training, reported high levels of satisfaction with the system, reported few reservations receiving medical information from an animated character, and said that they would follow the character's directions. In addition, 74% of hospital patients in the second study said that they would prefer receiving their discharge instructions from the virtual nurse over their doctors or nurses in the hospital, and another 16% said that the two modalities would be equally acceptable to them.

### Taking the Time to Care

One emergent theme from post-session interviews with our users was that they felt they did not receive nearly enough time and attention from their doctors and nurses in the hospital, and that they really appreciated that the virtual nurse would spend as much time as needed to ensure they understood all of the discharge instructions. The highly time-constrained environment that hospital clinicians work in is widely acknowledged within the medical community [11], but these time pressures can result in patients feeling uncared for, too intimidated to ask questions, and ultimately unprepared to care for themselves at home, which can lead to adverse events after discharge.

### Patient Empowerment

A second emergent theme was that our users often felt empowered by the information they received from the virtual nurse. Being a hospital patient is one of the most dis-empowering situations one can experience in modern society, and even more so for those with inadequate health literacy. The approach to medical care, in which the role of the patient is completely submissive, together with complete reliance on hospital staff for all needs, can translate into near-total helplessness for many patients. Users appreciated that the virtual nurse provided them with another authoritative source of information that they could discuss with their providers. While the virtual nurse is in no way intended to replace the role of human nurses, it is a way to augment the care given in hospitals and empower patients to become more actively involved in their health. Post-discharge healthcare empowerment is critical: several studies have shown that patients who are actively involved in managing their self-care, participate in treatment decisions and collaborate with their physicians have better health outcomes [32].

### Future Work

A three year clinical trial involving 750 patients is planned to begin in Fall 2008, in which the VN will be compared with a "usual care" control condition in which patients are discharged using the hospital's standard discharge procedure. Many process and outcome measures will be gathered, but the principal outcome of interest is whether the VN leads to fewer re-hospitalizations. We also plan several sub-studies to be run concurrently with the trial including versions of the VN with and without relational behavior, with and without multiple contacts per patient, and to investigate the role of racial concordance between patients and the VN. We are currently working on workflow improvements to the interface, such as pulling patient information directly from the hospital's electronic medical records systems, instead of requiring that the information be entered into a separate workstation. A project is also underway in which patients will be "followed home" from the hospital by a PDA programmed with each patient's AHCP information to help promote adherence to their post-discharge regimen.

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