Chapter 6: Relational Agents for Chronic Disease Self Management

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1. Introduction: The Challenge of Life-long Health Behavior Adherence for Individuals with Diabetes

In the United States, 90 million people, representing 45% of non-institutionalized Americans, are living with chronic health conditions, with direct health care costs accounting for 75% of US health care expenditures ($425 billion estimated for 1990) (Hoffman, Rice et al. 1996). For the individuals living with these conditions, following prescribed medication and self-care treatment regimens is a significant life-long challenge with life-threatening and costly consequences for non-adherence. Despite these potential consequences, 40-50% of chronic disease patients are non-adherent or poorly adherent to their treatment regimens,(Cerkoney and Hart 1980; Christensen, Terry et al. 1983; Glasgow, McCaul et al. 1987; Lee, Kusek et al. 1996; Feldman, Bacher et al. 1998) partly attributable to the fact that these regimens often require significant behavior change in patients, including permanent changes to their lifestyle in areas such as diet and physical activity.

Diabetes, in particular, is a major source of morbidity, mortality, and economic expense in the U.S. The overall prevalence of diabetes in the U.S. is 4.0%, climbing to 13.1% and 13.9% for white men and women aged 65-74, respectively, and 19.2% and 29.9% for black men and women aged 65-74 (Boyle, Honeycutt et al. 2001). The overall prevalence is expected to increase by 165% over the next 50 years, but for black men and women over 75, the projected increases are 352% and 555%, respectively.(Boyle, Honeycutt et al. 2001) People with diabetes are at risk for the development of several serious complications, such as coma, and a variety of chronic complications, including circulatory, renal, ophthalmic, neurological, and skin disorders (Association 1998). Direct medical and indirect expenditures attributable to diabetes in the U.S. in 1997 were estimated at $98 billion (Association 1998).

Maintaining long-term adherence to chronic disease treatment regimens requires significant effort on the part of patients and significant help and social support from healthcare providers, family and friends. The self-care regimen for patients with diabetes mellitus, in particular, is especially demanding given that patients must monitor their activity, diet, and blood sugar levels continually, which—even in the best of circumstances—is a tedious, anxiety-provoking, time-consuming, and demanding activity. Adherence by patients requires extraordinary commitment and patience. Furthermore, patients differ greatly in their understanding of what they must do, their perceived importance of their self-care regimen, their willingness to perform these routine tasks, and their ability to actually perform them, depending on the stage of their disease or presence of complications, their intellectual and educational levels, their physical abilities, and their home/living situations. Perhaps most challenging, relative to other areas of health behavior change, is that chronic disease self-care behaviors must be maintained not just for a few weeks or months, but typically for the rest of a patient's life.

Relational Agents—conversational computer agents that simulate face-to-face conversations, including the social, emotional and relational dimensions of these interactions—may be a particularly effective medium for automated chronic disease self-care interventions. In this chapter, I make the case for this claim, and present several systems that have been evaluated or are currently under development as evidence. First, however, I lay the groundwork by discussing what is special about face-to-face health counseling and how relational agents can effectively model this form of interaction.

2. Face-to-face Counseling as the "Gold Standard" for Health Behavior Change

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 low literacy levels (Colcher and Bass 1972; Madden 1973; Clinite and Kabat 1976; Morris and Halperin 1979; Morrish and Halperin 1979; Qualls, Harris et al. 2002). Face-to-face consultation is effective because it requires that the provider focus on the most salient information to be conveyed(Qualls, Harris et al. 2002) and that the information be delivered in a simple, conversational speaking style. Protocols for "grounding" in face-to-face conversation—the use of verbal and nonverbal cues such as head-nods, gaze and acknowledgement tokens ("uh-huh", "OK") to signal mutual understanding (Clark and Brennan 1991)—allows providers to dynamically assess a patient's level of understanding and repeat or elaborate information as necessary. Face-to-face conversation also allows providers to make their communication more explicitly interactive by asking patients to do, write, say, or show something that demonstrates their understanding (Doak, Doak et al. 1996). Finally, face-to-face interaction allows providers to use verbal and nonverbal behaviors, such as empathy (Frankel 1995) and immediacy (Argyle 1988; Richmond and McCroskey 1995), to elicit patient trust, enabling better communication and satisfaction. Provider nonverbal behavior alone has been associated with short- and long-term changes in the physical and cognitive functioning of older adult patients (Ambady, Koo et al. 2002).

Of course, one problem with in-person encounters with health professionals is that all providers function in health care environments in which they can only spend a very limited amount of time with each patient (Davidoff 1997). Time pressures can result in patients feeling too intimidated to ask questions, or to ask that information be repeated. Another problem is that of "fidelity": providers do not always perform in perfect accordance with recommended guidelines, resulting in significant inter-provider and intra-provider variations in the delivery of health information.

Disparities in Diabetes Prevalence and Treatment: Health Literacy

One particular area of concern in health communication is "health literacy", the ability of patients to perform the basic reading and numerical tasks required to function in the health care environment. Low health literacy affects patients' ability to understand medication labels and instructions, hospital discharge instructions, instructions for assistive devices and medical equipment, and educational material (Affairs 1999).

Low health literacy represents much more than an inconvenience; these patients report lower health status (Weiss, Hart et al. 1992; Baker, Parker et al. 1997), are less likely to use screening procedures, follow medical regimens, keep appointments, or seek help early in the course of a disease (Weiss 1994), have higher health-care costs (Weiss 1994), and have higher rates of hospitalization (Baker, Parker et al. 1997). Diabetes patients with low health literacy, in particular, demonstrate significantly less knowledge about their disease than diabetes patients with adequate literacy (Williams, Baker et al. 1998). For example, a recent study of patients with diabetes found that 94% of those with adequate health literacy knew the symptoms of hypoglycemia, compared with only 50% of those with inadequate literacy (Williams, Baker et al. 1998). Inadequate health literacy is also associated with worse glycemic control and higher rates of retinopathy in patients with Type 2 diabetes mellitus (Schillinger, Grumbach et al. 2002).

Health literacy is much more of a problem than most of us realize, especially within certain populations. More than one-third of U.S. adults over 65 have inadequate or marginal health literacy, and among indigent and minority patients in urban areas this number rises to over 80%(Williams, Parker et al. 1995).

A number of strategies have been proposed to compensate for inadequate health literacy in patients. The most commonly-suggested approaches are to simplify the information to be communicated to the patient as much as possible, simplify the language used in written materials (simpler words and grammatical structure, active voice, low concept density), and increase the use of contextualizing information such as topic sentences and advance organizers (Doak, Doak et al. 1996; Health 1998). However, no published studies have shown a beneficial effect on patients' health outcomes from using simplified written materials alone (Morrish and Halperin 1979; Affairs 1999).

The use of non-text-based media, such as audio tapes, video tapes, visual aides, and computer-based multimedia has also been suggested for use with low literacy patients (Doak, Doak et al. 1996; Health 1998). Although automated systems hold the promise to provide tailored, personalized information in a variety of media formats, most existent computer interfaces add to the hurdles these patients must surmount, by adding complex user interfaces with many menus and options that require rapid comprehension and response (Tun and Wingfield 1997). Overall, evaluations of alternative media for patient education have found that they increase short-term knowledge, but their impact on long-term knowledge retention remains unproven (Gaglioano 1988; Meade, McKinney et al. 1994; Health 1998).

Affective and Relational Aspects of Health Counseling

In healthcare, simply feeling cared for and empathized with has profound effects on physiology, cognition and emotional state in patients. According to Levinson, et al, "A growing body of literature suggests that outcomes of care are optimal when physicians address patients' emotional and personal concerns in addition to their biomedical problems. Patient satisfaction, patient adherence to treatment regimens, and medical outcomes can be improved with a patient-centered model of care that demonstrates respect and caring for patients"(Levinson, Gorawara-Bhat et al. 2000). Empirical studies demonstrate that lack of a supportive relationship is associated with low levels of motivation to engage in appropriate self-care, and may lead to treatment non-adherence (Drench, Noonan et al. 2003).

In the helping professions, there is a well-documented association between the quality of the professional-client relationship and outcomes (Okun 1997), and in mental health, the positive effect of a good therapist-patient relationship on outcomes has been hypothesized to be *the* common factor underlying the many diverse approaches to psychotherapy that seem to provide approximately equal results (Gelso and Hayes 1998). Within medicine, there is substantial evidence that the use of empathy and relationship-building behaviors by physicians interacting with chronic disease patients leads not only to increased patient satisfaction (Wooley, Kane et al. 1978; DiMatteo and Hays 1980; Bellet and Maloney 1991; Boon and Stewart 1998), but is associated with improved adherence to treatment regimens (Becker and Mainman 1975; Haynes 1976; Garrity 1981; Becker and Rosenstock 1984), and improved physiological outcomes (Shulman 1979; Kaplan, Greenfield et al. 1989; Stewart, Belle et al. 1995; Kaplan, Greenfield et al. 1996).

3. Relational Agents

Relational agents are computational artifacts designed to build long-term socio-emotional relationships with users. Within healthcare, the relational dimensions of interest include trust, rapport and therapeutic alliance, for the purpose of enhancing adherence to self-care treatment regimens. These agents are typically deployed as computer-animated humanoid agents that can simulate face-to-face conversation with patients so that real-time dialogue, speech, gesture, gaze and other verbal and non-verbal channels can be used both to communicate therapeutic information and to establish and maintain a therapeutic alliance relationship. In the systems that I have developed, the typical interface design includes an agent that talks using synthetic speech and synchronized nonverbal behavior animation, while user contributions to the conversation are made by selecting an utterance from a dynamically-updated multiple-choice menu (Figure 1).

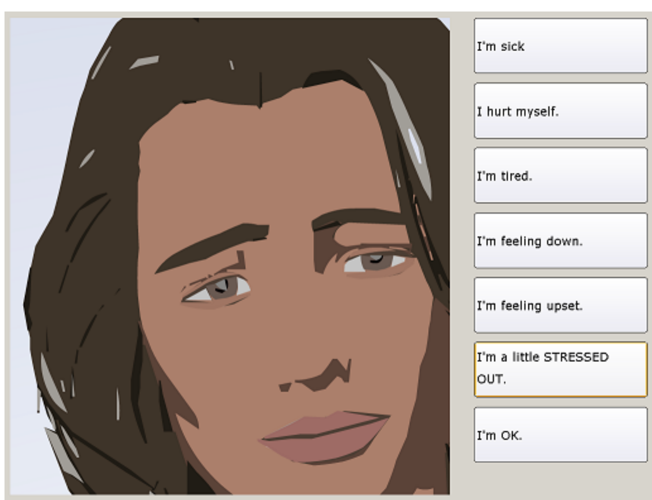

Figure 1. Relational Exercise Advisor "Laura"

These agents can convey information in redundant channels of information, including speech intonation (Prevost and Steedman 1994; Cassell, Bickmore et al. 1999), hand gesture (Andre, Muller et al. 1996; Thorisson 1997; Cassell, Bickmore et al. 1999; Lester, Towns et al. 2000), facial display (Thorisson 1997; Cassell, Bickmore et al. 1999), body posture shift (Cassell, Nakano et al. 2001), and eye gaze(Thorisson 1997; Rickel and Johnson 1998; Cassell, Bickmore et al. 1999)), in order to maximize message comprehension by patients.

Such agents can provide a “virtual consultation” with a simulated health provider, offering a natural and accessible source of information for patients. They can adapt their messages to the particular needs of patients and to the immediate context of the conversation. Finally, they can provide health information in a consistent manner and in a low-pressure environment in which patients are free to ask questions and take as much time as they need to understand the information they require.

In addition to these purely informational and interactional behaviors, relational agents can use the verbal and nonverbal behaviors used by health providers to establish trust and rapport with their patients in order to increase satisfaction and adherence to treatment regimens. Examples of relational behaviors that have been simulated include: verbal and nonverbal expressions of empathy; liking of the patient, demonstrated through (simulated) close proximity and more frequent gaze (Argyle 1988; Richmond and McCroskey 1995); humor; social dialogue, meta-relational communication (talk about the relationship); , reference to past interactions and future together; inclusive pronouns; expressing happiness to see the user; use of close forms of address (user’s name); and appropriate politeness strategies (Bickmore 2003).

In sum, relational agents can play a major role in the chronic disease management process by providing patients not only with an additional source of information about their disease, treatment regimen and adherence level, but with motivational support for taking care of themselves as well. I believe that frequent interaction over extended periods of time with a caring, empathic and knowledgeable disease management agent that assists users with self-care and lifestyle behavior change, health education, and disease and treatment tracking, offers the best hope of maximizing treatment regimen adherence in chronic disease patients.

Relational Agents for Patients with Low Health Literacy

There are several reasons why relational agents, as described above, could provide an effective medium for patient education targeted at patients with low health literacy. First, the human-computer interface relies only minimally on text comprehension and uses the universally understood format of face-to-face conversation, thus making it less intimidating and more accessible for patients with low literacy skills. In addition, one study of pedagogical agents compared information delivery to students via an agent that used speech output with an identical system that used text output instead, and found that students recalled more in the speech condition (Moreno, Lester et al. 2000).

Second, the use of propositional nonverbal conversational behaviors—such as hand gestures that convey specific information through pointing (“deictic” gestures) or through shape or motion (“iconic” and “metaphoric” gestures)(McNeill 1992)—provides redundant channels of information for conveying semantic content also communicated in speech. The use of multiple communication channels enhances the likelihood of message comprehension. One study found that listeners not only pay attention to hand gestures made by a speaker, they integrate this information into their understanding of the verbal message being communicated, and actually prefer information in the gesture channel when it conflicts with information in speech (Cassell, McNeill et al. 1998). In addition, all cultures have nonverbal means for marking emphasis (for example, eyebrow raises and "beat" or "baton" hand gestures in American English (Chovil 1991; McNeill 1992)), and these can be used to highlight the most salient parts of a message, a mechanism hypothesized to assist learners with low literacy skills (Affairs 1999).

Finally, relational agents provide a much more flexible and effective communication medium than a video-taped lecture or even combined video segments. The use of synthetic speech enables each agent utterance to be tailored to the patient (e.g., using their name and other personal information), to the context of the conversation (e.g., what was just said, the fact that the patient asked the same question 10 minutes earlier, whether it is morning or evening, etc.), and to nonverbal behavior exhibited by the patient (e.g., gazing at the agent to indicate that they don't understand what they were just told). To provide this level of adaptability with pre-recorded video would require a very large number (thousands) of video clips to be made and integrated, an approach that is not economical or logistically feasible.

Example Systems

In the rest of this chapter, I present several health counseling relational agents that have been evaluated or are currently under development, beginning with one that was developed especially for individuals with low health literacy.

4. Relational Agents for Patient Education

We are currently developing a "virtual nurse" to counsel patients on their self-care regimen before they are sent home from the hospital. A particular focus in this work has been the development of a relational agent that can explain written hospital discharge instructions to patients with low health literacy (Bickmore 2007). To develop this agent, we videotaped and studied several conversations in which nurses were explaining discharge instructions to patients (Figure 2). From these studies, and many conversations with our collaborators at Boston Medical Center, we developed models of the verbal and nonverbal behavior used by the nurses, and implemented two virtual nurse agents that could emulate much of this behavior (Figure 3 shows one them, named "Elizabeth"). In addition to significant knowledge about medications, follow up appointments and self-care regimens, the agent was programmed with "bedside manner" (relational behavior) gleaned from the literature and discussions with nurses. This agent will be wheeled up to a patient's hospital bed before they are discharged from the hospital (Figure 4), and spend an hour (on average) reviewing this material with the patient, testing for comprehension, and flagging any unresolved issues for a human nurse to follow up on.

Figure 2. Nurse Explanation of Hospital Discharge Instructions

Figure 3. “Virtual Nurse” Explaining Hospital Discharge Instructions

Figure 4. Hospital Cart

A randomized clinical trial involving 750 hospital patients is planned. However, as part of our development effort, we conducted a pilot study to see how well the virtual nurse would do at explaining a discharge document compared to a human explaining the document, for patients with different health literacy levels (evaluated using the REALM instrument (Davis, Long et al. 1993)). There were no differences on post-experiment knowledge tests among the groups. However, lower literacy participants were significantly more satisfied with the agent compared to the human, scored significantly lower on trust in the instructor (whether human or agent), how knowledgeable the instructor was, and desire to continue working with the instructor. Post-experiment interviews revealed that low literacy participants felt the agent exerted less pressure, was less biases, and was more receptive to questions than the human:

- "Elizabeth was cool, I would have taken that again. She was just so clear, she just went page by page so it wasn't missed. And then, I mean you can always just ask them [human] if you don't understand anyway, but it's different on a screen, I guess, because some people don't want to say that they don't understand. On a screen it's less embarrassing, no one's here so you can say 'Ok, let me hear that again.'"

5. Relational Agents for Exercise Promotion

One of the first relational agents I developed was "Laura" the exercise advisor (Figure 1). Laura was designed to have daily conversations with sedentary individuals on their home computers to attempt to motivate them to do more walking. The exercise promotion system has been evaluated in two studies to date. These studies are significant, both because of their ramifications for automated health behavior change counseling in general, and because exercise is typically an important component of the self-care regimen prescribed for patients with diabetes.

Exercise Promotion among MIT Students

Laura was first evaluated in a three-arm randomized trial with 101 (mostly) young adults from the MIT community in order to test the efficacy of the agent's relational behavior (Bickmore, Gruber et al. 2005). One group of study participants (RELATIONAL) interacted with a version of Laura in which all of her relational behavior (social dialogue, empathy, nonverbal liking behavior, etc.) was enabled, while a second group interacted with the same agent in which these relational behaviors were ablated (NON-RELATIONAL). A third group acted as a non-intervention control and simply recorded their daily physical activity (CONTROL). The Working Alliance Inventory—used to assess the quality of provider-patient relationships in clinical psychotherapy (Horvath and Greenberg 1989)—was used as a primary relational outcome measure.

Participants in the RELATIONAL condition reported significantly higher Working Alliance scores compared with subjects in the NON-RELATIONAL condition, both at one week, and at the end of the four-week intervention. Several other self-report and behavioral measures indicated that relational bonding with the agent was significantly greater in the RELATIONAL group compared to the NON-RELATIONAL group. Participants in the RELATIONAL and NON-RELATIONAL groups combined, increased the number of days per week that they engaged in at least 30 minutes of moderate or more vigorous physical activity significantly more than subjects in the CONTROL condition. However, there were no significant differences between the

RELATIONAL and NON-RELATIONAL groups with respect to gains in physical activity.

Exercise Promotion among Geriatrics Patients

Given the prevalence of diabetes among older adults, the frequency with which diabetic patients are prescribed exercise, and the low levels of exercise typically obtained by older adults (only 12% of adults over 75 get the minimum level of physical activity currently recommended by the CDC, and 65% report no leisure time activity (2000)), the evaluation of the exercise advisor agent within this population seemed critically important. However, there appeared to be significant challenges in getting new technologies such as this accepted and used by this population. Although some researchers have found that many older adults readily accept new technologies such as computers, this segment of the population lags behind all other age groups with respect co computer ownership (only 25.8% of senior households have a computer) and Internet access (14.6% of all senior households have Internet access) (1999).

To evaluate how well the exercise advisor relational agent would work with older adults, I teamed with geriatricians at the Geriatrics Ambulatory Practice at Boston Medical Center and conducted a pilot test with 21 patients from the clinic (Bickmore, Caruso et al. 2005). Several modifications were made to the MIT system for this new group of users. The user interface was modified to use large buttons with enlarged text, to allow for easy readability and touch screen input. A numeric keypad (used in conjunction with the touch screen) allowed users to enter their pedometer readings. The system was designed to be used stand-alone—since we could not assume our subjects had Internet connectivity—with subjects provided with a dedicated-use PC, 17” color touch screen monitor (no keyboard or mouse) and table for use during the study. Participants only needed to push the start button on the PC and it automatically ran the agent interface, conducted a 5-10 minute daily conversation, and then automatically shut down (Figure 6).

Figure 6. Geriatrics Exercise Promotion Study Participant

The randomized trial compared older adults who interacted with the agent daily in their homes for two-months (AGENT) with a standard of care control group who were only given pedometers and print materials on the benefits of walking for exercise (CONTROL). Participants ranged in age from 62 to 84, were 86% female, and 73% were African American. Seventeen (77%) were overweight or obese, and nineteen (86%) had low reading literacy (Lobach, Hasselblad et al. 2003). Eight (36%) had never used a computer before and six (27%) reported having used one "a few times".

All AGENT participants found the system easy to use, rating this an average of 1.9 on a 1 ("easy") to 7 ("difficult") scale. Satisfaction with the overall intervention was very high, with most AGENT participants acknowledging that it was for their benefit: "It was the best thing that happened to me, to have something that pushed me out and get me walking." "I appreciated having that kind of a reminder, because I don't have anybody who will tell me what to do, to remind me, you know, to get up, get out and get some fresh air." Comparisons between the AGENT and CONTROL groups on daily recorded pedometer steps indicated that the slope in the CONTROL group was not significantly different from 0 ($p = 0.295$), while the slope in the AGENT group showed significant increase in steps over time ($p = 0.001$) with this group roughly doubling the number of steps they were walking every day by the end of the study.

6. Relational Agents for Medication Adherence

As with most patients who have chronic conditions, patients with diabetes must typically follow a prescribed medication regimen. For patients with diabetes, this can range from a relatively simple, fixed schedule of oral tablets to a dynamically adjusted schedule of insulin injections. Although compliance for diabetes patients is of critical importance, diabetes patients as a group are largely non-adherent with some studies indicating that only 7% of patients are fully adherent with all aspects of their regimen (Kurtz 1990).

Medication adherence in general is a huge problem, with many studies indicating that adherence rates of 50% are common, meaning that, on average, patients only take half of the medication they are prescribed (Haynes, McDonald et al. 2006). In certain populations, rates of non-adherence are even higher. For example, given the complex regimens that many older adults have, studies have shown that adherence rates of only 40% to 75% are to be expected (Salzman 1995). Another population in which medication adherence is especially troublesome is the group of individuals with mental health conditions, such as schizophrenia. Schizophrenia affects 1% of the population worldwide, and medication adherence to antipsychotic treatments within this population is typically around 50%, leading to higher rates of hospital re-admissions and greater number of inpatient days, higher health care costs and reduced work productivity (Lacro, Dunn et al. 2002; Dolder, Lacro et al. 2003).

In collaboration with researchers from the University of Pittsburgh School of Nursing, I developed a relational agent-based intervention to promote medication adherence among adults with Schizophrenia (Bickmore and Pfeiffer 2008). The system runs on a laptop computer as a stand-alone system, and is designed for a one-month, in-home, daily contact intervention.

The agent tracks each patient's medication taking behavior for a single antipsychotic taken by mouth in pill or capsule form based on self-report, but it also reminds patients to take all of their other medications as prescribed. In addition to medication adherence, the agent promotes physical activity (walking) and talking to the agent every day. For each of these three behaviors, the agent first asks for a self report of behavior, provides feedback on the behavior (with the aide of self-monitoring charts, Figure 7), and negotiates a behavioral goal. Feedback and goal-setting are also provided in summary statements that integrate across the behaviors. For example: “Let’s review what you said you were going to do before we chat again. You said you were going to take two doses of Prolixin each day, you were going to try to go for a walk, and you said you would talk to me tomorrow.” Intervention on each behavior is started and terminated according to a schedule for the 30 day intervention.

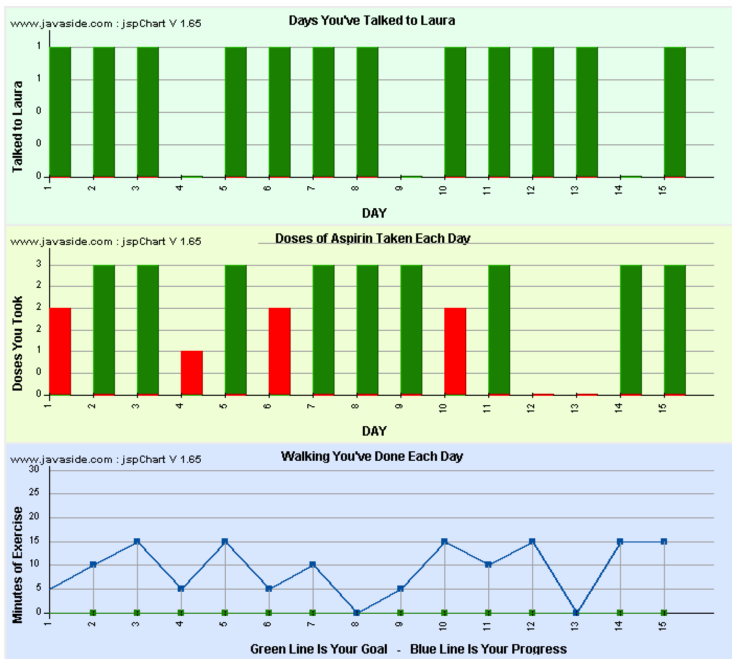

Figure 7. Self-Monitoring Charts for Medication Adherence Interention

There are several other unique aspects of the medication adherence dialogue used by the agent. Since the system is not networked to a central server, it asks the patient whether or not their prescription has changed at the start of each conversation, so that the agent does not promote an incorrect regimen. The system also keeps track of refill schedules and reminds patients to get refills before they run out of their tracked medication (including problem solving, such as recommending that a friend drive them to the pharmacy if they don’t have transportation). Finally, the system uses a form of “direct observation” – a technique used in human medication adherence interventions in which a health provider watches while the patient takes their medication. To accomplish this, the patient is asked to conduct their chats with the agent at one of their prescribed medication taking times. When the agent asks the patient about their medication taking behavior it asks whether they have taken their dose for the current time of day yet (e.g., “Have you taken you evening Prolixin yet today?”). If the patient has not, the agent asks them to go ahead and take it while it waits.

Towards the end of the month, the agent begins instructing patients in techniques for self-maintenance. It starts by asking patients to obtain a multi-compartment pill box and calendar for self monitoring, then asking patients about this during every conversation until they do so. Once the patient has obtained these, the agent reviews techniques for self monitoring at periodic intervals until the end of the 30-day intervention period.

A quasi-experimental pilot study is currently underway to evaluate the medication adherence system, led by researchers at the University of Pittsburgh School of Nursing. Twenty study participants are being recruited from a mental health outpatient clinic who meet the DSM IVR criteria for Schizophrenia, are 18-55 years old, are on any antipsychotic medication, and have had two or more episodes of non-adherence in the 72 hours prior to recruitment. Study participants are provided with a dedicated use laptop computer for the 30 days of the intervention, as well as Medication Event Monitoring (MEMS) caps to provide an objective measure of medication adherence for the one antipsychotic medication targeted by the intervention.

To date, 10 participants have completed the intervention. System logs indicate that study participants talked to the agent on 65.8% of the available days, with six of the participants talking to the agent at least 25 times during the 30 day intervention. Self reported medication adherence (gathered through dialogue with the agent; MEMS data is not yet available) was 97%. Self reported adherence to recommended physical activity (walking) was 89%. Self reported survey questions on participant attitudes towards the agent indicate that most participants liked and trusted the agent, and 80% of respondents indicated they would have liked to continue working with the agent (Laura) at the end of the 30 day intervention.

7. The Affordances of Mobility: Wearable Agents for Real-Time Counseling

Imagine an external conscience that goes everywhere with you, experiences everything that you do, and whispers suggestions about the "right" thing to do in your ear. Such a system could help you make healthy lifestyle decisions, such as choosing healthy over unhealthy foods, taking the stairs rather the elevator, or avoiding situations in which significant social pressure would exist to engage in unhealthy behavior such as smoking or eating or drinking too much. While most people could use such a system as their lifestyle health behavior coach, for individuals with diabetes, such a system could literally be a lifesaver. Rather than waiting for their monthly doctor’s visit, their evening checkup with their desktop relational agent, or even their occasional glucometer reading, patients with diabetes could receive immediate feedback on their dietary or exercise choices *at the moment they are making a decision*.

Such a system must have a number of essential features, above and beyond those for stationary relational agents, including (Bickmore 2007):

- **Portability.** Obviously, the conscience should be portable so that it can accompany users wherever they go. This is important so that: (1) it can intervene at the moment the user is making a relevant decision, wherever and whenever that occurs; (2) it is available whenever the user actively seeks counsel on a relevant topic; and (3) it can give the user the perception that it shares in a significant portion of their life, important for the establishment of credibility and a good working relationship.

- **Sensing Ability.** In order for the system to actively intervene, it must be able to detect when the user is at a point of decision making, or perhaps has just started to engage in an unhealthy behavior. Different health behaviors require different sensors, but some examples that have been developed include: accelerometers for detecting physical activity (Ho and Intille 2005); microphones for detecting chewing (Amft, Stäger et al. 2005); smoke detectors for identifying cigarette lighting; and GPS for detecting proximity to locations known to present the user with difficult health choices (e.g., stairs vs. elevator, fast food restaurant, grocery store, etc.).
- **Adeptness at Interruption.** The system must be adept at knowing not only how, but when to interrupt a user in order to maximize long-term compliance with a health regimen. Knowledge of a user's schedule and current task context would enable the system to know the precise moment when, for example, the user should be interrupted and reminded to take a morning dose of medication or given the suggestion to take a break from work and go for a walk.

Over the last two years I have been developing a general purpose relational agent interface for use on handheld computers that can meet the requirements described above (see Figure 8). The agent appears in a fixed close-up shot, and is capable of a range of nonverbal conversational behavior, including facial displays of emotion; head nods; eye gaze movement; eyebrow raises; posture shifts and "visemes" (mouth shapes corresponding to phonemes). These behaviors are synchronized in real time with agent output utterances, which are displayed in a text balloon rather than using speech, for privacy reasons. The words in the agent utterance are individually highlighted at normal speaking speed and the nonverbal behavior is displayed in synchrony. User inputs are constrained to multiple choice selections and time-of-day specifications at the bottom of the display.

Figure 8. Handheld Relational Agent

We have conducted a number of studies on the handheld agent. One study investigated the impact of the animated character and found that it was more effective at relational bonding compared to a static character image or a text-only display (Bickmore 2002). A series of studies also investigated the best methods to use for interrupting a user in order to maximize long-term health behavior adherence, finding that interruption methods that adhered to human social conventions were most effective (Bickmore, Mauer et al. 2008). The portable agent is currently undergoing a long-term field trial to evaluate the efficacy of "just in time" motivational counseling for physical activity promotion. In this study, the device is equipped with an accelerometer that can detect whether the user is currently walking or not, and this information is combined with information about the user's schedule to determine whether or not they should be interrupted and engaged in an exercise counseling session.

8. Conclusion

Relational agents can provide a "virtual consultation" with a persistent, caring health provider, whenever and wherever needed, and can offer a natural and accessible source of information, motivation and support for patients struggling with the demands of their chronic conditions.

In addition to functioning in a stand-alone fashion, such agents can also be networked with health providers to augment care by providing more frequent monitoring, feedback and counseling to patients than would otherwise be possible, and to involve providers in the care process only on an as-needed basis when problems are detected or for routine checkups (see Figure 9). With wearable and wireless technologies, the automated monitoring and counseling loop can become continuous, providing feedback and advice to patients immediately upon the detection of a medical or behavioral problem. With telemedicine technologies, the time between problem detection and provider involvement can also be minimized (Bickmore, Giorgino et al. 2006).

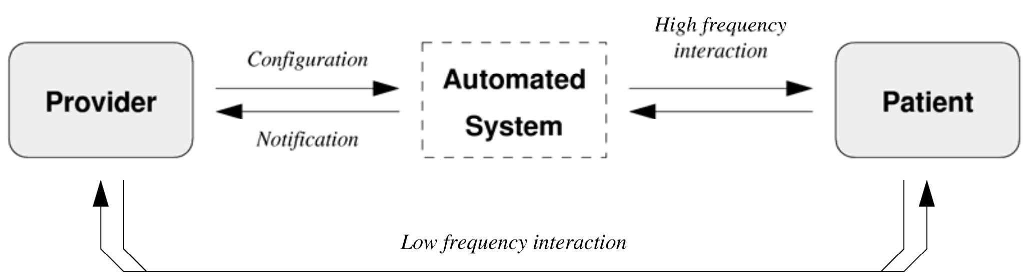

Figure 9. Augmented Chronic Disease Management System (from (Bickmore, Giorgino et al. 2006))

Our future work is focused in two areas. First, we are continuing basic research into the underlying technologies that make relational agents more effective and more practical to deploy by representing health behavior, counseling and relational knowledge in re-usable ontologies. Second, we are continuing to evaluate the efficacy of these agents through several large-scale clinical trials in healthcare environments with large patient populations over extended periods of time.

References

(1999). *Falling through the Net: defining the digital divide. A report on the telecommunications and information technology gap in America. Washington, DC, National Telecommunication and Information Administration.

(2000). Healthy People 2010. Washington, DC, Office of Disease Prevention and Health Promotion, US Dept of Health and Human Services.

Affairs, A. H. C. o. H. L. f. t. C. o. S. (1999). "Health literacy: report of the Council on Scientific Affairs." JAMA **281**: 552-557.

Ambady, N., J. Koo, et al. (2002). "Physical Therapists' Nonverbal Communication Predicts Patients' Health Outcomes." Psychology and Aging **17**(3): 443-452.

Amft, O., M. Stäger, et al. (2005). *Analysis of Chewing Sounds for Dietary Monitoring. UbiComp

Andre, E., J. Muller, et al. (1996). The PPP Persona: A Multipurpose Animated Presentation Agent. Advanced Visual Interfaces.

Argyle, M. (1988). Bodily Communication. New York, Methuen & Co. Ltd.

Association, A. D. (1998). "Economic Consequences of Diabetes Mellitus in the U.S. in 1997." Diabetes Care **21**(2): 296-309.

Baker, D., R. Parker, et al. (1997). "*The relationship of patient reading ability to self-reported health and use of services." Am J Public Health **87**: 1027-1030.

Baker, D., R. Parker, et al. (1997). "The relationship of patient reading ability to self-reported health and use of services." Am J Public Health **87**: 1027-1030.

Becker, M. and L. Mainman (1975). "*Sociobehavioral determinants of compliance with health and medical care recommendations." Med Care **12**: 10-24.

Becker, M. and I. Rosenstock (1984). *Compliance and medical advice. Health care and human behavior. A. Steptoe and A. Matthews. London, Academic Press.

Bellet, P. and M. Maloney (1991). "*The importance of empathy as an interviewing skill in medicine." JAMA **266**: 1831-2.

Bickmore, T. (2002). Towards the Design of Multimodal Interfaces for Handheld Conversational Characters. CHI 02.

Bickmore, T. (2003). Relational Agents: Effecting Change through Human-Computer Relationships. Media Arts & Sciences. Cambridge, MA, Massachusetts Institute of Technology.

Bickmore, T. (2007). What Would Jiminy Cricket Do? Lessons From the First Social Wearable. HCI International '07. Beijing, China.

Bickmore, T., L. Caruso, et al. (2005). ""It's just like you talk to a friend" - Relational Agents for Older Adults." Interacting with Computers **17**(6): 711-735.

Bickmore, T., T. Giorgino, et al. (2006). "Guest Editorial: Special Issue on Dialog Systems for Health Communication." J Biomedical Informatics **39**(5): 465-467.

Bickmore, T., A. Gruber, et al. (2005). "Establishing the computer-patient working alliance in automated health behavior change interventions." Patient Educ Couns **59**(1): 21-30.

Bickmore, T., D. Mauer, et al. (2008). Negotiating Task Interruptions with Virtual Agents for Health Behavior Change. Autonomous Agents and Multi-Agent Systems (AAMAS), Estoril, Portugal.

Bickmore, T., Pfeifer, L., and Paasche-Orlow, M. (2007). Health Document Explanation by Virtual Agents. Intelligent Virtual Agents. Paris.

Bickmore, T. and L. Pfeiffer (2008). Relational Agents for Antipsychotic Medication Adherence CHI'08 Workshop on Technology in Mental Health, Florence, Italy.

Boon, H. and M. Stewart (1998). "Patient-physician communication assessment instruments: 1986 to 1996 in review." Patient Educ Couns **35**: 161-76.

Boyle, J., A. Honeycutt, et al. (2001). "Projection of Diabetes Burden Through 2050." Diabetes Care **24**(11): 1936-1939.

Cassell, J., T. Bickmore, et al. (1999). Embodiment in Conversational Interfaces: Rea. CHI'99, Pittsburgh, PA.

Cassell, J., D. McNeill, et al. (1998). "Speech-Gesture Mismatches: Evidence for One Underlying Representation of Linguistic and Non-Linguistic Information." Pragmatics and Cognition **6**(2): 1-33.

Cassell, J., Y. Nakano, et al. (2001). Non-Verbal Cues for Discourse Structure. Association for Computational Linguistics, Toulouse, France.

Cerkoney, K. and L. Hart (1980). "*The relationship between the health belief model and compliance of persons with diabetes mellitus." Diabetes Care **3**: 594-598.

Chovil, N. (1991). "Discourse-Oriented Facial Displays in Conversation." Research on Language and Social Interaction **25**(1991/1992): 163-194.

Christensen, N., R. Terry, et al. (1983). "*Quantitative assessment of dietary adherence in patients with insulin-dependent diabetes mellitus." Diabetes Care **6**: 245-250.

Clark, H. H. and S. E. Brennan (1991). Grounding in Communication. Perspectives on Socially Shared Cognition. L. B. Resnick, J. M. Levine and S. D. Teasley. Washington, American Psychological Association**:** 127-149.

Clinite, J. and H. Kabat (1976). "Improving patient compliance." J Am Pharm Assoc **16**: 74-76.

Colcher, I. and J. Bass (1972). "*Peniccilin treatment of streptoccal pharyngitis." JAMA **222**: 657-659.

Davidoff, F. (1997). "*Time." Ann Intern Med **127**: 483-485.

Davis, T. C., S. W. Long, et al. (1993). "Rapid estimate of adult literacy in medicine: a shortened screening instrument." Fam Med **25**(6): 391-5.

DiMatteo, M. and R. Hays (1980). "*The significance of patients' perceptions of physician conduct: a study of patient satisfaction in a family practice center." J Community Health **6**: 18-34.

Doak, C., L. Doak, et al. (1996). Teaching patients with low literacy skills. Philadelphia, PA, JB Lippincott.

Dolder, C. R., J. P. Lacro, et al. (2003). "*Interventions to improve antipsychotic medication adherence: review of recent literature." Journal of Clinical Psychopharmacology **23**(4): 389-399.

Drench, M., A. Noonan, et al. (2003). Psychosocial Aspects of Health Care. Upper Saddle River, NJ, Prentice Hall.

Feldman, R., M. Bacher, et al. (1998). "*Adherence to pharmacologic management of hypertension." Can J Public Health **89**: 6-8.

Frankel, R. (1995). "Emotion and the Physician-Patient Relationship." Motivation and Emotion **19**(3): 163-173.
Gaglioano, M. E. (1988). "A Literature Review on the Efficacy of Video in Patient Education." Journal of Medical Education **63**: 785-792.
Garrity, T. (1981). "*Medical compliance and the clinician-patient relationship: a review." Soc Sci Med **15E**: 215-222.
Gelso, C. and J. Hayes (1998). The Psychotherapy Relationship: Theory, Research and Practice. New York, John Wiley and Sons.
Glasgow, R., K. McCaul, et al. (1987). "*Self-care behaviors and glycemic control in type I diabetes." Journal of Chronic Disease **40**: 399-412.
Haynes, R. (1976). *A critical review of the 'determinants' of patient compliance with therapeutic regimens. Compliance with therapeutic regimens. D. Sackett and R. Haynes. Baltimore, Johns Hopkins University Press.
Haynes, R., H. McDonald, et al. (2006). "Helping Patients Follow Prescribed Treatment." JAMA **288**(22): 2880-83.
Health, N. W. G. o. L. a. (1998). "Communicating with Patients Who Have Limited Literacy Skills." J of Family Practice **46**(2): 168-176.
Ho, J. and S. S. Intille (2005). Using Context-Aware Computing to Reduce the Perceived Burden of Interruptions from Mobile Devices. CHI.
Hoffman, C., D. Rice, et al. (1996). "*Persons with chronic conditions. Their prevalence and costs." JAMA **276**: 1473-9.
Horvath, A. and L. Greenberg (1989). "Development and Validation of the Working Alliance Inventory." Journal of Counseling Psychology **36**(2): 223-233.
Kaplan, S., S. Greenfield, et al. (1996). "*Characteristics of physicians with participatory styles." Ann Intern Med **124**: 497-504.
Kaplan, S., S. Greenfield, et al. (1989). "*Assessing the effects of physician-patient interactions on the outcomes of chronic disease." Med Care **27**: S110-S127.
Kurtz, M. (1990). "*Adherence to diabetes regimens: Empirical status and clinical applications." Diabetes Education **16**: 50-6.
Lacro, J. P., L. B. Dunn, et al. (2002). "*Prevelance of risk factors for medication adherence in patients with schizophrenia: a comprehensive review of recent literature." Journal of Clin Psychiatry **63**: 892-909.
Lee, J., J. Kusek, et al. (1996). "*Assessing medication adherence by pill count and electronic monitoring in the African American study of kidney disease and hypertension (AASK) pilot study." American Journal of Hypertension **9**: 719-725.
Lester, J., S. Towns, et al. (2000). Deictic and Emotive Communication in Animated Pedagogical Agents. Embodied Conversational Agents. J. Cassell. Cambridge, MA, MIT Press.
Levinson, W., R. Gorawara-Bhat, et al. (2000). "A Study of Patient Clues and Physician Responses in Primary Care and Surgical Settings." JAMA **284**(8): 1021-1027.
Lobach, D., V. Hasselblad, et al. (2003). Evaluation of a Tool to Categorize Patients by Reading Literacy and Computer Skill to Facilitate the Computer-Administered Patient Interview. AMIA, Washington, DC.
Madden, E. (1973). "Evaluation of outpatient pharmacy patient counseling." J Am Pharm Ass **13**: 437-443.

McNeill, D. (1992). Hand and Mind: What Gestures Reveal about Thought. Cambridge, Cambridge University Press.
Meade, C., W. McKinney, et al. (1994). "Educating Patients with Limited Literacy Skills: The Effectiveness of Printed and Videotaped Materials about Colon Cancer." Am J Public Health **84**: 119-121.
Moreno, R., J. C. Lester, et al. (2000). Life-Like Pedagogical Agents in Constructivist Multimedia Environments: Cognitive Consequences of their Interaction. ED-MEDIA Charlottesville, VA.
Morris, L. and J. Halperin (1979). "Effects of Written Drug Information on Patient Knowledge and Compliance: A Literature Review." Am J Public Health **69**(1): 47-52.
Morrish, L. and J. Halperin (1979). "Effects of Written Drig Information on Patient Knowledge and Compliance: A Literature Review." Am J Public Health **69**(1): 47-52.
Okun, B. (1997). Effective Helping: Interviewing and Counseling Techniques. Pacific Grove, CA, Brooks/Cole.
Prevost, S. and M. Steedman (1994). "Specifying intonation from context for speech synthesis." Speech Communication **15**: 139-153.
Qualls, C., J. Harris, et al. (2002). Cognitive-Linguistic Aging: Considerations for Home Health Care Environments. Human Factors Interventions for the Health Care of Older Adults. W. Rogers and A. Fisk. Mahwah, NJ, Lawrence Erlbaum**:** 47-67.
Richmond, V. and J. McCroskey (1995). Immediacy. Nonverbal Behavior in Interpersonal Relations. Boston, Allyn & Bacon**:** 195-217.
Rickel, J. and W. L. Johnson (1998). "Animated Agents for Procedural Traning in Virtual Reality: Perception, Cognition and Motor Control." Applied Artificial Intelligence.
Salzman, C. (1995). "*Medication Compliance in the Elderly." J Clinical Psychiatry **56, Suppl I**: 18-22.
Schillinger, D., K. Grumbach, et al. (2002). "Association of Health Literacy with Diabetes Outcomes." JAMA **288**(4): 475-482.
Shulman, B. (1979). "*Active patient orientation and outcomes in hypertensive treatment." Med Care **17**: 267-281.
Stewart, M., B. Belle, et al. (1995). *Patient-Centered Medicine: Transforming the Clinical Method. Thousand Oaks, CA, Sage.
Thorisson, K. R. (1997). Gandalf: An Embodied Humanoid Capable of Real-Time Multimodal Dialogue with People. Autonomous Agents '97.
Tun, P. and A. Wingfield (1997). *Language and communication: Fundamentals of speech communication and language processing in old age. Handbook of human factors and the older adult. A. Fisk and W. Rogers. San Diego, Academic Press**:** 125-149.
Weiss, B. (1994). "*Illiteracy among Medicaid recipients and its relation to health care costs." J Health Care Poor Underserved **4**(5): 99-111.
Weiss, B., G. Hart, et al. (1992). "*Health status of illerate adults: rleation between literacy and health status among persons with low literacy skills." J Am Board Fam Parct **5**: 254-257.

Williams, M., D. Baker, et al. (1998). "Relationship of functional health literacy to patients' knowledge of their chronic disease: a study of patients with hypertension and diabetes." Arch Intern Med **158**: 166-172.

Williams, M., R. Parker, et al. (1995). "Inadequate Functional Health Literacy Among Patients at Two Public Hospitals." JAMA **274**(21): 1677-1720.

Wooley, F., R. Kane, et al. (1978). "*The effects of doctor-patient communication on satisfaction and outcome of care." Soc Sci Med **12**: 123-128.