Patient Education and Counseling 59 (2005) 21–30

Patient Education and Counseling

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Establishing the computer–patient working alliance in automated health behavior change interventions

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Received 30 March 2004; received in revised form 23 August 2004; accepted 6 September 2004

Abstract

Current user interfaces for automated patient and consumer health care systems can be improved by leveraging the results of several decades of research into effective patient-provider communication skills. A research project is presented in which several such ‘‘relational’’ skills – including empathy, social dialogue, nonverbal immediacy behaviors, and other behaviors to build and maintain good working relationships over multiple interactions – are explicitly designed into a computer interface within the context of a longitudinal health behavior change intervention for physical activity adoption. Results of a comparison among 33 subjects interacting near-daily with the relational system and 27 interacting near-daily with an identical system with the relational behaviors ablated, each for 30 days indicate, that the use of relational behaviors by the system significantly increases working alliance and desire to continue working with the system. Comparison of the above groups to another group of 31 subjects interacting with a control system near-daily for 30 days also indicated a significant increase in proactive viewing of health information.

Keywords: Human–computer interaction; Relational agent; Embodied conversational agent; Social interface; Working alliance; Automated health behavior change; Exercise adoption

1. Introduction

The importance of good communication and quality relationships between health care providers and their patients is now widely recognized as a key factor in improving not only patient satisfaction, but treatment outcomes across a wide range of health care disciplines. The use of specific communication skills by physicians-including strategies for conducting patient-centered interviews and relationship development and maintenance – has been associated with improved adherence to treatment regimens [1–4], improved physiological outcomes [5–8], fewer malpractice suits [9–11], and more detailed medical histories [12–14], in addition to increased patient satisfaction [15–18], leading to several recommendations for training physicians in these skills [19–24]. Similar recommendations have been made for nurses [25–27] and pharmacists [28]. In psychotherapy, the positive effect of a good therapist–patient relationship on outcomes has been demonstrated in many studies, and has even been hypothesized to be the common factor underlying the many diverse approaches to psychotherapy that seem to provide approximately equal results [29].

Despite this recognition of the importance of communication and relationship in health care, there has not been any systematic investigation of the role of these phenomena in computerized health care systems that interact with patients. This is partly due to such systems not being in widespread use yet, and those that are deployed are designed for single, brief interactions with patients. More importantly, however, it reflects the attitude that the emotional and relational needs of the patient are unimportant relative to the informational objectives of the system and the overall

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0738-3991/$ – see front matter
doi:10.1016/j.pec.2004.09.008

efficiency of the interaction, an attitude reminiscent of the paternalistic physician-oriented relational stance that was the norm until fairly recently [30]. A notable exception to this attitude of ''computer as tool'', is a growing body of work in dialogue-based systems for health behavior change, chronic disease self-management and patient education, in which the systems simulate ''virtual visits'' with a provider [31–33]. However, these systems are scripted by physicians and other care providers based on their experience and intuition, resulting in relational and emotional communicative behaviors that are integrated into the health intervention content and thus cannot be factored out for evaluation, or generalized for use in other systems.

There are several reasons for incorporating emotional and relational communicative behaviors into health-oriented computer systems. First, these communicative behaviors should be important for the same reasons they are important in human–human interactions: to improve patient satisfaction and health outcomes. Second, the development of patient-centered systems technology opens up new opportunities for health care that could not have been pursued before. Systems that can patiently listen to patients, give them assurance and information, and negotiate daily treatment plans, could be accessed from home whenever needed or follow a patient through his or her hospitalization, providing access to both the practical and emotional aspects of care when human health providers are not available. Finally, systems that accurately emulate the communication behaviors of health providers in limited domains could be used in training and communication research. For example, these systems could be used as stimuli in studies in which the effects of subtle but precise changes in physician nonverbal behavior on patient understanding could be assessed, something that would be very difficult to do with human confederates.

There is a significant amount of evidence that patients and consumers should respond positively to emotional and relational communicative behaviors used by a computer. A series of studies by Nass & Reeves and their students has demonstrated that people respond in social ways to computers (and other media), when provided with the appropriate social cues, even though they are typically unconscious of this behavior [34]. Examples of some of the effects found by these studies are that people tend to like computers more when the computers flatter them, match their personality, or use humor [34,35]. Of particular relevance to this work, Klein et al. demonstrated that empathy expressed by a software agent can be effective in managing a user's emotional state [36]. In addition to these studies in which experimenters intentionally tried to evoke social-emotional responses to computers, there is ample evidence that people tend to anthropomorphize complex technology even when designers do not intend this to happen. In a qualitative study of user perceptions of an telephony-based health behavior intervention system, Kaplan et al. found that users not only talked about the system using anthropomorphic terms (e.g., using personal pronouns), they described the system in ways indicative of having a personal relationship with it (e.g., ''friend'', ''helper'', ''mentor'') and seemed to be concerned about impression management (e.g., choosing to only interact with the system on days in which they met the system's health behavior goals) [37].

In the remainder of this paper, we describe the design and evaluation of a computer system that uses several emotional and relational communication behaviors – a ''relational agent'' – in the context of an exercise adoption program. Our goal was to add these behaviors to a standard health behavior change intervention in such a way that we could evaluate their impact on patient perceptions of the system and behavior change outcomes independent of the standard intervention.

Since we were primarily interested in evaluating the effects of emotional and relational communication behaviors by an agent on the quality of the relationship between the agent and study participants, we used the Working Alliance Inventory (WAI) as our primary outcome measure [38]. The working alliance is a construct used in psychotherapy that is defined as the trust and belief that the helper and patient have in each other as team-members in achieving a desired outcome. The working alliance has three sub-components: a goal component, reflecting the degree to which the helper and client agree on the goals of the therapy; a task component, reflecting the degree to which the helper and client agree on the therapeutic tasks to be performed; and a bond component, reflecting the trusting, empathetic relationship between the client and helper [29,38].

2. Development of a relational agent for exercise adoption

We have developed a first-generation computer agent capable of using relational behaviors, based on a series of studies of interactions between human exercise trainers and their clients, surveys of representative subjects, and literature reviews of the social psychology of personal relationships, sociolinguistics and communication studies.

The agent plays the role of an exercise advisor that interacts with patients on a daily basis to motivate them to exercise more. The agent has an animated human body and interacts with users in a simulated face-to-face conversation (an ''embodied conversational agent'' [39], see Fig. 1). The agent's behavior includes speech together with synchronized hand gestures, facial displays, body posture shifts and other nonverbal behavior derived from studies of human–human conversation. An embodied representation was used because human relationships are primarily constructed in the context of face-to-face conversation, and nonverbal behavior has been found to be especially crucial for the social aspects of interaction [40]. Also, studies have found that nonverbal

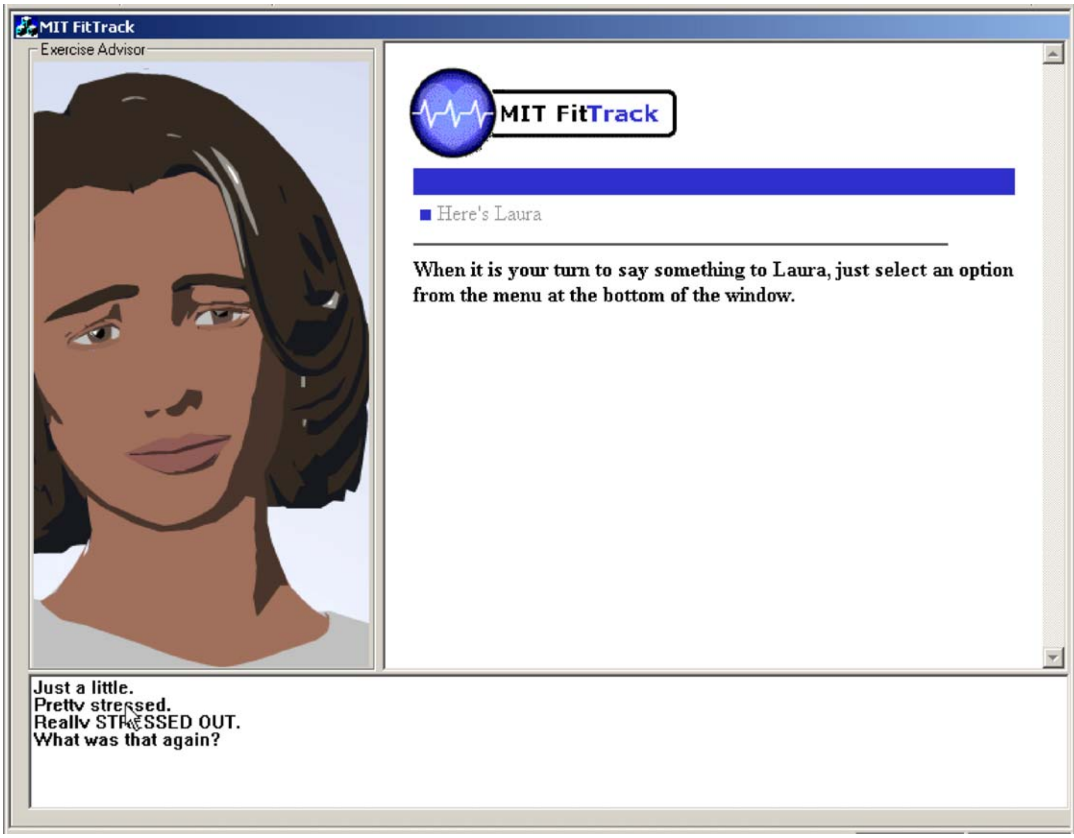

Fig. 1. Relational agent used in the exercise adoption study.

behavior by a health provider can have significant impacts on patient satisfaction and health outcomes [41].

Both verbal and nonverbal relational behaviors are used by the agent to establish and maintain a working alliance with users. Verbal behaviors include expressing empathy for the user [42,43], social dialogue [44], reciprocal self-disclosure [45], humor [46,47], meta-relational communication (talk about the relationship) [46,48], expressing happiness to see the user [43], talking about the past and future together [49], continuity behaviors (appropriate greetings and farewells and talk about the time spent apart) [50], and reference to mutual knowledge. Specific language constructs such as inclusive pronouns [42], politeness strategies [51] and greeting and farewell rituals [52] indicative of a close relationship are also used. Many of these behaviors require a database of information about the user and prior interactions with them to be kept between sessions.

Nonverbal behaviors used for relationship-building include "immediacy" behaviors – close conversational distance, direct body and facial orientation, increased and direct gaze, smiling, pleasant facial expressions and facial animation in general, nodding, and frequent gesturing – which project liking for the other and engagement in the interaction, and is correlated with increased solidarity [53,54]. The agent also uses appropriate affective facial displays depending on the conversational context: neutral for talk about health behavior, happy for social dialogue, and concerned for empathetic dialogue. All agent nonverbal behavior (including hand gestures, eyebrow raises, gaze cues, posture shifts, and head nods, in addition to the relational behavior) was automatically generated and synchronized with synthetic speech using the BEAT text-to-embodied-speech system [55].

User contributions to the dialogue are made primarily by selecting items from multiple-choice menus, dynamically updated based on the conversational context (shown at the bottom of Fig. 1, with a sample interaction transcript shown in Fig. 2). We have experimented with speech recognition and natural language understanding [56], but find that the current state-of-the-art in these technologies does not come close to supporting the social dialogue required for relationship-building. In addition to authoring user input choices in a casual conversational style, occasional, strategically-placed use of free-format text input prompts (as in lines 20, 24 and 30 in Fig. 2) help maintain the feel of a social chat, even though most of these user inputs are ignored by the system or responded to using simple pattern-matching techniques.

Surveys of subjects who have used our menu-based approach indicate that most found the interaction to be natural and fluid for both social and health-related dialogue. More importantly, by tightly constraining what the user can say in every context, the agent has a much

1. A: Hi Chrissy.
2. U: Hi Laura, great to see you.
3. A: How are you doing today?
4. U: I'm not feeling so great.
5. A: I'm sorry to hear that.
6. A: Tell me more about how you are feeling
7. U: I'm sick
8. A: I'm sorry you're sick. What do you think is wrong?
9. U: I have the flu
10. A: You must be feeling miserable. Have you been to see a doctor?
11. U: Yes.
12. A: That's good. It can make you feel better just seeing a health professional about a problem. Do you think this illness might affect your ability to exercise?
13. U: Definitely.
14. A: I'm sorry to hear that. As soon as you feel well enough, you might try to get out for a short walk. The fresh air will do you good, and it will help you to stay in the habit.
15. A: So, are you a student?
16. U: Yes
17. A: Do you go to MIT?
18. U: No
19. A: Oh, what school do you go to?
20. U: Cambridge Continuing Education, right now. I am working toward a degree at Tufts.
21. A: Really? Are you a grad student, or an undergraduate?
22. U: Senior
23. A: Cool. What's your major?
24. U: English
25. A: So, now I'd like to ask you a little about your exercise behavior. Do you currently do any kind of sport?
26. U: No, I don't
27. A : Do you currently do any other kind of aerobic exercise regularly?
28. U: I do something else
29. A: What do you do?
30. U: I do tap dancing. I also walk to and from work.
31. A: And, do you think you would like to exercise by yourself, or with a buddy?
32. U: With a buddy
33. A : Great. So, did you manage to go for a walk since we last talked?
34. U: Yes!
35. A: That's wonderful. Before we chat again, do you think you could get out and go for another walk? It doesn't matter how long or how far.
36. U: Sure.
37. A: OK. Here is some information about how to make a walk a workout. Casual strolls don't quite count. Remember, when we end our sessions, you can spend as much time as you like browsing this library. Just close the Fit Track application when you are finished.
38. A: So, when can we get together again?
39. U: Tomorrow.
40. A: Great. Take care Chrissy , I'll talk to you tomorrow. Good night.

Fig. 2. Sample agent dialogue. Day 2; RELATIONAL condition; A, agent; U, user.

more accurate understanding of the user's communicative intent, including descriptions of emotional states required for empathetic feedback, compared with free-form natural language input.

The appearance and name (''Laura'') of the agent shown in Fig. 1 were selected on the basis of surveys of representative subjects. Laura refers to herself using ''I'' as a first person pronoun but, while she does express empathy for the user, she does not claim to have other emotions of her own or any personal history. Anecdotes describing how the user can overcome obstacles to exercise are delivered as third-person narratives (''I know someone who thought she couldn't find the time to exercise...''). Dialogue content was developed in advance for each of the 30 days of the intervention (scripted in Augmented Transition Networks [57]), but was automatically tailored based on each subject's exercise behavior and current and past dialogue responses. Fig. 3 shows a fragment of the dialogue network for the interaction in Fig. 2.

The health behavior intervention for exercise adoption used several state-of-the-art techniques from social learning theory and behavioral and cognitive-behavioral psychotherapy, including: goal setting, shaping, positive feedback, self-monitoring, overcoming obstacles (''problem solving''), and education [58]. Exercise adoption was selected as the target behavior for the study because it gave participants a motive to interact with the system on a daily basis, given that the current recommendations by the American College of Sports Medicine and the Centers for Disease Control and Prevention are that all adults engage in 30 min or more of moderate-intensity physical activity on most, and preferably all, days of the week [59].

A typical daily conversation with the agent lasted 5–10 min, and included a greeting, checking on the user's emotional and physical state, social dialogue, follow up on previously set exercise goals, goal setting for the next day, exercise tips, ''problem solving'' (working through obstacles to exercise), and farewell (see Fig. 2).

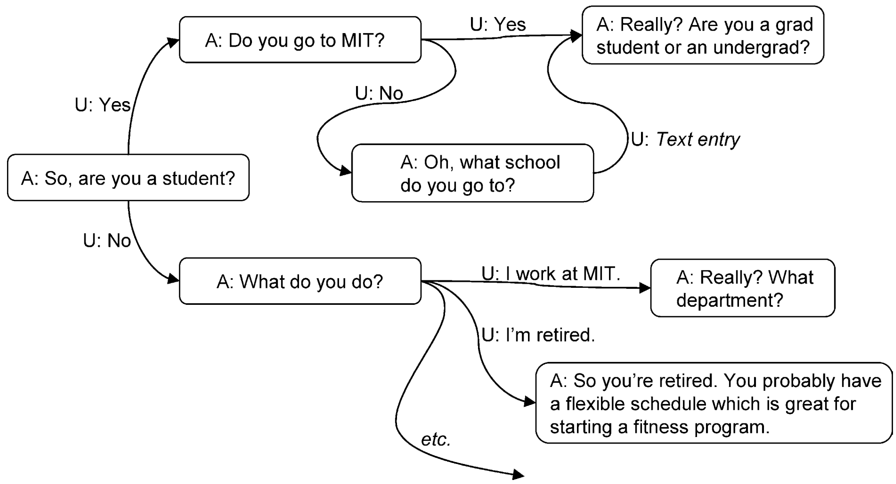

Fig. 3. Dialogue network fragment for lines 15–21 in Fig. 2.

3. Methods

We conducted a pilot study to evaluate the effectiveness of having the agent use emotional and relational communication strategies to establish a working alliance with subjects within the context of a health behavior change intervention.

The study was approved by the institutional review board at the Massachusetts Institute of Technology.

3.1. Study design

The study was a randomized, parallel-group, six-week trial conducted in Cambridge, Massachusetts between October and December 2002, consisting of a four-week intervention and two-week follow-up. The program was designed for subjects to use on a daily basis, but this was not a requirement, and most subjects used it on a near-daily basis. There were three treatment groups in the study: CONTROL, NON-RELATIONAL and RELATIONAL.

3.2. Study participants

The target population consisted of generally healthy adults who were interested in becoming more physically active, but were not yet maintaining the recommended 30 min per day of moderate activity. All had access to a home computer with Internet connectivity. Participant health was screened using the Physical Activity Readiness Questionnaire [60]. Physical activity ‘‘stage of change’’ was assessed by asking a single question about exercise behavior and intentions [61], with eligibility limited to those in contemplation, preparation and action.

3.3. Procedure

All 91 participants were recruited using fliers and newspaper ads which directed them to a web site. Forms on the web site screened participants for the eligibility requirements, randomly assigned them to a group in the study, and scheduled them for intake interviews. As an incentive to participate, subjects were given the pedometers used in the study to keep ($25 value), plus $25 cash at the completion of all tasks.

Participants were given software to install on their home computers, which they were instructed to run on a daily basis. A typical daily interaction lasted 10 min, and included: connecting to the server, logging on, entering data for self-report of physical activity and pedometer readings, viewing self-monitoring charts of physical activity, filling out any questionnaires scheduled for the day, and viewing educational content about physical activity. Participants in the RELATIONAL and NON-RELATIONAL groups also had a brief conversation with the exercise advisor agent shown in Fig. 1. Participants could log into the system as often as they liked, but they would have at most one conversation a day with the agent.

All groups received behavior change interventions according to current standards of practice, including self-monitoring, overall goal setting, shaping and education [58]. All participants were given a goal of reaching 30 min of moderate activity [59] and 10,000 steps per day [62] by the end of the 30-day intervention.

The CONTROL group interacted with the system via web forms only (they never saw the exercise advisor agent).

The NON-RELATIONAL group received the same software and intervention as the CONTROL group, but with the addition of the exercise advisor agent. The agent would talk with participants about their exercise behavior, negotiate and follow up on daily exercise goals (including positive reinforcement when goals were met), provide suggestions to help subjects overcome obstacles to exercise, and use a number of additional cognitive-behavioral techniques for health behavior change [42,58].

The RELATIONAL group received the same software and intervention as the NON-RELATIONAL group. However, in addition to purely instrumental talk about exercise, the agent used a number of social-emotional behaviors to build a working alliance with participants, as discussed in Section 1. These include the use of social dialogue (e.g., ''So, are you from the east coast?''), empathetic feedback (''Sorry to hear you're not feeling well. It can be frustrating...''), meta-relational communication (''How is this working out for you? Am I talking too much?''), humor (''If I actually had a mouth I think I'd like Japanese food.''), close forms of address (use of first name), and nonverbal immediacy behaviors (visually closer proximity, more frequent facial animation, gesture, headnods and gaze at user, relative to the NON-RELATIONAL agent).

Participants came into the lab once for an intake interview to fill out consent forms and initial questionnaires, and received instructions on how to use the software and pedometers. Following this, participants ran the software from home on a near-daily basis for 30 days during the intervention period. A follow-up was conducted two weeks later, at which time participants ran the software one final time to fill out questionnaires.

3.4. Measures

The chief outcome measure was the WAI, a 36-item self-report measure used to assess the relationship between participants and the agent [38], slightly modified for exercise adoption and use with an animated character. The WAI was administered on days 7 and 27 of the intervention.

Four additional questions were asked about subjects' attitudes towards the agent: ''How much do you like Laura?'' (responses rated on a 7-point Likert scale on day 30), ''How would you characterize your relationship with Laura?'' (from ''Complete stranger'' to ''Close friend''), ''How useful were your discussions with Laura?'' (rated on a 5-point Likert scale on day 30) and ''How much would you like to continue working with Laura?'' (rated on a 4-point Likert scale on day 30 and again at follow-up).

Participants were allowed to access all of the pages of educational content about walking for exercise in a library at the end of each session. The average number of pages they accessed per session was tracked as a behavioral measure of their engagement with the intervention.

Physical activity outcome measures included number of days per week over each of the criterion measures during the final week of the intervention (30 min of moderate or greater activity and 10,000 steps).

3.5. Statistical analysis

A power analysis based on previous studies of therapist experience level and working alliance [63], working alliance and outcome in cognitive therapy [64], and cognitive-behavioral interventions and exercise adoption behavior [65] indicated that at least 30 subjects per condition were required to achieve statistical significance (based on a one-tailed power analysis, with a power of 0.8, and a type I error rate of 0.05). Allowing for 10% attrition in the longitudinal study, this indicated that a total of 99 subjects would be needed.

Between-group comparisons were evaluated at specific time points using one-tailed, planned comparisons between RELATIONAL and NON-RELATIONAL groups and between groups with the agent (RELATIONAL and NON-RELATIONAL together) and without it (CONTROL).

4. Quantitative results

Participant flow is shown in Fig. 4, and the base-line demographic characteristics of the participants are shown in Table 1. A total of 101 participants started the study, 91 of which completed the first week of the intervention, with 31 in the control group, 27 in the non-relational group and 33 in the relational group. While the majority of participants were students, 31% were non-students, including administrative staff, and analyses indicated no significant differences between students and non-students on outcomes.

Results are shown in Table 2. Participants in the RELATIONAL group scored significantly higher on the bond subscale of the Working Alliance Inventory than those in the NON-RELATIONAL group, assessed on both days 7 and 27 ($p = .043$ and $p = .014$, respectively), although there were no significant differences between groups on the overall composite Working Alliance score. Table 3 shows results on the individual items of the bond subscale. There were no significant differences between groups on the other Working Alliance subscales or the overall Working Alliance measure. Participants in the RELATIONAL group also reported significantly higher liking of the agent ($p = .023$) and desire to continue working with the agent ($p = .009$) compared to participants in the NON-RELATIONAL group, as reported on day 30. The two agent groups chose to view significantly more educational pages following their interactions than did the CONTROL group ($p < .05$).

There were no significant differences between the RELATIONAL and NON-RELATIONAL groups on physical activity outcome measures, although the RELATIONAL and NON-RELATIONAL groups combined did outperform the CONTROL group on a few of these measures (approaching significance; see Table 2).

5. Qualitative feedback

Interviews were conducted with 28 subjects (16 in RELATIONAL and 13 in NON-RELATIONAL) during the follow up period or just before final debriefing to get a qualitative sense of their reaction to the FitTrack program and Laura. Overall impressions of Laura and FitTrack were very positive. Although some subjects reported that they really liked interacting with an animated trainer and some

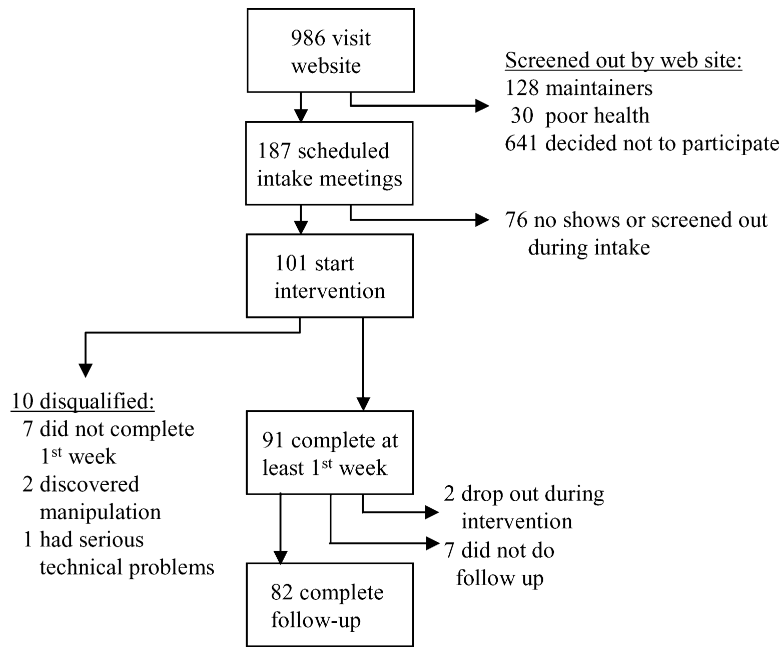

Fig. 4. Participant flow in the study.

really disliked it, none of the subjects reported feeling uncomfortable or unable to conduct interactions with her:

I like talking to Laura, especially those little conversations about school, weather, interests, etc. She's very caring. Toward the end, I found myself looking forward to these fresh chats that pop up every now and then. They make Laura so much more like a real person. (RELATIONAL)

Table 1
Participant demographics

	Mean (S.D.)
Age (year)	24.8 (7.4)
Height (inch)	66.7 (4.0)
Weight (pound)	154.5 (36.2)
Body mass index	24.4 (4.3)
Gender	
Female (%)	55
Occupation	
Student (%)	69
University staff (%)	14
Industry (%)	6
Faculty (%)	4
Other (%)	7
Education	
High school (%)	41
Bachelors (%)	34
Graduate degree (%)	25
Marital status	
Single (%)	69
Married (%)	25
Domestic partner (%)	5

When asked whether they would have rather interacted with a human trainer than with Laura, subjects gave a wide range of opinions. Of those who did prefer Laura, most cited convenience as the primary reason. Some subjects indicated that they would prefer interacting with Laura to interactions with a personal trainer because they felt less guilty about letting her down if they were not able to exercise.

Several subjects also talked about Laura's ability to motivate them. Most said that they felt responsible to her for meeting their goals, and would feel guilty if they hadn't met them:

Because I knew I had to enter the numbers every day, it was like a responsibility to someone else. (RELATIONAL)

When I said I couldn't exercise I felt bad. When she said "are you sure you can't exercise?" it would make me think about it. (NON-RELATIONAL)

It kept you on your toes because you didn't know if you were going to meet with the animated person. (RELATIONAL)

As silly as it sounds, I find that I found a little motivation to exercise knowing that Laura would ask if I did or not. Now that I don't have anyone checking, I find it harder to get motivated. (RELATIONAL)

One surprising finding was that, even though there were over 1000 states (unique dialogue moves) in the dialogue network developed for the 30 days of interaction, most subjects felt that at some point their conversations with Laura became very repetitive. This was more than an

Table 2
Between-group planned comparisons

Measure	Day of study	CONTROL		NON-RELATIONAL		RELATIONAL		RELATIONAL > NON-RELATIONAL			AGENT > CONTROL		
		Mean	S.D.	Mean	S.D.	Mean	S.D.	d.f.	*t*	*p*	d.f.	*t*	*p*
Relational													
WAI/composite	7			4.80	0.82	4.86	0.66	58	1.09	0.14			
	27			4.77	0.91	4.90	0.80	57	1.19	0.12			
WAI/bond	7			4.30	0.93	4.51	0.80	58	1.75	0.04			
	27			4.33	0.95	4.64	1.00	57	2.26	0.01			
AI/task	7			5.13	0.93	5.27	0.65	58	1.32	0.10			
	27			5.11	1.00	5.21	0.86	57	0.59	0.28			
WAI/goal	7			4.97	0.84	4.81	0.89	58	0.24	0.41			
	27			4.86	0.98	4.86	0.93	57	0.21	0.42			
Liking of Laura	30			4.61	1.31	5.21	1.35	57	2.03	0.02			
Relationship with Laura	30			2.26	0.75	2.52	0.83	57	1.62	0.06			
Desire to continue	30			2.04	0.93	2.52	0.95	57	2.43	0.01			
How useful Laura was	30			2.35	0.98	2.62	0.98	57	1.26	0.11			
Educational pages viewed	1–30	1.07	0.08	1.16	0.23	1.39	0.89	58	1.31	0.10	88	1.7	0.05
Physical activity													
Days/week over 30 min	22–30	5.32	2.85	6.25	2.54	6.22	2.41	57	0.24	0.40	86	1.54	0.06
Days/week over 10 K steps	22–30	2.68	2.63	3.96	2.81	3.56	2.46	56	0.65	0.26	84	1.54	0.06

annoyance-several subjects reported that this was a key factor in their losing motivation to work with the system-although none reported that this led to them feeling that using the system was a waste of their time:

The first couple of days I was impressed by it. But, there didn't seem to be a lot of variety going on after that, so it kind of lost my interest, it lost the engagement factor. Maybe, six or seven days into the study I could almost predict what she was going to say, and once the engagement was lost you sort of lose the power of the animated instructor. (NON-RELATIONAL)

The negative aspects of it were that Laura was very repetitive, so it was actually more motivating in the beginning to talk to her than later on, which is sort of the opposite, I think, of what is intended. Because she would go through the same routine every single time, so it wasn't very realistic. As a result I didn't feel obligated, I didn't feel like I had to impress her in any way. (RELATIONAL)

6. Discussion

This initial evaluation of a relational agent in a health behavior change intervention indicates that patients are generally receptive to the technology and respond in ways analogous to how we would expect them to respond when the same emotional and relational communication behaviors are used by human health providers.

We did not find any evidence in the qualitative interviews that participants' feelings of alliance or responsibility was towards the programmers or experimenters rather than the agent itself, which is consistent with prior findings that users attribute socialness directly to a computer rather than to its programmers [66]. However, we do not know what the

Table 3
Between-group comparisons on WAI bond subscale items RELATIONAL > NON-RELATIONAL

	Day 7			Day 27		
	t	d.f.	*p*	*t*	d.f.	*p*
I feel uncomfortable with Laura	1.20	61	0.24	0.13	60	0.90
Laura and I understand each other	1.16	61	0.25	2.52	60	0.01
I believe Laura likes me	2.49	61	0.02	2.56	60	0.01
I believe Laura is genuinely concerned about my welfare	1.76	61	0.08	2.19	60	0.03
Laura and I respect each other	1.60	61	0.12	3.15	60	0.00
I feel that Laura is not totally honest about her feelings toward me	0.23	61	0.82	0.27	60	0.78
I am confident in Laura's ability to help me.	1.30	61	0.20	1.42	60	0.16
I feel that Laura appreciates me	1.67	61	0.10	1.53	60	0.13
Laura and I trust one another	1.54	61	0.13	2.05	60	0.05
My relationship with Laura is very important to me	0.83	61	0.41	1.37	60	0.17
I have the feeling that if I say or do the wrong things, Laura will stop working with me	0.50	61	0.62	0.15	60	0.88
I feel Laura cares about me even when I do things that she does not approve of	1.60	61	0.11	2.39	60	0.02

differences in alliance or motivation would be had this not been a study and subjects had to pay for the software on their own. This is an interesting empirical question for future research.

In addition to significant increases on the bond dimension of the Working Alliance Inventory, perhaps the most important result of the study was a significantly greater reported desire to continue working with the relational agent, compared to subjects who interacted with the non-relational agent. Given the high attrition rates in most exercise adoption programs, simply keeping patients engaged in and committed to an intervention over an extended period of time represents an important potential use of the technology, and prior studies have demonstrated significant associations between adherence to a physical activity intervention and increases in moderate to vigorous physical activity behavior [67].

These results need to be interpreted in light of the study limitations. First, we believe the small number of subjects combined with the relatively short intervention period contributed to the absence of statistically significant differences among the groups on measures of exercise outcomes. A much longer study spanning 6–18 months would be needed to determine if a human–computer relationship can be maintained over the duration of a typical health behavior change intervention. Second, the study population – comprising 69% MIT students – may not be representative of the average sedentary American. These students tend to be highly motivated and very comfortable with technology.

6.1. Future work

This study is one of the first in a new field that might be dubbed ''patient-centered computing'' and, as such, points the way to many areas of future work. First, increasing the task and goal components of the Working Alliance Inventory requires that a detailed model of patient-provider negotiation be developed so that a relational agent can truly negotiate exercise goals and tasks with the patient. Negotiation and collaboration are the cornerstones of patient-centered medicine and are required to obtain a patient's commitment to an intervention. The issue of perceived repetitiveness is an important research problem that must be solved in order to maintain patients' engagement in the intervention over long periods of time. Exactly how much variability, longitudinal change, and new content are required to make an agent seem non-repetitive represents a fruitful area of communication research. Finally, many of the hundreds of studies in health communication can be replicated using an embodied conversational agent to determine if the results are repeatable using this new medium-an approach similar to the one Reeves & Nass have taken with studies in social psychology.

6.2. Practice implications

This work suggests that computer systems that interact with patients – especially those that engage patients in dialogue or in long-term, repeated interactions – can benefit by explicitly designing in emotional and relational communication behavior. Not only should these behaviors lead to increased patient satisfaction (liking of the system), but we would also expect them to lead to higher participation rates in long-term regimens, thereby leading to better outcomes across a wide range of health behavior change and chronic disease management interventions. Computer systems that engage people in such long-term interventions will become increasingly important as the proportion of the population that suffers from chronic disease (e.g., older adults) and engages in unhealthy lifestyles continues to increase.

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