A COMPUTATIONAL APPROACH TO EXPOSE CONVERSATION DYNAMICS IN ENGINEERING DESIGN ACTIVITIES

Wulvik, Andreas (1); Menning, Axel (2); Steinert, Martin (1)
1: Norwegian University of Science and Technology, Norway; 2: Hasso-Plattner-Institut, Germany

Abstract

This paper presents work in the field of using computational tools to expose conversation dynamics in design activities. We are considering quantitatively how designers engage in design conversations as opposed to the semantic content they provide to the discussion. The latter has been explored extensively through Protocol Analysis and Conversation Analysis, while the former is a relatively new field of study. This work presents the process of applying Temporal Static Visualisations to transcript data. In addition application of the approach is shown in a case study consisting of two sessions comprising 300 lines of text each. The results of the analysis reflect the task structure of the sessions.

Keywords: Visualisation, Design process, Computational approaches, Design engineering, Conversation dynamics

Contact:
Andreas Wulvik
Norwegian University of Science and Technology
Department of Engineering Design and Materials
Norway
andreas.wulvik@ntnu.no

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1 INTRODUCTION

In this paper, we apply a computational approach to expose conversation dynamics in design conversations. We apply this approach to a case study comprising of two sessions, with 300 speaker turns respectively. The resulting analysis of the variance in speaker score (based on speaker turns and word count) allows the researcher to expose the conversation dynamics throughout the session and creates the foundation for more in-depth analysis of design team interaction.

Our main interest are these design team interactions, more specifically design conversations. These conversations are made up of information content (semantics) and temporal patterns of information exchange (dynamics). Many design researchers have focused on semantics (e.g. Schön, 1993; Goldschmidt, 2014; Dorst and Cross, 2001), while the dynamics of design conversations has not received the same attention in the past. We believe that there is a mutual interaction between semantics and dynamics, which must be taken into account when studying design activities. The dynamics of a design team is governed by the combined contribution of the individual participants, for example a single person dominating the conversation, or the whole team interacting in equal proportions. In this work, we explore the concept of conversation dynamics.

2 THEORETICAL BACKGROUND OF THE COMPUTATIONAL APPROACH

Measuring, coding and analysing design team interaction is essential to create knowledge about the design process itself. According to Stempfle and Badke-Schaub (2002) analysing design team interaction compared to the thought process of individuals is more feasible because "groups have to communicate what is going on during their current thinking and thus provide us with the basic thinking process". Secondly, this analysis is important in organisational contexts because "with increasing complexity, groups of individuals work together to accomplish problems they cannot solve on their own." (Stempfle and Badke-Schaub, 2002). Protocol Analysis (PA) (Ericsson and Simon, 1993) and Conversation Analysis (CA) (Sacks, 1992) are frequently applied qualitative methods to study design team interaction. For PA and CA, design conversations are recorded, transcribed and parsed into communicative acts, typically speaker turns. Based on the data, a coding scheme is developed and applied. The resulting sequences of coded interaction are used for further analysis. With PA and CA researchers have been able to investigate the frequency of process and content talk during design conversations (Stempfle and Badke-Schaub, 2002), creative analogy use (Christensen and Ball, 2016), vagueness and interpretative flexibility (Glock, 2009), and the use of reported speech (Oak, 2013).

These manual forms of analysis are time intensive and often involve multiple analysts. Therefore, computational measurements of design interaction are rapidly gaining attention. Dong (2004) characterized the quality of design performance by measuring the coherence of design documentations. Dong (2005) measured the relation between the coherence of individual team members and the team's overall coherence. Chan et al. (2015) measured the conceptual distance between design ideas and inspirational sources. Menning et al. (2017) presented a mixed computational and manual procedure to systematically probe for distinct low coherent turns in design conversations. Wulvik et al. (2017) introduced the initial version of the Temporal Static Visualisation (TSV). We want to illustrate the basic mechanism of the TSV with the following example:

Table 1. Example of transcript data

Turn	Speaker	Text
1	E	But err... the contradiction that I got... or I got the feeling of a contradiction later. I, err, only asked him about ignorance and about how he feels about people ignoring him, so you know. Actually it's, err, umm, it's ok to have this kind of bond just as something you wear, so it's something special, he wouldn't like to have it every day that someone smiles to him and gives him this kind of feeling. It's much more work if it's just sometimes.
2	A	Yeah, ok.
3	E	That's somehow...
4	A	Yeah so, kind of a... treat.
5	E	Yeah so... like having... having a good piece of cake for us, having it just sometimes is probably for him being treated well, and seen as a person.
6	A	But is that something... you want to elaborate (??)?
7	E	It just surprised me somehow. I didn't, err, thought about that. I would naturally think it's probably cool to have this attention all the time. But he said no, he actually doesn't want this attention... umm...
8	A	Maybe it's just not valued as much as if it's everyday...
9	E	Somehow. But I'm not sure, what do you guys think about, err, this topic? It was... also in combination with this “boot“ thing.
10	C	Yeah.

In this segment, we can count the number of turns contributed by each speaker (speaker activity). A speaker turn begins when a speaker begins to speak and ends when the speaker ends her or his articulation deliberately or is interrupted. In addition, we can also count the number of words spoken per turn. During these ten speakers turns, Speaker E contributes five turns and 138 words, Speaker A contributes four turns and 29 words, and Speaker C contributes one turn and one word. We argue that perceived conversation dynamics are not only influenced by the alternation of different speakers but also by the length of contributions.

In all design studies that use transcript analysis, this temporal information exists but is difficult to extract. It is practically impossible for the human analyst to keep track of the conversation on two levels, turn-by-turn and overall conversation dynamics. By trying to follow the conversation on a turn-by turn basis, the analyst being in the middle of the transcript is not able to see the bigger picture. It is a case of not seeing the forest for the trees. Conversation participants may have an implicit assumption about the dynamics, but only a formal assessment of the conversation ensures reproducibility and comparability of conversation dynamics across several conversation segments.

3 TEMPORAL STATIC VISUALISATION

In order to visualise interaction in design conversations we apply Temporal Static Visualisations (TSV) to transcript data. This approach provides a resource efficient overview of the conversation dynamics. This is done by loading transcript data into a Python script. Below, we go through the computational steps of creating the visualisations. These steps are as follows: Speaker activity and number of words spoken make up what we define as speaker score. Comparing the speaker score of group members

constitutes the conversation dynamics. This comparison is made by calculating the variance of the speaker scores.

3.1 Input and pre-processing

The Temporal Static Visualisation is created from transcript data containing information about speaker sequence (Turn), who is talking (Speaker), and what is being said verbatim (Text). See Table 1, Section 2. Input data is pre-processed before creating the Temporal Static Visualisations by removing punctuation and transcription comments written in parentheses. In addition, we currently do not take parallel talk into consideration, but rather treat them as sequential occurrences.

3.2 Speaker Activity

As a first approximation to each speaker's participation in the group discussion we count the number of turns spoken in a predefined time period, N, looking backwards from time t_i. This is not taking into account how long each participant p_j has spoken, but we would say that there is an interaction even though utterances might be very short. Given the nature of how transcripts are segmented in alternating turns between speakers the maximum possible turns spoken in the last N turns is given by rounding N/2 up to the closest integer, e.g. maximum 10 if N is 20.

$$Activity(t_i, p_j) = \sum_{t=t_i-(N-1)}^{t_i} (p_t = p_j \rightarrow 1) \quad (1)$$

Figure 1 shows the activity of different participant throughout a session. We see here that participant B and F are very active in the conversation around speaker turn 80.

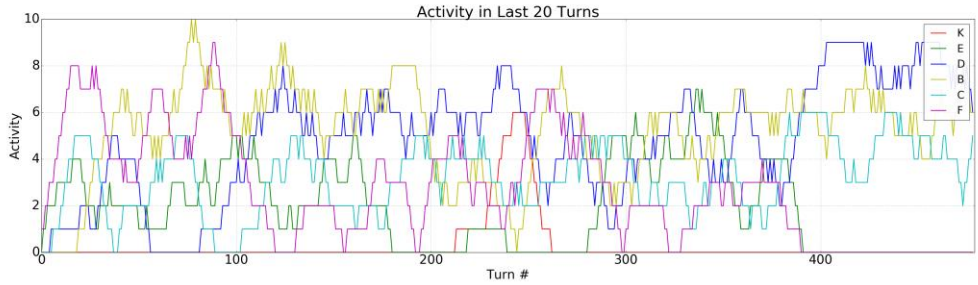

Figure 1. Day 4 Team Right Activity, N = 20

3.3 Words spoken

To highlight the amount of content each participant is providing in addition to how often they interact, number of words spoken in the last N speaker turns is extracted as a second participation metric (Equation 2).

$$Words(t_i, p_j) = \sum_{t=t_i-(N-1)}^{t_i} (p_t = p_j \rightarrow \#words(t)) \quad (2)$$

Figure 2 shows the cumulative sum of words spoken by each participant over the last N=20 turns, e.g. around turn 170 we can see an increase in number of words spoken by participants B, D, and E.

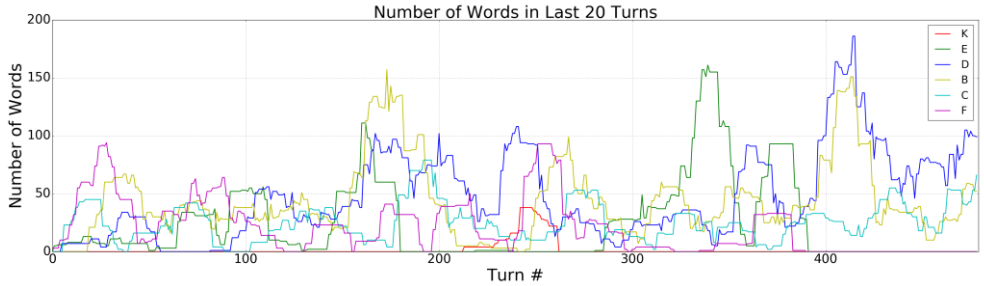

Figure 2. Day 4 Team Right Number of words, N = 20

3.4 Speaker Score

By combining the contributions from speaker activity and words spoken we calculate the speaker score as a metric for conversation participation. The score is calculated by multiplying rescaled speaker activity and rescaled words spoken (Equation 3). Speaker activity (Equation 1) is divided by the maximum possible number of turns as described in Section 3.1 and ranges from 0 to 1. Words spoken (Equation 2) is similarly rescaled to a range from 0 to 1 by dividing the number of words spoken by a given participant with the total number of words spoken in the given time period *N*. This should provide a balanced view of how much each speaker is participating in the design conversation. A high speaker score denotes both frequent activity and longer contributions, while a low score can come from either low activity, consistently short utterances, or both.

$$Score(t_i, p_j) = \frac{Activity(t_i, p_j)}{ceil(\frac{N}{2})} \times \frac{Words(t_i, p_j)}{\sum_{t=t_i-(N-1)}^{t_i} \#words(t)} \quad (3)$$

Figure 3 shows how the calculated participant score develops throughout the design conversation. Here we can see peaks in score for participant D around turn 230 and participant F around turn 90. This can be interpreted as the respective participants taking a greater role in the conversation at those points in the conversation.

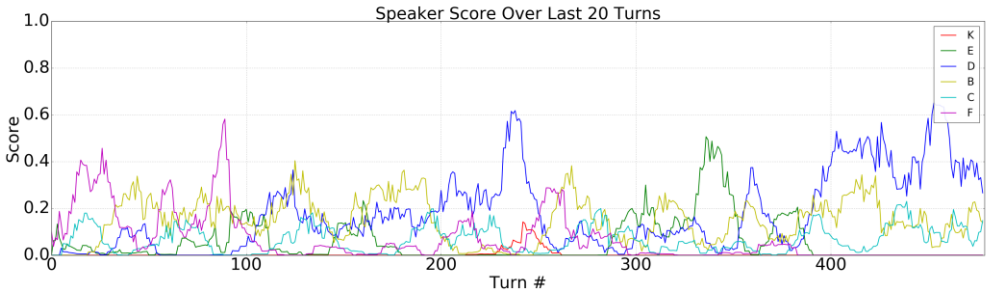

Figure 3. Day 4 Team Right Speaker Score, N = 20

3.5 Variance

As a measure of how the group conversation is distributed, we calculate the variance of the scores for each session (Equation 4). High variance indicates more one-sided conversation and low variance a more equal conversation participation. In order to make variance comparable across sessions and cases with a different number of participants, the calculated variance is rescaled to range from zero to the maximum possible value variance can be for the given number of participants.

$$Variance(t_i) = \frac{\sum_{p_j}^{p} (Score(t_i, p_j) - \overline{Score(t_i)})^2}{\#participants \times max\ possible\ variance(\#participants)} \quad (4)$$

Figure 4 depicts changes in variance during the design conversation. The conversation is dominated by long periods of low variance, i.e. participants are contributing equally to the conversation. Around speaker turn 90 and 230 there are spikes of higher variance, indicating more one-sided conversation at these points.

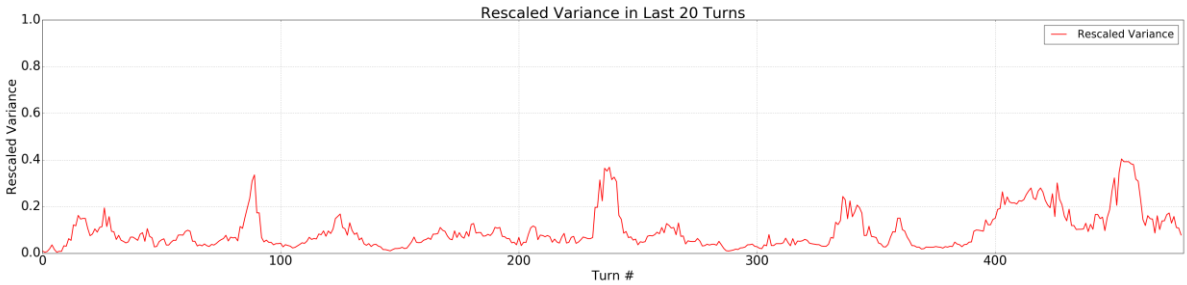

Figure 4. Day 4 Team Right Variance, N = 20

3.6 Temporal Static Visualisation application

When applying the Temporal Static Visualisations, one needs to consider the size of the sliding time window, N, where N is the number of speaker turns. Selecting an appropriate size of N is dependent on the number of participants in the design conversation, and research question. Different values of N will give distinctly different output in the Temporal Static Visualisations. It is therefore helpful for the researcher to consider several values of N. In the case of explorative studies, different sizes of N allow for new perspectives, potentially providing new insights from the data. Selecting N is also influenced by the scope of the study. For shorter turn-by-turn mechanisms, the dynamics of the conversation will be more visible with small N. A large value for N will provide an overview of the dynamics in longer time periods. One might be suitable to investigate group dynamics, while the other could provide insight into the process dynamics of the team.

When aligning results from Temporal Static Visualisations to other sources of data, e.g. Protocol or Conversation analysis, we strongly recommend conducting a sensitivity analysis by varying N. This should provide insights towards the robustness of results obtained from the analysis.

4 CASE STUDY

The data for this case study consists of video recordings from two different design teams, Team Right and Team Left. The recordings took place at the HPI School of Design Thinking in Potsdam during a six-day design thinking project. The design brief for both teams was: "Design a way to enable homeless people to live a better life". This case study is based on data from the second day of the project. The overall task of day two was "observation and synthesis". The members of Team Left & Right are students with diverse academic backgrounds, experience in design, and knowledge about the design challenge. Both teams work closely together with coaches who have several years' experience in design education.

Participants were asked to indicate the "most relevant 30 minutes of each day in terms of concept generation" through a post-experiment survey. Based on this, key episodes for the respective teams was selected and transcribed.

Members of each group is denoted with an uppercase letter in figure legends, while external participants in the sessions are denoted with a lowercase *e* followed by a number, e.g. e1, e2, e3 etc. Lowercase *n* is used for speaker turns were transcribers could not identify the speaker.

4.1 Day 2, Team Left: Storytelling

In this episode, a team of four students and a coach are working together on the design challenge to improve the lives of homeless people. The subtask of this specific episode can be titled as storytelling. Their purpose is to exchange their different insights from field research. The coach is supporting the sharing process. The general interaction pattern of this task is as follows: One team member reports her or his findings to the group. Since the field research was performed in subgroups of two, the report of one team member gets supplemented by comments of the second member. The group makes notes on sticky notes and collects them on a whiteboard. Questions from the addressed subgroup are directly asked. At one point the coach intervenes and advises to focus more on interesting parts rather than sharing everything. Sometimes, team members conclude and rephrase interesting findings. At the end the coach suggests to take a break, which they do. This episode is considered to show divergent behaviour.

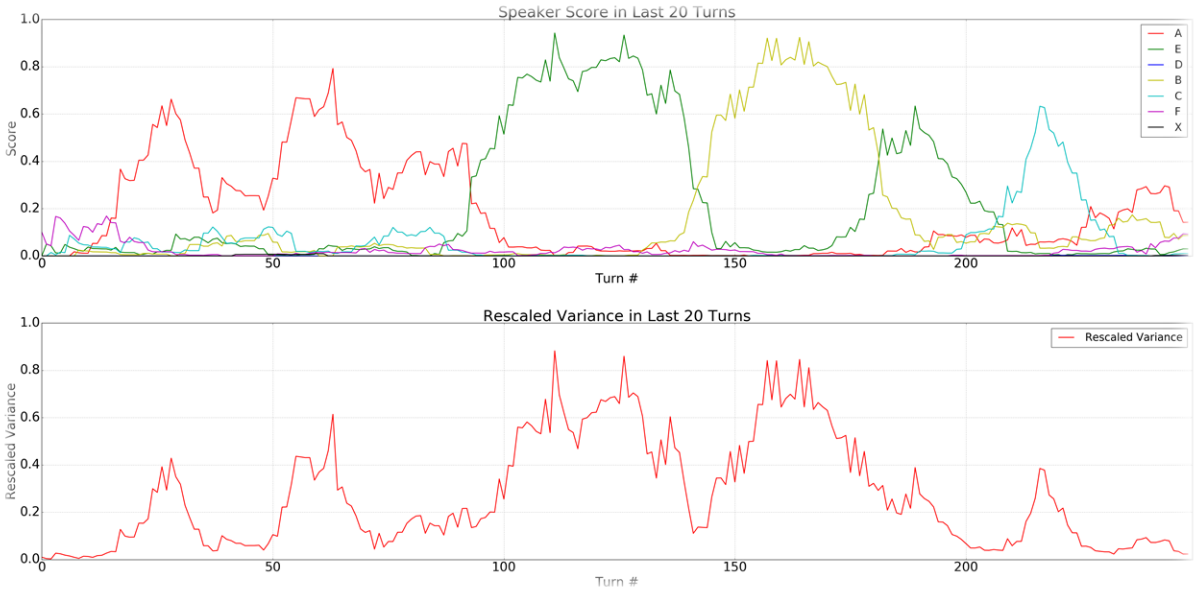

Figure 5. Speaker Score and Variance - Team Left - Day 2 - Storytelling

In Figure 5 (for larger figure see appendix) we can see individual speakers taking active roles in the conversation in turn. This is in line with the activity of reporting insights from the field to the rest of the design team.

4.2 Day 2, Team Right: Synthesis

The episode selected by Team Right takes place later in day 2 compared to the episode from Team Left. Team Right has finished the storytelling task and is now interpreting the collected data from field research. In general, the team has one conversation, but sometimes the conversation is split up into two sub-groups. All team members are standing in front of the whiteboard on which the sticky notes from field research were previously collected. They discuss which of the reported insights were the most surprising and meaningful to them, they infer meaning and reflect about these situations. Sometimes external people enter the team space and interact with one or more team member. This form of clustering and abstraction considered as a convergent task.

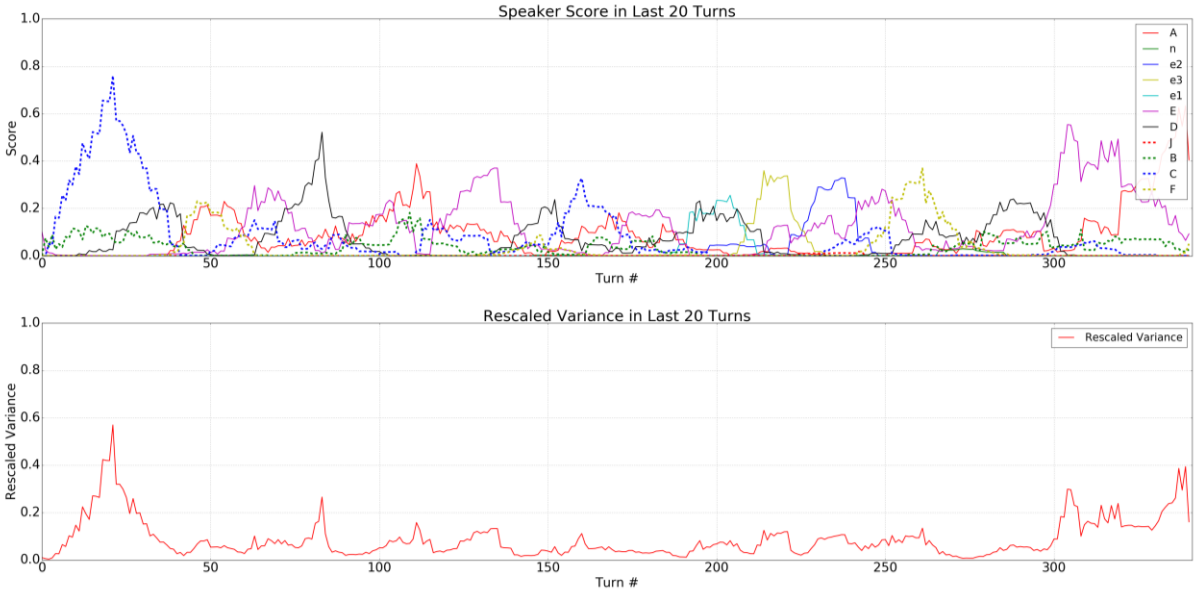

Figure 6. Speaker Score and Variance - Team Right - Day 2 - Synthesis

In Figure 6 (for larger figure see appendix) we can observe rapid exchanges in the conversation. No one person is dominating the conversation, maybe except of in the beginning where participant C has a

slightly more active role. This equal participation in conversation is in line with a group discussing insights and creating a shared understanding of their observations.

4.3 Summary of case study

Looking at the two sessions, we see distinctly different conversation dynamics based on in-case grounded variance thresholds of 0.1 and 0.3. Like the N beforehand, these thresholds are thoroughly case and research question dependent and should be selected and tuned by the applying researcher.

Table 2. Variance for N=20

Variance (N=20)	Team Left – Day 2		Team Right – Day 2	
	Speaker Turns	%	Speaker Turns	%
Low Variance (below 0.1)	78	31.3 %	246	72.1 %
Medium Variance (between 0.1 and 0.3)	77	30.9 %	87	25.5 %
High Variance (above 0.3)	94	37.8 %	8	2.4 %
TOTAL	249	100 %	341	100%

In Team Left, 37.8 % of speaker turns are classified as high variance, and 31.3 % as low variance. We find this in the speaker score plots (Figure 5) as a sequence of single participants dominating the conversation in turns. In contrast, for Team Right only 2.4 % of the speaker turns are high variance, and 72.1% low variance. The conversation of team Right can be seen in Figure 6 as frequent exchanges throughout the whole session by multiple participants, with only shorter segments where one participant sticks out.

5 CONCLUSION AND FURTHER WORK

In this paper, we apply a computational approach to expose conversation dynamics in design conversations. The Temporal Static Visualisations is a window into the conversation dynamics of a design team. We suggest that TSV information can be used to further investigate the patterns of conversation dynamics, and their characteristics. Second, the approach can be used for selection of meaningful segments of transcript data in a resource efficient manner. These segments can then be further studied using qualitative research methods. Third, the calculated metrics can be aligned with PA and CA codes. Appropriate research questions might be how conversation dynamics relate to e.g. the use of creative analogies, vagueness and reported speech.

By applying TSV to a case study comprising of two sessions, with approx. 300 speakers turns respectively, the variance in speaker score (based on speaker turns and word count) allows us to uncover the conversation dynamics throughout the session and creates the foundation for more in-depth analysis of design team interaction. We are able to see, that the story-telling activity yields a high variance, while the synthesis phase consists of a majority of low variance segments. Based on these results we can hypothesize that a relation between speaker variance and task structure exists. We may assume that each design method and has its own speaker variance pattern. We recommend to apply Temporal Static Visualisations to further cases in order to validate this hypothesis and align TSV patterns to different design methods and task structures. By doing so, design conversations could be retrospectively segmented into phases and activities through the use of TSV. This should reduce time and effort currently spent by researchers on pre-selection of material for in-depth analysis.

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APPENDIX – SPEAKER SCORE DAY 2 TEAM LEFT & RIGHT

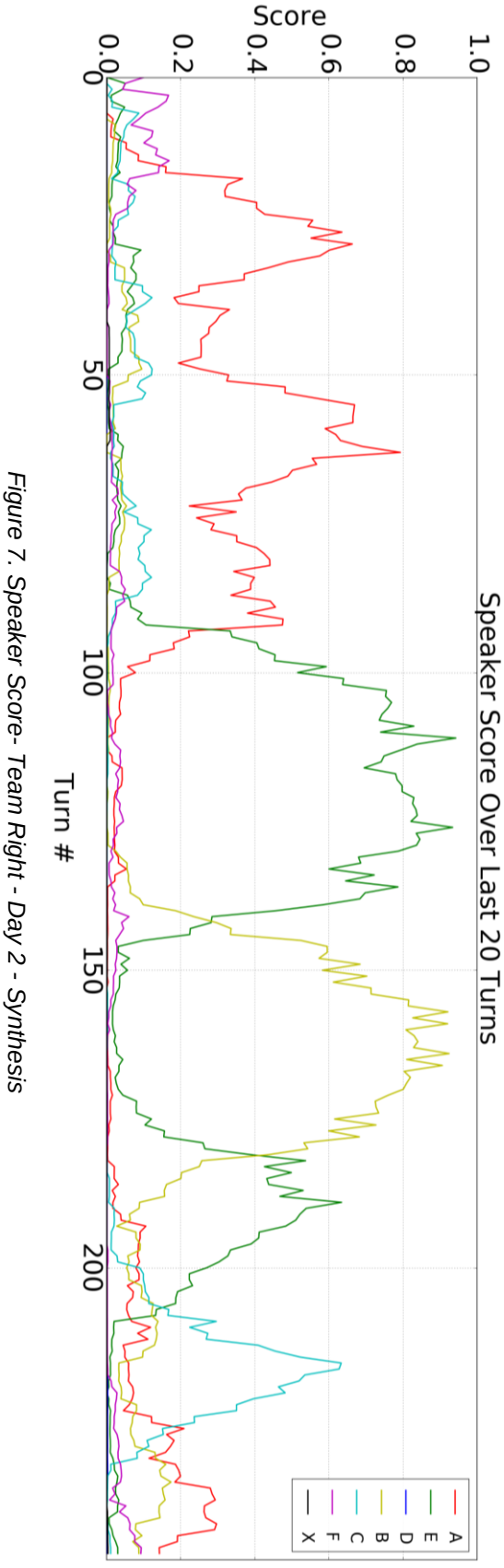

Figure 7. Speaker Score- Team Right - Day 2 - Synthesis

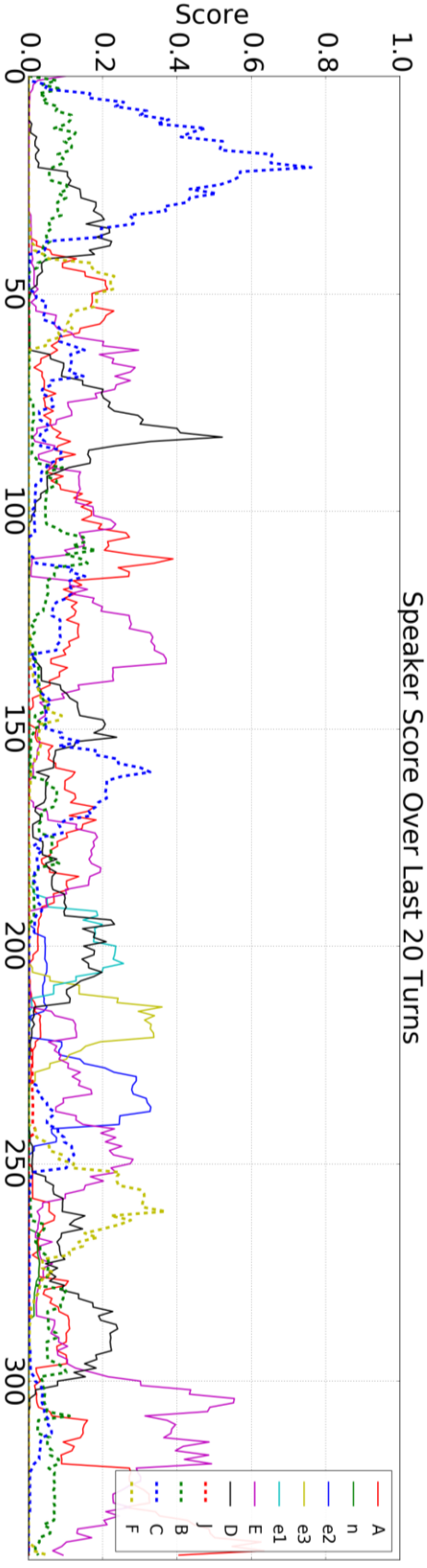

Figure 8. Speaker Score- Team Left - Day 2 - Storytelling