Relating Entrainment, Grounding, and Topic of Discussion in Collaborative Learning Dialogues

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Abstract: In conversational dialogue, *grounding* refers to the joint activity of speakers and listeners establishing common ground—a shared understanding of their mutual knowledge, beliefs, and assumptions. Grounding is a critical component of successful collaborative interactions and plays an important role in collaborative learning. In this work, we investigate grounding utilizing acoustic-prosodic entrainment. Acoustic-prosodic entrainment occurs in spoken dialogue when speakers adapt their tone, loudness, voice quality, or speaking rate to that of their partner. We explore the relationship between grounding and acoustic-prosodic entrainment within on-task and off-task dialogue, and we find that grounding behaviors in both on-task and off-task dialogue are differentiated by how speakers entrain.

Keywords: collaborative dialogue, acoustic-prosodic entrainment, grounding, off-task discussion

Introduction

Effective conversational grounding is a critical component of successful collaborative interactions and collaborative learning tasks (Baker et al., 1999). From a cognitive perspective, grounding in problem-solving dialogue enables people to coordinate knowledge and co-construct solutions, playing a critical role in the learning process (Clark & Brennan, 1991). From a social perspective, grounding may aid in the development of rapport with one's collaborator (Semin & Cacioppo, 2008). These social attributes have in turn been shown to be predictive of learning (Ogan et al., 2012).

In this work, we explore how properties of speech relate to how students are engaging in these critical grounding behaviors in problem-solving conversations. Specifically, we investigate the phenomenon of **acoustic-prosodic entrainment**, when speakers adapt their tone, loudness, or voice quality to that of their partner. Previous works in non-collaborative dialogues have shown that entrainment correlates with grounding behaviors such as backchannels (Levitan et al., 2012). In addition, acoustic-prosodic entrainment has been shown to be positively correlated with cognitive and social processes that grounding is thought to facilitate (Gweon et al., 2012; Lubold & Pon-Barry, 2014). We focus on grounding behaviors within different topics of conversation, investigating: **How does the interaction between grounding behaviors and topic of conversation influence the ways in which students entrain on each other's speech?**

Method

We collect a set of eight 30-40 minute dialogues from 16 undergraduate college students. The students work together in pairs as peers and were randomly assigned to their partners. We give each student a tablet containing a version of the Formative Assessment with Computation Technologies (FACT) application (http://fact.engineering.asu.edu/). The application encourages collaborative interaction through the use of a shared workspace. Each pair works together to solve two math problems using the tablets. We record high-quality audio data using unidirectional microphones and we manually label dialogue turns.

Entrainment, known also as accommodation or adaptation, occurs when participants adapt their behavior to each other during an interaction. We explore acoustic-prosodic entrainment where speakers adapt their tone (pitch), loudness (intensity), or voice quality (jitter and shimmer) to that of their conversational partner. We extract these features using OpenSmile (Eyben, Wöllmer, & Schuller, 2010), obtaining the mean for each feature. The dynamics of social and knowledge coordination occur at a turn-by-turn level so we measure entrainment on a turn-by-turn basis, adapting an approach from Thomason, Nguyen, and Litman (2013).

To analyze grounding, we label our corpus with common ground features based on Nakatani & Traum (1999). Grounding contributions are contributions which are defined as specifically adding, confirming, or updating mutual knowledge. In grounding contributions, a turn is labeled as grounding if it is relevant to the preceding turn. We define how it is relevant by analyzing whether it contains the response to a question or if there is a clear reference to repeated content from a previous turn by the other speaker. Grounding behaviors were coded by two annotators and average inter-rater agreement was calculated with Cohen's kappa at 0.74.

While much research in the past has focused on the benefits of on-task dialogue, recent research has found that off-task discussion has rapport-building potential. We analyze the grounding and entrainment across *problem-solving*, *social*, and *activity-related* dialogue. In problem-solving dialogue, students are actively working on the problem. Social dialogue pertains to social, off-task conversation. In activity-related dialogue, students are specifically discussing the application or activity itself.

Results

We perform all analysis using regression. Analyzing grounding and entrainment in problem-solving, social, and activity-related dialogues, we find that controlling for differences between dyads, entrainment on voice quality (i.e. jitter and shimmer) is a pertinent feature of grounding. In problem-solving dialogue, shimmer contributes significantly in discerning grounding from non-grounding behaviors, and in social dialogue jitter approaches significance. Jitter is defined as variations in pitch; shimmer consists of variations in loudness. Table 1 depicts the parameter values for the regression models of grounding with acoustic-prosodic entrainment.

Table 1: Parameter values for modeling grounding in on-task/off-task dialogues with entrainment

Type of Dialogue		Dyad	Intensity	Pitch	Jitter	Shimmer	Chi-square (overall model)	p-value (overall model)
Problem-Solving	*B*	-0.04	-0.08	0.45	-0.09	-0.67*	7.968	0.158
Activity Related	*B*	-0.01	0.10	0.17	-0.09	-0.27	0.239	0.77
Social	*B*	-0.29*	-1.55	1.73	-1.75*	2.35	11.69*	0.04

(*) indicates $p \leq 0.05$

Discussion & Future Work

We found that within different topics of conversation, entrainment on voice quality can be helpful in differentiating meaningful grounding behaviors. Our results suggest that people entrain more when engaging in social dialogues, and that, within both social and problem-solving dialogues, grounding turns have higher entrainment. Future work will use these findings to develop an automatic entrainment detector that assesses grounding in real-time. These methods will allow us to better understand the quality of student collaborative processes without needing to depend on inaccurate speech recognition technologies.

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