Relational Agents Improve Engagement and Learning in Science Museum Visitors

Timothy Bickmore, Laura Pfeifer, Daniel Schulman

College of Computer & Information Science, Northeastern University. 360 Huntington Ave, WVH202, Boston, MA 02115
{bickmore, laurap, schulman}@ccs.neu.edu

Abstract. A virtual museum guide agent that uses human relationship-building behaviors to engage museum visitors is described. The agent, named "Tinker", appears in the form of a human-sized anthropomorphic robot, and uses nonverbal conversational behavior, empathy, social dialogue, reciprocal self-disclosure and other relational behavior to establish social bonds with users. Tinker can describe exhibits in the museum, give directions, and discuss technical aspects of her own implementation. Results from an experiment involving 1,607 visitors indicate that the use of relational behavior leads to significantly greater engagement by museum visitors, measured by session length, number of sessions, and self-reported attitude, as well as learning gains, as measured by a knowledge test, compared to the same agent that did not use relational behavior. Implications for museum exhibits and intelligent tutoring systems are discussed.

Keywords: Relational agents, social interfaces, interactive installation, embodied conversational agent, intelligent virtual agent, pedagogical agent, intelligent tutoring system.

1 Introduction

Contemporary museums use interactive exhibits, multimedia, games, automated mobile guides, and other mechanisms for entertaining and engaging visitors so that learning has an opportunity to take place, even as visitors flit from exhibit to exhibit. The use of animated pedagogical agents that incorporate principles from the social psychology of human personal relationships represents a promising and important direction of research to further engage museum visitors. For example, the use of reciprocal self-disclosure is known to lead to increases in intimacy and trust in people, and has been demonstrated to work when used by computers [1]. Museum exhibits that engage visitors in this and other human bonding rituals could result in increased visitor satisfaction and engagement, and ultimately lead to increases in learning.

As an initial experiment in building a relational museum exhibit, we have developed a virtual museum guide agent named "Tinker" who is currently installed in the Computer Place exhibit at the Boston Museum of Science (Figure 1). Tinker appears as a six-foot-tall 3D cartoon robot, projected in front of visitors, and

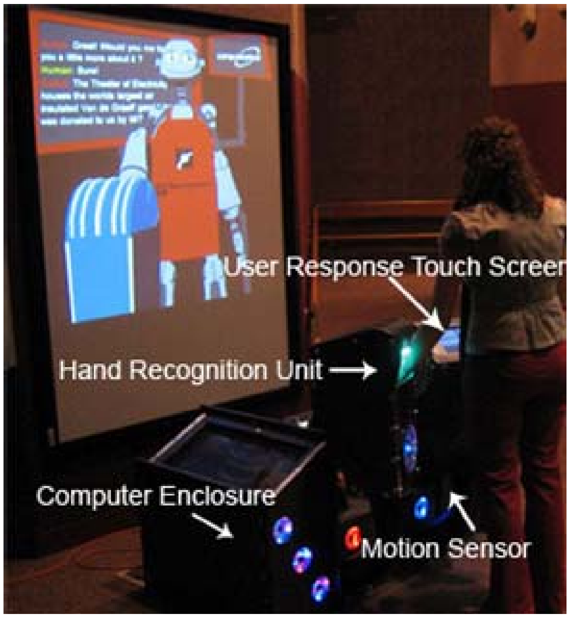

Fig 1. "Tinker" System Installation

communicates with them using synthetic speech and synchronized nonverbal behavior. Tinker can provide visitors with information on and directions to a range of exhibits in the museum, as well as discuss the theory and implementation underlying her own creation. Most importantly, Tinker uses a range of human relationship-building behavior to engage users, along with a biometric sensor to re-identify return visitors so that the conversation, and relationship, can be continued [2]. Since Tinker began operation in April, 2008, over 125,000 museum visitors have interacted with her.

In this work we report on an experimental study designed to evaluate the effect of Tinker's relational behavior on engagement and learning in museum visitors. Several studies have demonstrated that quality of human-human personal relationships in a learning environment has a significant impact on student motivation, academic effort, and learning [3]. We wanted to demonstrate these effects using an animated pedagogical agent in a setting in which a very large sample size was possible, given that meta-analyses have indicated that conversational agent features, such as degree of realism, have only a small effect on user attitudinal measures and little or no effect on task outcomes, such as learning [4, 5].

2 Related Work

Several studies have demonstrated the importance of human relationships in learning environments. Within K-6 education, there is evidence that relationships between students are important in peer learning situations, including peer tutoring and peer collaborative learning methodologies [6]. Collaborations between friends involved in these exercises has been shown to provide a more effective learning experience than collaboration between acquaintances [7]. Friends have been shown to engage in more extensive discourse with one another during problem solving, offer suggestions more readily, 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. Student perception of teacher empathy and caring—prerequisites for quality social-emotional relationships—has also been shown to have significant influences on student motivation and learning. In one longitudinal study of 248 6^{th} to 8^{th} grade students, teacher caring, as perceived by students, was shown to be a significant predictor of student motivation, pro-social goals, academic effort, and grade point average [3].

2.1 Embodied Pedagogical Agents

There have been several explorations into the use of embodied agents in educational software systems, designed to teach material to children and adults [8-12]. Several of these studies have demonstrated positive impacts on student motivation and/or learning [12]. In one series of studies, researchers found that: 1) students who interacted with an educational software system with a pedagogical agent produced more correct solutions and rated their motivation to continue learning and interest in the material significantly higher, compared to the same system without the agent; 2) students who interacted with an agent that used speech output, rated the lessons more favorably and recalled more compared with students who interacted with an agent that used text output; and 3) students who interacted with an agent that used personalized dialogue recalled more than students who interacted with an agent that communicated using non-personalized monologues (as in video-based education) [10]. In another study, students using a pedagogical agent in addition to their normal coursework outperformed both a control group (no additional intervention), and a group directed to reread relevant material from their textbooks [13]. In a review of over a dozen experiments, Graesser et al conclude that the AutoTutor system improves learning by nearly one letter grade compared with control conditions [14]. However, other researchers have failed to demonstrate positive learning outcomes, and some have posited that any gains observed may be due primarily to the use of voice rather than embodiment or social presence [12].

2.2 Interactive Museum Guide Agents

There has also been a significant amount of research on the development of interactive museum exhibits and mobile guide devices over the last decade. Here we briefly review humanoid conversational agents (virtual and robotic) that are deployed in public spaces, three of which are installed in museums as guides (Kopp, et al [15], Shiomi, et al [16], Swartout, et al [17]) and one which acts as a receptionist (Gockley, et al [18]). None of these agents use explicit models of the user-agent relationship, and they have a very limited repertoire of relational behavior (typically limited to form of address and social dialogue). Two are able to identify visitors (Shiomi, based on RFID tags, and Gockley, based on magnetic strip ID cards), but only use this information to address users by name. These systems also only support very limited dialogue: Shiomi's robots can only talk at users (no dialogue support), while Kopp's and Shiomi's use typed-text input and pattern-matching rules which support social chat but do not provide the deep dialogue models required for extended coherent conversation about a given topic. Swartout, et al, developed the "Ada and Grace" exhibit, installed near Tinker in the Boston Museum of Science [17]. In this system, two conversational agents interact with each other and a human handler via speech (visitors are not permitted to talk directly to the agents), discussing the museum and science topics. Summative evaluation results (visitor satisfaction, etc.) have not been published.

2.3 Relational Agents

Bickmore, et al, have conducted a series of studies of conversational agents that use human relationship-building behavior in their interactions with users. In one study, an exercise coach agent was systematically manipulated to use relational behavior (empathy, social chat, form of address, etc.) or not in addition to task-oriented exercise counseling in its daily 10-minute conversations with study participants. In a 30-day longitudinal study, participants who interacted with the agent with the relational behavior enabled scored the agent significantly higher on a standardized measure of patient-counselor working relationship (the Working Alliance Inventory) compared to those participants who interacted with the same agent with the relational behaviors disabled, although no effects on task outcome (exercise behavior) were observed [19].

3 Tinker

Tinker was developed over an eight-month period of time in collaboration with the staff at Computer Place in the Boston Museum of Science. This is a staffed area of the museum that provides visitors with explorations in computer science, communications, and robotics. Work on Tinker's dialogue content, character animation, and physical installation proceeded in parallel. Details on the design principles and methodology used in Tinker's development, and user identification technology employed, have been previously reported [2, 20].

3.1 Dialogue Content and Nonverbal Behavior

Tinker's main purpose is to provide museum visitors with descriptions of and directions to museum exhibits, and to talk about her own implementation. Development of these dialogue scripts began by videotaping museum staff giving descriptions of exhibits and interacting with visitors, in order to characterize these conversations and the nonverbal behavior they used. We then developed the scripts using a hierarchical transition network-based dialogue model [19]. Computer Place staff felt that it was important that Tinker's dialogue about computers be tailored to each visitor's level of computer literacy. Consequently, Tinker establishes each visitor's computer literacy level through dialogue before discussing any technical content, and remembers this for future conversations. We also developed dialogue to answer questions about privacy issues related to the biometric hand reader, explaining that the system only stores a small amount of information and erases it after a short period of time.

Tinker's nonverbal behavior was primarily generated using BEAT [21], including beat (baton) hand gestures and eyebrow raises for emphasis, gaze away behavior for signaling turn-taking, and posture shifts to mark topic boundaries. In addition, some nonverbal behavior was specified explicitly, including deictic (pointing) gestures (e.g., during direction giving) and facial displays of emotion.

3.2 Installation: Deploying Relational Agents in Museums

Tinker is projected human-sized to facilitate naturalness of interaction. We use multiple-choice touch screen input for user utterances, based on other work in developing a conversational agent for users who had no prior computer experience [22]. In addition to multiple choice utterance input screens, additional inputs were designed to enable visitors to input their given name and to quickly jump to different high-level topics using iconic representations (Figure 2).

Fig. 2. Sample User Input Screens (Left: Given Name; Right: Museum Topics)

There are several significant challenges in deploying such relational agents in crowded settings such as museums. These include: user re-identification; user presence detection (for conversation initiation and termination, and to tell if a visitor has just walked away in the middle of a conversation); and user location detection (so that the agent can appear to be looking directly at the visitor, required for human conversational turn-taking and grounding cues [23]). We solved all three of these problems by using a glass plate that visitors rest their hand on during their conversations with Tinker. Sensors on the plate provide presence detection, and a camera underneath provides hand shape-based user identification. In addition, with a visitor's left hand on this plate and their right hand using the touch screen, their location is fixed between the two, solving the agent gaze problem. We also use a motion sensor to determine if visitors are in Tinker's general area so that she can beckon them over to talk and begin conversation initiation behaviors.

We also added several other objects to Tinker's virtual environment to address problems that may be unique to museum settings. A large scrolling text screen was placed behind Tinker, showing the content of the last several conversational turns. We felt this was important in order to support the involvement of bystanders who might be near Tinker once a conversation is underway, as well as supporting individuals with hearing problems or who have difficulty understanding the synthetic voice. We also placed a smaller sign behind Tinker to display system status information (e.g., indicating the system is down) as well as a demonstration animation sequence showing approaching visitors how to use the hand reader. Finally, a virtual hand recognition reader was placed in Tinker's environment so that she could demonstrate putting her hand in the reader when visitors approach.

The current installation is located at the entrance to Computer Place (Figure 1). Tinker is projected onto a 3' by 6' tall screen using a short-throw projector, and runs on two networked computers. Hand recognition is performed by extracting geometric features from hand images, and comparing them to those from the last 20 visitors [2].

3.3 Relational Behavior

We implemented a variety of dialogue and nonverbal behavior to enable Tinker to establish a sense of trust and rapport with visitors [19]. These behaviors could be turned on or off independently from all task-oriented behavior to facilitate evaluation of their efficacy (as described in Section 4).

Empathy. Empathy is the process of attending to, understanding, and responding to another person's expressions of emotion, and is one of the core processes in building and maintaining relationships [24, 25]. There are many places in Tinker's dialogue in which she can express empathy for a feeling state expressed or implied by a visitor. For example, after asking about a visitor's experience at the museum, a positive response results in Tinker's saying "That is great. I hope you are learning a lot too." (with a happy facial display), while a response expressing boredom results in "I am sorry to hear that. I hope you can find some part of the museum that interests you." (with a concerned facial display), and an expression of being tired yields "I am sorry to hear that. Yes, walking around can be tiring. Maybe you could pick up some refreshments at the cafeteria?".

Getting Acquainted. Early in her interaction with a new visitor, Tinker will ask them about themselves, including their age, who they are visiting with, and where they are from, with appropriate social responses for each possible visitor response [26].

Self-Disclosure and Reference to Common Ground. Tinker will make references to information disclosed by a visitor about themselves at appropriate points in the dialogue, as an indirect way of reminding them of their shared knowledge and interaction history (e.g., "Be sure to take your kids to the exhibit. I am sure they will find it interesting.") [27].

Reference to Shared Values and Beliefs. Tinker will agree with many of a visitor's expressed likes and dislikes [28]. For example, if the visitor indicates they are a Red Sox (Boston baseball team) fan, Tinker will say she is a fan as well (if the visitor does not indicate this, Tinker does not talk any further about the team).

Humor. Tinker will interject humor at appropriate points in the conversation [29]. For example, when telling a visitor how she works and that she does not have the ability to see them with computer vision, she might say "So, you could have three purple heads and be twelve feet tall and I would not know the difference!".

Form of Address. Once visitors have entered their given name, Tinker will use it to greet them [30]. She will also greet them by name on return visits, if the biometric hand reader recognizes them [2] (e.g., "Hi Bob, welcome back!").

Expressing Liking of the User and the Interaction and Desire to Continue. During farewells and subsequent greetings, Tinker expresses liking of the user, e.g., "It has been great talking with you. I hope to see you again." [31].

3.4 Pilot Testing

Pilot testing with 72 visitors (reported in [2, 20]) indicated that most participants thought Tinker was fun and engaging to interact with, many (56%) preferred to talk to her rather than museum staff (only 31% said they would rather have talked to a person), and none expressed privacy concerns regarding the biometric identification system (78% had no concerns, the rest were unsure). Most (94%) visitors conducted a single conversation lasting 7 minutes on average, with 6% returning for follow up conversations. The most popular topics that visitors ask about are Tinker's design (41%), the Computer Place exhibit (23%), and directions to other parts of the museum (21%). A minority of users (25%) expressed concerns about the privacy issues related to the use of biometric identification, although most added that they were not concerned about this particular application ("This is okay, but if that was being used on a daily basis, I'd be very concerned about my fingerprints being taken.").

4 Evaluation Study

In order to evaluate the impact of relational behavior on visitors' engagement and learning, we conducted an experimental study in the museum beginning in March, 2009. The study was a two-group, between-subjects experimental design. The study compared the full version of Tinker described above (RELATIONAL), to an identical version in which all of the relational behavior (described in Section 3.4) was switched off (NON-RELATIONAL). All task-related dialogue, including all educational content, was the same in both conditions.

Based on studies of the effects of perceived empathy and caring in human teacher-student relationships [3], we hypothesize the following:

H1. Visitors who interact with the RELATIONAL Tinker will demonstrate a significantly more positive attitude towards the agent (overall satisfaction, liking, desire to continue) compared to visitors who interact with the NON-RELATIONAL agent.

H2. Visitors will exhibit greater engagement with the RELATIONAL Tinker compared to the NON-RELATIONAL version, as demonstrated by the length of time they spend at the exhibit and the number of times they return to it during the day.

H3. Visitors will learn significantly more from the RELATIONAL Tinker compared to the NON-RELATIONAL agent. By 'learning' we mean retention of information told to visitors by Tinker, as evidenced by correct answers on a knowledge test.

Further, we hypothesize (**H4**) that engagement mediates (at least partially) any relationship between study condition (RELATIONAL vs. NON-RELATIONAL) and learning [32] (study condition causes changes in engagement which, in turn, causes changes in learning, as in Figure 3).

4.1 Methods

Measures. ***Engagement*** was assessed by the total time in minutes each visitor spent with Tinker and the number of visits they made to the exhibit in a given day, determined from a log file analysis. ***Attitude*** towards Tinker was assessed using the first five single-item questions shown in Table 1, administered after a visitor's first interaction with Tinker. ***Learning*** was assessed using a five-item, multiple-choice knowledge test, covering topics distributed throughout Tinker's educational content (e.g., "How can Tinker recognize you?", correct answer "Looking at my hand."), administered after a visitor's first interaction with Tinker, and scored as number of correct answers. Note that visitors may or may not hear the content tested by these questions, depending on which topics they ask Tinker about. Visitor perception of how much they learned from Tinker was assessed using the last single-item question in Table 1.

Table 1. Self-Report Attitude Questions (all 5-point scales)

Measure	Question	Anchor 1	Anchor 5
SATISFACTION	How satisfied are you with this exhibit?	Not At All Satisfied	Very Satisfied
CONTINUE	How much would you like to talk to Tinker again?	Not At All	Very Much
LIKE	How much do you like Tinker?	Not At All	Very Much
RSHIP	How would you describe Tinker?	A Complete Stranger	A Close Friend
LIKEPERSON	How much is Tinker like a person?	Just like a computer	Just like a person
LEARNFROM	How much do you think you learned from Tinker?	Nothing	A lot

Protocol. As soon as Tinker identified a visitor as a new user (see [2]) the visitor was randomized into either a RELATIONAL or NON-RELATIONAL condition, and they then conducted their interaction with the system, with relational behavior turned on or off according to study condition. Once a first-time visitor indicated they were done with the conversation, the touch screen input display would ask (via text) if they were over 18 years old (our only eligibility criteria) and would be interested in participating in a study. If the visitor indicated they were, an unsigned informed consent was administered, the six Attitude questions asked in succession, and the five-item knowledge test administered, all via text on the touch screen. Subsequent interactions by enrolled participants on the same day (if any) were also tracked to assess Engagement, but no further questionnaires were administered.

4.2 Results

Primary results from the study are shown in Table 2.

Table 2. Primary Study Results (significance levels are for t-tests for independent means)

Measure	RELATIONAL (mean)	NON-RELATIONAL (mean)	StdDev	df	t	p (sig)
Session Length	5.76	4.95	3.49	1605	4.41	<.001
Number Sessions	1.13	1.09	0.34	1605	2.65	0.008
SATISFACTION	4.34	4.11	0.90	1605	5.06	<.001
CONTINUE	4.04	3.74	1.09	1604	5.22	<.001
LIKE	4.29	4.00	1.01	1604	5.44	<.001
RSHIP	3.00	2.79	1.19	1603	3.44	0.001
LIKEPERSON	3.27	2.96	1.22	1603	4.88	<.001
LEARNFROM	3.65	3.36	1.21	1603	4.55	<.001
Knowledge	2.30	2.17	1.05	1602	2.35	0.019

Participants. 1,607 visitors participated in the study (completing all questionnaires) during the two years the study has been active, with 63% in the NON-RELATIONAL condition. An analysis of a subset of the given names input to the system indicates that roughly equal numbers of males and females participated. Participants indicated they had relatively low levels of computer literacy (41.5% indicated they did not have much experience with computers, 29.8% indicated they had significant experience, and 28.7% did not report).

Engagement. Engagement was significantly greater with the RELATIONAL Tinker compared to the NON-RELATIONAL Tinker, measured both by total time interacting with Tinker, $t(1605)=4.41$, $p<.001$, and number of conversations held with Tinker on the day of the study, $t(1605)=2.65$, $p=.008$.

Attitude Towards Tinker. Overall visitor satisfaction was greater with the RELATIONAL Tinker compared to the NON-RELATIONAL version, $t(1605)=5.06$, $p<.001$. Desire to continue interacting with Tinker ($t(1604)=5.22$, $p<.001$) and liking of Tinker ($t(1604)=5.44$, $p<.001$) were both significantly greater in the RELATIONAL condition. Participants in the RELATIONAL condition rated their relationship with Tinker more like that with a close friend than a stranger, $t(1603)=3.44$, $p=.001$, and felt Tinker was more like a person than a computer, $t(1603)=4.88$, $p<.001$, compared to those in the NON-RELATIONAL condition.

Learning. Participants felt they learned significantly more from the RELATIONAL Tinker compared to the NON-RELATIONAL version, $t(1603)=4.55$, $p<.001$, even though the educational content was the same in both conditions. Most importantly, participants actually learned more from the RELATIONAL Tinker, scoring significantly higher on the knowledge test, $t(1602)=2.35$, $p<.05$, compared to participants who interacted with the NON-RELATIONAL Tinker.

Mediation. Following Baron & Kenny [32], we first regress the independent variable (RELATIONAL vs. NON-RELATIONAL) onto engagement (session length), finding a significant model ($p<.001$) and unstandardized coefficient $b=48.27$ (std err=10.95). We next regress the independent variable *and* engagement onto knowledge. The relationship between engagement and knowledge in this model is also significant ($p<.001$) with unstandardized coefficient for engagement $b=.001$ (std err<.001). The Sobel test [33] indicates that the mediation is significant, although the mediation is incomplete, since the regression coefficient relating the independent variable to knowledge is non-zero (Figure 3).

4.3 Discussion & Limitations

All study hypotheses were supported. Use of relational behavior by a virtual museum guide agent leads to significantly more positive attitude towards the agent by visitors, increased engagement, and improved learning, as measured both by visitor perception and actual knowledge test scores. The mediation test confirms that relational behavior

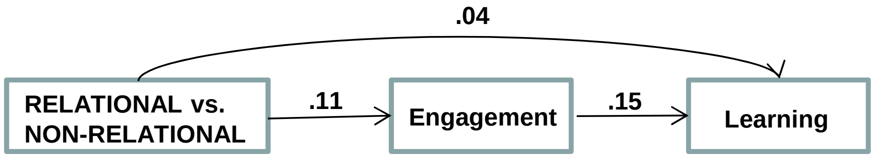

Fig. 3. Results of Mediation Test (standardized regression coefficients shown). Relational behavior primarily affects learning by affecting engagement.

primarily impacts learning via increased engagement (e.g., due to an increased likelihood of discussing the topics that were tested), but also directly impacts learning through, for example, greater psychological involvement caused by increased trust in the agent.

We acknowledge that session length (one of our measures of engagement) is affected directly by relational behavior, since we did not subtract out the time taken in purely relational dialogue from this measure. However, significant differences in engagement are also demonstrated by the attitude measures (desire to continue, in particular) and the number of times visitors returned to talk to Tinker during the day. In addition, visitors did choose to voluntarily spend more time with the RELATIONAL Tinker, regardless of what they were doing during this time.

We also acknowledge that while the results are highly significant (given the very large number of participants), the effect sizes are very small, ranging from .05 to .31, excluding session length. However, given the scales at which popular museum exhibits operate, even small effects can be meaningful. For example, the additional 48 seconds spent by visitors in the RELATIONAL condition results in an additional 670 hours of visitor contact time per year given the 50,000 visitors who have interacted with Tinker annually since the exhibit opened.

The study may also have suffered from a self-selection bias by those visitors who chose to answer the questionnaires following their interaction with Tinker. In our case, however, more visitors in the NON-RELATIONAL condition chose to participate. This may have been due to the longer interaction times in the RELATIONAL condition, under the assumption that visitors were only willing to spend a total fixed amount of time at the exhibit.

5 Conclusion

We have demonstrated that relational behavior used by an intelligent virtual agent can significantly impact not only positive attitudes towards the agent, but task outcomes such as engagement and learning. In addition, overall satisfaction with Tinker remains high: 82.3% of the 1,607 visitors who completed the study (across both groups) indicated they were either “somewhat satisfied” or “very satisfied” with the exhibit.

There are many possible future directions of research that could be pursued to enhance Tinker. User presence is currently determined by pressure on the hand reader plate, which is not always ideal and could be replaced using computer vision. Vision techniques could also be used to allow Tinker to track visitors to provide a more lifelike interaction. Accommodation for multi-party conversation would engage more visitors, since they usually arrive in groups. Finally, Tinker could be deployed on multiple kiosks in the museum, mobile devices, or on the web, to provide a more ubiquitous and continuous presence before, during, and after a visit to the museum.

Acknowledgments. Thanks to Sepalika Perera, Chaamari Senanayake, and Ishraque Nazmi, who helped develop the original Tinker system, to Dan Noren, Taleen Agulian and the staff at Cahner's Computer Place for their assistance, and to Juan Fernandez for maintaining Tinker over the last two years. This work was supported by NSF CAREER IIS-0545932.

References

1. Moon, Y.: Intimate self-disclosure exchanges: Using computers to build reciprocal relationships with consumers. Harvard Business School (1998)
2. Schulman, D., Sharma, M., and Bickmore, T. : The Identification of Users by Relational Agents. Autonomous Agents and Multi-Agent Systems, (2008)
3. Wentzel, K.: Social-Motivational Processes and Interpersonal Relationships: Implications for Understanding Motivation at School. Journal of Educational Psychology 91, 76-97 (1999)
4. Yee, N., Bailenson, J., Rickertsen, K.: A meta-analysis of the impact of the inclusion and realism of human-like faces on user experiences in interfaces In: Conference A meta-analysis of the impact of the inclusion and realism of human-like faces on user experiences in interfaces (2007)
5. Dehn, D.M., Mulken, S.v.: The Impact of Animated Interface Agents: A Review of Empirical Research. International Journal of Human-Computer Studies 52, 1-22 (2000)
6. Damon, W., Phelps, E.: Strategic Uses of Peer Learning in Children's Education. In: Berndt, T., Ladd, G. (eds.) Peer Relationships in Child Development, pp. 135-157. Wiley, New York (1989)
7. Hartup, W.: Cooperation, close relationships, and cognitive development. In: Bukowski, W., Newcomb, A., Hartup, W. (eds.) The company they keep: Friendship in childhood and adolescence, pp. 213-237. Cambridge University Press, Cambridge (1996)
8. Lester, J.C., Voerman, J.L., Towns, S.G., Callaway, C.B.: Cosmo: A Life-like Animated Pedagogical Agent with Deictic Believability. In: Conference Cosmo: A Life-like Animated Pedagogical Agent with Deictic Believability. (1997)
9. Lester, J., Stone, B., Stelling, G.: Lifelike Pedagogical agents for Mixed-Initiative Problem Solving in Constructivist Learning Environments. User Modeling and User-Adapted Interaction 9, 1-44 (1999)
10. Moreno, R., Lester, J.C., Mayer, R.E.: Life-Like Pedagogical Agents in Constructivist Multimedia Environments: Cognitive Consequences of their Interaction. In: Conference Life-Like Pedagogical Agents in Constructivist Multimedia Environments: Cognitive Consequences of their Interaction, pp. 741-746. (2000)
11. Graesser, A., al, e.: AutoTutor: A simulation of a human tutor. Cognitive Systems Research 1, (1999)
12. Krämer, N.C., Bente, G.: Personalizing e-Learning. The Social Effects of Pedagogical Agents. Educational Psychology Review 22, 71-87 (2010)
13. Person, N.K., Graesser, A.C., Bautista, L., Mathews, E.C.: Evaluating Student Learning Gains in Two Versions of AutoTutor. In: Moore, J.D., Redfield, C.L., Johnson, W.L. (eds.)

Artificial intelligence in education: AI-ED in the wired and wireless future, pp. 286-293. IOS Press, Amsterdam (2001)
14. Graesser, A.C., Jackson, G., McDaniel, B.: AutoTutor holds conversations with learners that are responsive to their cognitive and emotional states. Educational Technology 47, 19-22 (2007)
15. Kopp, S., Gesellensetter, L., Krämer, N., Wachsmuth, I.: A conversational agent as museum guide -- design and evaluation of a real-world application. . In: Conference A conversational agent as museum guide -- design and evaluation of a real-world application. , pp. 329-343. Springer-Verlag, (2005)
16. Shiomi, M., Kanda, T., Ishiguro, H., Hagita, N.: Interactive Humanoid Robots for a Science Museum. In: Conference Interactive Humanoid Robots for a Science Museum. (2006)
17. Swartout, W., Traum, D., Artstein, R., Noren, D., Debevec, P., Bronnenkant, K., Williams, J., Leuski, A., Narayanan, S., Piepol, D.: Ada and Grace: Toward realistic and engaging virtual museum guides. 10th International Conference on Intelligent Virtual Agents, pp. 286–300 (2010)
18. Gockley, R., Bruce, A., Forlizzi, J., Michalowski, M., Mundell, A., Rosenthal, S., Sellner, B., Simmons, R., Snipes, K., Schultz, A.C., Wang, J.: Designing Robots for Long-Term Social Interaction. In: Conference Designing Robots for Long-Term Social Interaction. (2005)
19. Bickmore, T., Picard, R.: Establishing and Maintaining Long-Term Human-Computer Relationships. ACM Transactions on Computer Human Interaction 12, 293-327 (2005)
20. Bickmore, T., Pfeifer, L., D, S., Perera, S., Senanayake, C., Nazmi, I.: Public Displays of Affect: Deploying Relational Agents in Public Spaces. CHI, Florence, Italy (2008)
21. Cassell, J., Vilhjálmsson, H., Bickmore, T.: BEAT: The Behavior Expression Animation Toolkit. In: Conference BEAT: The Behavior Expression Animation Toolkit, pp. 477-486. (2001)
22. Bickmore, T., Caruso, L., Clough-Gorr, K., Heeren, T.: "It's just like you talk to a friend" - Relational Agents for Older Adults. Interacting with Computers 17, 711-735 (2005)
23. Cassell, J., Sullivan, J., Prevost, S., Churchill, E. (eds.): Embodied Conversational Agents. The MIT Press, Cambridge, MA (2000)
24. Havens, L.: Making Contact: Uses of Language in Psychotherapy. Harvard University Press, Cambridge, MA (1986)
25. Gelso, C., Hayes, J.: The Psychotherapy Relationship: Theory, Research and Practice. John Wiley and Sons, New York (1998)
26. Svennevig, J.: Getting Acquainted in Conversation. John Benjamins, Philadephia (1999)
27. Altman, I., Taylor, D.: Social penetration: The development of interpersonal relationships. Holt, Rinhart & Winston, New York (1973)
28. Gill, D., Christensen, A., Fincham, F.: Predicting marital satisfaction from behavior: Do all roads really lead to Rome? Personal Relationships 6, 369-387 (1999)
29. Cole, T., Bradac, J.: A Lay Theory of Relational Satisfaction with Best Friends. Journal of Social and Personal Relationships 13, 57-83 (1996)
30. Laver, J.: Linguistic routines and politeness in greeting and parting. In: Coulmas, F. (ed.) Conversational routine, pp. 289-304. Mouton, The Hague (1981)
31. Okun, B.: Effective Helping: Interviewing and Counseling Techniques. Brooks/Cole, Pacific Grove, CA (1997)
32. Baron, R., Kenny, D.: The Moderator-Mediator Variable Distinction in Social Psychological Research: Conceptual, Strategic, and Statistical Considerations. Journal of Personality and Social Psychology 51, 1173-1182 (1986)
33. MacKinnon, D.P., Lockwood, C.M., Hoffman, J.M., West, S.G., Sheets, V.: A comparison of methods to test mediation and other intervening variable effects. Psychological Methods 7, 83-104 (2002)