Tracing changes over the course of the conversation: A case study on filled pauses rates

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Abstract

In this paper, we suggest methods to trace the flow of the use of filled pauses over the course of the conversation. Beyond using a normalized time with respect to each session's duration, we calculated the accumulative number of filled pauses and the accumulative number of words per speaker, whenever the speaker has expressed a filled pause or a new word. We then computed the ratio between these values at each such point in time, resulting in relative filled pauses use. The output produces a visualization of the global contour slopes that represents each speaker and the dynamics between the two speakers, in terms of the relative filled pauses use. The dialogues are taken from MaTaCOp, the Hebrew map-task corpus, in which each speaker participated twice, once as a leader and once as a follower. Findings suggest that there are significant differences between two different speakers in the same session. We did not find a difference in the use of filled pauses between the same speaker in different roles. Moreover, the use of filled pauses shows convergence. These findings strengthen previous studies on the influence of sociolinguistic variables on the use of Filled Pauses.

Index Terms: communicative dynamics, dialogues, filled pauses, dynamic measures

1. Introduction

In recent years, spoken interaction studies are striving to find how a conversation should be modeled in order to get closer towards a complete account of the structure of dialogues and multiparty casual conversation [1], [2], [3], and [4]. Partly, this line of research is motivated by its implications for the design of spoken dialog systems and human-device interaction. However, no one disputes that speech scientists concern is mainly towards a greater understanding of the fundamental human behavior – speech communication. Following [5], [6], [7], and [8], this study focuses on filled pauses (FPs) rates in spontaneous task-oriented conversations by highlighting the changes over time and the effects of the speakers' role. Focusing on filled pauses is treated here as a reflection of speaking rate, on the one hand and as the distribution of one of the most common discourse markers [9], [10], and [11], on the other hand. Previous studies that dealt with FPs rates in conversation, showed that reductions in use of filled pauses are often associated with greater perceived confidence on the part of a talker [12], [10]. Moreover, [13] found that the main speaker in multi-party spontaneous conversations used more filled pauses than the other speakers, possibly to indicate intention to continue. Studying FPs rates in a Map Task setting, [14] found that instruction givers were more disfluent per word than instruction followers. However, the type of moves (either Instruct or Response) is a predictor of the use of FPs. According to [19], Response moves had high filled pause and repetition rates which may suggest that speakers used these disfluency types to buy time.

By focusing on changes over the course of the conversation, we draw inspiration from accommodation studies (also known as the entrainment phenomenon [15], [16], [17], and [18]). Therefore, our questions are somewhat similar to entrainment studies: At what point do the speakers adapt? Does entrainment occur at the beginning of the conversation, or is it an ongoing process of coordination? Do speakers become more similar in absolute or relative terms? Does the coordination improve over the course of the dialogue? How localized is the phenomenon?

Moreover, as previous studies discriminated between several types of entrainment (such as global versus local), our main concern in this study is tracing a feature over the entire conversation, and not turn-by-turn (also called local-entrainment (inter alia, [15], [19]). Our proposed measures do follow [19] in the sense that we wish "to represent conversations as a whole and the dynamics through them." [p. 79].

Our main goal is to represent speakers' filled pauses rate along the dialogue in a comparable manner. To illustrate our proposal, we show a naive representation of the frequencies of FPs over the course of a single conversation in our corpus (Figure 1). The y-axis represents FPs occurrences, (from 0 to three) in a single utterance and the x-axis represents the conversation time (0-940 seconds). This representation shows a dominance in the use of FPs of one speaker (annotated as the Leader. In black circles) compared to the other (the Follower. In red squares), during almost the whole conversation. Although, putting the FP annotation in such a way might be good for illustration of a single dialogue, it does not provide measures to analyze interactions between the speakers nor to compare between interactions.

Our goal is therefore to suggest measurements that will allow the following information:

1. Relative use of FP: Measuring the temporal ratio between the FPs and the tokens. The higher the change over time, the steeper the curve;
2. Directionality: Measuring the direction (slope) of the uses over time – either decrease (negative sign) or increase (positive sign);
3. Interaction: Measuring the temporal gap between the two speakers. The closer the gap to 0, the more similar the use of FPs by the speakers.

The measurements will be detailed in the method section.
The transcripts were manually aligned to the speech signal at the Inter-Pausal Unit (IPU) level of each turn. Every speech interval (i.e., IPU) in our dataset was assigned to a speaker and could only contain silences shorter than 100 milliseconds. However, it does not necessarily correspond to uninterrupted speech, as it may overlap in time with a speech interval of the other speaker.

A speech interval is characterized by five features:
1. **session** (dialogue id),
2. **role** (speaker’s role in the dialogue – leader or follower),
3. **tmin** (starting time, normalized by dividing the starting time by the session’s duration),
4. **tmax** (normalized ending time),
5. **text** (transcribed words that the speaker uttered).

Speech intervals were listed in ascending order of **tmax** values. In this study, this timing is sometimes the timing of the speech interval the FP(s) was produced in. Among the 2,017 IPUs with FPs, only 352 (17.5%) are IPUs that consist of a single FP, while the other FPs are within multi-word IPUs.

Each interval was augmented with the following data:
6. **total_tokens**: The number of tokens in text, including both words and pause fillers.
7. **FPs**: The number of filled pauses in text.
8. **words**: The number of words (excluding FPs) in text.
9. **accum_token**: The accumulative number of tokens uttered by each speaker in the dialogue up to and including this interval (accum_token_{leader}, accum_token_{follower}).
10. **accum_FP**: The accumulative number of FPs uttered by each speaker in the dialogue up to and including this interval (accum_FP_{leader}, accum_FP_{follower}).
11. **accum_FP/accum_token**: The relative FP use, that is, the ratio of the accumulative number of FPs to the accumulative number of tokens for each speaker (accum_FP/accum_token_{leader}, accumFP/accum_token_{follower}).

In the second stage of the processing, we merged the speech intervals of the two sessions (A and B) of each pair of speakers. The merged dataset thus contains the intervals of both sessions, intertwined in ascending order of **tmax**. The merged dataset was augmented with four additional vectors corresponding to the four possible combinations of role (leader or follower) and session (A or B). These vectors contain the relative FP use at each point **tmax**, separated by session. The size of the four vectors (of the two speakers in each session) was thus constructed to be the same. The vector’s size reflects the number of points in time were at least one of the speakers in one of the sessions A or B expressed either a filled pause or a word. The value in such a point is the current new value for the speaker who spoke in that session, and remained equal to the previous value for the other speaker and session. In this way, the last value of each of the four vectors reflects the total number of relative filled pauses use in a respective session (A or B) for a respective speaker (1 or 2). These four vectors are used in

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1 Recordings and aligned transcriptions are available according to the term of use:
subsequent calculations as vectors characterizing the four combinations of role and session.

Vector1: accum_FN/accum_token (leader)_A
Vector2: accum_FN/accum_token (follower)_A
Vector3: accum_FN/accum_token (leader)_B
Vector4: accum_FN/accum_token (follower)_B

Figure 2 presents an example of the relative FP use vectors of a single pair of speakers in two consecutive sessions (A and B).

![Figure 2](image.png)

**Figure 2**: *An example of the convergence between the relative FP use curves of a single pair of speakers in two consecutive sessions (A top) and B (bottom).*

2.2. Comparisons

In each dialogue pair, we conducted four comparisons among these vectors relating to two facets ("session" and "person"):

1. Session facet:
   - Session A: Compares vector1 to vector3 (the leader versus the follower in session A).
   - Session B: Compares vector3 to vector1 (the leader versus the follower in session B).
2. Person facet:
   - Person1: Compares vector1 to vector4 (the leader in session A to the follower in B (same person in a different role)).
   - Person2: Compares vector2 to vector3 (the follower in session A to the leader in session B (same person in a different role)).

2.3. Features and Measures

The following features were computed for each vector:

- **Relative use of FPs**: We calculated the median value of each vector to represent the relative use of FPs. Hence we call it Median;
- **last value**: The last value of each vector represents the relative use of FPs in the whole session; and
- **vector’s slope**: The slope reflects the direction of change along the session.

The following three measures were computed for each comparison:

- **Volume of difference**: As the four vector’s length is equal, we could calculate the ED between the relevant vectors. We assume that if the ED is higher in the vector1 versus vector2 pair than in the vector3 versus vector4 pair, we may say that speakers in sessions A differ more from each other compared to speakers in sessions B, in terms of the relative FPs use along the session. This measure thus calculates all oscillations between two speakers over the course of the dialogue. Hence, *Euclidean Distance (ED)*;
- **Gap of Relative use of FPs**: We calculated the absolute value of the gap between the two medians ([Median(Vector1) − Median(Vector2)]). This *gap* measures the difference between the relative uses of filled pauses of the compared vectors. We assume that the higher this number is the more different the behavior. Hence, *Gap of Medians*;
- **Directionality of the gap**: For each comparison, we computed the difference between the two vectors, and then we calculated the slope of the differences along the dialogue. Negative slopes suggest getting closer (i.e., entrainment) while positive slopes suggests drifting apart (i.e., dis-entrainment). Hence, *Slope of gap*.

As there is no theoretical connection between the three metrics and there is no reason to assume dependency between them, we use t-test (and not MANOVA).

2.4. Classification Algorithm

To predict the role in each session (session facet) and the role per speaker (speaker facet), we used Logistic regression algorithm via WEKA [22].

3. Results

The first descriptive finding is that the number of FPs correlates with the amount of speech (The correlation coefficient is 0.612). This is also how we explain the difference between the two sessions: 1,334 FPs in sessions A versus 923 FPs in sessions B. In sections 3.1-3.4, we present the t-tests results of the comparisons. In section 3.5, we present the results of classification carried out by Weka's Logistic function [22].

3.1. Medians

The medians of speakers in the same session (session facet: vector1 vs. vector2 and vector3 versus vector4) were found very significantly different by t-tests (mean values are shown in

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1 Interactive visualizations of all the speakers are available here: [https://public.tableau.com/profile/nehorayc#!/vizhome/MaTaCOp/MaTaCOp](https://public.tableau.com/profile/nehorayc#!/vizhome/MaTaCOp/MaTaCOp)
Table 1: In sessions A, p = 0.0047 and in sessions B, p = 0.0134. This is in congruence with our session-wise hypothesis. Speaker-wise, the medians of the same speaker in two different roles (person facet: vector1 versus vector2 and vector2 versus vector3) were found extremely statistically significant (mean values are shown in Table 1). This is also in congruence with our hypothesis. For speakers who started as leaders, p is less than 0.0001; for speakers who started as followers p = 0.0012.

### 3.2. The last value of the vector

For the last vector's values, the differences between speakers in sessions A were found by t-tests significantly different: p = 0.0066 and in sessions B, p = 0.0492. The same trends was found in sessions B (p = 0.0007 and p = 0.0012, respectively). This is in congruent with our session-wise hypothesis (and independently of the first role each speaker was assigned to).

<table>
<thead>
<tr>
<th>Vector</th>
<th>Median</th>
<th>Last Value</th>
<th>Average of slopes</th>
<th>STD of slopes</th>
</tr>
</thead>
<tbody>
<tr>
<td>leader A</td>
<td>0.065</td>
<td>0.082</td>
<td>0.055</td>
<td>0.030</td>
</tr>
<tr>
<td>follower A</td>
<td>0.029</td>
<td>0.026</td>
<td>0.051</td>
<td>0.033</td>
</tr>
<tr>
<td>leader B</td>
<td>0.055</td>
<td>0.001</td>
<td>0.012</td>
<td>0.008</td>
</tr>
<tr>
<td>follower B</td>
<td>0.030</td>
<td>0.029</td>
<td>0.029</td>
<td>0.022</td>
</tr>
</tbody>
</table>

### 3.3. Euclidian Distances and the gap of medians

Session-wise, in a paired t-test, the differences in ED values in the two sessions were found significantly different (t = 3.050; df = 14; p = 0.009). The mean is higher in sessions A compared to sessions B (Table 2). The same trend was found for the gap of Medians (t = 2.162; df = 14; p = 0.048). The mean values are shown in Table 2. These results suggest that the difference between speakers in FP use in sessions A is significantly larger than in sessions B.

Table 2: Average values of the three features (boldface marks values above average).

<table>
<thead>
<tr>
<th>Facets</th>
<th>ED</th>
<th>Gap of Medians</th>
<th>Slope of gap</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total average</td>
<td>0.993</td>
<td>0.027</td>
<td>-0.042</td>
</tr>
<tr>
<td>A</td>
<td>1.577</td>
<td>0.040</td>
<td>-0.068</td>
</tr>
<tr>
<td>B</td>
<td>0.910</td>
<td>0.025</td>
<td>-0.029</td>
</tr>
<tr>
<td>Leader-first (Person1)</td>
<td>1.347</td>
<td>0.035</td>
<td>-0.034</td>
</tr>
<tr>
<td>Follower-first (Person2)</td>
<td>1.036</td>
<td>0.026</td>
<td>-0.047</td>
</tr>
</tbody>
</table>

### 3.4. Slope of gap

Overall, we found significant association between the roles and the direction of the slopes (negative versus positive) ($X^2$ (1, N = 30) = 6.69, p = .009). Leaders decrease their relative FPs use along the dialogue, while followers increase their use. Moreover, all the mean slopes of gaps were found negative (Table 2), which implies a convergence between the two compared vectors: two speakers in the same session; and the same speaker in two different roles. To summarize, Table 2 shows that, on average, the highest ED and Gap of Medians are in session A and for Person1 (who started as a leader in session A). These results show that the difference between speakers in FP use in sessions A is significantly larger than in sessions B (t = -2.789; df = 14; p = 0.014). And that Person1 (leaders-first) tend to change their behavior more then Person2 (followers-first). In addition, Person2 have ED above the average. On the other hand, all slopes of gaps are very moderate (which can be attributed to the vectors' length) and all averages of the slope of gap are negative (which indicates that speakers are getting closer). On average, highest absolute slope of gap (which indicates that speakers are getting closer faster) is in sessions A and for Person2.

### 3.5. Logistic regression classification

We ran Logistic classification for the session and the person facets. We used the following variables: the relevant ED, gap of medians slope of the gaps; and an additional binary variable, that is true whenever the gap of medians is higher than the average over all the medians of the relevant facet. The results for the session facet show 20 Correctly Classified Instances (out of 30 instances) = 66.67 % and for the person facet 19 Correctly Classified Instances (out of 30 instances) = 63.33%.

### 4. Discussion

Our main concern was to represent speakers' filled pauses use along the dialogue, as a case study to a new methodology of tracing changes over the course of the conversation. Our findings are different then those reported on FPs use in American-English Map Task [17]. Our first main finding is that there are significant differences in all measures between two different speakers in the same session. Our first hypothesis was confirmed. Unlike our speaker-wise hypothesis, we did not find a difference in relative filled pauses use between the same speaker in different roles. We interpret these results as a change in FPs use due to the roles in both sessions, but to a certain extent that does not produce a change in the speakers’ own FP rate.

We also showed that FP rates are going under a convergence process in two ways: in both sessions Person1’s slope is decreasing, Person2’s slope is increasing; the gaps in sessions B are smaller than in sessions A. These findings strengthen previous studies on the influence of extra-linguistic variables on the rate of FPs ([8], [17]). Moreover, unlike separate measures for local and global entrainment in previous studies ([5], [13]), we argue that our method of analysis combines both a global and a local perspectives. The medians over the entire session for the global measures and the distance between each pair of adjacent FPs (each FP in the pair uttered by a different participant) for the local measures.

### 5. Conclusions

In this study, we demonstrated a methodology to measure the degree of use and the interaction between speakers in terms of FPs use in task-oriented dialogues. We believe this case study can be adapted to other prosodic and linguistic annotations as well. Regarding our findings, FPs are somewhat still enigmatic vocal trait. In future study, we intend to examine speakers' sex differences and to ask if the use of FPs is affected by the interlocutor's sex by comparing mixed- and same-sex pairs.

### 6. Acknowledgements

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7. References


