

Towards a Dyadic Computational Model of Rapport Management for Human-Virtual Agent Interaction

Ran Zhao, Alexandros Papangelis, and Justine Cassell

ArticuLab, Carnegie Mellon University, 5000 Forbes Ave, Pittsburgh, PA, USA

Abstract. Rapport has been identified as an important function of human interaction, but to our knowledge no model exists of building and maintaining rapport between humans and conversational agents over the long-term that operates at the level of the dyad. In this paper we leverage existing literature and a corpus of peer tutoring data to develop a framework able to explain how humans in dyadic interactions build, maintain, and destroy rapport through the use of specific conversational strategies that function to fulfill specific social goals, and that are instantiated in particular verbal and nonverbal behaviors. We demonstrate its functionality using examples from our experimental data.

1 Introduction

Rapport, a feeling of connection and closeness with another, feels good, but it also has powerful effects on performance in a variety of domains, including negotiation [15], counseling [19] and education [4]. As agents increasingly take over tasks such as those described above, we maintain that it is important to evoke a feeling of rapport in people interacting with those agents so as to improve their task collaboration – and recognize rapport in people interacting with agents so as to know when the system has been successful. It turns out, however, that what constitutes rapport-evoking and rapport-signaling behavior varies widely. For example, our prior work [22] demonstrated that, in pairs of friends tutoring one another, rudeness had a positive social function and was correlated with learning. In pairs of strangers, however, the opposite function and correlation was found. These results indicate that long term rapport (such as one might find among friends) may have an effect on rapport signaling behavior (such as polite vs. rude language). While prior work [e.g., 20] has confirmed that some rapport-signaling behavior such as attentiveness is capable of enhancing task performance, there do not exist computational models to tell us how that rapport-signaling behavior should change over the course of a long-term collaboration between a human and an agent. One obstacle to models of this sort is the fact that, as [3] has written, “rapport is a social construct that must be defined at the level of a dyad or larger group.” Dyadic processes of this sort have traditionally posed challenges to modeling since, as Kelley *et al.*, 1983 [as cited in 8] have described, a change in the state of one partner will produce a change

in the state of the other. We believe that prior attempts have not sufficiently distinguished between the social functions that lead to rapport, the conversational and behavioral strategies that play a role in those social functions, and the observable phenomena that make up those strategies. Rapport is sometimes experienced on a first meeting but most often it must be built and maintained – or it will be destroyed. Drawing these distinctions has also allowed us to move toward an implementable computational architecture, described in a separate paper in this same volume [23], that takes into account both participants’ cognitions, intentions, actions and beliefs, and their interplay, within one person and across the dyad.

In what follows we first review prior literature from the social sciences on the components that make up the experience of rapport, the way people assess rapport in others, and the goals and strategies people use to build, maintain and destroy rapport. Drawing all of these components together, we next propose a model for rapport enhancement, maintenance, and destruction in human-human and human-agent interaction. Throughout we rely on a rich background of literature across the social sciences, as well as on data [33] from our own research into peer tutoring between dyads of friends and of strangers across several months. These data have been annotated for verbal and nonverbal behaviors, as well as for relevant conversational strategies. Our contributions in this work are two-fold: (1) an analysis of the social functions and conversational strategies that go into building, maintaining and breaking rapport; (2) a computationally viable dyadic model of rapport over time built from that analysis.

2 Theoretical Framework for Rapport Management

[30]’s work on the changing nonverbal expression of rapport over the course of a relationship has had significant impact on the development of virtual agents. They provide an actionable starting point by outlining the experience of rapport as a dynamic structure of three interrelating behavioral components: positivity, mutual attentiveness and coordination. Behavioral positivity generates a feeling of friendliness between interactants; mutual attentiveness leads to an experience of connectedness; and behavioral coordination evokes a sense of “being in synch”. The work posits that the relative weights of those components change over the course of a relationship; the importance of mutual attentiveness remains constant, while the importance of positivity decreases and that of coordination increases.

While [30]’s work is predicated on a dual level of analysis - what they call “molecular” and “molar,” researchers in virtual agents have relied more on the molecular level, meaning that they have translated [30]’s components directly into observable behavioral expression or action. [30], however, propose that it is the molar level that is more predictive - that is, that theory should attend to the conversational strategies and goals of communication that interactants use to be positive, be attentive and to coordinate. In fact, they suggest that “initial encounters are rigidly circumscribed by culturally acceptable and stereotypical

behavior” while, after some time, “rather than following more culturally-defined communication conventions, they would develop their own conventions and show more diversity in the ways they communicate thoughts to one another.” This aspect of their work has largely been ignored in subsequent computational approaches to rapport. In the development of agent models and an architecture to realize them, however, this leaves us less than well-informed about what the agents should do. How do we determine what is meant by “stereotypical behavior” or “more diversity in the ways they communicate”? How should we represent the goals of two interactants and conversational strategies to fulfill the goals? In the current work, then, we discuss a broad range of literature that allows us to understand the kinds of strategies that interactants use in rapport management, and the kinds of goals and functionality those interactants intend. As we do so, we pay particular attention to the dyadic nature of these constructs, and how they change over the course of a relationship. Our review focuses on 3 top-level goals that make up rapport - **face management**, **mutual attentiveness**, and **coordination** - and some of the subgoals that achieve those top-level goals - such as *becoming predictable*, *appreciating the other’s true self*, and *enhancing the other’s face*. We also describe many of the conversational strategies that achieve those goals - **initiating mutual self-disclosure**, **adhering to behavioral expectations or norms**, and so forth. While we believe that something like the experience of rapport is probably universal and perhaps even that the subgoals of face, attentiveness, and coordination as important contributors to rapport might also be (somewhat) universal, there is no doubt that the sub-sub-goals and conversational strategies differ in different sociocultural contexts. Here, for the purposes of the discussion, we adduce evidence from our own data collection with teenage middle-class Americans, and that context therefore serves as our object of study. We hope, however, that in outlining an approach to building this kind of dyadic model of rapport, we will have opened the way to discussions of other contexts, and that other strategies and goals will be thereby be discovered.

Spencer-Oatey [26] offers an alternative approach to [30]’s to conceptualizing the strategies and behaviors that contribute to rapport, and we find it more complete and more convincing for our purposes. She points out that rapport management comprises the task of increasing rapport, but also maintaining, and destroying it. In her perspective, each of these tasks requires management of face which, in turn, relies on behavioral expectations, and interactional goals. Our data support the tremendous importance of face, as the teens alternately praise and insult one another, all the while hedging their own positive performance on the algebra task in order to highlight the performance of the other. The data also contain numerous examples of mutual attentiveness and coordination as putative input into rapport management, but we found it difficult to code positivity independently of its role in face. Our formulation below, therefore, posits a tripartite approach to rapport management, comprising mutual attentiveness, coordination, and face management.

Face Management: [10] define positive face as, roughly, a desire by each of us to be approved of. They posit that politeness functions to avoid challenging that desire, as well as to boost the other's sense of being approved, while *face-threatening acts* (FTA) challenge face. [27], however, points out that this definition ignores the interpersonal nature of face, and she defines "identity face" as the desire to be recognized for one's positive social identity, as well as one's individual positive traits. In this context, FTAs can challenge one's sense of self or one's identity in the social world. On the flip-side, *face-boosting acts* can create increased self-esteem in the individual, and increased interpersonal cohesiveness - or rapport - in the dyad. Of course [26] points out that what constitutes politeness, other face-boosting acts, and FTAs, is not fixed, and is largely a subjective judgement about the social appropriateness of verbal and non-verbal behaviors. She attributes these judgments about social appropriateness to our "sociality rights and obligations" - how we feel entitled to be treated based on the behaviors we expect from others - which in turn derive from sociocultural norms, including the relative power and status of the two members of the dyad, and interactional principles. Fulfilling these rights and obligations induces a feeling of being approved and, in turn, increases rapport.

What, however, are these sociocultural norms and interactional principles? A key aspect of the theory laid out here is that *behavioral expectations* (the instantiation of "sociality rights and obligations") are allied with sociocultural norms early in a relationship, and become more interpersonally determined as the relationship proceeds. Thus, the stranger dyads in our data spend a fair amount of time agreeing with one another when they first meet, in ways that fit upper middle class politeness norms (when asked what he wants to be when he grows up, one teen responds "I kind of want to be a chef" to which the other politely responds "I'd think about that too"). Friends, on the other hand, are less likely to demonstrate polite responses (one teen asks the other "wait why do you have to keep your hat on" to which the other responds "it's [his neck] not supposed to be in the sun" and receives in reply "yeah it's really swollen and ugly"). In both cases while the behavioral expectations have changed (politeness has been replaced by teasing), the fact of meeting them continues to be rapport-increasing.

How does one learn enough about the other to adapt behavioral expectations? **Mutual attentiveness** is an important part of the answer, as [30] have described. Mutual attentiveness may be fulfilled by providing information about oneself through small talk [11] and self-disclosure [21]. Social penetration theory [29] describes the ways in which, as a relationship deepens, the breadth and depth of the topics disclosed become wider and deeper, helping the interlocutor to gain common ground as a basis for an interpersonally-specific set of behavioral expectations. Self-disclosure, however, plays another role in rapport-building, as when successful it is reciprocal [14] - self-disclosure in our data is most often met with reciprocal self-disclosure at a similar level of intimacy. This kind of mutual responsiveness signals receptivity and appreciation of another's self-disclosure [14] and the very process enhances **coordination** among the

participants (much as we argued is the case for small talk [11]), likewise increasing a sense of rapport. The goal of coordination as a path to rapport is also met by verbal and nonverbal synchrony [34], and this is common in our own data.

In addition, while self-disclosure is not always negative, it may be, and this is a way to challenge one's own face, and thereby boost the face of the other. For that reason it is common in rapport management. In our own data, for example, strangers quickly began to share superficial negative facts about themselves, such as their presumed poor performance on the algebra pre-test at the beginning of the session. When met with a self-disclosing utterance at the same level of intimacy and with the same negative valence ("oh my gosh I could not answer like half of those"), the interlocutors increased mutual gaze and smiling, and proceeded to more intimate topics, such as their poor performance at keeping their pets alive. In fact, [9] found that in a negotiation setting not reciprocating negative self-disclosure led to decreased feelings of rapport. [31] point out the role of humor in rapport; it is a particularly interesting rapport management strategy as it too follows behavior expectations, whereby generally-accepted humor is successful early in the relationship, and humor that violates sociocultural norms may be successful as a strategy to increase liking and rapport only later in the relationship. In our data from teenagers, this rule is only sometimes observed, and the effect of humor that violates behavior expectations is swift and negative.

Self-disclosure, then, serves multiple goals in rapport management. Yet another is to reveal aspects of one's "true self" as a way of indicating one's openness to being truly seen by the other, and hence one's availability for rapport. According to [24], the "true-self" is composed of important aspects of one's identity that are not always validated in one's daily life. People are highly motivated to make these important aspects of identity a 'social reality' - to have these attributes acknowledged by others so that they become authentic features of their "self-concept" [1]. This explains *why* interlocutors engage in self-disclosure - perhaps even why rapport is sought in interactions with strangers.

Based on the literature surveyed above, it is clear that mutual attentiveness to, and learning about and adhering to, the behavioral expectations of one's interlocutor is helpful in building rapport. Initially, when interactants are strangers, without any knowledge of their interlocutor's behavioral expectations, they adhere to a socioculturally-ratified model (general expectations established as appropriate in their cultural and social milieu). This may include behaving politely and in accordance with their relative social roles. As the relationship proceeds, interlocutors increasingly rely on knowledge of one another's expectations, thereby adhering to a shared and increasingly interpersonally-specific set of sociality rights and obligations, where more general norms may be purposely violated in order to accommodate each other's behavioral expectations.

Why, however, might two interactants violate sociocultural norms when others around them are adhering to those norms? [2] suggests that people have an unconscious motivation to affiliate themselves to a group, which drives them to participate in social activities and search for long-term relationships. The fact

of violating sociocultural norms may in fact reinforce the sense that the two belong in the same social group and this may enhance their unified self-image [28] through reinforcing the sense of in-group connectedness through a comparison with other individuals who don't know these specific rules of behavior. This is supported by our own findings on peer tutoring, whereby rudeness predicts learning gain [22]. We know that rapport between teacher and student increases learning. When tutor and tutee are strangers, their behavior complies with sociocultural norms. Impoliteness may reduce the learning gain in strangers by challenging rapport through violating those sociocultural behavioral expectations. When tutor and tutee are friends, however, they have knowledge of one another's behavioral expectations and are thus able to follow interpersonal norms and sacrifice sociocultural norms. Rudeness, may be a part of the interpersonal norms. It may also be a way to cement the sense that the two are part of a unified group, and different from those around them. The topics they are rude about may also serve to index commonalities between the two, as referring to shared experience also differentiates in-group from out-group individuals.

3 Towards a Computational Model of Rapport Management

The literature review above, while not allowing each component sub-goal or strategy the space it deserves, provides a sense of the complexity, but also of the mundane nature of rapport management between people. We wish to be seen and known the way we truly are, and we want the way we are to be approved; we desire affiliation with a social group; we are more comfortable when the behavior of our interlocutors matches our expectations; we wish for the success of our interpersonal and our task goals. These common sense and everyday goals work together to lead us to desire rapport, and to build it, even with strangers, and to put effort into maintaining it with friends and acquaintances.

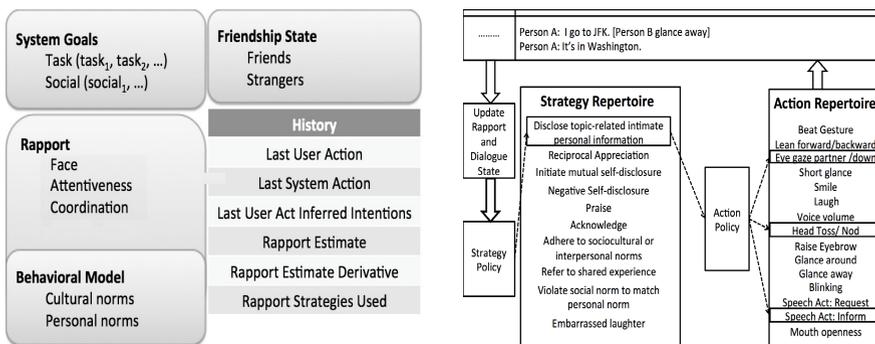


Fig. 1. Dyadic state (left) and Strategy/Action repertoire (right)

In order to represent these goals and desires in a computational model, we must take into account the fact that while rapport is dyadic, it nevertheless depends on the cognition, actions, beliefs and intentions of each interlocutor, and on the perception by each interlocutor of these aspects of the mind of the other interlocutor. In the computational model, therefore, we represent the state of each participant, and of that participant's perception of the state of the interlocutor, which enables us to reason about the cognition and rapport orientation (enhancement, maintenance, destruction) of the dyad, based on observable behaviors. Immediately after each dialogue turn, we represent the participants' modified self-images and their assessment of the modification of their interlocutor's self-image and, based on this reasoning, the sub-goals they wish to achieve, and the consequent appropriate strategy for the next dialogue turn. More specifically, Figure 1(left) presents the *dyadic state*, which may be updated after each user's turn or incrementally. Figure 1(right) displays how a user and system state leads to a choice of *Strategy* and then of *Action* (although the latter is beyond the scope of the current paper). Of course, in order to allow rapport state monitoring and management, we need to detect the goals and conversational strategies of the interlocutors on the basis of the behaviors we observe them engaging in, and we need to assess their contribution to each rapport orientation. Below, for rapport enhancement, maintenance and destruction we list, from the perspective of the agent trying to achieve those goals, the strategies and their contribution to the series of sub-goals and interrelating behavioral components of rapport we laid out above - face, mutual attentiveness, coordination. The conversational strategies enumerated here are no doubt not exhaustive. However they include all phenomena found in the literature that were also represented in our data. To give a more complete sense of many of the possible "response pairs" (the conversational strategy of one interlocutor and the strategy it is met with by the other interlocutor) and their effect on the four behavioral components, we provide a more complete set here: <http://tinyurl.com/dyadic-rapport>. For instance, if a speaker discloses topic-related personal information and the listener deploys the same strategy, both face and coordination will be updated. If a speaker initializes self-disclosure but the listener verbally attacks the speaker, face will decrease, as will coordination.

In the **rapport-enhancement** orientation (Figure 2), people are assumed to begin at state T_1 (stranger) and to have a desire to build rapport with each other, for the reasons laid out above. If we regard rapport-enhancement as a shared task of the dyad, there are different paths to achieve it. In terms of face, people might establish the sub-goal of boosting the interlocutor's face in order to achieve the goal of increasing rapport. Some conversational strategies to accomplish this are to self-disclose negative information, to praise or acknowledge the other's social value, or embarrassed laughter. Social comparison theory [16] describes how individuals are able to realize and claim more positive social value for themselves through comparison with the other's weaknesses. Our peer tutors illustrate this when they engage in embarrassed laughter around their weaknesses in algebra, giving an opportunity for their partner to feel more competent.

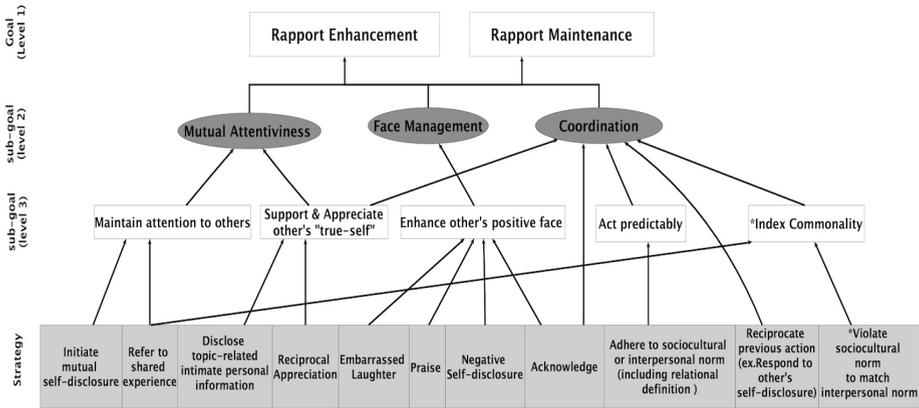


Fig. 2. Social Functions and Conversational Strategies for Rapport Enhancement and Maintenance

As described above, predictability is a core part of coordination. In order to achieve this sub-goal, interactants adhere to behavior expectations. At the initial state T_1 , the expectations are guided by sociocultural norms which include the obligation to engage in social validation of the interlocutor’s self-disclosures, and to reciprocate with similarly intimate self-disclosure. This also functions to signal attentiveness to the interlocutor. In fact, initiating mutual self-disclosure is a compelling strategy for learning about an individual at the initial stage of the relationship as well as for signaling attentiveness. In our data we also observed that peers often demonstrate mutual attentiveness by referring to past shared experience. As well as increasing common ground, acknowledging and reciprocating reference to previous experience function to increase coordination.

In the **rapport-maintenance** orientation (Figure 2), people are assumed to begin at state T_2 (Acquaintance) and have a desire to maintain the current harmonious relationship. Those marked with (*) refer to rapport maintenance only. Typically, friends have some knowledge of each other’s behavioral expectations and in order to maintain high rapport, dyads mark their affiliation with one another, and their shared membership in a social identity group. Indexing commonality strengthens connectedness between in-group members. Compared to stranger peers, friend peers refer to more intimate shared experiences. Moreover, contrary to the sociocultural norms that govern behavior during rapport enhancement, friends may violate sociocultural norms to match their interlocutor’s behavioral expectations for example, through rudeness to one another or swearing, both of which were common among friends in our corpus.

In the two orientations just described, we presented strategies for building and maintaining rapport with our interlocutor, and it’s hard to imagine instances in which a virtual agent might want to challenge rapport. However, the **rapport-destruction** orientation (Figure 3) is useful in the sense that detecting it will help us choose appropriate rapport “recovery” strategies. Here people are assumed to begin at state T_2 and have a desire to destroy or challenge the

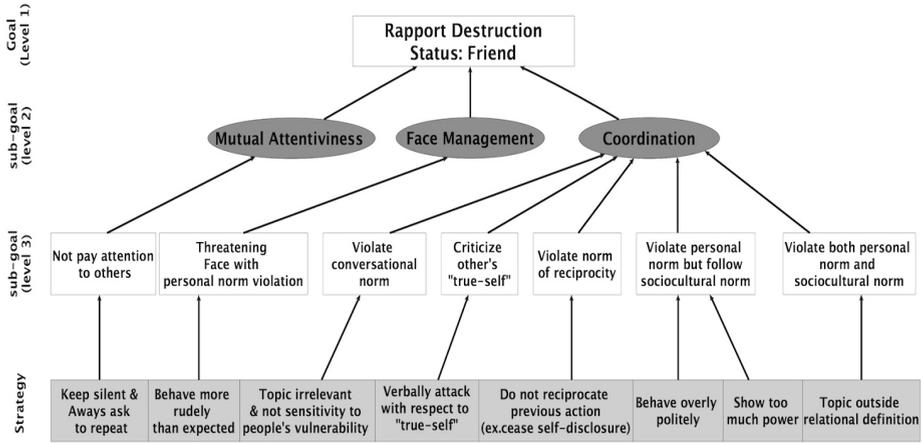


Fig. 3. Social Functions and Conversational Strategies for Rapport Destruction

current harmonious relationship with their friends. According to the rapport management perspective [27], even though some FTAs in politeness theory do not diminish the listener’s positive social value, there still exist some highly FTAs. For instance, challenging one’s friends during peer tutoring could be seen as a way of showing rapport, while physically or verbally attacking without reason ruins rapport due to the lack of justification for those actions, meaning that this behavior is too rude to fit expectations of any kind.

In this orientation, people pay no attention to learning about their interlocutor’s behavioral expectation. Strategies to achieve this include keeping silent or continually asking others to repeat themselves. Although friends’ actions are mainly guided by interpersonal norms, Derlega [14] suggests that people, even in close relationships, should follow several sociocultural norms with respect to self-disclosure. In particular, reciprocity, interactional and conversational norms and social validation of the “true-self” remain important over the long term. Ceasing self-disclosure is a strategy to violate reciprocity. An interlocutor could also try to attack the vulnerability of the self-discloser by scoffing at the content or responding with an irrelevant remark. Furthermore, they could verbally attack or neglect the self-disclosure’s “true-self” [24] instead of reciprocally appreciating. As we mentioned before, self-disclosure is successful when dyadic. Thus, all of the strategies above do not only violate the sociocultural norms but also block the road to reciprocal self-disclosure. Another way to break rapport is to violate interpersonal norms while following sociocultural norms. For instance, suddenly behaving too politely to one’s friend may lead to awkwardness and a reduced feeling of coordination. Suddenly changing demonstration of power or status would have the same effect. Last, one could violate both personal and sociocultural norms, by talking about a topic that does not match the relationship definition of the dyad (for instance, a student choosing to discuss sexual information with an advisor).

3.1 Examples from Corpus Data

In order to demonstrate the functioning of the computational model, six examples are taken from our data, collected in [33]. In this experiment, 12 dyads of 12-15 year old students (half boys and half girls, half friends and half strangers) tutor each other in algebra over a period of 5 weeks. Table 1(left) shows how dyads of strangers interact early in the 5-week period. Table 1(right), shows dyads of friends. Labels indicate how the computational model would generate the same output, based on our annotations of the data for nonverbal behavior and for conversational strategies such as disagreement and agreement, politeness and rudeness, and on- and off-task talk (while we continue to annotate the data for additional phenomena, Cohen's Kappa inter-rater reliability for all annotations to date is between 0.7 and 0.8). Note that while the data serve here to adduce evidence for the goals and strategies of rapport management in this age group and this task context, in other work we have pursued a data-driven approach to analyzing the relationship between the conversational strategies and

Table 1. Stranger examples (left) and Friend examples(right) session, where s is a rapport strategy, t_d is topic depth and R is dynamics of rapport. During the first session, most topics are discussed in shallow depth, while during the second, more personal information is being disclosed.

Stranger-Example 1

P1: *b equals nineteen over nine*

[$s_1 = N/A, t_d = 1$]

P2: *{laughter} good job*

[$s_2 = \text{praise}, t_d = 1$]

$R = \text{Increase}$

Stranger-Example 2

P1: *I suck at negative numbers*

[$s_1 = \text{negative self-disclosure}, t_d = 1$]

P2: *it's okay so do I*

[$s_2 = \text{reciprocate self-disclosure}, t_d = 1$]

$R = \text{Increase}$

Stranger-Example 3

P1: *x equals sixty-four over three*

[$s_1 = N/A, t_d = 1$]

P2: *yep*

[$s_2 = \text{acknowledge}, t_d = 1$]

$R = \text{Increase}$

P1: *x all right thanks .. all right*

[$s_1 = \text{adhere to sociocultural norm}, t_d = 1$]

P2: *it was a complicated one*

[$s_2 = \text{face-boosting acknowledgment}, t_d = 1$]

$R = \text{Increase}$

Friend-Example 1

P1: *are there any girls you like*

[$s_1 = \text{elicit self-disclosure}, t_d = 3$

more personal topic]

P2: *all of them are not the best looking*

[$s_2 = \text{reciprocate self-disclosure}, t_d = 3$]

$R = \text{Increase}$

Friend-Example 2

P1: *remember you went to Connecticut*

[$s_1 = \text{Refer to shared experience}, t_d = 2$]

P2: *that was just to visit my cousin*

[$s_2 = \text{disclose topic-related intimate$

personal information}, t_d = 2]

$R = \text{Increase}$

Friend-Example 3

P1: *silly goose that's a backwards two*

[$s_1 = \text{violate sociocultural norm to adhere to interpersonal norm}, t_d = 1$]

P2: *two*

[$s_2 = N/A, t_d = 1$]

$R = \text{Increase}$

observable behaviors (or actions) [33]. We continue to pursue an analysis of those data by using hand annotation as ground truth for the automatic assessment of rapport through multimodal analysis. That automatic detection will serve as input to the dialogue system.

4 Related Work

A number of prior papers have addressed the issue of rapport, or related notions such as trust, friendship, and intimacy, between people and virtual agents. Some have looked at what we have referred to as “instant rapport” [13] where a sense of connection is not acquired but instantaneous, and some have addressed the building of rapport over time. An early paper [12] used prior work in sociolinguistics and social psychology to develop a computational model of trust, and a computational architecture to establish trust between a person and virtual agent. The system, however, did no assessment of the user’s level of trust, and only built trust through verbal behavior - primarily small talk. While successful in building trust - particularly with extroverts - a subsequent paper [5] demonstrated the need for incorporating nonverbal behavior into the model. Since then, Bickmore and his colleagues have gone on to develop a model that describes strategies for an agent to build a relationship with a user over time.

Until recently, much like the early work described above, these systems have primarily engaged in a set of predetermined conversational strategies without associated updates in underlying goals or representations of the user or the user-system dyad [inter alia 32]. While not always successful at promoting rapport, these strategies have had positive effects on the non-dyadic construct of engagement [6]. More recently [7] has relied on accommodation theory to design conversational strategies intended to generate discourse that matches a user’s level of intimacy, and to increase intimacy. The prior goal was met but not the latter, perhaps because, as the authors themselves indicate, the model of intimacy was quite simplistic, without the kinds of goals, subgoals, and conversational strategies laid out here. On the other hand, accommodation theory provided a successful means for assessing the user’s level of intimacy, which bears keeping in mind for future work. Following on from this work, [25] developed a planning algorithm that keeps track of the intimacy level of the user, and produces session plans that target both relational and task goals. The activity planning approach seems promising, however the session plans appear to be made up of activities that are appropriate at a particular level of closeness rather than activities that have been shown specifically to *increase* closeness. Our approach, whereby conversational strategies target sub-goals that specifically manage rapport, might be more successful at moving the system and user further along on the relational continuum.

An alternative approach is represented by the work of Gratch and colleagues [17, 18], who target immediate rapport in the service of implementing a sensitive listener. In this work, the level of goals and conversational strategies are avoided, and instead the agent attempts to elicit the experience of rapport by working at

the level of observable phenomena - coordinating its nonverbal behavior to the human user. Rather than treating rapport as a dyadic or interpersonal construct, they address it similarly to other display functions and perhaps not surprisingly, as with other engaging displays, they have found increased user engagement. Most recently they have extended this approach to the analysis of the nonverbal behaviors that accompany intimate self-disclosure [19]. However, by not taking into account the relative roles of the two interlocutors, and the nature of their relationship, they have ignored the significant difference in conversational strategies between interlocutors with different levels of power in the relationship. In contrast to the prior work described here, our work distinguishes between the dyad's goals (overarching goals such as "create rapport" or sub-goals such as "index commonality"), their conversational strategies (such as "violate sociocultural norms through rude talk" or "initiate self-disclosure") and the observable verbal and nonverbal phenomena that instantiate those phenomena (such as mutual eye gaze, embarrassed laughter, or insults). This tri-partite distinction allows us to generate the same behaviors (insults, for example) in different contexts (early or late in the relationship) to achieve different goals (destroy rapport or enhance it). The unit of analysis of the computational model we present is the dyad, with system state updates impacting the model of the user, and of the user's model of the system, and particular weight placed on intrinsically dyadic constructs such as reciprocity.

5 Conclusion and Future Work

In this article, leveraging a broad base of existing literature and a corpus of data of friends and strangers engaging in peer tutoring, we have made steps towards a unified theoretical framework explaining the process of enhancing, maintaining and destroying rapport in human to human interaction. Based on this framework we have designed a computational model of rapport that can be applied to interactions between humans and virtual agents. In turn, that computational model allows us to make first steps towards a dyadic computational architecture for a virtual agent. A first sketch of the details necessary to realize this work computationally is described in a sister paper to this one, also published in this volume [23], in which we suggest reinforcement learning as an approach to learning behavioral expectations, rapport strategies, and dialogue act policies.

The potential benefits of such a dyadic approach to rapport management between human and virtual agent are numerous, including the fact that increased rapport leads to better task performance by humans [4, 15, 19], and could therefore lead to more effective virtual agent tutors and counselors, among other roles. It should be noted that in the current paper we have traced the relationship between rapport management goals and sub-goals and their associated conversational strategies. We have occasionally described how a conversational strategy is instantiated by a set of observable verbal and nonverbal actions but we have not formalized that step of the process, which will form the content of future work (currently in process, as described in [33]). That future work will also

serve as ground truth against which our computational model will be evaluated. We then plan to implement the model and architecture in a virtual peer tutoring application. Foreseeable challenges include recognition of the human users' rapport strategies (which may span several dialogue turns or interleave with other strategies) in order to correctly update our model as well as react in the appropriate fashion, and to develop an appropriate domain-specific user model for the algebra tutoring that interacts appropriately with the rapport management. Some of these issues evoke core AI challenges, such as representing many aspects of the mental state of participants. Nevertheless, we believe that here we have made the first step towards a dyadic and more realistic computational model of rapport. We expect the future challenges to be substantial, but rewarding, as we begin to model those aspects of human-human interaction that are not only helpful to human-agent collaboration, but also sustain aspects of what we cherish most in being human.

Acknowledgments. The authors would like to thank Zhou Yu for her contribution to this work, as well as the other students and staff of the ArticLab. This work was partially supported by the R.K. Mellon Foundation, and NSF IIS.

References

1. Bargh, J.A., McKenna, K.Y., Fitzsimons, G.M.: Can you see the real me? activation and expression of the "true self" on the internet. *Journal of Social Issues* 58(1), 33–48 (2002)
2. Baumeister, R.F., Leary, M.R.: The need to belong: desire for interpersonal attachments as a fundamental human motivation. *Psychological Bulletin* 117(3), 497 (1995)
3. Bernieri, F.J., Gillis, J.S.: Judging rapport: Employing brunswik's lens model to study interpersonal sensitivity. In: *Interpersonal sensitivity: Theory and measurement*, pp. 67–88 (2001)
4. Bernieri, F.J., Rosenthal, R.: Interpersonal coordination: Behavior matching and interactional synchrony. In: *Fundamentals of Nonverbal Behavior*, p. 401 (1991)
5. Bickmore, T., Cassell, J.: Social dialogue with embodied conversational agents. In: *Advances in Natural Multimodal Dialogue Systems*, pp. 23–54. Springer, Heidelberg (2005)
6. Bickmore, T., Pfeifer, L., Schulman, D.: Relational agents improve engagement and learning in science museum visitors (2011)
7. Bickmore, T., Schulman, D.: Empirical validation of an accommodation theory-based model of user-agent relationship (2012)
8. Bickmore, T.W., 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(6), 711–735 (2005)
9. Bronstein, I., Nelson, N., Livnat, Z., Ben-Ari, R.: Rapport in negotiation the contribution of the verbal channel. *Journal of Conflict Resolution* 56(6), 1089–1115 (2012)
10. Brown, P., Levinson, S.: Universals in language usage: Politeness phenomena. questions and politeness: Strategies in social interaction, ed. by e. goody, 56–311 (1978)

11. Cassell, J., Bickmore, T.: Negotiated collusion: Modeling social language and its relationship effects in intelligent agents. *User Modeling and User-Adapted Interaction* 13(1-2), 89–132 (2003)
12. Cassell, J., Bickmore, T., Billinghurst, M., Campbell, L., Chang, K., Vilhjalmsson, H., Yan, H.: Embodiment in conversational interfaces: Rea (1999)
13. Cassell, J., Gill, A.J., Tepper, P.A.: Coordination in conversation and rapport (2007)
14. Derlega, V.J., Metts, S., Petronio, S., Margulis, S.T.: *Self-disclosure*. Sage Publications, Inc. (1993)
15. Drolet, A.L., Morris, M.W.: Rapport in conflict resolution: Accounting for how face-to-face contact fosters mutual cooperation in mixed-motive conflicts. *Journal of Experimental Social Psychology* (1), 26–50 (2000)
16. Festinger, L.: A theory of social comparison processes. *Human Relations* 7(2), 117–140 (1954)
17. Gratch, J., Okhmatovskaia, A., Lamothe, F., Marsella, S., Morales, M., van der Werf, R.J., Morency, L.-P.: *Virtual rapport* (2006)
18. Huang, L., Morency, L.-P., Gratch, J.: *Virtual rapport 2.0* (2011)
19. Kang, S.-H., Gratch, J., Sidner, C., Artstein, R., Huang, L., Morency, L.-P.: Towards building a virtual counselor: modeling nonverbal behavior during intimate self-disclosure (2012)
20. Karacora, B., Deghani, M., Krämer-Mertens, N., Gratch, J.: The influence of virtual agents' gender and rapport on enhancing math performance (2012)
21. Moon, Y.: Intimate exchanges: Using computers to elicit self-disclosure from consumers. *Journal of Consumer Research* 26(4), 323–339 (2000)
22. Ogan, A., Finkelstein, S., Walker, E., Carlson, R., Cassell, J.: Rudeness and rapport: Insults and learning gains in peer tutoring (2012)
23. Papangelis, A., Zhao, R., Cassell, J.: Towards a computational architecture of dyadic rapport management for virtual agents. In: Bickmore, T., Marsella, S., Sidner, C. (eds.) *IVA 2014. LNCS*, vol. 8637, pp. 320–324. Springer, Heidelberg (2014)
24. Rogers, C.R.: *Client-centered therapy*. American Psychological Association (1966)
25. Sidner, C.: Engagement: Looking and not looking as evidence for disengagement. In: *Workshop at HRI 2012* (2012)
26. Spencer-Oatey, H.: (im) politeness, face and perceptions of rapport: unpacking their bases and interrelationships (2005)
27. Spencer-Oatey, H.: *Culturally speaking: Culture, communication and politeness theory*. Continuum Int. Publishing Group (2008)
28. Tajfel, H., Turner, J.C.: An integrative theory of intergroup conflict. *The Social Psychology of Intergroup Relations* 33, 47 (1979)
29. Taylor, D.A., Altman, I.: *Communication in interpersonal relationships: Social penetration processes* (1987)
30. Tickle-Degnen, L., Rosenthal, R.: The nature of rapport and its nonverbal correlates. *Psychological Inquiry* 1(4), 285–293 (1990)
31. Treger, S., Sprecher, S., Erber, R.: Laughing and liking: Exploring the interpersonal effects of humor use in initial social interactions. *European Journal of Social Psychology* 43(6), 532–543 (2013)
32. Vardoulakis, L.P., Ring, L., Barry, B., Sidner, C.L., Bickmore, T.: Designing relational agents as long term social companions for older adults (2012)
33. Yu, Z., Gerritsen, D., Ogan, A., Black, A., Cassell, J.: Automatic prediction of friendship via multi-model dyadic features (August. 2013)
34. Zanna, M.P.: *Advances in experimental social psychology*, vol. 31. Elsevier (1999)