Predicting Collaboration based on Students' Pauses in Online CSCL Conversations

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PREDICTING COLLABORATION BASED ON STUDENTS' PAUSES IN ONLINE CSCL CONVERSATIONS

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As Computer Supported Collaborative Learning (CSCL) gains a broader usage as a viable alternative to traditional educational scenarios, the need for automated tools capable of evaluating active participation and collaboration among peers in online discussions increases. In this study, we validate a quantitative model of predicting involvement in CSCL chats based on student's pauses throughout the timeline of the conversation. Starting from a corpus of 10 chat conversations, our proposed model explains 55% of the variance in terms of student participation and 42% in terms of collaboration, although relying on simple quantitative indices.

Keywords: Computer Supported Collaborative Learning, pause analysis, fluency, speed, automatic evaluation of participation and collaboration

1. Introduction

Computer Supported Collaborative Learning (CSCL) is an emerging branch of learning sciences that encourages social knowledge building facilitated by technology. CSCL considers online conversations, in particular chats, as central constituents [1] to support students, facilitate collaboration among them, encourage the exchange of ideas and stimulate creativity. Learning processes are associated at both individual and group levels, and may vary according to the concentration and development capacity that each learner manifests. However, according to Stahl [1], the best results from a collaborative endeavor in terms of interactions is given by the use of small groups.

The *polyphonic model* of CSCL [2-5] was inspired by Bakhtin's dialogism and polyphony [6-8]. It considers the inter-animation patterns of voices in an extended sense (participants' points of view and/or discussed ideas or concepts) that span through the conversation [3-5]. Using this analogy, utterances may

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contain one or more voices that overlap, interact one with another, and generate through their intertwining the underlying discussion threads [2, 3].

Utterances are considered, in our vision, as the basic unit within our evaluation process, in alignment with Bakhtin's dialogical perspective [6]. The utterance is, in general, a sequence of text, which expresses "communicative acts" [9]. Another concept found in interdependent relationship with dialogism is the *voice* that is, as mentioned above, an idea on a subject of discussion, both pertaining to one person and to a group of people. Several voices can occur throughout a conversation in a ventriloquism phenomenon, when "a person can resume all or part of another voice and so, each utterance will contain an unlimited number of voices" [10, 11].

In conversations with several participants, the *inter-animation* phenomenon [3-5, 12] is encountered, and, together with the polyphonic model, may be used for the analysis of the CSCL conversations. Several classes of inter-animation patterns may be identified [3] such as: adjacency pairs [13] in which the first type of utterance implies the second one, repetitions that, according to Tannen [14, 15], "induce a phenomenon similar to the rhythm in music, reflecting involvement" or collaborative utterances [16] in which "participants build an utterance together, as a single person".

Starting from Bakhtin's work on dialogism [8], which can be considered a framing for CSCL [17], the central element of analysis in our approach is the utterance whose importance can be quantified from different perspectives: word count, speech acts [18], or topics coverage and relevance throughout the discourse [19]. High impact utterances emerge by taking into account the following conditions [14]: a) a high density of keywords from the conversation; b) a high subsequent impact on the evolution of the discussion; c) a high degree of referential links from further utterances.

A series of CSCL analytics systems were developed starting from Bakhtin's dialogism and inter-animation theories, implemented within the polyphonic model introduced by Trausan-Matu [3-5]. The first system in the series, Polyphony [20] is based on Natural Language Processing methods, one of the main (and meanwhile difficult) tasks being the identification of implicit connections between utterances based on cue phrases and patterns. A successor of Polyphony was PolyCAFe [21], developed within the project FP7 LTfLL (Language Technologies for Lifelong Learning - http://www.ltfll-project.org/) project. This system also considers the detection of implicit connections between utterances. In this aim, Latent Semantic Analysis (LSA) [4] was used and integrated with Social Network Analysis (SNA) [5, 22], under the unifying view of the polyphonic model. ReaderBench [23] builds on top of previous approaches and combines Social Network Analysis with cohesion into Cohesion Network Analysis [23] which can be reliably used to assess collaboration. Moreover, ReaderBench extends the dialogical model aimed at automatically evaluation of collaboration [24].

Starting from the polyphonic model, we can state that the duration between participants' utterances (pauses) in a chat conversation is also an important, supplementary dimension. By following the analogy to polyphonic music, pauses define the tempo behind the discourse, as well as the perceived rhythm of the conversation. Shorter pauses reflect an alert rhythm, with an increased number of contributions, thus potentially denoting a higher participant engagement in the ongoing conversation. Pauses also define the sequencing of events and refine the emerging voice inter-animation patterns from the polyphonic model by taking into account a new dimension of the analysis – *time*. This paper presents preliminary research results in using pauses for analyzing CSCL chats.

2. Types of Pauses and Conversation Analysis

Pauses have multiple connotations ranging from their acoustic nature to non-silent elements that are being uttered. The silent pause is a break in which any oral expression is interrupted (except for eventual breathing noises), while voiced pauses consist of quasi-lexical items that are being expressed (e.g., "er" or "em" in English) [25, 26]. Another interpretation of *silence* is highlighted by Sacks [13] as hollows / gaps, interruptions (i.e., "lapses") or pauses. The pause aspects can be presented in the form of an offset (i.e., gap; "between speaker silence"), overlay (i.e., "between speaker overlap") or "within speaker silence" (i.e., pauses when an overlap has no direct correspondence) [13, 27].

Different taxonomies have been proposed based on the nature of the conducted experiments. For example, Campione and Veronis [28] ran an experiment in which a group of people were asked to read a text consisting of five paragraphs in five different languages (French, Spanish, English, Italian, German). On the basis of their study, a threshold of 200ms was considered as being significant for a short/brief pause, 1000ms was considered the upper value for medium pauses, while long pauses exceed 1000ms.

Pause terminology is vast and is presented in various forms from the perspective of several authors, as follows: response times [27, 29], alternation silences [27, 30], switching pauses [27, 31], transition pauses [27, 32], silent or unfilled pauses [27, 33, 34]. According to Simone [35], "pauses are silent intervals of variable duration located between linguistic units that can be compared to suprasegmental elements". Thus, we can infer that shorter pauses facilitate a faster communication between participants by relying on a structure of short and frequent utterances. Pauses of longer duration may have advantages in terms of offering better, more elaborated answers, but may also lead to disruption in the cognitive flow caused by the long distance between utterances. In addition, Zellner [36, 37], considers that "pauses are more frequent and longer between words that have lower cohesion, whereas they are less frequent and shorter between words that are strongly connected".

Following the previous definitions of pauses, our scope is to reflect their importance in evaluating the learners' degree of participation (active involvement throughout the conversation), as well as their degree of collaboration among themselves within the CSCL environment – in our case, ConcertChat [39]. To this aim, our analysis relies on chat conversations containing the following attributes for each utterance: nickname, GenID (the unique identifier associated with each utterance), RefID (the identifier corresponding to the explicitly referred utterance; 0 denotes no explicit link added by the user within the GUI) and a time attribute reflecting the moment when the utterance was submitted.

Table 1 presents a dense conversation segment, with intense participation between 4 participants, small pauses (8 significant contributions in less than 3 minutes) and high collaboration indicated also by the explicit links between different speakers. In contrast, Table 2 depicts a monologue from one participant, characterized by lack of active involvement from other participants, as well as low cohesion between contributions and longer pauses in the discourse.

Table 1

Chat excerpt denoting intense participation and collaboration

ParticipantID	**GenID**	**RefID**	**Time**	**Utterance text**
1	19	0	12:10:35	Let's begin with the description of our project
2	20	19	12:11:39	well, our software company has produced many applications for mobile phones and other mobile devices. so far we have many satisfied customers and employees, but we need more
3	21	0	12:12:18	ok, so basically we need to add some ways for our employees to communicate better, in order to increase our productivity
2	22	21	12:12:30	exactly, one of the essential things we need is good collaboration between our staff members, and that includes everything from chit-chat to technical details
1	23	20	12:12:32	Ok and in order to do this we need to use the best technologies
4	24	21	12:12:33	and to improve our customer service support
1	25	24	12:13:05	You are all right
1	26	25	12:13:29	I propose to start by talking about the chat

Table 2

Chat excerpt denoting a discourse monologue

ParticipantID	GenID	RefID	Time	Utterance text
5	224	0	04:08:12	unlike chats, the information is well structured (if the admin is smart) and you can store it very well
5	225	0	04:08:27	good documentation tool
5	226	0	04:09:01	everything is stored, and if a company wants to organize an information it can
5	227	0	04:09:32	available anytime and easy access with a good search engine
5	228	0	04:09:58	ease of use
5	229	0	04:10:17	anyone can add a post on a forum

In order to quantify participation, as well as collaboration, Table 3 introduces a series of indices that are later on assessed in terms of their statistical significance and are used for automated prediction.

Table 3

Description metrics

Type of Metric	Description
Contributions	Number of utterances of each participant throughout a conversation
Words	Number of words written by a given participant
Words per contribution	Average number of tokens per uttered contribution
Pauses	Distance in time (seconds) between two subsequent utterances pertaining to the same speaker
Fluency	Average number of characters written by a participant in the timeframe corresponding to a pause between his/her two subsequent utterances
Speed	Average number of words written by the participant divided by the pause between two replies

3. Results and Validation

The validation experiment consisted of an in-depth evaluation of ten chat conversations (see Table 4) selected from a corpus containing more than 100 chats [38], previously evaluated with PolyCAFe [21] and ReaderBench [23]. Chats are particularly representative as CSCL environments due to their high density of contributions within a short timeframe and fluctuating pause lengths, without exceeding a time horizon of a couple of minutes. The discussions were representative for the whole collection in terms of different collaboration and participation patterns (high/low collaboration segments, alternation of monologues versus active involvement from multiple members). Fourth year undergraduate students from the Faculty of Automatic Control and Computers, University POLITEHNICA of Bucharest, debated about the advantages and disadvantages of CSCL technologies (i.e., forum, chat, wiki, blog, Google wave). Afterwards, the conversation included also a brainstorming session in which they had to combine the benefits of all individual technologies in order to create a tailored solution for a fictional enterprise [38].

Table 4

Descriptive statistics

Conversation	No. Utterances	No. Participants	Duration (approx. hours)
Chat 1	339	5	2
Chat 2	283	5	1.5
Chat 3	405	5	2.5
Chat 4	251	5	1.5
Chat 5	416	5	1.5
Chat 6	378	5	1.5
Chat 7	270	5	1.5
Chat 8	389	4	2
Chat 9	190	4	1
Chat 10	297	4	1.5
Average	***321.8***	***4.7***	***1.65***

The manual annotation process of the conversations was performed by a different sample of 110 4th year undergraduate and master degree students. Thus, all participants (47 in total from the 10 selected conversation) were evaluated on a Likert scale of 1 to 10 for their participation and, separately, for their collaboration to their peers throughout the conversations. All raters with an Intra-Class Correlation (ICC) score lower than .30 with other coders were disregarded, thus increasing Cronbach's alpha to .96 which denotes an excellent agreement between selected raters.

All evaluation indexes introduced in the previous section were considered as being potentially relevant in the automated assessment model applied on the selected conversations. Table 5 presents an overview of the descriptive statistics corresponding to the used evaluation indices.

Table 5

Descriptive statistics (*N* = 47)

	Min	Max	Mean	Stdev	Skewness	Kurtosis
Mean participation	5.47	9.66	7.87	1.05	-0.68	-0.01
Mean collaboration	5.76	9.12	7.76	0.78	-0.75	0.41
Contributions	23	126	68.47	26.88	0.49	-0.23
Pause (secs)	258	2,531	1,216.19	511.14	0.52	-0.10
Words	220	2,020	720.15	412.53	1.45	2.48
Fluency	3.45	5.36	4.72	0.32	-1.07	4.76
Speed	0.29	1.39	0.60	0.23	1.28	2.53

Pearson correlations were computed between the considered evaluation indices and manual scores for participation and collaboration (Table 6). Significant correlation ($p < .001$) were obtained for the following three evaluation indices: the number of contributions, pauses (secs) and number of words.

Table 6

Pearson correlation of the evaluation indices with manual participation/collaboration scores

Correlations	Mean participation	Mean collaboration
No. Contributions	.859** ($p < .001$)	.774** ($p < .001$)
Pause (sec)	.739** ($p < .001$)	.650** ($p < .001$)
No. Words	.617** ($p < .001$)	.563** ($p < .001$)
Fluency	.145 ($p = 0.332$)	.064 ($p = .667$)
Speed	.057 ($p = 0.704$)	.066 ($p = .657$)
Words per contribution	.079 ($p = 0.596$)	.079 ($p = .597$)

All variables were checked for normality and multi-collinear indices were removed (Pearson correlation $r > .7$; see Table 7). Due to the fact that the number of contributions is not a predictor of interest for the current analysis, we opted to disregard it from subsequent linear regressions in which we considered only the following indices: a) pauses, b) the number of words and c) fluency, although not significantly correlated with both participation and collaboration.

Table 7

The cross-correlation matrix between the considered indices ($p^{**} < .001$; $p^{*} < .05$)

Correlations	No. Contributions	Pause (secs)	No. Words	Fluency	Speed	Words/ contribution
No. Contributions	1	.736**	.656**	0.148	0.168	0.01
Pause (sec)	.736**	1	.695**	.330*	-0.094	.329*
No. Words	.656**	.695**	1	.479**	.603**	.741**
Fluency	0.148	.330*	.479**	1	.341*	.562**
Speed	0.168	-0.094	.603**	.341*	1	.608**
Words/ contribution	0.01	.329*	.741**	.562**	.608**	1

From the point of view of members' active participation, the conducted stepwise regression yielded a significant model, $F(1, 45) = 54.092$, $p < .001$, $r = .739$, $R^2 = .546$. Pauses represented the significant predictor for the model, accounting for 55% of the variance in the manual annotations of participation [$\beta = .739$, $t(1, 45) = 7.355$, $p < .001$]. From the collaboration point of view, the stepwise regression generated a significant model, but with a lower effect than for participation $F(1, 45) = 32.875$, $p < .001$, $r = .650$, $R^2 = .422$. Similar to the previous analysis, pauses represented the significant predictor of the model, accounting 42% of the variance in the manual annotations of collaboration [$\beta = .650$, $t(1, 45) = 5.734$, $p < .001$].

4. Conclusions and Future Work

This paper presents the first steps of a research towards analyzing pauses, which constitute a new dimension of CSCL chat analysis in the aim of providing useful data to tutors and students alike about collaboration and other related features, such as inter-animation and polyphony. Pause analysis opens new perspectives in terms of providing just-in-time feedback – for example, if longer pauses are encountered, automated triggers can be used to encourage participation and stimulate creativity in on-going conversations.

Pauses show a high correlation with the number of contributions and both indices are correlated with participation and collaboration scores. This result was expected due to the intrinsic correlation between a high density of contributions and potentially shorter pauses within the considered timeframe. Therefore, a limitation of our preliminary study emerges, namely that the simple quantitative metrics presented in this study do not provide in-depth details about the collaboration processes that arise in particular moments within chat conversations. Nevertheless, pauses are indicative of a higher engagement which, in return, can lead to higher collaboration if an equitable involvement of multiple chat participants is observed.

The first results of our analysis are encouraging, showing that pauses, coupled with other quantitative indices, can be used to reliably predict participation and collaboration in CSCL conversation. Follow-up analyses that consider semantic relationships between utterances [23], as well as textual complexity indices applied on learner’s contributions [40], will provide a more comprehensive and integrative perspective of underlying collaborative processes.

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