Statistical Verification of Computational Rapport Model

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Abstract

Rapport plays an important role during communication because it can help people understand each other's feelings or ideas and leads to a smooth communication. Computational rapport model has been proposed based on theory in [36]. But there lacks solid verification. In this paper, we apply structural equation model (SEM) to the theoretical model on both dyads of friend and stranger. The results indicate some unfavorable paths. Based on the results and more literatures, we modify the original model to integrate more nonverbal behaviors, including gaze and smile. Fit indices and other examination show the goodness of our new models, which can give us more insight into rapport management during conversation.

Keywords: Rapport Model, SEM, Non-verbal Behavior

1 Introduction

Rapport, defined as a close and harmonious relationship in which the people or groups understand each other’s feelings or ideas and communicate well, plays a significant role during daily life, including health [14], education [7] and negotiation [13]. As virtual agents gradually involved into tasks such as those described above, it is necessary for agents to recognize, understand and even build and manage the rapport with human being. While it turns out that the behavior of this essential feeling, for instance rapport-evoking and rapport-signaling, depending largely on relationship among people. An explicit example would be the work of Ogan et al. [30], which indicated that the function of rudeness was opposite between friend dyads and stranger dyads. Taking these variance into account, R Zhao et al. [36] proposed a computational rapport model which consists of three main goals: mutual attentiveness, face management, coordination, together with behaviors that supports these goals. (See Section 2 for details)

While the model in [36] is mainly theoretically driven, there lacks a formal way to verify the correctness of this model. Moreover, the model doesn’t take much nonverbal behavior into account, which may play an important role during communication [22] [29]. In this paper, we apply statistic methods (specifically structural equation model) to verify the theoretically driven model. By merging the theoretical result and statistical result together, we will further propose two modified models, one for friends and one for strangers, by integrating more nonverbal behavior. These models would allow us to (1) get a better understanding of rapport between friends/strangers and obtain more insight into the difference between friend dyads and stranger dyads. (2) guide embedded conversational agents (ECAs)’ choice of conversational strategies and nonverbal behavior generation. Particularly, ECAs can alter their behaviors better when they switch between new users and old users.

The rest of paper will structured as follows. Section 2 will introduced the related work, especially the theoretical rapport model. Section 3 will briefly introduce the corpus used in this paper, together with some short definition and notation of conversational strategies, nonverbal behavior and rapport level. Section 4 will include introduction of the methods used in the paper: structural equation model and some additional preprocess methods. Section 5 will present the statistic result of theoretical model, modification procedure and result of modified model. Section 6 will summarize the meaning of both origin and new models. Finally Section 7 and 8 will conclude the work throughout this paper, as well as some limitation and future work.

2 Related Work

Tickle-Degnen et al. suggested that the experience of rapport requires a dynamic model with three basic behavioral components: positivity, mutual attentiveness and coordination [35]. Positivity helps to build a friendly relationship between people. Mutual attentiveness connects the speakers and listeners
and finally coordination provides a feeling of synchronousness. However, concentrated only on nonverbal behaviors.

Spencer-Oatey offered another perspective. She proposed that the task of managing rapport included not only increasing, but also maintaining and destroying rapport. Each of them involved face management, such as praising which could help to raise face or insulting which could challenge one’s face.

These two works contributed to the prior highly conceptual level of rapport model. There exist three top-level goals making up rapport management: face management, mutual attentiveness and coordination.

2.1 Face Management

Brown and Levinson defined positive face as a desire by everyone to be approved of. They suggested the function of politeness to boost the sense of being approved as well as the function of face-threatening acts (FTAs) of challenging face. Spencer-Oatey pointed out the lack of an interpersonal dimension to face and defined identity face as the desire to be recognized for one’s positive social identity and individual positive traits. FTAs will challenge someone’s self identity as well as social identity and face-boosting acts (FBAs) (such as politeness in) will contribute to self-esteem, social identity, and improve the rapport between the dyad. She also pointed out the subjective property of both FTAs and FBAs, which is largely depended on the individual’s judgment. She suggested that sociality rights and obligations derived from sociocultural norms - how we feel entitled to be treated based on the behaviors we expect from others - determines one’s judgment. Fulfilling these rights and obligations would help to build up the feeling of being approved, and hence the level of rapport.

2.2 Mutual Attentiveness

A tight connection between speaker and listener smooths the conversation. The connect attributes largely on the mutual attention between interlocutors. In order to keep up with the sociocultural norms, proper behavioral expectation is a significant factor allied, which can be attributed to mutual attentiveness. Small talk by providing self-information is another way to achieve mutual interaction. These behavior can push both speaker and listener to stay alert during conversation.

2.3 Coordination

Behavioral expectation serves as one of the most significant role in coordination. Mutual fulfillment of the interlocutor’s expectation would build up the coordination while the violation of the expectation would, for the most case, destroy the coordination. Self-disclosure can play another important role for reciprocity. Dyads can get good coordination when the self-disclosure is successful, which can be achieved by the mutual signal for receptivity and appreciation of the other one’s self information.

Zhao et al. presented a computational model of rapport management. He suggested three the top-level goals, for the purpose of managing rapport, including Face Management, Mutual Attentiveness and Coordination. These three behavioral components never change whenever the interactants intend to enhance, maintain or destroy the rapport. However, the inner structure of the models are quite different, which is explained by two models respectively: the model during rapport enhancing and maintaining and the model during rapport destruction. For instance, during enhancing and maintaining rapport, there are different approaches to achieve the final goals. In terms of the coordination, people may first try to realize the sub-goals such as indexing community or supporting and appreciating other’s true-self, which respectively consists of different conversation strategies. Strategies such as reference to shared experience and violation of social norm can contribute to indexing commonality. Self-disclosure and reciprocal appreciation can contribute to supporting true-self. We refer reader to obtain a more detail view of the computational model in.

However, Zhao’s model didn’t involve much nonverbal behavior other than laughter, which may also influence the rapport management. A naive example would be an insult with smile against an insult without smile. Insulting is a former of violation of social norm and both types of insult could be casual jokes between friend dyads. While for strangers, the former insult might be a kidding but the latter, for the most of the time, could be a way of challenging face. Although Gratch’s group took nonverbal behavior as a feature and recently they even combined self-disclosure with nonverbal gesture, they interpreted rapport just as the function of display, which
was quite different from the models in [35] and inevitably missed some information such as the relative role of the interlocutors. Hence it is necessary to integrate more nonverbal behavior as new model elements.

3 Corpus

In this paper we use the Articulab 2013 RAPT Corpus, as described in [37]. In the experiment, 12 dyads of 12-15 year old students (half boys and half girls, half friends and half strangers) tutored each other in algebra over a period of 5 sessions in 5 weeks (totally 60 sessions). Each session lasts approximately one hour. During each session, dyad would start with a social period, followed by a task period (peer tutoring alternatively), followed by a breaking social period, followed by another task period and finally a social period. All interactions were videotaped by three cameras (two front view camera for each of the dyad and a side view camera). All speech was recorded by lapel microphones in separate channels. The dataset had been fully transcribed, including conversational strategies, nonverbal behaviors, rapport level estimation (each 30 seconds). Some important codings are summarized below.

3.1 Coding Conversational Strategy

**Self-disclosure (SD)** (Krippendorf’s $\alpha = 0.753$): Dialogue act that people reveal aspects of themselves (private information) that otherwise would not be seen or known by the person being disclosed to. We distinguish negative self-disclosure (denoted as $SD_{neg}$) from total self-disclosure (denoted as $SD$) in the corpus. $SD_{neg}$ are $SD$ that involves information that undesirable (e.g. Math sucks me!), forbidden (e.g. I cheated on that math examination.) or not socially-acceptable (e.g. I killed my dog when I was five.). The reason of such division can be reviewed in [27], [6], as discussed in 5.2.

**Refer to Shared Experience (SE)** ($\alpha = 0.798$): Verbal expression that people mention the event, activity or experience (but not interests) which is shared by the person in the conversation (e.g. Do you remember the math questions we did last week?).

**Praise (PR)**: $\alpha = 1$: The expression of a positive judgment of a product, behavior or attitude of the person in the conversation. (e.g. Awesome! You did a great job!)

**Social Norm Violation (SV)** ($\alpha = 0.753$): Verbal behavior that go against socially/culturally acceptable or stereotypical behaviors. (e.g. teasing, insulting). We distinguish three kinds of SVs in the corpus. The first type, denoted as $SV_1$ is for behaviors that breaks the conversational rules of the experiment, school-like activities, or general social norms (e.g. Off-task talk during tutoring session). The second type ($SV_2$) includes negative invading behaviors, which is a part of FTAs (e.g. criticizing, teasing, or insulting math task performance). The third type ($SV_3$) includes referring to self or other persons conversational social norms violations or general social norm violations (e.g. Referring to the need to focus on work during off-task talking).

**Backchannel (BC)** ($\alpha = 0.72$): A phoneme, word or phrase that is used to inform the speaker that the current listener is keeping attention in the conversation. It have no meaning other than that the person is still listening. (e.g. huh, hmmm)

All of the conversational strategies are based on sentence and hence sentence-unit. **Reciprocity (RCP)** ($\alpha = 0.77$): Strategy that responds a conversational strategy or move by the same conversational strategy or move. (e.g. P1: I don’t like the show on the town yesterday. P2: Me too. Especially that dancer. That’s awful!) The reciprocity can be divided by the conversation strategy involved. Some examples include $RCP_{SD}$, $RCP_{SE}$, etc.

3.2 Coding Nonverbal Behavior

**Gaze** ($\alpha = 0.893$): The gaze was coded continuously and four types of gaze were coded in our corpus: Gaze at the partner ($GP$), Gaze Elsewhere ($GE$), Gaze at ones own working sheet ($GO$) and Gaze at ones partners working sheet ($GN$). $GO$ and $GN$ are particularly to our corpus. We mostly focus on $GP$ in this paper because it is more involved in the form of mutual interaction. More details will be discussed in Section 5.2. **Smile** ($\alpha = 0.746$): Here smile didn’t just mean the raising of the lip, but also included the cheeks being pushed up and eye beginning to crease. It was more like a synchronized effort.

**Laughter** (transcribed in natural language): Simple spontaneous sounds and movements of the face (sometimes also body) with U-shape, open mouth.
3.3 Coding Rapport Level

Rapport Level: The rapport was assessed by thin slice annotation \cite{2}, based on short exposure to dyad’s visual and verbal behavior. Three naive coders were taught with simple definition of rapport and annotated every 30 seconds video segment (with audio, shuffled) for rapport using a 1-7 likert scale. Weighted majority rule was employed to reduce bias.

In order to fit the model, we need to concatenate all different dimension of data. As rapport level are annotated by thin slice method, conversational strategies and nonverbal behaviors are simply summarized (by counting) every 30 seconds accordingly. For instance, during some 30 second slice, dyads use ‘backchannel’ three times, then the BC during this slice would be 3. Note that Gaze is continuous and treated specially as binary of each type. Hence one data sample would be a set of integers (e.g. Rapport Level, 4; SD, 3; SE, 2; RCP, 0; PR, 0; SV, 4; BC, 1; GP, 1; GE, 0; GO, 1; GN, 1; Smile, 3; Laughter, 0).

Overall approximately 7200 samples are recorded. We concern the effect of conversational strategies in the corpus \cite{36}. Hence we remove those 30 second slices without any of the strategy, i.e. all of SD, SE, RCP, PR, SV, BC are counted as zero. We also remove slices whose annotated rapport level is lower than 5: we focus on the rapport enhancement and maintenance. Low rapport data sample has bias and need to be removed. Moreover, we also separate friend dyads and stranger dyads because of their difference. The sample size of friend dyads is 973, and size of stranger dyads is 237. It is interesting to see that friend dyads tend to use more conversational strategy than strangers.

4 Method

4.1 Structural Equation Model

Structural Equation Model (SEM) is a combination of confirmatory factor analysis and path analysis. It is usually employed as a powerful method to confirm and modify models with latent variables. \cite{1} \cite{20} The purpose is to verify the theoretical driven relationships among both observed and unobserved (latent) variables and explore better relationships, if possible. The model proposed by Zhao \cite{36} is suitable for this approach. Specifically, the conversational strategies such as self-disclosure, non-verbal behavior such as laughter, and rapport level, are all observed variables, while the top-goals of building rapport (or destroying rapport) including face management, mutual attentiveness and coordination, is latent variables, or factors.

It is noted that the model proposed in \cite{36} is slightly different from the annotation of our corpus described in Section 3. Moreover, the theoretical model has two-level latent structure, which can be simplified by capturing the relationship between behaviors, top-goals and rapport level. The graph is shown in Figure 1. The data preprocess and data analysis will be presented in the Section 5.

4.2 Preprocess

Shapiro-Wilk Normality Test on each type observed variables shows significance (p < 0.001). This is expected, although those 30 seconds slices without any conversation strategy have been filtered, the behaviors (both verbal and nonverbal) are still sparsely distributed on the time series, which will not fall into any normal distribution. This also indicates the inappropriateness of normal maximum likelihood (ML) estimation. Instead, robust ML (MLR) is applied.

Outliers are not removed form the dataset because of its social meaning: all outliers imply the fact that during some 30 seconds slices, particular behavior happens frequently (such as frequent smile, frequent social norm violation), which might have impacts on rapport level.

5 Result

We first present the result of SEM on the theoretical model, after which we will modify the model based on some literatures and discuss the result of new model.

5.1 Theoretical Model

5.1.1 Friend Dyads

Although the $\chi^2$ test shows the significance ($\chi^2 = 162.71$, p < 0.001), the fit indices indicates that our theoretical model is not as acceptable (CFI = 0.898 < 0.95, SRMR = 0.055 > 0.05, both after robust modification). The examination of residual shows the small value between SD and PR. However they belong to two different top-goals (SD with Mutual Attentiveness and PR with Face Management) hence
Figure 1: Theoretical Rapport Model for Friend Dyads

will not be considered. The coefficients examination shows insignificance of [PR – Face Management] (p = 0.375), [SDneg – Face Management] (p = 0.594) and [RCP – Mutual Attentiveness] (p = 0.704). Details of the coefficients is presented in the Fig. 1. Meanwhile, the SDneg, RCP is observed in the modification indices as [SDneg cor RCP]. The index is difficult because of the different top-goals.

5.1.2 Stranger Dyads

Similar analysis can also be applied on stranger dyads. Χ² test shows the significance (Χ² = 49.122, p < 0.001). And the fit indices also indicates no acceptance (CFI = 0.923 < 0.95, SRMR = 0.055 > 0.05). Coefficient examination is, as expected, different from previous one of friend dyads. The effect of SE is insignificant, both on Mutual Attentiveness and Coordination, corresponding to [SE – Mutual Attentiveness] (p = 0.935) and [SE – Coordination] (p = 0.688). [SV – Coordination] (p = 0.744) is another insignificant path. Coefficient details can be seen in Fig. 1.

5.2 Modification

5.2.1 Friend Dyads

The reason of PR may be explained by the fact of sparsity: PR is the least frequent behavior, only 92 among 1860 samples, compared to SDneg as 214 samples and RCP as 791 samples. Although praise is relatively rare between friend, there is some literatures discussing the effectiveness of praise between friend [21] hence this relation is left untouched.

Some theoretical results are found to guide the modification of RCP and SDneg (to mutual attentiveness). For [RCP – Mutual Attentiveness], on the one hand, [9] and [36] emphasized the role of reciprocal social behavior (RSB) in the coordination. [12] and [26] suggested RSB to be applied for the detection and remedy of autism, which functions more on Coordination than Mutual Attentiveness during communication. On the other hand, the RCPSD, as a subset of RCP, does contribute to Mutual Attentiveness together with SD [15] [17]. However, as described in [3] RCP includes all kinds of reciprocal conversational strategy, which may lead to bias.

While for [SDneg – Face Management], it is difficult to interpret. Although [32] pointed out the subjectiveness of judging FBAs and FTAs and it might be explained that friend dyads may count less on the SDneg for face boosting [27] [6]. There lacks any literature to further discuss the relationship between SDneg and Face Management. We leave this puzzle here for future work. Based on both the statistical analysis and theoretical analysis, we make modification to one path

- change [RCP – Mutual Attentiveness] to [RCPSD – Mutual Attentiveness]

5.2.2 Stranger Dyads

Our observation indicates that SE for strangers, same as the PR for friend dyads, is distributed sparsely in the corpus, compared to other conversational strategy (SE 12/237, PR 46/237, SD 102/237). This is intuitive: strangers didn’t share any experience before they participated in the study, which make the effect of SE meaningless in the model.

The insignificance of [SV – Coordination] may be caused by the bias of SV2, as described in Section 3.1. The teasing and invading behavior among stranger is rare when rapport level is high but may lead to undesirable effect to the model [34]. To
achieve clarification, we rename $SV_2$ as $SV_{neg}$, which imply the negative sentiment (under most scenario between strangers). $SV_1$ and $SV_3$ are grouped into $SV_{nonneg}$.

We modify the following three paths:

- remove $[SE – Mutual Attentiveness]$ 
- remove $[SE – Coordination]$ 
- change $[SV – Coordination]$ to $[SV_{nonneg} – Coordination]$ 

5.2.3 Integrating Nonverbal Behavior

As pointed out in Section 2, previous model in [36] didn’t integrate nonverbal behaviors other than laughter. We are intended to expand the model to Gaze (at the partner, actually GP), Smile and Backchannel of the interlocutors. The social function of Gaze have been mentioned by several literatures. Mutual gaze have a great impact on Coordination and Mutual Attentiveness [4]. We refer readers to a good review of relevant works [19]. Smile has been found positively correlated with social status [10]. During conversation, Smile can convey a combination of meanings including amused, polite, embarrassed etc. [1]. These functions contribute to Face Management during rapport management. Backchannel functions as pushing conversation forward. Some literatures pointed out the function of Backchannel on Mutual Attentiveness and Coordination. It helps convey the attentiveness from listener and speaker [23]. At the mean time, interlocutors are tented to use similar back-channel-preceding cues (BPCs), which contributes to the dialogue coordination [24].

Based on these work, we add five paths to the models (both friends and strangers):

- $[Gaze – Mutual Attentiveness]$ 
- $[Gaze – Coordination]$ 
- $[Smile – Face Management]$ 
- $[Backchannel – Mutual Attentiveness]$ 
- $[Backchannel – Coordination]$ 

The result of modified model is summarized in the next part.

5.3 Modified Model

5.3.1 Friend Dyads

The modified model is presented in the Fig. $\chi^2$ test shows the significance ($\chi^2 = 378.60, p < 0.001$). The fit indices also indicate the acceptance of the modified model (CFI = 0.951 > 0.95, SRMR = 0.044 < 0.05, both after robust modification). Residual examination still shows the small value between SD and $PR$. It is neglected again because of their different top-goals. Coefficient examination only finds $PR$ to be insignificant, which can be explained by its sparsity. The detail of coefficients can be seen in the Fig. 2.

5.3.2 Stranger Dyads

As shown in Fig. $\chi^2$ test ($\chi^2 = 378.60, p < 0.001$) and fit indices (CFI = 0.973 > 0.95, SRMR = 0.030 < 0.05, both after robust modification) are favorable. Residual examination implies the small value between Smile and BC and it is also neglected with the same reason. Coefficient examination doesn’t show any insignificance. Details are presented in Fig. 2.

Generally, both modified models fit better than the previous ones. More discussion will be involved in Section 6.

6 Discussion

We first get some insight from the graphs of both modified friend model and modified stranger model. Then we discuss the difference between these two models.

6.1 Commonness

Two models both indicate the important role of $SD$ on Mutual Attentiveness, with the largest loading factor among all observed variable to Mutual Attentiveness. This implies the function of self-disclosure on attentiveness between interlocutors [28]. Same conclusion can be drawn as $SV$ on Coordination.

Face Management has the largest loading factor on Rapport Level in both models. This is an interesting phenomenon. People has a strong intention to get approval from others during conversation [8]. It can happen more frequently when task performance
is trivial. Our corpus collects data during peer tutoring which lacks a strong task-oriented atmosphere. This may help explain, to some extent, the reason of Face Management as the most important top-goal during rapport management.

Positively correlation is observed between Face Management and Mutual Attentiveness, which is easy to interpret because keeping the mutual connection can be regarded as the prerequisite of being approved. How can a person get approved when no one leaves any attention on him/her? Face Management and Coordination are weakly correlated in both models. However, the correlation between Mutual Attentiveness and Coordination is different between friends and strangers, which will be discussed in the next part.

Unsurprisingly, Gaze and Backchannel can positively affect both Mutual Attentiveness and Coordination. Smile positively contributes to Face Management. Compared to the theoretical driven model, the modification is supported both by statistics ($\chi^2$ test, fit indices, residual examination and coefficient examination) and theories ([1][6][19][32]). The new models are able to integrate more nonverbal behaviors, which would help us gain more insight into rapport among people.

### 6.2 Distinction

The difference two models are more interesting. PR happens more frequently among strangers than friends (stranger: 46/237, friend: 56/973). Correspondingly, the effectiveness of PR on Face Management is significant on strangers but not on friends. This indicates that strangers tend to rely more on praise to enhance and maintain rapport. Similar phenomenon can be observed on $SD_{neg}$ to Face Management: $[SD_{neg} – Face Management]$ is significant among strangers but not on friends, which means $SD_{neg}$ might be another powerful ‘weapon’ for strangers (still with puzzle). Overall we can notice that strangers usually resort to more conversational strategies for boosting face.

Strangers also avoid using invading violation of social norm during conversation (stranger: 1/237, friend: 432/973). It is dangerous to teasing or insulting a stranger. But friends may use it just for fun and they are more easily to understand and accept the invading behavior from their partner.

The correlation between Mutual Attentiveness and Coordination is strongly positive between friends but weak between strangers, which implies that friends are more like to keep mutual attention during coordination or achieve coordination when mutual attentiveness is established. This may be explained by the fact that friends are familiar with each other and more ‘proficient’ to collaborate and strangers may be more conservative during interaction.

### 7 Limitation and Future Work

Some limitation and future work will be list here. First, the annotation of each verbal and visual behavior in corpus is not fully identical to the element of Zhao’s model. For instance, Zhao split self-disclosure into ‘initial mutual’, ‘topic related’, ‘negative’, and so forth. The this paper, we only distinguish negative self-disclosure and non-negative self-disclosure. The distinction between corpus and theoretical model may lead to undesired bias.

Second, some verbal behavior are too sparse during conversation, such as praise (PR, 92 in 1860 sam-
The sparsity may cause the difficulty in fitting the model. The path of [Face Management to PR] in both origin and modified model are insignificant. Third, weak positive autocorrelation is observed both among friends and strangers data. Although slices without any conversational strategy have been removed and the time lag between the data sample is not constant. It still indicates that time may be another factor in the model. Longitudinal structural equation model worth an attempt in the future.

8 Conclusion

In this paper, we use SEM to verify the theoretical model on both friends dyad and stranger dyads proposed in [26]. The test results shows some undesirable path in the origin model. Based on statistics and theories, we remove, alter some paths and integrate more nonverbal behaviors into the model. We modified the theoretical model on friends and strangers separately. Fit indices and other examination support both new models. With modified computational model we can better understand the rapport building and maintenance behavior patterns among dyad.

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