Using Real-time Trace Data to Predict Collaboration Quality and Creative Fluency in Design Teams

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Abstract: In this study, sixteen Engineering students were assigned to small groups (n=4) to work collaboratively on engineering design tasks. Using wearable sociometric devices, we collected real-time non-linguistic speech data on team interaction including turn-taking, successful interrupts and overlaps. Results from 2-stage regression models indicate that speech and conversational dynamics such as turn-taking and successful interrupts are significant in predicting the perceived collaboration quality and creative fluency of design teams.

Keywords: collaboration quality, creativity, sociometrics, design learning

The social processes in computer supported collaborative engineering design settings are influential to collaborative outcomes (Dillenbourg, 1996). In real-world settings, engineering design is predominantly collaborative and relies extensively on social interaction to generate creative design ideas and maintain collaboration quality (Bucciarelli, 1994). Therefore, it is important that we identify key social interaction dynamics to promote engineering design learning. In this study, we demonstrate a novel and unobtrusive method for capturing and analyzing social interaction dynamics among students working on collaborative engineering design task.

In recent research, data from sociometric sensors that collect real-time speech and behavioral data have been found to be successful indicators of collaboration in different settings (Pentland, 2012). We explore the possibility of using such data to predict creative and collaborative outcomes in learning teams, by quantifying their speech and behavioral dynamics.

Methods
We recruited 16 students (14 men and 2 women) aged 21-37 years), from a mechanical engineering graduate design course, and randomly assigned to four teams of four participants each. Each participant team was assigned to one of the four experimental conditions that varied in *context* (Standard or Commons room) and *sketch tool* (skWiki or paper). Each team was given one toy and instructed to first classify it based on the play pyramid (Kudrowitz & Wallace, 2010). Then the students changed the play value of the toy and sketched ideas for new toys. Each team spent roughly 60 minutes on the entire task.

Materials
Participants sketched on iPad tablets using capacitive-touch styli running skWiki (Zhao et al., 2014), a browser-based application for collaborative sketching. The sketches generated by each team member were synchronized across all other team devices, allowing sketches to be shared, elaborated, and collaboratively developed.

Measures

Collaboration dynamics
We used wearable sociometric sensors to capture real-time data on a series of non-linguistic social signals (Pentland, 2012). In this study we focused on measures of speech and conversational turn-taking, analyzing four measures: turn-taking *by* a speaker and *after* a speaker, successful interruptions, and speech overlaps. 10-second speaking segments were calculated from data captured every second.

Collaboration and creativity measures
Participants completed two surveys at the end of the session and a brief 1-minute probe in the middle of the session to assess collaboration quality, and creative fluency and flow. To assess the participants' perceived

collaboration quality, we used a 9-item scale (α = .90) adapted from a scale for collaboration readiness of scientific teams (Mâsse et al., 2008). For flow, we used an 8-item scale (α = .91) derived from Arici (2008). Both used 5-point Likert scales. We measured fluency as the number of sketches created by each participant.

Findings

Regression model for creative fluency
We analyzed the data using a two-stage hierarchical regression model. We controlled for context, sketching tool, and students' sense of flow in the first stage of the model, followed by turns after, successful interrupts and overlap in the second stage of the model. Results showed that the model was significant in predicting fluency, $R^2 = .73$, F(6,9)=4.18, p=.03. While the sketch tools and context were not significant in the model, turns taken after a student has spoken, $\beta = -2.62$, t(16)=-3.32, p=.009, and successful interrupts, $\beta =2.42$, t(16)=3.22, p=.01, were significant predictors of creative fluency.

Regression model for collaboration quality
Similarly, in the two-stage hierarchical regression model for collaboration quality, we first controlled for sketching context, sketching tool, gender, and student classification (i.e. undergraduate/graduate). In the second stage of the model, we included turn-taking, turns taken after a student spoke, successful interrupts, and speech overlap as predictors. The model significantly predicted collaboration quality, $R^2 = .85$, F(8,7)=5.07, p=.023. While the sketching tool and context were not significant predictors of collaboration quality, turn-taking, $\beta = -1.14$, t(16)=-3.56, p=.009, turns taken after a student has spoken, $\beta = -2.91$,t(16)=-2.98, p=.02, and successful interrupts, $\beta = 4.22$, t(16)=4.003, p=.005 were significant predictors.

Conclusions and implications
This study contributes to the literature on computer supported collaborative learning by demonstrating that regardless of the context or materials for collaboration, social interaction dynamics are significant predictors of creative fluency and collaboration quality in engineering design learning. These findings are aligned with social construction theories that highlight the importance of inter-subjectivity and the joint construction of ideas (Stahl, Koschmann & Suthers, 2006).

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