

Real-Time Feedback on Nonverbal Behaviour to Enhance Social Dynamics in Small Group Meetings

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Abstract. We present a service providing real-time feedback to participants of small group meetings on the social dynamics of the meeting. The service visualizes non-verbal properties of people's behaviour that are relevant to the social dynamics: speaking time and gaze behaviour. The service was evaluated in two studies, in order to test whether the feedback influences the participants' visual attention and speaking time and enhances the satisfaction with the group interaction process. In a qualitative evaluation it was found that groups in general perceive the social feedback during the meeting as a useful and positive experience, which makes them aware of their group dynamics. In a second study, aiming at a more quantitative analysis, we obtained preliminary evidence that the feedback service affected participants' behaviour and resulted in more balanced participation and gaze behaviour. We conclude that services providing automatic feedback about relatively low-level behavioural characteristics can enable groups to adjust the social dynamics in group meetings.

1 Introduction

Current technology supports mainly content and information exchange during meetings, whereas social aspects have been addressed only recently. The use of technology to support group meetings has appeared as early as 1971 [8]. Tools like electronic whiteboard, projector, video and audio recorders, and electronic minutes have been used for brainstorming, idea organizing and voting, and the associated methods for working with these tools have been refined over the last two decades. The methods focused on the content and information exchange and productivity in meetings.

Technologies to support group cohesion and satisfaction of meeting members have received much less attention [9]. Cohesiveness is the descriptive term that psychologists use to refer to an important property of groups. It is captured in common usage by a wider range of terms like solidarity, cohesion, team spirit, group atmosphere, unity, 'groupness' [5]. It is known from psychological studies that cohesive groups can achieve goals more efficiently and with higher satisfaction [16].

In this paper we focus on social dynamics. In this context, we define social dynamics as the way verbal and nonverbal communicative signals of the participants in a meeting regulate the flow of the conversation [1], [14]. Analyses of conversations

in meetings have shown that there are two mechanisms governing the flow of conversation [14]. Either the current speaker selects the next speaker, by a combination of verbal and nonverbal signals, e.g., by addressing a participant explicitly and/or by gaze behaviour and additional cues. Or the next speaker selects him/herself: if the current speaker has finished, one of the other participants may take the turn (possibly after a brief transition phase where several participants try to get the floor simultaneously). The first mechanism has prevalence over the second one. From these observations it follows that the nonverbal behaviour of the participants influences the flow of the conversation. Here, we summarize the most important mechanisms.

- Plain speaking time is a first determinant of social dynamics. Since interrupting the speaker is bound to social conventions, within certain limits the current speaker determines how long s/he remains speaking. Speaking means having the opportunity to control the flow of conversation and influence the other participants. Depending on personality, speakers may try to monopolize the discussion, with the risk that not all arguments relevant to the topic of discussion come to the surface, which may ultimately lead to a “groupthink” situation, when a member of the group attempts to conform his or her opinion to what s/he believes to be the consensus of the group [6].
- Speaker eye gaze is a second determinant of the social dynamics, in two ways. The current speaker controls the flow of conversation by having the privilege of selecting the next speaker. Often, this is indicated by non-verbal means such as eye gaze [2], [7], [19]. In addition, when addressing all participants, the speaker should take care to look at all participants in due time to avoid giving the impression that s/he is neglecting particular participants. However, due to the nature of conversation, it is highly likely that the next speaker reacts to what the current speaker said. As a result, the respondent will look at the previous speaker, and interactive sequences involving two speakers may arise [11], leaving little opportunity for the other members of the group to participate in the discussion.
- Listener eye gaze is a third determinant of the social dynamics. The participant who is speaking is being looked at by the other participants, indicating that s/he is in the focus of attention [20], [17]. However, when the speaker is speaking for a long time, other participants may lose interest, which is signalled by gazing elsewhere.

Recently, researchers have taken inspiration from the observation that socially inappropriate behavior such as imposing one’s own views instead of giving the others the opportunity to contribute may result in suboptimal group performance, and they have developed systems that monitor and give feedback on social dynamics [3], [4]. Research has mostly focused on group decision-making tasks where balanced participation is essential to solving the task at hand. The systems capture observable properties like speaking time, posture and gestures of the meeting participants, analyze the interaction of people and give feedback through offering visualizations of the social data. For instance, DiMicco offered feedback about the speaking time of different participants visualized through a histogram presented on a public display. Evaluations showed that real-time feedback on speaking activity can result in more equal participation of all meeting members [4].

These findings and observations lead us to believe that audio-visual cues of human behaviour, namely eye-gaze and speaking time, directly relate to the dynamics of the meeting at the social level. In the framework of the EU-funded CHIL project, we designed a service that generates an unobtrusive feedback to participants about the social dynamics during the meeting, on the basis of captured audio-visual cues. Our goal is to make the members aware of their own and others behaviour, and in this way influence the group's social dynamics. It is assumed that such feedback may influence the participants' behaviour to create more appropriate social dynamics in a group, and therewith increase the satisfaction of the group members with the discussion process.

In the remainder of the paper, we first describe a focus group study, aiming at getting feedback on our ideas. We proceed with the design concept, which presents information on current and cumulated speaking activity in combination with the visual focus of attention of speakers and listeners. We then present the outcomes of two evaluations, one qualitative study to inform the design, and one quantitative evaluation, to assess the effects of the service on participants' behaviour in meetings. We conclude with a discussion of our findings and future prospects.

2 Focus Group

A focus group meeting was arranged to get insight into social dynamics problems that group members encounter during meetings. Our interest was whether information on the social dynamics of a meeting to be useful for them. The focus group addressed the following five main questions:

1. Do you remember any problematic situations during meetings?
2. To what extent do you feel social dynamics was the cause of the problem?
3. Do you think feedback about social dynamics can be useful? If so, at what moment, how and where?
4. Do you think this type of visualized feedback (examples as demonstrated on slides) would be useful during the meeting?
5. Do you have any ideas about other solutions for solving problems related to social dynamics in meetings?

The focus group consisted of 8 participants (two project teams of a post-graduate curriculum at the Technische Universiteit Eindhoven) and lasted about 90 minutes. Before the focus session we recorded 2 real meetings on video to obtain illustrative materials for the focus group session. The focus discussion was led by a facilitator and one participant was appointed to take notes. After each question the participants were asked to note down their answers for our later reference.

The most important outcome was that participants considered the social dynamics feedback during the meeting potentially useful, as it might improve the efficiency of the meetings. It was also considered useful for people who want to participate more in a meeting but do not manage to do so: participants indicated that it is important to make the group aware of the degree to which individual group members participate in the discussion. They all had experience with problems during the meetings related to the social dynamics, such as: two people discussing for a long time in a subgroup; one person talking for a long time and behaving like a chair of the meeting without being

appointed as such, etc. The fact that one person speaks for a long time, neglecting the others, can cause a bad mood and annoyance.

Participants agreed that feedback, such as a notification to the speaker that the audience is bored, should be provided during the meeting rather than afterwards. Furthermore, feedback should be objective, positive, general, and public. In addition to public feedback, private feedback providing more details might be useful as well.

3 Design

We applied an iterative design process: we worked out a first concept, set up a series of group meetings in which the initial concept was applied and then adjusted the concept on the basis of the remarks by the meeting participants and ran a further evaluation.

Design concept. Concept development was guided by the literature, the results from the focus group, the group meetings, a CHIL deliverable on user requirements for the various CHIL services [13], unpublished ethnographical studies of meetings conducted at TUE and general usability considerations. The concept emerged from discussions within the design team and with an expert in information visualization and interaction design. The resulting concept consisted of a visualization of the ongoing social dynamics on a shared display, showing the following aspects of social dynamics:

- Cumulative speaking time of each participant.
- Duration of the current turn.
- Cumulative and current visual attention for speakers.
- Cumulative and current visual attention for listeners.

The visualization is projected in the centre of a table, as shown in Figure 1 for a four meeting participants setting.

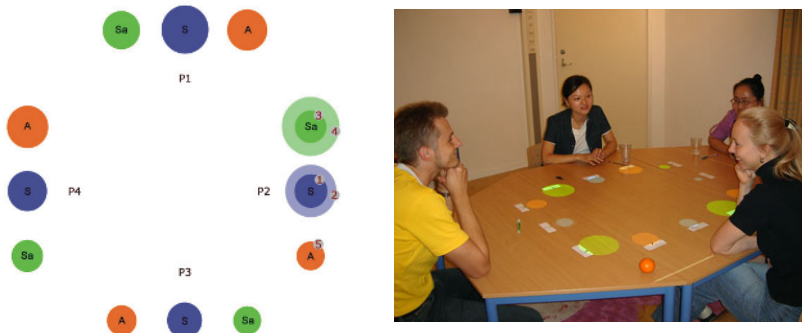


Fig. 1. Left: Visualization of current and cumulative speaking activity and visual attention for each participant P#, with P2 as the current speaker. Right: Snapshot from experimental session. Further explanation in text.

The four “wind directions” (corresponding to four sides of the meeting table) represent participants P1, P2, P3 and P4, respectively. The visualization contains the following components: (1) The right-hand circle (coded **Sa**) represents how much attention a participant received while speaking from the other participants since the beginning of the meeting. (2) For the current speaker, this circle is surrounded by an outer, lighter-coloured ring representing how much visual attention s/he receives from the other participants. (3) The middle circle (coded **S**) represents the participant’s cumulative speaking time since the beginning of the meeting. (4) Again, for the current speaker, this circle is surrounded by an outer, lighter-coloured ring, the size of which represents the duration of the ongoing turn. (5) The left-most circle (coded **A**) indicates how much visual attention the participant – as a listener - has received from the other participants while they were speaking (added up across all other participants). The different circles are distinguished by different colours (the codes are not included in the visualization). The information is updated dynamically in real-time. Visual attention is derived from eye gaze. In order to facilitate users’ memory of the meaning of the different circles, we designed icons serving as mnemonics which are displayed underneath the circles (see Figure 2).

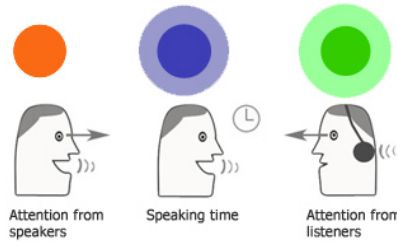


Fig. 2. Icons explaining the meaning of each circle

The visualization is generated on the basis of combined audio (speech) and visual (focus of attention) cues, captured in real-time during the meeting. In order to implement the concept, different technologies might be applied (some of which are being developed in the CHIL project). In order to determine speaking time for individual participants, it suffices to equip individual participants with close-talking microphones and to detect onset and offset of voice activity from the separate microphone signals. In order to determine visual focus of attention, eye gaze might be determined from a panoramic camera in combination with a context model. Or, depending on the spatial arrangement of participants, eye gaze might be inferred from head orientation, determined from a panoramic camera, as in [17], or from special devices mounted to the heads of the participants that can be tracked with an Infrared camera.

4 Qualitative Evaluation

In order to get a first impression of whether the concepts under development make sense and to identify problems, we conducted a formative evaluation. Several groups

consisting of 4 people engaged in discussion sessions during which feedback was provided on the social dynamics by means of the visualization concept. We invited both pre-existing teams and ad-hoc groups. Pre-existing teams may be expected to behave differently from ad-hoc teams as they have already an established social structure. The discussion was followed by a semi-structured interview with a focus on identifying usability problems and soliciting suggestions for improvement, alternative solutions, and preferences for design options.

Since the purpose of the current experiments was to evaluate the visualization concept, rather than implementing the technologies we applied a Wizard of Oz approach. A simple web interface was developed to enable 4 wizards to simulate the perceptual components of visual attention tracking and speech activity detection for meetings of four participants, where each wizard monitored the speaking activity and the eye gaze of one participant. The four wizards monitored the meeting through one-sided mirrors and/or tv-screens. During the meeting, wizards indicated the state of the eye-gaze and speaking activity whenever there was a change in the behaviour of the participant. All the wizards' codings were recorded by the central server. Obviously, such a set-up requires that we calculate the inter-wizard reliability and the reliability of the wizard codings vis-a-vis the actual events. These checks are still in progress and will be reported in later publications.

The results of the experiment were encouraging: groups in general perceived the social feedback during their meeting as a useful and positive experience which made them aware of their group dynamics. Importantly, most of the group members expressed their satisfaction with the visualisation feedback and indicated that the changes in the feedback were noticeable, even though the feedback was provided in the periphery of the visual field. A few participants indicated that they were distracted at the beginning and this was mainly because they wanted to see explicitly how the patterns of verbal and non-verbal communication were reflected in the display. Some of the participants said that the visualised feedback influenced their behaviour and as a result the participants were enthusiastic and motivated to establish balanced participation in the meeting. Ultimately, they tried to provide others with the opportunity to speak.

5 Quantitative Evaluation

Hypotheses and setup. Small adjustments were made to the visualization on the basis of the formative evaluation, mainly concerning the increment reflecting changes over time for the different visualization components. Next, a comparative evaluation was conducted to assess the influence of the feedback on the social dynamics during the meeting both qualitatively and quantitatively, comparing meetings without and with feedback. With the second evaluation we aimed to validate the following hypothesis:

1. Speaking time will be balanced more equally in sessions with feedback than in sessions without feedback. Concretely, participants who under-participate in NoFeedback conditions will participate more in Feedback conditions and participants who over-participate in NoFeedback conditions will participate less in Feedback conditions.

2. Attention from the speaker will be divided more equally between listeners in Feedback conditions than in NoFeedback conditions. Concretely, listeners who receive less attention from the speaker in NoFeedback conditions will receive more attention in Feedback conditions and listeners who receive more attention from the speaker in NoFeedback conditions will receive less attention in Feedback conditions
3. Shared attention (attention from listeners for the speaker) will be higher in Feedback conditions.
4. Participants' satisfaction about group communication and performance will be higher in the presence of feedback visualization.

In order to evaluate hypothesis 4, subjective judgments about participant's satisfaction with the visualization feedback were collected by means of a questionnaire. Group satisfaction was assessed by a satisfaction questionnaire combining questionnaires about group process and decision making [10], [12]. An additional set of questions was included to address participants' subjective judgements about usefulness and usability of the service (including aspects such as participation, distraction, awareness and privacy).

The experiment applied a within-subjects (or rather "within-group") design. Every group participated in two discussion sessions in which the members discussed the best solution for a particular topic. In one condition feedback was provided, in the other no feedback was provided. At the beginning participants were told that participation was voluntary and they were asked to sign the consent form. All groups were asked for a written permission for audio and video recording. Next they filled in a standard personality questionnaire. In each condition (with and without feedback), the groups first had a 5 minutes discussion about a topic that they could select from a list provided by the experimenter. The 5 minutes discussion served for the group members to get used to each other and to the environment, and to familiarize with the feedback. The five minutes discussion in the Nofeedback condition was included to ensure that both target conditions would be preceded by an initial discussion. To avoid order effects, order of feedback and Nofeedback conditions was balanced across groups. It was left up to the participants to reflect or not on the displayed information.

Experimental task. First we planned to use a hidden profile decision task [18], making groups discussing the selection of a student from a set of students for admission in a programme in one session and the choice of a location for a shop from a number of possible locations in the other session [4]. However, a pilot test showed that people started reading their hidden facts from the paper during the discussion in order to find the best decision. As our intention was to observe the visual attention, it was decided to redesign the hidden profile tasks. All members received the same facts, but each participant had to defend a different position, representing a particular set of beliefs and values (a profile). E.g., for the student selection task one participant would emphasize financial incentives associated with admission of particular students whereas another member would emphasize intellectual ability. The goal of each task for the group was to reach consensus about the optimal choice during a 20 minutes group discussion. Users were told in advance that no task description would be

available during the discussion. First the experimenter instructed the participants to study their profile and the alternatives independently and make a preliminary choice. They had 15 minutes to write down and memorize the important arguments. In order to simplify the memorizing task, the amount of choice parameters was reduced and the number of options to choose from was limited to three for each task. The discussion began only when every member is ready; additional time was given on request. A pilot test showed that people discussed actively and defended their beliefs and values according to the profile very enthusiastically. The main tasks were counterbalanced with feedback conditions. The total duration of an experiment was about 2 hours. As in the first test, for the visualization condition a Wizard of Oz approach was applied.

Participants. In total 44 (18 female and 26 male) participants took part in the experiment in groups of 4 persons. Members of at least two groups knew each other in advance. Participants were Dutch and foreign students and researchers of the different departments of the University (Technische Universiteit Eindhoven). The average age of participants was 29,5. All groups had members of both genders and were composed of the people of the same or close social status in order to prevent higher-status dominance [15]. In particular, students were in different group than senior researchers. One of the groups was eliminated from the data analysis due to missing speaking activity data for one participant, leaving 10 groups, comprising 40 subjects.

Measures. Measures for speaking time, attention from speaker and shared focus of attention were obtained from the log files of the Wizard codings, indicating speaking time and gazing behaviour for individual participants once a second. All parameters were expressed as percentages. For Speaking time, each participant's speaking time was expressed as the percentage of time that participant had been speaking of the overall speaking time for that session. For Attention from the speaker, the attention for each individual participant when listening was expressed as the percentage of time that the participant had been looked at by the speaker, summing over the different speakers throughout the session. Shared attention for the speaker was expressed as the number of participants that had been looking at the speaker simultaneously, converted to percentages, for each individual participant when speaking. For instance, if during a particular turn all other three members had been looking at the speaker all the time, it would amount to 100% shared attention for that turn. If two speakers had been looking all of the time and the third listener not at all, it would amount to 67% shared attention. Percentages were summed across all turns of each individual participant.

Quantitative results

Speaking time. Figure 3 shows a scatter plot containing the speaking time (%) for each individual participant in the NoFeedback and the difference score in the Feedback and NoFeedback condition. As can be seen, there is a clear negative trend, meaning that participants who speak relatively much in the NoFeedback condition show a decrease in Speaking Time (a negative difference score) and participants who

underparticipate in the NoFeedback condition speak relatively more in the Feedback condition (show a positive difference score). The Pearson correlation is $-.53$, with an associated t of -3.88 ($df = 38$), $p < .05$. The same results are obtained if we compute the correlation on deviation scores for individual participants against the group mean. However, this analysis assumes that scores of individual participants are independent, which is clearly not the case. Therefore, we also computed deviation scores for each participant from the group mean ($li_{i=1,4} - \text{group mean}$) and calculated the mean deviation per group in the no-feedback and feedback condition. In this analysis, the difference between no-feedback and feedback conditions was in the predicted direction (group mean deviation no-feedback: 9.07 , feedback: 7.74) but not significant ($t(9) = 1.26$, $p = .24$). Thus, although we find some evidence supporting hypothesis 1, stating that speaking time will be balanced more equally in sessions with feedback than in sessions without feedback, the difference between the two conditions is not significant.

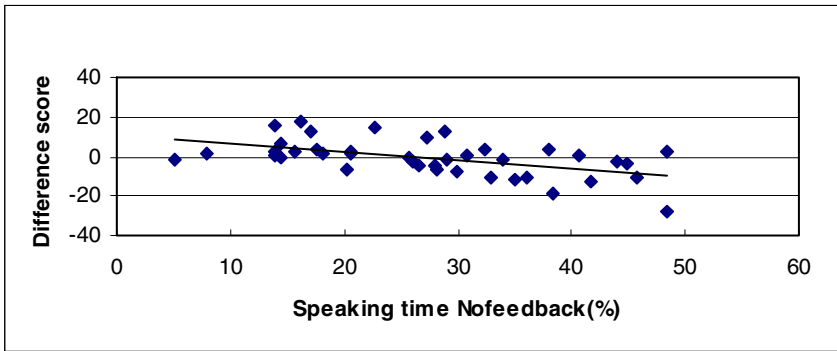


Fig. 3. Scatter plot of speaking time in NoFeedback condition and Difference score Speaking time Feedback-NoFeedback, for individual participants

Attention from speaker. Fig. 4 shows a scatter plot containing the attention from the speaker (%) for each individual participant in the NoFeedback and the difference score in the Feedback minus the NoFeedback condition. As can be seen, there is a clear negative trend, meaning that participants who get relatively little attention from the speaker in the NoFeedback condition receive more attention from the speaker in the Feedback condition, while the reverse holds for participants who receive relatively much attention from the speaker in the NoFeedback condition. The Pearson correlation is $-.36$, with an associated t of -2.36 ($df = 38$), $p < .05$. Again, computing deviations from the group mean and comparing the mean deviation per group in the no-feedback and feedback condition showed that the difference between the no-feedback and feedback condition was in the predicted direction but not significant: no-feedback: 9.45 , feedback: 8.38 ($t(9) = 0.94$, $p = .37$). Thus, although we find some evidence supporting hypothesis 2, holding that the attention from the speaker will be divided more equally between listeners in Feedback conditions than in NoFeedback conditions, the difference between conditions is not significant.

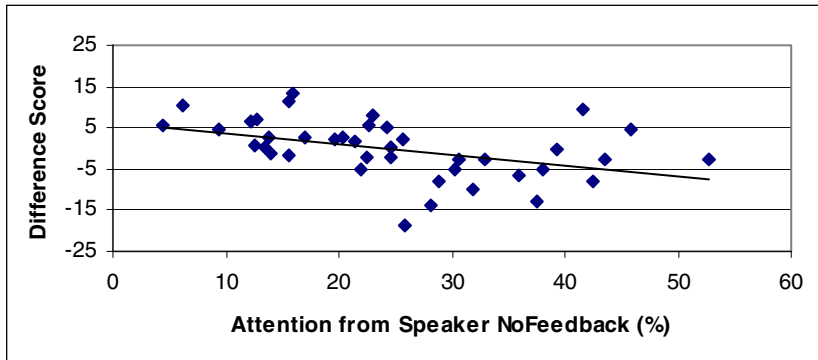


Fig. 4. Scatter plot of Attention from speaker in NoFeedback condition and Difference score Attention from Speaker Feedback-NoFeedback, for individual participants

Shared attention. For shared attention, our hypothesis stated that there would be an overall increase in shared attention from the NoFeedback condition to the Feedback condition. This was not supported by the data, neither for individual scores ($t(39)=-1.81$, $p=.08$) nor for group means ($t(9)=-1.78$, $p=.11$), although the difference between the NoFeedback and Feedback conditions was in the predicted direction: 68.17% shared attention for NoFeedback and 70.64 %shared attention for Feedback. So, hypothesis 3 is not confirmed.

Questionnaire results. The results of the group process satisfaction show that the feedback had a positive influence on the group process satisfaction. All questionnaires used 7-point Likert-scales. Analysis of questions on satisfaction with the group process showed a significant difference between answers for Feedback and NoFeedback in favour of Feedback in 7 out of 15 questions.

Table 1. Paired T-test for the Difference D between Feedback and NoFeedback condition

Feedback-NoFeedback	Mean D	SD	t	Sig.
Group participation worked very well	0.53	1.57	2.12	.04
There was no disruptive conflict	0.63	1.74	2.28	.03
Comments reflected respect for one another	0.40	1.24	2.05	.05
Participants reached agreement	0.78	2.07	2.37	.02
People were friendly	0.48	1.06	2.83	.01
General quality of participants' contributions was very good	0.43	1.22	2.21	.03

Table 1 shows the results for the statements where the largest scores were observed. Analysis of the satisfaction with the decision making process showed no significant result. Results for questions about satisfaction with the service were quite positive and all above the middle value. Results for additional questions demonstrated that it was not embarrassing for the users to have the feedback in front of the group (mean=4.97), and they didn't find the information distracting (mean=4.25). Interestingly, even

though participants often looked at the information, they also could easily forget about it. In our vision this is the advantage of peripheral information.

6 Conclusion and Discussion

We have presented a visualization service that generates feedback on speech activity and visual attention for participants in small group meetings. Evaluations provided preliminary evidence that the feedback service affected the amount of time participants spoke during the meeting; also, we obtained preliminary evidence that feedback influenced the way speakers distributed their visual attention across listeners during the meeting. Finally, we found that the feedback had a positive influence on the group process satisfaction. No effect was found for Shared attention. Possibly, the presence of the visualization itself may have drawn visual attention of the participants away from the speakers, interfering with our predicted effects. Further analyses are needed to get a better understanding of the data.

Several explanations may be conceived to explain the preliminary effects that we observed. At a basic level, the visualization may create a global awareness for social dynamics, as a result of which participants adjust their speaking behaviour and gazing behaviour. Alternatively, or in addition, the concrete moment to moment feedback may make participants aware that their current turn is getting rather long and that they are systematically neglecting particular listeners. Again, further analyses are needed to shed light on possible explanations.

Finally, it needs to be pointed out that our current experiments and results concern situations where equal participation is valuable, since participants need to reach agreement and each participant's viewpoint should receive due attention. Obviously, equal participation is not always useful. In a meeting where there is a chairman whose main purpose is to inform the audience, or when a team has invited an expert, one would not want the chairman or expert to pursue equal participation as an aim in itself, and a completely different rhythm of the conversation will be appropriate. However, even in those cases the speaker's eye gaze may serve to make feel people connected and committed to contribute when appropriate. Thus, even though the precise patterns will differ across different types of meetings, we believe that feedback on social dynamics will help to improve meeting behaviour.

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