Establishing and Maintaining Long-Term Human-Computer Relationships

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This research investigates the meaning of "human-computer relationship" and presents techniques for constructing, maintaining, and evaluating such relationships, based on research in social psychology, sociolinguistics, communication and other social sciences. Contexts in which relationships are particularly important are described, together with specific benefits (like trust) and task outcomes (like improved learning) known to be associated with relationship quality. We especially consider the problem of designing for long-term interaction, and define *relational agents* as computational artifacts designed to establish and maintain long-term social-emotional relationships with their users. We construct the first such agent, and evaluate it in a controlled experiment with 101 users who were asked to interact daily with an exercise adoption system for a month. Compared to an equivalent task-oriented agent without any deliberate social-emotional or relationship-building skills, the relational agent was respected more, liked more, and trusted more, even after four weeks of interaction. Additionally, users expressed a significantly greater desire to continue working with the relational agent after the termination of the study. We conclude by discussing future directions for this research together with ethical and other ramifications of this work for HCI designers.

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1. INTRODUCTION

As computers interact with us in increasingly complex and human ways through robots, wearable devices, PDAs, and various other ubiquitous

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interfaces, the psychological aspects of our relationships with them take on an increasingly important role. It is important to not only understand the nature of this phenomenon and its effects in work and leisure contexts, but also to develop strategies for constructing and managing these relationships, which directly impact productivity, enjoyment, engagement and other important outcomes of human-computer interaction. Maintaining relationships involves managing expectations, attitudes and intentions, all of which should be of interest to HCI researchers and practitioners.

People claim to have relationships not only with their computers, but also with their pets, cars and other inanimate objects. In this article, we review work in the social psychology of personal relationships, sociolinguistics and communication research that is relevant to the meaning of personal relationship when applied to a human-computer dyad, as well as applicable strategies for building and maintaining such relationships.

We define *relational agents* as computational artifacts designed to build long-term, social-emotional relationships with their users. These can take on a number of embodiments: jewelry, clothing, handheld, robotic, and other nonhumanoid physical or nonphysical forms. In our work we have focused on the development of purely software humanoid animated agents, but the techniques described in this article are not restricted to embodied software agents.

Inherent in the notion of relationship is that it is a persistent construct; incrementally built and maintained over a series of interactions that can potentially span a lifetime. We feel that this focus on maintaining engagement, enjoyment, trust—and productivity (in work contexts)—over a long period of time is something that has been missing from the field of HCI and represents perhaps some of the most important lessons from the social psychology of personal relationships for the HCI community.

Relationships are also fundamentally social and emotional; thus, detailed knowledge of human social psychology—with a particular emphasis on the role of affect—must be incorporated into these agents if they are to effectively leverage the mechanisms of human social cognition in order to build relationships in the most natural manner possible.

The development of relational agents draws heavily from two existent threads of work in HCI: natural multimodal interfaces (including embodied conversational agents [Cassell et al. 2000b] and robots [Breazeal 2002], and studies of computers as social actors [Reeves and Nass 1996]. People primarily build relationships in the context of face-to-face conversation thus, most of the relationship-building strategies discussed in the social sciences literature are most directly implementable as verbal or nonverbal conversational behaviors. This requires, at a minimum, some kind of natural conversational interface and, at a maximum, the use of embodied conversational agents, robots, or some other articulate physical form factor to enact both verbal and nonverbal communicative actions.

A series of studies by Nass and Reeves and their students in the computers as social actors paradigm 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. To date, most of

the agents that have been developed to have relational behaviors, are systems built to support such short-term studies, and have been (intentionally) very simple implementations from a technical standpoint. Examples of some of the relational effects found by these studies are that people tend to like computers more when the computers flatter them, match their personality, or use humor. However, nobody has investigated any long-term effects of such techniques, especially whether the benefits can be sustained over multiple interactions.

The long-term concern is of special significance because of many users' experience with the well-known Microsoft Office Assistant ("Clippit"). Clearly, the assistant did well in short-term evaluations or it wouldn't have been brought to market. Yet it is no secret that many users feel outrage toward this character upon repeated interaction. One way to get insight into the problem is to consider an "equivalent" human-human interaction. Imagine an individual that shows up in your office uninvited, with no introduction, barging in when you are busy (perhaps while working on an important deadline). He offers useless advice while projecting the image of being helpful, and then proceeds to ignore your initially polite expressions of annoyance. This character persists in trying to help despite that you increase the clarity of your emotional expression (perhaps through facial expressions or explicit verbalizations). Finally, you have to tell the character explicitly to leave, which he eventually does, but first he gives you a wink and a little dance. Would you want to see this character again? If this behavior were that of a human office assistant, then he would eventually be fired, or at least severely marginalized. In contrast, most human colleagues, even if they can't help you with your problem at the moment, can at least do a better job of reading and responding to social-emotional cues, and maintaining a beneficial relationship with you.

Overview. In this article, we first motivate the use of relational agents by identifying characteristics of work contexts in which attention to relational issues is likely to impact performance outcomes. We then review literature in the social sciences to establish a foundation for understanding human-computer relationships, and identify a set of human-human relational strategies that may be useful in HCI. We then review previous work related to the development of relational agents, and present an agent we have recently developed and evaluated in the context of a health behavior change application. We conclude with future directions for the research, a short discussion of ethical issues, and some lessons learned for the HCI practitioner.

2. THE IMPORTANCE OF PERSONAL RELATIONSHIPS IN TASK CONTEXTS

A range of applications for relational agents can begin to be delimited by investigating the range of things that human relationships are good for. Provision models of relationships in social psychology give an idea of the possibilities. Some of the types of support that relationships have been found to provide are: emotional support (e.g., esteem, reassurance of worth, affection, attachment, intimacy), appraisal support (e.g., advice and guidance, information, feedback), instrumental support (e.g., material assistance), group belonging, opportunities to nurture, autonomy support, and social network support (e.g., providing

introductions to other people) [Berscheid and Reis 1998]. A large amount of empirical work has been done in social psychology and other fields that demonstrate a significant association between social support and health and survival. In addition to general health and well-being, social support has also been shown to play a significant role in adjustment to specific illnesses, such as cancer and cardiovascular disease. Some of the features of relationships that have been hypothesized to lead to health benefits include: provision of physical and emotional security, establishment of a frame of reference for social reality, normative and informational social influence, and cooperative goal-directed activity. Health and well-being may also be augmented simply because relationships are emotionally gratifying [Berscheid and Reis 1998]. Relational agents could play a significant role in helping individuals—especially those in acute need (e.g., suffering from an illness and not having any human support network)—cope with their illnesses, and maintain high levels of well-being.

2.1 Persuasion

For better or for worse, relationships can also play a role in persuasion. Trustworthiness and likableness of a source of potentially persuasive information play a significant role in the Elaboration Likelihood Model of persuasion [Petty and Wegener 1998]. In this theory, if a decision is of low personal importance then source characteristics—such as trustworthiness and likableness of the source of information—have a significant influence on the decision. However, if the outcome of the decision is of high personal importance then these factors have little or no influence on the outcome. Thus, relational agents could be used, for example, as salespeople, which attempt to build relationships with their clients just as good human salespeople do [Anselmi and Zemanek 1997]. Some researchers of personal relationships have also defined interpersonal "closeness" as the degree to which relational partners influence each others' behavior [Kelley 1983].

2.2 Education

Within elementary school education, students' feelings of relatedness to their teacher and classmates have been found to be strong predictors of their cognitive, behavioral, and emotional engagement in classroom activities [Stipek 1996]. In addition, there is evidence that relationships between students are important in peer learning situations, including peer tutoring and peer collaborative learning methodologies [Damon and Phelps 1989]. Collaboration between friends involved in these exercises has been shown to provide a more effective learning experience than collaboration between acquaintances [Hartup 1996]. Friends have been shown to engage in more extensive discourse with one another during problem solving, offer suggestions more readily, and are more supportive and more critical than non-friends. In at least one experiment, friends worked longer on the task and remembered more about it afterwards than non-friends.

2.3 Business

Even in areas in which the more personal, non-task-oriented, aspects of relationships are downplayed, there is evidence that relationships play an important role in task outcomes. One example of such an area is the world of corporate bureaucracy. Even here, the development of a network of interpersonal relationships has been found to be critical to a general manager's ability to implement his or her agenda, and the quality of these relationships has been found to be a key determinant of managerial effectiveness. In other studies, subordinates reporting good relationships with superiors have been found to be better performers, assume more responsibility and contribute more to their units than those reporting poor relationships [Gabarro 1990].

In the study of service interactions, researchers differentiate between *service relationships*, in which a customer expects to interact again in the future with the same service provider (and vice-versa), *pseudorelationships*, in which a customer expects to interact again in the future with the same firm (but not the same person), and *service encounters*, in which there are no such expectations of future interactions. In a series of surveys involving 1,200 subjects, Gutek et al. [2000] found that customers who are in service relationships reported more trust in and knowledge of their service providers, more interest in continuing the interaction, and more willingness to refer the provider to others, than customers in either pseudorelationships or service encounters. The results also indicate that a service relationship with a particular human service provider is significantly more effective at engendering trust, commitment and referrals than attempts to establish brand or firm loyalty.

2.4 Helping

Finally, although some level of trust is important in all human-computer and human-human interactions [Cassell and Bickmore 2000], trust and engagement are especially crucial in applications in which a change in the user is desired and which require significant cognitive, emotional or motivational effort on the part of the user. In the helping professions—including clinical psychology, counseling, and coaching—there is a well-documented association between the quality of professional-client relationship and outcomes [Okun 1997]. The positive effect of a good therapist-patient relationship on psychotherapeutic outcomes has been demonstrated in several 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 [Gelso and Hayes 1998]. Thus, computer agents that function in helping roles, especially in applications in which the user is attempting to undergo a change in behavior or cognitive or emotional state, could be much more effective if they first attempted to build trusting, empathetic relationships with their users.

A number of instruments have been developed for use in clinical psychotherapy to measure the quality of the client-therapist relationship. One of the most common measures in the literature is the Working Alliance Inventory, which measures the trust and belief that the therapist and patient have in each other as team-members in achieving a desired outcome [Horvath and Greenberg

1989]. This inventory (and similar measures) has been used in therapy to assess the impact of the alliance on problems as wide-ranging as alcoholism, depression, drug use, and personality disorders, and has been demonstrated to have a significant correlation with outcome measures ranging from percentage of days abstinent, drinks per drinking day, and treatment participation (weeks in program) for alcoholism, to employment and compliance with medication, to more general measures such as premature termination, Global Assessment Scale, MMPI, and many, many others [Mallinckrodt 1993; Gaston 1990; Bachelor 1991; Horvath and Symonds 1991; Horvath and Luborsky 1993; Henry and Strupp 1994; Horvath 1994; Luborsky 1994; Raue and Goldfried 1994; Connors et al. 1997; Keijsers et al. 2000].

2.5 Summary

In summary, the quality of human relationships can have significant impacts on task outcomes in diverse areas, including sales, education, psychotherapy and many types of service encounters. Thus, managing relationships in these contexts (and many others) is not simply a matter of socializing for personal gratification; it can have significant impacts on performance.

3. PERSONAL RELATIONSHIPS

Dictionaries define relationship as "the state of being related by kindred, affinity, or other alliance" [Webster 1998] or "a particular type of connection existing between people related to or having dealings with each other" [American Heritage 2000], so what exactly do people mean when they say they have a relationship with their computer? What is the nature of this alliance or connection, and to what extent can people have the same kinds of connections with computers as they have with other people? In this section, we review work in the social sciences on the meaning of relationship and representations and trajectories of relationships over time.

3.1 Dyadic Models

Most recent work in the social psychology of personal relationships takes a fundamentally dyadic approach to the concept of "relationship" [Berscheid and Reis 1998]. Kelley [1983] defines this concept as referring to two people whose behavior is interdependent, in that a change in the state of one will produce a change in the state of the other. Thus, a relationship does not reside in either partner alone, but in their interaction with each other. Further, a relationship is not defined exclusively by generic patterns of interaction (e.g., associated with stereotypical roles), but by the unique patterns of interaction for a particular dyad [Berscheid and Reis 1998].

This objective view of relationship as a pattern of interaction is also echoed in a recent study of peoples' relationships with the man-made objects in their environment [Csikszentmihalyi and Rochberg-Halton 1998]. According to this study, much of the past work in psychology on the nature of people's interactions with objects has mostly been concerned with objects as symbolic representations for the self, for others, or for relationships (e.g., Freud, Jung, and even

Winnicott's treatment of "transitional objects" [Winnicott 1982]), but are not at all concerned with the actual experience that people have with concrete objects in the world or their sense of connection to them. Their work demonstrates that man-made objects exert a significant influence on the patterns of our daily lives, as well as our identities, and through these phenomena we establish a sense of connectedness with them.

3.2 Provision Models

The objective view of relationship has also led many researchers in social psychology to characterize relationships in terms of what the people in them provide for one another. Duck, for example, defines the following list of provisions that "friends" in our culture are expected to provide for each other [Duck 1991]:

—Belonging and a sense of "reliable alliance". The existence of a bond that can be trusted to be there for a partner when they need it.

—Emotional integration and stability. Friendships provide necessary anchor points for opinions, beliefs and emotional responses.

—Opportunities for each partner to talk about themselves. Friendships help fulfill the need for self-expression and self-disclosure.

—Provision of physical, psychological and emotional support. Physical support involves doing favors, such as giving someone a ride or washing the dishes. Psychological support involves showing appreciation for the other and letting them know their opinions are valued. Emotional support includes affection, attachment and intimacy.

—Reassurance of worth and value, and an opportunity to help others. We value friends because of their contribution to our self-evaluation and self-esteem, directly via compliments and indirectly by telling us of the good opinions of others. Also, friends increase our self-esteem by simply attending to us, by listening, asking our advice and valuing our opinions.

3.3 Economic Models

Incorporating the notion of relational provisions, economic models of relationship, such as social exchange theory, model relationships in terms of costs vs. benefits [Brehm 1992]. These models are not strictly objective in that rather than being based on actual provisions, they are based on *perceived* benefits, costs, investments in and alternatives to a relationship, by the individuals in the relationship, and relate these factors to desire to stay in the relationship (which is a strong predictor of relationship longevity). Social exchange models have received more empirical validation than any other theoretical framework in the social psychology of personal relationships.

3.4 Dimensional Models

Perhaps the most common way of representing a relationship in the social sciences is with the use of dimensional models, which attempt to abstract the characteristics of a given relationship to a point in a small-dimensional Euclidean space. The most commonly used dimensions are power and social distance

[Brown and Gilman 1972; Burgoon and Hale 1984; Spencer-Oatey 1996; Svennevig 1999]. Power refers to the ability of one individual to control the resources of another. Social distance refers to the dimension that differentiates between strangers and intimates at its extremes, and has been further decomposed into as many as 14 subdimensions. Other dimensions used to characterize relationships include equal vs. unequal, hostile vs. friendly, superficial vs. intense, and informal vs. formal [Wish et al. 1976]. While abstracting away from specific patterns of behavior, these models often attempt to characterize the notion of "connectedness" present in relationships through dimensions such as solidarity and affect.

A relational dimension that has received a great deal of attention in the HCI community lately is trust [Fogg and Tseng 1999; Cassell and Bickmore 2000; Bickmore and Cassell 2001]. The literature on trust spans the disciplines of sociology, social psychology, and philosophy. Social psychologists have defined trust as "people's abstract positive expectations that they can count on partners to care for them and be responsive to their needs, now and in the future," and one model of the development of trust describes it as "a process of uncertainty reduction, the ultimate goal of which is to reinforce assumptions about a partner's dependability with actual evidence from the partner's behavior" [Berscheid and Reis 1998]. In Section 6, we will discuss work that has been done on conceptualizing and manipulating peoples' trust in computers.

3.5 Stage Models

In addition to models that capture a steady-state snapshot of a relationship, some researchers have attempted to develop "stage models", which assume there are a fixed set of stages that different types of relationships go through. For example, one model hypothesizes that all relationships go through four stages: initial rapport; mutual self-revelation; mutual dependency; and personal need fulfillment. Stage models are now generally considered to provide very weak predictive power given their assumption of a fixed sequence of stages, since actual relationships often jump around among various stages in a nonlinear manner [Brehm 1992].

3.6 Summary

In summary, there is no single agreed-upon concept of what a relationship is or how to represent it. However, the various approaches that have been put forward in the social sciences provide interesting frames of reference and starting points for developing a science of human-computer relationships. Importantly, there is nothing in any of these conceptual frameworks that would seem to prevent computers from eventually fulfilling the role of relational partner. And, while it is entirely possible to construct relational agents that do not use explicit representations of their relationship with the user (e.g., that simply exhibit the right behaviors at the right time to achieve a desired level of trust), the use of such representations will ultimately be required for generality and adaptability.

4. PERSONAL RELATIONSHIP MANAGEMENT

People use myriad behaviors to establish and maintain relationships with each other, most of which could be used by computer agents to manage their relationships with their users. One distinction that can be made in delineating these behaviors is between those used to establish or change a relationship (such as small talk [Schneider 1988] or getting acquainted talk [Svennevig 1999]) and those used to maintain an on-going relationship (e.g., continuity behaviors, such as partners talking about what they did during times apart [Gilbertson et al. 1998]). Another distinction made by many researchers is between routine and strategic relational behaviors, with strategic behaviors being those intentionally used to manage a relationship (e.g., talking about the relationship) while routine behaviors are those people engage in for other reasons but which serve to maintain a relationship as a side effect (e.g., simply engaging in everyday tasks together on an on-going basis) [Stafford et al. 2000]. Routine interactions with a computer thus can be seen as contributing to a relationship, even when no relational skills have been explicitly designed into the machine. Here, we will focus primarily on strategic relational behaviors that could be employed by a computer, since our ultimate interest is in designing computers that can plan interactional behaviors to satisfy explicit relational goals, such as increasing trust with the user.

4.1 Relational Communication

As mentioned above, most human relationships are constructed in the context of face-to-face conversation. All language can be seen as carrying (at least) two kinds of meaning: propositional information of the sort studied in classical semantics, and relational information commenting on the nature of the relationship between the speaker and hearer and the attitude of the former towards the latter [Duck 1998]. Thus, all forms of talk can be seen as instrumental in negotiating the relationship between interlocutors, and talk that is particularly lacking in task-oriented propositional content is often referred to as "social dialogue" (also known as "small talk" or "phatic communion"). For example, the social greeting of "good morning" has lost much of its semantic meaning, but whether or not you choose to say it, as well as *how* you say it, can influence the development of a relationship. Social dialogue can be used to maintain a relational dial-tone even when no explicit task is being performed (the "phatic" function of utterances [Jakobson 1960]). Of course, merely conducting social dialogue tends to establish rapport between interlocutors by increasing familiarity and establishing common ground between them [Malinowski 1923]. Thus, for many computer applications, simply engaging a user and keeping them engaged—even when not performing a task—will help to establish a bond with the system.

The encoding of relational status in language is a phenomenon known as "social deixis" and has been extensively studied in pragmatics and sociolinguistics [Levinson 1983]. A familiar example in English is the form of address and greeting and parting routines that are used between people having different relationships, with titles ranging from professional forms ("Dr. Smith") to

first names (“Joe”) and greetings ranging from a simple “Hello” to the more formal “Good Morning”, etc. [Laver 1981]. Another example is politeness theory, which prescribes different forms of indirectness for a request given how burdensome the request is and the nature of the relationship between the requestor and requestee (e.g., think of the differences between how you would ask your boss for $5 vs. a subordinate or close friend) [Brown and Levinson 1987]. There are many other types of social deixis, especially in other languages (e.g., the *tous*/*vous* distinction in French) that encode many different relational features including power, social distance, kinship relations, clan membership, and others [Levinson 1983]. Thus, the appropriate use of social deixis can serve to ratify and maintain the status of an existing relationship, while using language features indicative of a different form of relationship can signal a desire to make a change in relational status [Lim 1994]. Thus, the forms of language used in a computer application, even it is only in menus or text messages, signals a certain set of relational expectations on the part of the user.

4.2 Relational Dynamics

Given the definition of relationship as patterns of interaction, one way people can change their relationship is by simply performing new activities together. However, this must be achieved through a negotiation in which both parties agree to the new activity. Since rejections are normally a threat to both party’s self-esteem, people engage in elaborate routines to negotiate new activities so that they can ask without appearing to ask. Examples of strategies that can be employed include: hedged or indirect requests (“You wouldn’t possibly want to go to the movies, would you?”); pre-requests (“Do you like movies?”); pre-invitations (“What are you doing this evening?”); and pre-announcements (“You know what I’d like to do?”). Rejections are almost always indirect and often nonverbal, including such behaviors as pausing (allowing the proposer to retract their suggestion), gazing away, preface markers (“Uh”, “Well”), and affective facial displays [Levinson 1983].

Another strategy for maintaining a relationship that is particularly relevant for HCI is meta-relational communication [Stafford and Canary 1991; Dainton and Stafford 1993]. This “talk about the relationship” is particularly important in the early stages of a relationship to clearly establish expectations when things are in transition, but is also important to periodically ensure that everything is going all right (and of course, it is crucial when things go awry). Just imagine if computer systems could periodically check in with their users to ask how everything is going and offer to make changes every few weeks; the mere act of asking would demonstrate concern and caring for the user.

Empathy—the process of attending to, understanding, and responding to another person’s expressions of emotion—is one of the core processes in building and maintaining relationships. This isn’t true just for intimate relationships; it is cited as one of the most important factors in building good working alliances between helpers and their clients, and in physician-patient interactions it has also been shown to play a significant role in effecting prescription compliance

and reducing patient complaints. Empathy is a prerequisite for providing emotional support which, in turn, provides "the foundation for relationship-enhancing behaviors, including accommodation, social support, intimacy, and effective communication and problem solving" [Berscheid and Reis 1998]. Even though computers can't demonstrate true empathy since they don't yet have the capacity for real feelings (more on this below), Klein et al. [2002] demonstrated that as long as a computer appears to be empathetic and is accurate in its feedback, that it can achieve significant behavioral effects on a user, similar to what would be expected from genuine human empathy. There are many other strategies described in the literature for decreasing social distance along various dimensions:

—Reciprocal deepening self-disclosure increases trust, closeness and liking, and has been demonstrated to be effective in text-based human-computer interactions [Altman and Taylor 1973; Moon 1998].

—Use of humor is cited as an important relationship maintenance strategy and has been demonstrated to increase liking in human-computer interaction [Stafford and Canary 1991; McGuire 1994; Cole and Bradac 1996; Morkes et al. 1998].

—Talking about the past and future together and reference to mutual knowledge are cited as the most reliable cues people use to differentiate talk between strangers and acquaintances [Planalp and Benson 1992; Planalp 1993].

—Continuity behaviors to bridge the time people are apart (appropriate greetings and farewells and talk about the time spent apart) are important to maintain a sense of persistence in a relationship [Gilbertson et al. 1998].

—Emphasizing commonalities and de-emphasizing differences is associated with increased solidarity and rapport [Gill et al. 1999]. This can also be achieved indirectly through the process of mirroring (or "entrainment") in which one person adopts some aspects of the other's behavior. "Lexical entrainment"—using a partner's words to refer to something—is a technique used by helpers to build rapport with clients.

4.3 Relational Nonverbal Behavior

Nonverbal behavior in face-to-face conversation can also play a significant role in relationship management. Nonverbal behavior is used to perform a number of functions in this context, including conveyance of propositional information, regulation of the interaction ("envelope" functions such as turn-taking), expression of emotions, self presentation, the performance of rituals such as greetings, and for communication of interpersonal attitudes [Argyle 1988]. Of these, the last is perhaps the most important for relationship management. One of the most consistent findings on the nonverbal display of interpersonal attitudes is that the use of "immediacy" behaviors—including close conversational distance, direct body and facial orientation, forward lean, increased and direct gaze, smiling, pleasant facial expressions and facial animation in general, nodding, frequent gesturing and postural openness—projects liking for the other

and engagement in the interaction, and is correlated with increased solidarity [Argyle 1988; Richmond and McCroskey 1995].

There is empirical evidence that while such nonverbal behavior may not be very important in task-oriented interactions, it is much more important in interactions that are more social in nature. In a review of studies comparing video and audio-mediated communication, Whittaker and O'Conaill [1997] concluded that video was superior to audio only for social tasks while there was little difference in subjective ratings or task outcomes in tasks in which the social aspects were less important. They found that for social tasks, such as getting acquainted or negotiation, interactions were more personalized, less argumentative and more polite when conducted via video-mediated communication, that participants believed video-mediated (and face-to-face) communication was superior, and that groups conversing using video-mediated communication tended to like each other more, compared to audio-only interactions. Obviously, some nonverbal communication must be responsible for these differences.

5. PREVIOUS WORK ON RELATIONAL AGENTS

There have been several attempts to develop and evaluate relational agents in HCI research, as well as several commercial products with similar goals. In the commercial arena these products have been mostly toys designed to cultivate a sense of relationship with their users. Most of these artifacts play on people's need to express nurturance by requiring caretaking in order to thrive, or by engaging in familiar social interaction patterns. Many of these artifacts also change their behavior over time or otherwise provide a highly variable, rich set of expressions to give the sense of uniqueness crucial for relationships. Examples include the Tamagotchi (one of the first and simplest, yet wildly successful in Japan), Hasbro's Furby, Sony's AIBO (robotic dog) and iRobot's My Real Baby (robotic baby doll). In a recent study of postings to an online AIBO discussion forum, Friedman et al. [2003] found that 28% of participants reported having an emotional connection to their robot and 26% reported that they considered the robot a family member or companion.

While some human relational strategies can be implemented in almost any medium, many of the strategies are most effectively conveyed in natural language dialogue, or even require an animated human body to enact (e.g., nonverbal immediacy behaviors). The former builds on work in natural language processing, but especially work that incorporates social deixis, such as the system by Walker et al. [1997] that implemented aspects of politeness theory. The implementation of appropriate use of nonverbal behavior in simulated face-to-face conversation with an animated interface agent has spawned the field of embodied conversational agents [Cassell et al. 2000b].

Given that relational agents are those intended to produce a relational response in their users, such as increased liking for or trust in the agent, the studies by Reeves and Nass and their students on relational aspects of human-computer interaction constitute the bulk of work in this area to date. The majority of these studies use nonembodied, text-only human-computer interfaces.

In their book on the Media Equation, Reeves and Nass [1996] demonstrated the following relational effects:

—Computers that use flattery, or which praise rather than criticize their users are better liked.
—Computers that praise other computers are better liked than computers that praise themselves, and computers that criticize other computers are liked less than computers that criticize themselves.
—Users prefer computers that match them in personality over those that do not (the "similarity attraction" principle).
—Users prefer computers that become more like them over time over those which maintain a consistent level of similarity, even when the resultant similarity is the same.
—Users who are "teamed" with a computer will think better of the computer and cooperate more with it than those who are not teamed (the "in-group membership" effect, which can be achieved by simply signifying that the user and computer are part of a team).

Other studies within this computers as social actors paradigm include one by Morkes, Kernal and Nass, who demonstrated that computer agents that use humor are rated as more likable, competent and cooperative than those that do not [Morkes et al. 1998]. Moon [1998] also demonstrated that a computer that uses a strategy of reciprocal, deepening self-disclosure in its (text-based) conversation with the user will cause the user to rate it as more attractive, divulge more intimate information, and become more likely to buy a product from the computer.

In a recent attempt to challenge the Media Equation, Shechtman and Horowitz [2003] did a study in which participants interacted with a computer system in solving the Desert Survival Problem via a text chat interface, with half of the subjects told they were interacting with a computer and half told they were interacting remotely with another human. They found that participants used significantly more words and spent longer in discussion, and used over four times as much relational language, when they thought they were interacting with another human compared to when they thought they were interacting with a computer. However, given that subjects were told they were interacting with a computer, that the interface itself did not present any social cues beyond those in the natural language text, and that these text responses apparently included little or no relational language (and no uptake on subject's relational language), their outcome does not say anything about the inclination of people to use relational language with a truly relational agent or their ability to bond with them.

Following a long line of research on the impact of mirroring behaviors on social distance (e.g., LaFrance [1982]), Suzuki et al. [2003] evaluated the degree to which a computer character's mirroring a user's intonation patterns affected the user's attitudes towards the character. They demonstrated that the more frequently the computer matched the user in intonation (producing nonlinguistic, hummed outputs) the higher the user rated the computer on measures of familiarity, including comfortableness, friendliness, and perceived sympathy.

Trust was mentioned in Section 3.4 as an important dimension of human relationships. There has also been a fair amount of work over the last few decades on people's perceptions of trust in man-made artifacts, particularly in machinery and, more recently, computers. Tseng and Fogg [1999] define trust as "a positive belief about the perceived reliability of, dependability of, and confidence in a person, object, or process," and claim that it is one of the key components used in assessments of "computer credibility". Research on human-computer interfaces has found several interesting results with respect to trust. It has been found that trust in intelligent systems is higher for systems that can explain and justify their decisions [Miller and Larson 1992]. There have also been studies showing how specific design elements, such as the use of color and clipart [Kim and Moon 1997] or the inclusion of comprehensive product information [Lee et al. 2000] can influence a user's perception of trust in an interface. In anthropomorphic interfaces, pedagogical agents, especially those that are highly expressive, have been found to affect students' perceptions of trust; such agents are perceived as helpful, believable, and concerned [Lester et al. 1997]. However, van Mulken et al. [1999] found that personification of an interface by itself does not appear to be a sufficient condition for raising the trustworthiness of a computer. These studies indicate that, while personification alone is not sufficient to build trust with a user, there are interface features and specific behaviors that an interface agent can use to increase a user's trust in it.

5.1 Relational Modeling for Social Discourse Planning

Few systems in the literature have used explicit relational models in an ongoing way, and only one has used such a model for assessing ever-changing relational variables and generating dialogue moves based on these variables: the REA agent. The social dialogue planner developed for the REA system was the first to use an explicit model of the agent-user relationship, which was both dynamically updated and used for dialogue planning during the course of a conversation [Bickmore and Cassell 2001]. The planner was designed to sequence agent utterances—both task and social—in order to satisfy both task and relational constraints.

REA is a real-time, multimodal, life-sized embodied conversational agent that plays the role of a real estate agent who can interview potential home buyers and show them around virtual houses for sale [Cassell et al. 1999, 2000a]. Real estate sales was selected as the application domain for REA specifically because of the opportunity it presented to explore a task domain in which a significant amount of relational dialogue normally occurs. Within this domain the initial interview between an agent and a prospective buyer was modeled.

The system used a dimensional relational model with three scalar components (inspired by Svennevig [1999]):

—*Familiarity-Depth*. Based on social penetration theory, this indicates the depth of self-disclosure achieved.

—*Familiarity-Breadth*. Indicates the amount of information known about each other.

—*Solidarity*. Indicates "like-mindedness" or having similar behavior dispositions.

The planner makes contributions to the conversation in order to minimize the threat to the user (e.g., talk about personal finances is more threatening than talk about the weather), while pursuing task goals in the most efficient manner possible. That is, it attempts to determine the threat of the next conversational move, assess the solidarity and familiarity that currently holds with the user, and judge which topics will seem most relevant and least intrusive to users. As a function of these factors, it chooses whether or not to engage in social dialogue, and what kind of social dialogue to choose.

The discourse planner integrates a number of nondiscrete factors in an activation network framework [Maes 1989] in which each of the actions represents a conversational move the agent can make. These factors include: threat to the user (a property of topics, for example, finance is more threatening than talk about the weather); coherence of the move with the current topic of conversation (based on a measure of similarity between the move's topic and the current topic); and relevance of the move to the user (based on a measure of similarity between the move's topic and topics known to be relevant to the user). Within this framework, REA decides to do small talk whenever closeness with the user needs to be increased (e.g., before a task query can be asked), or the topic needs to be moved little-by-little to a desired topic and social dialogue contributions exist that can facilitate this.

In an empirical evaluation experiment involving 31 human subjects in which REA was controlled by a confederate in a Wizard of Oz setup, small talk was demonstrated to increase users' trust in REA for extroverts (for introverts it had no effect) ($F = 5.0; p < .05$). This model and study indicates that it is possible for computer agents to successfully plan and execute behaviors designed to achieve relational goals with users.

6. A RELATIONAL AGENT FOR LONG-TERM HELPING

A key aspect of relationship is that it is a persistent construct, spanning multiple interactions. Yet, all studies to date on relational agents—and conversational agents in general—have used single-session experimental designs. In order to explore this longitudinal aspect of human-computer relationship, we thought it was important to develop and evaluate a relational agent that could support multiple interactions with a user over an extended period of time. Thus, we constructed a platform to deploy and evaluate strategies for not only creating a relationship, but maintaining it as well.

Given the range of possible applications for relational agents described in Section 2, we decided to evaluate these relationship maintenance strategies within the context of a health behavior change application. The reason for this is that the dimension of the therapist-patient relationship that is credited with the significant influence on outcome—the *working alliance*—is well-understood and measurable (e.g., Horvath and Greenberg [1989]). Further, there already exist brief duration techniques for effecting health behavior change, many of which have been successfully computerized [Velicer and Prochaska 1999; Riva et al.

2000; Celio et al. 2002]. 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 government guidelines are that all adults engage in thirty minutes or more of moderate-intensity physical activity on most, and preferably all, days of the week [Pate et al. 1995]. In addition, effective health behavior change is of direct benefit to study participants, and exercise adoption is particularly relevant to the college population that comprised the subject pool for our study [Pinto et al. 1998].

6.1 Design of the FitTrack System

The MIT FitTrack system was designed to be used by study participants on their home computers on a daily basis during a one-month intervention, with each interaction lasting approximately ten minutes. The intervention coupled state-of-the-art behavior change techniques with a relational agent who played the role of an exercise advisor that participants talked to about their physical activity. Major aspects of the system design were based on studies of interactions between professional exercise trainers and clients, surveys of representative study participants, literature reviews of therapist-client and physician-client interactions and health behavior change methodology.

In order to support a large number of study participants on a wide range of personal computers, a client-server architecture was developed in which the client (running on participants' computers) was kept as lightweight as possible. The client consists of two web browsers coupled with a vector-graphics-based embodied conversational agent synchronized with a text-to-speech engine (see Figure 1). All dialogue and application logic, as well as the relational database backend, was kept on the server.

Although the agent uses synthesized speech and synchronized nonverbal behavior, user contributions to the dialogue are made primarily by selecting items from multiple-choice menus of text phrases, dynamically updated based on the conversational context (shown at the bottom of Figure 1). We experimented with speech recognition and natural language understanding in the REA project [Bickmore and Cassell 2001], but found that the current state-of-the-art in these technologies does not come close to supporting the social dialogue (and conversational speech register) required for long-term relationship-building. Even in the Wizard-Of-Oz setup used in the REA study, in which understanding was performed by a human confederate, subjects found that the agent's fixed repertoire of output utterances left them feeling that REA wasn't really listening to them. 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 constraining what the user can say in every context, the agent's responses can be crafted to cover the entire space of possible inputs.

Dialogues were scripted, using a custom scripting language that compiled into Augmented Transition Networks (ATNs [Woods 1986]) so that common subdialogues could be factored out and re-used across interactions. In addition to network branching operations, ATN actions can include saving values to

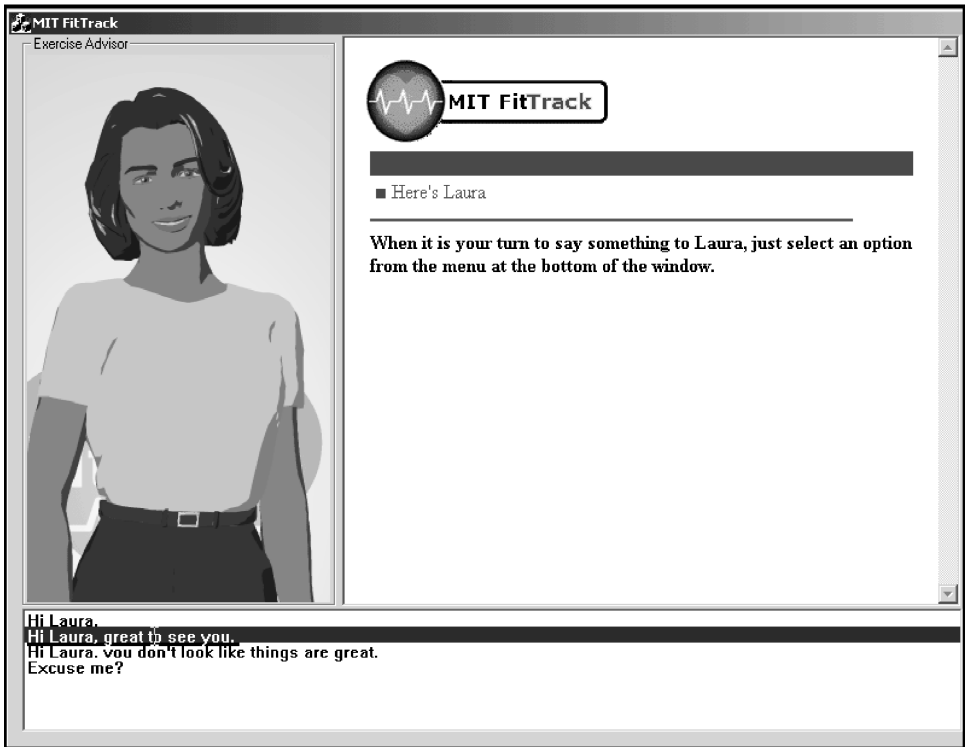

Fig. 1. FitTrack client with exercise advisor and browsers.

the database or retrieving and testing values from the database, in order to support the ability to remember things about users and to be able to refer back to prior conversations. For example, it could remember that the user said she liked to exercise with a buddy, and ask her about such opportunities in a future dialogue. Utterances output to the agent could be tailored at runtime through the inclusion of phrases derived from information in the database or other sources (template-based generation).

The embodied agent had a range of nonverbal behaviors that it used for co-verbal communicative and interactional functions, including: hand gestures [McNeill 1992], body posture shifts [Cassell et al. 2001], gazing at and away from the user [Torres et al. 1997], raising and lowering eyebrows, head nods, and walking on and off the screen. It also supported four different facial expressions, variable proximity (wide to close-up camera shots) and several idle-time behaviors (subtle shifts or self-adaptors). Co-verbal behavior was specified one utterance at a time in XML messages sent from the server to the client. This behavior was determined for each utterance using the BEAT text-to-embodied-speech system [Cassell et al. 2001b], with several enhancements to support the exercise dialogues. One such enhancement was that conversational frame (task-oriented, social, empathetic, or encouraging) could be specified in the script and automatically translated into appropriate changes to facial expression, proximity and speech synthesizer intonation outputs by BEAT. Selection

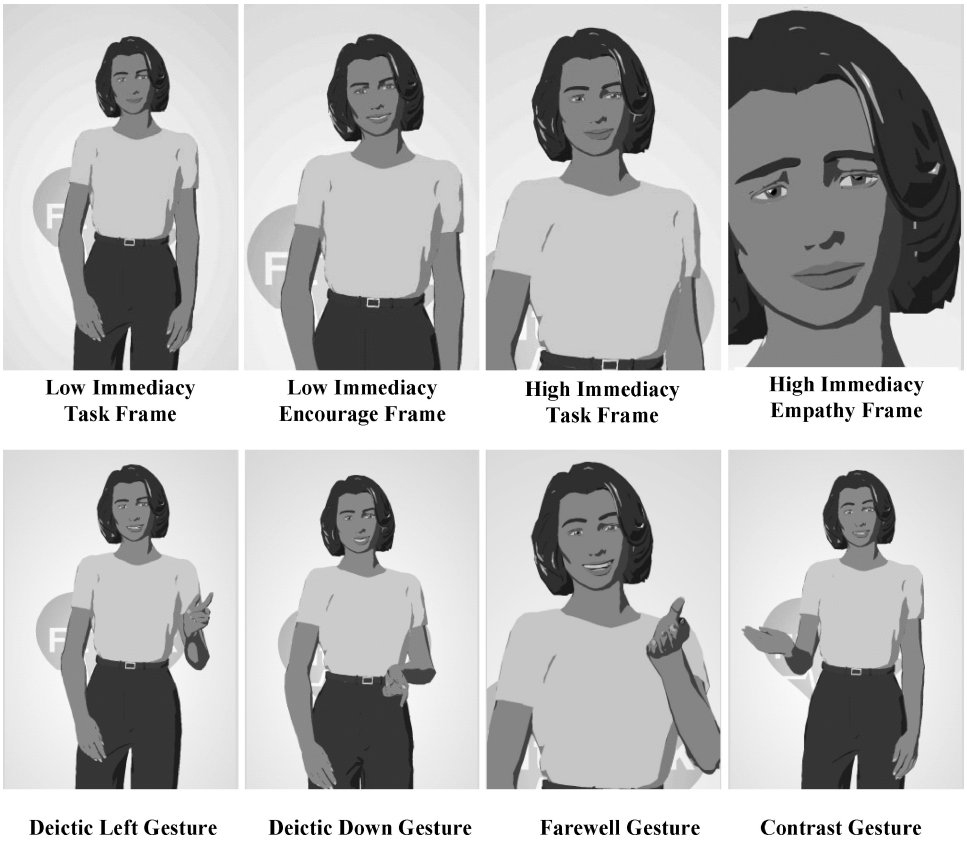

Fig. 2. Example of nonverbal behavior produced by the exercise advisor.

of the nonverbal behavior used in the system was based on reviews of relevant literature (e.g., on immediacy behavior), and analysis of videotaped interactions between human exercise trainers and subjects from our study population. Figure 2 shows examples of nonverbal behavior used by the agent.

6.2 Relational Behavior

The model of relationship used by the FitTrack agent is essentially a stage model, in which the trajectory of change in the relationship is fixed over the 30 scripted dialogues. The working alliance is thought to increase to a stable level after approximately seven sessions in psychotherapy [Horvath and Symonds 1991], so the relational strategies used by the agent are phased in over the first seven interactions.

All of the relational strategies described in Section 4 were implemented, and all were used in the interaction dialogues, including social dialogue, empathy dialogue meta-relational communication, humor, continuity behaviors, and appropriate social deixis (forms of address and politeness strategies). Also, nonverbal behavior was modulated to reflect high or low immediacy via an extension to BEAT, that translated this setting into modulations in the frequency

Close form of address

```
A: Hi Chrissy.
U: Hi Laura, great to see you.
```

Empathy exchange

```
A: How are you doing today?
U: I'm not feeling so great.
A: I'm sorry to hear that.
U: Tell me more about how you are feeling
...
```

Social dialogue

```
A: So, are you a student?
U: Yes
A: Do you go to MIT?
U: No
A: Oh, what school do you go to?
U: Cambridge Continuing Education, right now.  I am working
   toward a degree at Tufts.
...
```

Task dialogue

```
A: So, now I'd like to ask you a little about your exercise
   behavior. Do you currently do any kind of sport?
U: No, I don't
A: Do you currently do any other kind of aerobic exercise
   regularly?
U: I do something else
A: What do you do?
U: I do tap dancing.  I also walk to and from work.
...
```

Continuity behavior

```
A: So, when can we get together again?
U: Tomorrow.
A: Great. Take care Chrissy , I'll talk to you tomorrow.
   Good night.
```

Fig. 3. Interaction transcript fragment demonstrating verbal relational behaviors used by the exercise advisor ('A' is agent; 'U' is user).

of hand gestures, eyebrow raises, headnods, and gaze-aways, as well as the proximity of the agent (e.g., she would appear to move closer to the user in the high immediacy condition). Figure 3 shows a fragment of an interaction transcript demonstrating many of the verbal relational behaviors used by the agent.

6.3 Experimental Methods

An evaluation of the exercise advisor agent was conducted using a longitudinal, between-subjects design to evaluate the effects of different intervention strategies on the level of physical activity in study participants over a six-week period of time. The experiment followed the standard pattern for a behavior change study with an initial baseline measurement of the behavior of interest, followed by an intervention period (30 days), followed by removal of the intervention, and finally a follow-up measurement to check if the new behavior extinguished (14 days after the end of the intervention) [Sunde and Sandra

Table I. Differences Between RELATIONAL and NONRELATIONAL Versions of the FitTrack Exercise Advisor Agent

Relational Behavior	Study Condition	
	RELATIONAL	NON-RELATIONAL
Social dialogue (Cassell and Bickmore 2003)	Daily	None
Meta-relational dialogue (Stafford and Canary 1991)	Frequent	Minimal
Form of address (Laver 1981)	Friend	Stranger
Politeness (Brown and Levinson 1987)	Indicative of small social distance	Indicative of large social distance
Empathy exchanges (Klein et al. 2002)	Daily	None
Humor (Morkes et al. 1998)	Frequent	None
Continuity behaviors (Gilbertson et al. 1998)	Daily	None
Nonverbal immediacy (Richmond et al. 1995)	High	Low

1999]. The primary target behavior in this study is the current national standard recommended minimum level of physical activity: "Every US adult should accumulate 30-minutes or more of moderate-intensity physical activity on most, preferably all, days of the week" [Pate et al. 1995]. A secondary goal of 10,000 steps walked per day was also given to subjects, as this is roughly equivalent to 30 minutes of moderate activity [Tudor-Locke and Myers 2001].

The study was designed to ensure that subjects interact with the system for a brief period of time every day to provide the agent with an opportunity to build and maintain a relationship with them. The study had three conditions: RELATIONAL, NON-RELATIONAL, and a baseline CONTROL condition. In all conditions subjects recorded their daily activity via self-report forms, using 7-day recall at the start of the experiment and the end of the follow up period [Sallis 1997], and daily recall during the balance of the first month. All subjects were also given pedometers and asked to report the number of steps taken each day during the intervention, to provide an objective measure of their physical activity level. In all conditions, subjects received standard behavioral interventions, including self-monitoring (progress charts showing their activity levels over time) and educational content on the topic of walking for exercise [Knapp 1988]. All subjects in RELATIONAL and NON-RELATIONAL conditions also had a daily conversation with the exercise advisor agent about their progress, any obstacles they had to exercising, and the educational content. In the RELATIONAL condition the agent also used the relational strategies described above in an attempt to build a working alliance with subjects, whereas in the NON-RELATIONAL condition this relational behavior was ablated (see Table I).

Measures. There were several measures used to assess the quality of the relationship between participants and the agent (named "Laura"). The most important of these was the Working Alliance Inventory (WAI) [Horvath and Greenberg 1989], a 36-item self-report instrument (introduced in Section 2.4), which has three subscales: bond—the degree to which the helper and helpee like and trust each other (e.g., "My relationship with Laura is very important to me."); task—the degree to which the helper and helpee agree on the therapeutic tasks to be performed (e.g., "The things that Laura is asking me to do don't make sense."); and goal—the degree to which the helper and helpee agree on the goals

of therapy (e.g., "Laura perceives accurately what my goals are."). The WAI was slightly modified to make its questions appropriate for reference to a machine, for example, the statement "I understand (person) and she understands me." was changed to "I understand Laura and she understands me, at least in the best way she can." to allow for people who know that computers don't really *understand* things to answer more honestly. The WAI was administered on day 7 of the intervention because studies with human therapists indicate that alliance reaches a peak by the 7th session [Horvath and Symonds 1991]. It was administered again near the end of the intervention (day 27) to see if it had changed over the course of the month. Several additional questions were used to assess other aspects of the relationship, including: "How much do you like Laura?", "How would you characterize your relationship with Laura?" (ranging from "Complete Stranger" to "Close Friend"), and "How much would you like to continue working with Laura?". These questions were asked on day 30 of the intervention, and the last one was asked again as part of the follow-up two weeks after the FitTrack sessions were terminated.

We also assessed relationship quality using a behavioral measure. At the end of the last interaction with Laura (day 30), the choices given to subjects for saying farewell included a brief farewell ("Bye.") and a "sentimental" farewell ("Take care Laura, I'll miss you."). This measure tracked whether each subject chose the sentimental version or not, under the assumption that a closer bond would lead to an increased frequency of sentimental partings.

The efficacy of the agent was also assessed by asking "Who was most helpful in getting you to exercise over the last month?", with possible responses being "Laura", "friends", "family", "workout buddy" or "none of the above" asked on day 30 of the intervention.

Participation is another type of measure often used in behavior change studies; assessing the degree to which participants interacted with the intervention. In order to measure this we allowed participants to access all of the educational content in a library at the end of each session, and tracked the average number of pages they accessed per session. We also asked subjects about the degree to which they would like to continue using the overall FitTrack system, at the end of the intervention and at follow-up.

Population. Our target population consisted of generally healthy adults who were interested in becoming more physically active, but were not yet maintaining the recommended 30 minutes per day of moderate activity [Prochaska and Marcus 1994], and had access to a home computer with Internet connectivity. Participants were recruited via fliers and newspaper ads, and were compensated with $25 at the completion of the study, plus they were allowed to keep their pedometers.

Analysis. 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).

Our hypotheses were that subjects in the RELATIONAL condition would score higher on all measures than those in the NON-RELATIONAL condition, and that subjects in the RELATIONAL and NON-RELATIONAL conditions

Table II. Results for All Subjects

	Day of	CONTROL		NON-REL		RELAT'NAL		REL>NON-REL			AGENT>CONT		
Measure	Study	Mean	SD	Mean	SD	Mean	SD	df	t	p	df	t	p
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**			
WAI/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			
LIKE LAURA	**30**			4.61	1.31	5.21	1.35	57	2.03	**0.02**			
RELATIONSHIP	**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**			
with Laura	**44**			2.04	0.88	2.62	1.05	53	1.83	**0.04**			
SENT FAREWELL	**30**			0.35	0.49	0.69	0.47	54	2.80	**0.00**			
Minutes/Day of	**−6–0**	50.51	41.92	40.24	33.44	54.92	75.51	58	0.90	0.19	88	0.05	0.48
Moderate Activity	**1–7**	41.37	20.30	41.90	19.07	40.11	17.79	58	0.08	0.47	88	0.87	0.19
	8–14	37.54	19.10	39.94	23.45	37.20	17.12	58	0.10	0.46	88	0.13	0.45
	15–21	40.57	19.66	42.62	20.79	39.26	15.28	58	0.82	0.21	87	0.38	0.35
	22–30	39.08	22.21	41.09	19.20	38.86	18.20	57	0.17	0.43	86	0.03	0.49
	38–44	27.49	12.58	34.26	19.81	32.35	26.34	53	0.20	0.42	81	0.38	0.35
Days/Week over	**−6–0**	4.08	2.80	3.54	2.43	3.74	2.78	58	0.87	0.19	88	0.06	0.48
30 minutes of	**1–7**	4.32	2.10	4.42	1.59	4.19	1.73	58	0.24	0.41	88	0.27	0.40
Moderate Activity	**8–14**	4.64	2.33	4.38	2.00	4.48	2.19	58	0.68	0.25	88	0.01	0.50
	15–21	4.36	2.18	5.13	2.01	4.59	1.89	58	0.93	0.18	87	1.06	0.15
	22–30	5.32	2.85	6.25	2.54	6.22	2.41	57	0.24	0.40	86	1.54	0.06
	38–44	3.08	2.00	3.88	2.29	3.67	2.45	53	0.01	0.50	79	1.34	0.09
Steps/Day	**1–7**	8242	2654	9425	2891	8800	3359	58	0.34	0.37	88	1.14	0.13
	8–14	8869	2998	9926	3343	9414	3796	58	0.57	0.28	88	0.76	0.22
	15–21	9709	3291	10208	3025	10091	3031	57	0.45	0.33	86	0.10	0.46
	22–30	9052	3890	10435	3597	9523	3277	57	0.98	0.16	86	0.60	0.28
Days/Week over	**1–7**	2.04	1.79	2.25	1.54	2.52	1.95	55	0.78	0.22	84	0.66	0.26
10,000 steps	**8–14**	2.12	1.92	3.21	2.30	2.67	2.30	55	0.75	0.23	84	1.05	0.15
	15–21	2.76	2.01	3.46	2.04	3.26	2.10	55	0.16	0.44	83	0.42	0.34
	22–30	2.68	2.63	3.96	2.80	3.56	2.45	56	0.65	0.26	84	1.54	0.06
PAGES VIEWED	**1–30**	1.07	0.08	1.16	0.23	1.39	0.89	58	1.31	0.10	88	1.70	**0.05**
Desire to Continue	**30**	2.93	0.68	2.92	0.81	3.00	0.83	57	0.98	0.17	86	0.13	0.45
with FitTrack	**44**	2.70	0.87	2.76	0.88	3.00	0.79	53	1.07	0.15	79	0.89	0.19

combined would score higher than those in the CONTROL group on activity and participation measures.

6.4 Results

Of the 101 participants who started the study, 89 completed the intervention and 84 completed the follow-up survey, with drop-outs distributed equally across conditions. Participants were randomly assigned to the three conditions of the study, which were also balanced by gender.

Results for all subjects are summarized in Table II. Figure 4 shows the means for the two administrations of the working alliance inventory questionnaire. The only significant differences are on the bond subscales of both surveys, in the hypothesized direction (greater for RELATIONAL): for day 7, $t(58) = 1.75$, $p < .05$; and for day 27, $t(57) = 2.26$, $p < .05$.

In response to the question "How much do you like Laura?", subjects in the RELATIONAL condition reported that they liked her significantly more than

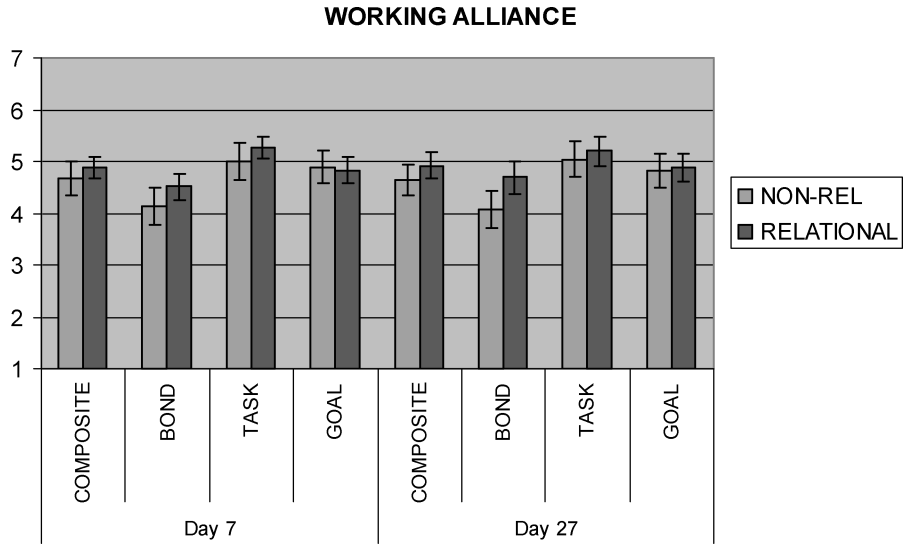

Fig. 4. Working alliance scores for all subjects.

those in the NON-RELATIONAL group, $t(57) = 2.04$, $p < .05$. Subjects in the RELATIONAL condition also reported a closer relationship with Laura ("How would you characterize your relationship with Laura?"), $t(57) = 1.62$, $p = .06$, approaching significance.

When asked at the end of the intervention period (30 days) and again at follow up (two weeks later) if they would like to continue working with Laura, subjects in the RELATIONAL condition responded much more favorably compared with the NON-RELATIONAL group, $t(57) = 2.43$, $p = .009$ and $t(53) = 1.83$, $p < .05$, respectively.

Although there were no significant differences in the degree to which subjects said they wanted to continue working with the FitTrack system, the means for these measures were in the hypothesized direction at both end of intervention and follow-up (CONTROL < NON-RELATIONAL < RELATIONAL). In addition, during post-experiment debriefs three subjects (all in RELATIONAL condition) actually pleaded with the experimenters to leave the system running so they could continue to use it.

Given the opportunity to give Laura a sentimental farewell at the end of the intervention period, significantly more subjects in the RELATIONAL group took this option (69%) than in the NON-RELATIONAL condition (35%), $t(54) = 2.80$, $p = .004$.

Figure 5 shows the results of asking subjects about who had been the most helpful in getting them to exercise over the intervention period. The "None of the Above" category is problematic, since it represents the cases in which the subject thought they helped themselves most, another person not listed helped them most, or if they felt that no-one helped them most. Thus, excluding this category from analysis, significantly more subjects said that Laura helped them than friends, family or their workout buddy, $X^2(df = 3, n = 41) = 11.19$, $p < .05$.

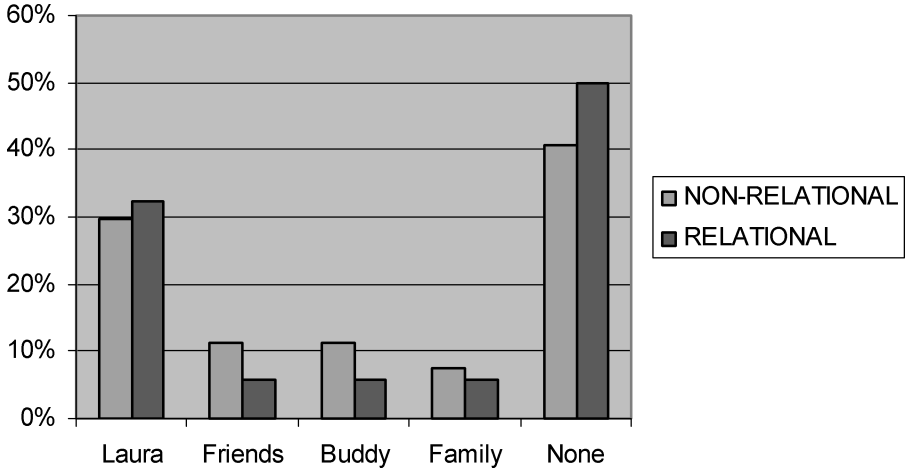

Fig. 5. Who had been most helpful in motivation for all subjects.

Unfortunately, these differences in relational measures did not translate into differences in exercise behavior. All groups significantly increased their level of physical activity during the intervention (in both days/week over 30 minutes activity, paired $t(81) = 6.27$, $p < .001$, and days/week over 10,000 steps, paired $t(77) = 3.99$, $p < .001$), and significantly decreased their activity during the two-week follow-up (in days/week over 30 minutes activity, paired $t(81) = 8.99$, $p < .001$); there were no significant differences between groups with respect to the planned comparisons.

After the study had started we discovered that a significant number of subjects were already performing an average of 30 minutes per day of moderate activity at baseline assessment, so the analyses were repeated for the most sedentary subset of participants. This subset was defined as those who performed less than 30 minutes per day of activity (on average) at baseline or in week one of the intervention, resulting in a group of 45 for analysis (19 RELATIONAL, 11 NON-RELATIONAL, 16 CONTROL). Within this subgroup, there were significant differences in exercise behavior between the CONTROL group and the other two groups in the final week of the intervention, with the RELATIONAL and NON-RELATIONAL groups reporting more days per week over 30 minutes of moderate activity (5.66 vs. 3.36 days per week over 30 minutes/day, $t(42) = 2.07$, $p = .022$, see Figure 6) and more days per week over 10,000 steps (3.65 vs. 2.09 days per week over 10,000 steps/day, $t(41) = 1.92$, $p = .031$, Figure 7). Additionally, the relational results reported above for all subjects still held, and were even more significant (WAI bond day 7 $t(28) = 2.55$, $p = .008$; WAI bond day 27 $t(28) = 3.46$, $p = .001$; liking of Laura $t(28) = 2.60$, $p = .007$; desire to continue with Laura day 30 $t(28) = 3.39$, $p = .001$; desire to continue with Laura day 44 $t(26) = 1.88$, $p < .05$; sentimental farewell $t(26) = 4.98$, $p < .001$).

Figure 8 shows the number of educational content pages viewed by subjects. The results of the planned comparisons indicate that the two agent groups chose

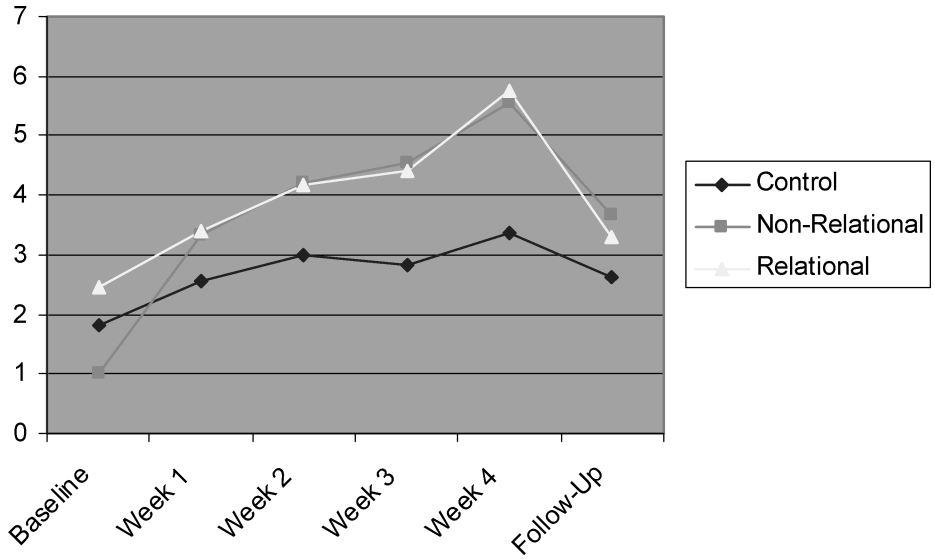

Fig. 6. Days per week at or over 30 minutes moderate activity goal by sedentary subjects.

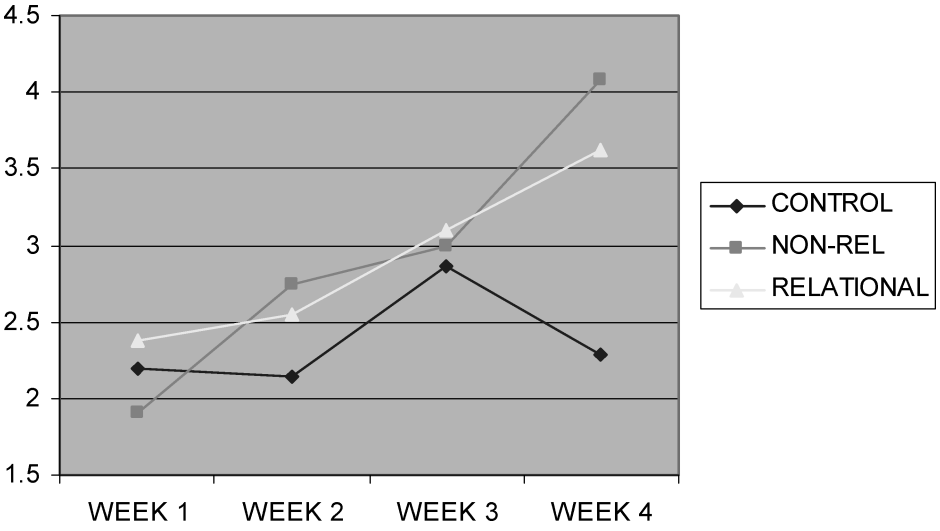

Fig. 7. Days per week at or over 10,000 steps goal by sedentary subjects.

to view significantly more informational pages following their interactions than did the CONTROL group, $t(88) = 1.70$, $p < .05$.

6.5 Discussion

Use of relational behaviors by an animated exercise advisor resulted in significant increases in participants' perceptions of the quality of the working relationship: measures such as liking, trust, and respect were significantly

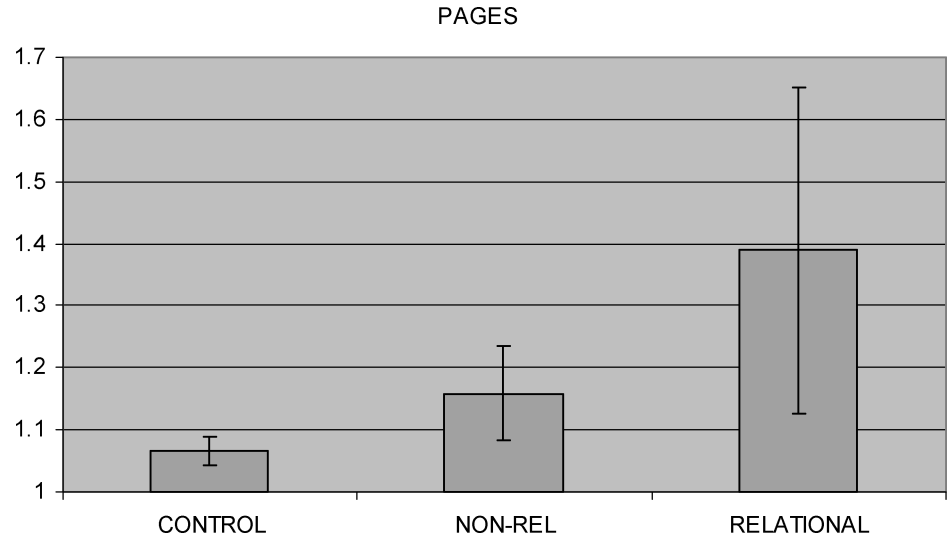

Fig. 8. Number of educational content pages viewed by all subjects.

higher for the relational agent than for the nonrelational one. Additionally, subjects expressed significantly higher desire to continue interacting with the relational agent, even after four weeks of interaction. Use of relational behaviors did not simply make the agent less annoying—subjects in the two agent groups expressed a stronger desire to continue using the FitTrack system than those in the CONTROL group (although the differences were not significant)—and subjects who interacted with an agent to do daily goal setting and follow up significantly increased their physical activity relative to the CONTROL group (for the most sedentary participants).

The significant drop off in exercise behavior during the brief follow up period indicates that a lasting change in behavior was not achieved. Sixty-three percent of subjects who completed the study reported levels of activity at or below their baseline levels at follow up. The drop off was most acute for those in RELATIONAL condition. According to one expert in health behavior change, a rapid increase in behavior change during intervention followed by a rapid decrease following the removal of intervention is characteristic of face-to-face interactions with behavior change professionals [J. Prochaska 2003 Personal Communication]. By this measure, it would seem that the RELATIONAL agent has succeeded in replicating some of the effects of face-to-face counseling. One way to reduce the rapid relapse rate is to gradually "wean" subjects off the advisor by having them reduce the frequency of their interactions before terminating the intervention completely, although with a low-cost automated system there may actually not be any reason for people to stop using it.

The lack of significant differences between RELATIONAL and NON-RELATIONAL groups with respect to physical activity measures may be due to several factors. The working alliance has three dimensions, and the significant effect achieved in this experiment on the bond dimension may be insufficient in

and of itself to translate into changes in exercise behavior; significant changes in the task and goal dimensions may also be required, requiring more dialogue and negotiation on these topics. It may simply be a matter of too few subjects; our initial power analysis indicated that 90 (30 per condition) would be required (one-tailed power analysis, with $\alpha = 0.05$, $\beta = 0.2$ based on prior alliance and behavior change studies), while only 41 subjects in the sedentary group actually completed the study. Finally, the study was too short in duration to detect any real long-term changes in exercise behavior. Attrition is probably one of the most important measures of success (or lack thereof) in this kind of program, and a study with a much larger set of subjects over a much longer period of time would be required to detect significant changes in this metric.

Interviews were conducted with a number of the participants in the RELATIONAL and NON-RELATIONAL groups to obtain qualitative feedback on the system and experience. Overall impressions of the system were very favorable. Participants found interacting with the agent to be relatively natural; however, as one would expect given individual variations in preferences, subjects were divided on how they felt about talking to an animated character:

> It was a really, really great idea to have some kind of animated character because it makes you feel like you're actually talking to a person rather than having words on the computer screen.
>
> 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.
>
> Once I kind of got used to Laura in general, I didn't really see her as a computer character. It didn't really bother me.
>
> I didn't really like Laura very much. . . . Actually, I liked all of the software except for the animated conversation thing.

One surprising finding from the interviews was that, even though the dialogue scripts had been authored to provide significant variability in each days' interaction, most participants found the conversations repetitive at some point during the month. This repetitiveness annoyed subjects, and a few subjects even indicated that it negatively impacted their motivation to exercise:

> In the beginning I was extremely motivated to do whatever Laura asked of me, because I thought that every response was a new response. Whereas, towards the end I could tell what she was going to say to a couple of my responses.

7. CONCLUSIONS

In this article, we have motivated the development of relational agents as a new field of research, and presented a platform for the design, development, and evaluation of such an agent that builds and maintains a relationship with its users over time, using many of the relational strategies that people use in face-to-face conversation.

The evaluation study of the exercise advisor system demonstrated that people will readily engage in relational dialogue with a software agent, and that this can have positive impacts on users' perceived relationship with the agent. The embodied conversational agent used in this system incorporated many firsts. It is the first designed for long-term interactions with users, and which incorporates the ability to remember relational information about users between interactions and refer back to such in subsequent dialogues. It is the first interactive embodied conversational agent designed for use on home computers that incorporates a wide range of naturalistic coverbal behavior, including hand gestures, posture shifts, and facial animation. It is the first interactive embodied conversational agent designed for scalable client-server deployment to support a large number of users. It also includes the widest range of verbal and nonverbal behaviors yet developed for relationship-building and emotional support. And, it is the first to demonstrate significant impact of the long-term use of a large set of relational behaviors.

7.1 Research Challenges

There are many fruitful directions this research could be advanced in the future. In the area of natural language dialogue, the issue of repetitiveness is a very interesting research problem; exactly how much variability, and what kinds of variability, are required to keep a user engaged in a given task over a long period of time? Although the scripting language for the exercise advisor agent was fairly sophisticated, ultimately it should be replaced with a natural language text generation system. Interesting research problems for long-term relationships relative to this change include how to refer back to prior conversations (what does a historical discourse context look like?) and how to incrementally populate such a system with new knowledge and topics of conversation so that someone could use such a system for an indefinite period of time without it repeating itself. Additionally, it would be interesting to investigate introduction of variability by changing nonlinguistic vocal characteristics that, in people, would arise from natural changes in mood, energy-level, and health. These could be achieved by having internal models for these states within the agent, and using parameters of these models to modulate the verbal output.

Empathic dialogue itself poses some very interesting research questions. Which input and output modalities are best for communicating emotional understanding? Is it better to allow a user to express himself in an unconstrained manner (free text or speech) given that the system cannot completely understand what he is saying, or is it better to constrain him to a small set of feeling state choices, each of which results in the system providing an empathically accurate response?

Additionally, there is much work to be done on recognition of user affect. The current system is asymmetric in that it expresses affective cues to the user through both verbal and non-verbal channels, while it only reads them from the user through menu selections. Research in affect perception is actively trying to address machine recognition of human expression [Picard 1997].

Fig. 9. Handheld embodied conversational agent.

As mentioned, the relational agent described in this article incorporates all the relational strategies described in Section 4. However, it is possible that some of these were ineffective, possibly due to misunderstood theory or poor implementation, and that a different subset might lead to different results. More work should be done to examine which relational strategies are most effective for particular interaction design goals.

The exercise advisor represents a single point in a large space of possible helping applications. There are potentially many other helping domains that could benefit from the deployment of a relational agent, from other health behavior change domains (e.g., smoking cessation, diet) to coaching, counseling and therapy. Within each of these areas there are many additional strategies that could be explored for relationship building and therapeutic intervention.

Finally, relational agents on mobile devices could provide a particularly powerful combination, both for relationship building (a "buddy" who is always with you) and for behavior change (e.g., providing interventions at the time and place of need, having a workout coach that you can take to the gym, etc.). Our initial plan for the health advisor was to deploy it on a PDA, motivating a study of how people would interact with embodied conversational agents on handheld devices (see Figure 9) [Bickmore 2002]. This remains a fruitful area for further research.

7.2 Lessons for the HCI Practitioner

We have described several important components of human relationships, and made a case for thinking systematically about relational variables in designing future human-computer interactions, even if such interactions do not involve software agents. Most of the relational strategies we described can be

implemented in any conversational system, including the nonverbal strategies: think R2D2 in Star Wars, who communicated affective expression with mechanical beeps and movements. We think that our findings have several important messages for today's developers of user interfaces.

First, deploying a "conversational" interface does not imply that natural language understanding must be used. The dynamic menu-based approach (also used in Rich et al. [2001]) provided many of the benefits of a natural language interface, such as naturalness and ease of use, without having to rely on error-prone understanding of unconstrained input. In our study all 101 subjects managed to use the conversational interface without any training (they were simply told they would be having a conversation with an animated character), without any reported problems, or without having their expectations dashed (a common criticism of natural language and anthropomorphic interfaces).

Meta-relational communication—being very clear up front about the roles of each of the parties in a human-computer relationship, and checking in from time-to-time to see how everything is going and making adjustments as needed—is very important for managing user expectations, and making them feel understood and cared for. Being conscious of the use of social deixis in the interface, including such language features as politeness and forms of address, allows the design of more consistent interfaces and interfaces which are more tailored to individual users or classes of users.

And, as noted by Klein et al. [2002], appropriate use of empathy by a computer can go a long way towards making them feel understood and alleviating negative emotional states such as frustration.

Perhaps most importantly, thinking about human-computer interactions as relationships allows designers to take a long-term view of these collaborations, and the ways in which these relationships should unfold over time. While reliability and consistency are highly prized in most aspects of interface design, there are some applications areas in which variability is important for keeping the user engaged in the task.

7.3 Ethical Issues

One concern that has been raised is that relational agents could conceivably lead to further fractionating of society if, rather than supplying additional social bonds they tend to replace the ones that people already have, or would have had, with other people. This may be true; however, relational agents could also play a positive role in socialization. One way is by acting as social role models. In developing FitTrack we joked that it could actually teach socially backward MIT students to conduct social dialogue. More seriously, there are a number of user groups, such as autistics, for whom social interaction does not come naturally, but can be learned from highly repetitive training with patient therapists, family, and friends. Relational agents could be used to potentially augment such interactions, and they can be infinitely patient if desired.

Another way that relational agents could actually increase socialization is by providing social network support. Imagine if, after a series of set backs at work, your agent contacts your best friend on your behalf, tells them what is going on

and arranges an outing for you. Alternatively, your agent could introduce you to a support group of people who are currently going through similar problems. As with any new technology that is proactive in sharing information about you, this scenario raises issues of privacy and security: with whom do you let it share which pieces of relational or personal information, and how does it earn your trust to do so?

Relational agents, as any technology, can be abused. Agents that earn our trust over time can be used to provide more potent means of persuasion for marketers than more passive forms of advertising. If we eventually come to rely on our agents as sources of grounding for our beliefs, values and emotions (one of the major functions of close human relationships [Duck 1991]) then they could become a significant source of manipulation and possibly even control over individuals. Educating users about the capabilities of relational agents is one important step toward prevention of such manipulation.

This research is also likely to raise questions about the role of sincerity in relational strategies: is being deliberate about the relational strategies you use a bad thing, especially if you know the strategies are likely to increase the probability of some desirable outcome for you? In some ways, relationship formation can be seen as a negotiation, with the potential for win-win, win-lose, and lose-lose outcomes. Now that a variety of relational strategies can be systematically implemented in machines, these strategies can be more carefully examined to understand the role they play in transacting a variety of outcomes, in both human-machine *and* human-human interactions.

A final issue, raised by Picard and Klein [2002] is the ethic of building agents that pretend to care, understand and empathize, when, in fact, they have no emotions of their own. As observed by Turkle [1995], people today seem quite comfortable with computational artifacts that only appear to have emotions and, as confirmed by most users in the FitTrack study, the end seems to justify the means. As one subject put it:

> She's a computer character. I don't know if she cared about me. I don't know if she feels. She's a character and has a role, but I don't know if she has feelings. But, it worked for me and I'm happy.

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