Teacher-student eye contacts during whole-class instructions and small-group scaffolding:

A case study with multiple mobile gaze trackers

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Recent gaze tracking research have illustrated patterns of teachers' visual attention in the classroom. However, the reciprocity of teacher-student interaction needs to be explored using multiple mobile gaze tracking. This descriptive case study is our first step to chart the role of dyadic eye contacts in the teacher-student interaction during collaborative mathematical problem solving. Our results indicate that, during mathematical problem solving, teacher gaze at student faces and student gaze at teacher face vary between whole-class instruction and small-group scaffolding moments. As a conclusion, we suggest that forming dyadic eye contact requires optimal interactional, personal, and environmental states, and this method can offer us fruitful information on the micro-level processes of teacher-student interaction.

Keywords: classroom orchestration, multiple gaze tracking, mathematical problem solving, teacher-student interaction

Introduction

The teachers' complex task of orchestrating the classes and lessons consists of interaction on various social levels (Prieto, Sharma, Kidzinski, & Dillenbourg, 2017). In the classroom, a great deal of teacher's visual attention focuses on her students (McIntyre, Mainhard, & Klassen, 2017). The teacher's visual attention is affected by the social interaction in the classroom (Prieto, Sharma, Kidzinski & Dillenbourg, 2017).

Recent research have illustrated the patterns and characteristics of teachers' visual attention during instructing the students (cf. Haataja et al., 2018a; McIntyre, Jarodzka, & Klasse, 2017; Prieto et al., 2017). This study brings new dimensions to this discussion by using multiple gaze tracking between the teacher and the students in the context of collaborative problem solving. We claim that connecting teacher's gaze at student face and student's gaze at teacher face in authentic classroom contexts reveals us unexplored micro-level information on teacher-student interaction.

Classroom interaction as whole-class instruction and small-group scaffolding

Teacher actions of classroom orchestration vary from whole-class instructing to guiding an individual student (Prieto et al., 2017). In whole-class interaction, the teacher's visual attention distributes unevenly between the students (Dessus, Cosnefroy & Luengo, 2016). Gaze tracking research has shown that instructing the class as a whole and paying attention at students' faces increase the cognitive load of a teacher. Cognitive load decreases when the teacher focuses on single student's solutions or his own notes (Prieto et al., 2017). Cognitive load increases person's perseverance and experiences of positive emotions during the task (Maranges, Schmeichel, & Baumeister, 2017).

In this study, we investigate two forms of teacher-student interaction during collaborative problem solving: whole-class instructing and small-group scaffolding. Scaffolding refers to the teacher's actions in a student group during a problem-solving learning process (Wood, Bruner, & Gail, 1976). The content and the direction of scaffolding influence the learning and the social interaction of the group. The teachers offer scaffolding on both mathematical contents and procedures and on peer interaction (Akkus & Hand, 2011; Ding, Li, Piccolo & Kulm, 2007). Our previous analysis on the data of this study showed that the teacher's intention in scaffolding interaction directs her visual attention mostly between mathematical solutions, student faces and hands (Haataja et al., 2018a; Haataja, Garcia Moreno-Esteva, Toivanen, & Hannula, 2018b). The teacher's role in supporting beneficial collaboration and successful discourse within the class is crucial (Cross, 2009).

Eye contact in teacher-student interaction

In social interaction, eye contact conveys warmth and communion on one hand, and agency and status on the other (Mehrabian, 1972). The occurrence of eye contact is found to be dependent of various variables. Other person's friendly response to eye contact initiative increases the experienced liking of her (Frischen et al., 2007). Teacher's eye contact, together with her open body position, use of personal examples, and humor form warmth that encourages students into participation and interaction (Roberts & Friedman, 2013). Teacher's gaze towards students, while asking questions and listening to them, increases their experience of close interpersonal relationship with the teacher (McIntyre et al., 2017).

The teacher can also address her authority in the classroom with direct gaze at student face (Mehrabian, 1972). With eye contact, the teacher can communicate that the students are in the locus of her attention and instructions (Adams, Nelson, & Purring, 2013; McIntyre et al., 2017). Additionally, an eye contact can convey the teacher's emotional state to students (Zeki, 2009).

The shorter the distance between the teacher and student is, the higher is the quality and amount of visual interaction between them. Beyond five metres, the visual interaction decreases significantly, as the distance to the source of information distracts the attention (Cardellino, Araneda & García Alvarado, 2017).

Research questions

The aim of this case study was to explore the general tendencies of teacher-student eye contacts during mathematical problem solving. Thus, our research question were:

1. How do one-way face-targeted gazes and dyadic eye contacts between teachers and students distribute during collaborative problem-solving phase of a mathematics lesson?
2. Does this distribution differ between whole-class instruction and scaffolding interactions?

Methods

The participants of this study were two Finnish mathematics teachers and their 9th grade classes. Both classes included 19 students. The first teacher, called by pseudonym Joanne, was 39 years old and had 14 years of teaching experience at the time of the data collection. In Joanne's class, the target group students were four girls. The second teacher, Fred, was 30 years old with three years of teaching

experience. In his class, the target group consisted of four boys. Both teachers and their students had volunteered for participating in this research. Written consent for data collection was inquired from the school principals, all the students in the classes, and the teachers.

We collected the data in both schools in May 2017. To record the interaction in the classrooms, we used three video cameras and several microphones. The teachers' and target students' visual attention was recorded using self-made mobile gaze tracking devices consisting of eye cameras, a scene camera and goggles (for further information, see Toivanen, Lukander, & Puolamäki, 2017). The laptops, that recorded the gaze-tracking data, were located in backpacks to enable moving around the classroom for the participants. After the lessons, we conducted stimulated recall interviews with the teachers and target students. Unfortunately, one student gaze data and Joanne's interview were missing due to technical problems.

During the data collection lessons, the students worked on a geometrical problem task. The goal of the problem solving process was to find the shortest way to connect vertices of a square. For this report, we have analyzed the collaborative phases of the lessons. During these phases (16 minutes in Joanne's and 18 minutes in Fred's class), the students worked on the problem task collaboratively. They were encouraged to discuss their ideas and solutions in small groups. In both classes, the four target students worked together as a collaboration group. Both teachers walked around the classrooms scaffolding student groups one-by-one. Additionally, they gave whole class instructions to orchestrate the course of the lesson.

To analyze the gaze data, we used ELAN software. Using gaze targets and dwell times as coding units, we annotated the gaze data during the collaborative phases of lessons. Dwell time means the duration of one gaze at a certain target, (Holmqvist et al., 2011) such as a student face, and offers us information on the distribution of a person's visual attention. Further analysis was conducted on IBM SPSS and Microsoft Excel. The face-targeted gazes from the same lessons were synchronized and categorized into four categories. The categories were *1) Teacher gaze at student face, 2) Teacher-started dyadic eye contact, 3) Student-started dyadic eye contact*, and *4) Student gaze at teacher face*. We chose this analysis to explore the amount of reciprocal nonverbal interaction between teachers and students and these categories to chart the initiative roles of this interaction. We also compared the gaze data with the transcribed stationary video data from the lessons to form qualitative and quantitative descriptions. From the classroom videos, we separated the moments of teacher instructions to the whole class from moments of scaffolding with collaboration groups of two to four students. In this report, we analyze these variables of face-targeted gazes and teacher interaction descriptively.

Results

The teacher-student interaction differed between Joanne's and Fred's lessons despite the similar problem task and lesson structure. Joanne's students seemed more motivated and the atmosphere in class was warm and supportive throughout the lesson. Fred's students expressed more negative emotions, but also enthusiasm and joy of learning. The Figure 1 shows all the indiviual face-targeted gazes across the collaborative phase in Joanne and Fred's lessons.

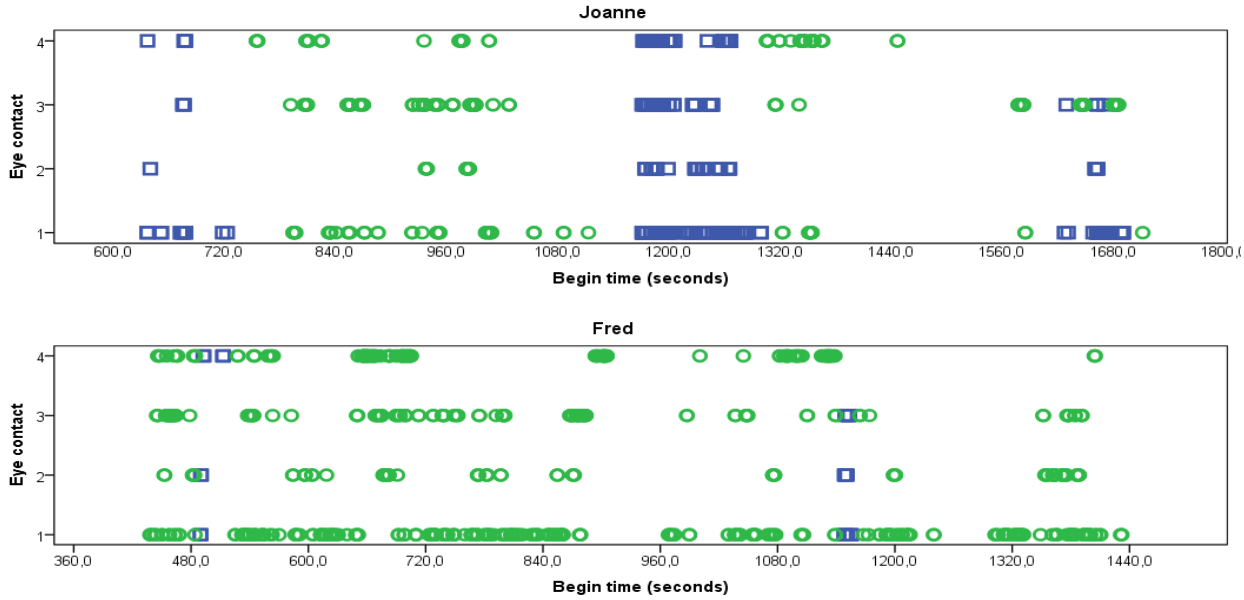

Figure 1 Face-targeted gazes during the collaborative problem solving sessions. The moments of whole-class instructions marked with blue squares and the phases of small-group scaffolding with green circles. The horizontal axis shows the beginning time of the gazes (seconds from the beginning of the lesson) with the frequency of 0.5 seconds and the vertical axis (1-4) the division into four categories: 1) teacher gaze at student face, 2) teacher-started dyadic eye contact, 3) student-started dyadic eye contact, and 4) student gaze at teacher face.

During collaborative problem solving phase, Joanne instructed the whole class more than Fred. In these moments, Joanne gave the students information and instructions on the progress of the lesson. During Joanne's problem solving phase, 63% (n = 149) of gazes occurred during whole-class instructions, while in Fred's class the proportion was only 4% (n = 13). While instructing, Joanne looked at her student's faces 88 times, even though the instruction moments covered only four minutes of the 16-minute-long collaboration phase.

During whole-class instructions, the target students looked at Joanne's face 20 times, and dyadic eye contacts between students and Joanne occurred 41 times, thrice with the target group. Fred gazed at his students' faces only five times and they looked at him twice without eye contact. Dyadic eye contacts occurred six times between a student and Fred during whole-class instructions but none of these was with a target student.

In Fred's class, the proportion of dyadic eye contacts was higher during the short moments if whole class instructions (46%, n = 6) than in Joanne's class (27%, n = 41). When giving whole-class instructions, Joanne spoke with loud voice and stood in front of the class. In these moments, the students' tendency to create or respond to dyadic eye contacts with the teacher decreased. In Fred's class, the interaction during collaborative problem solving phase happened almost completely in scaffolding interaction with student groups and he did not seek for capturing the attention of the whole class while the students were working on the task.

Figure 2 presents the distribution of four types of face-targeted gazes between the teacher and target students. Again, the gazes are categorized according to the direction between the teachers and students, and compared between interactional categories of whole-class instructions and scaffolding.

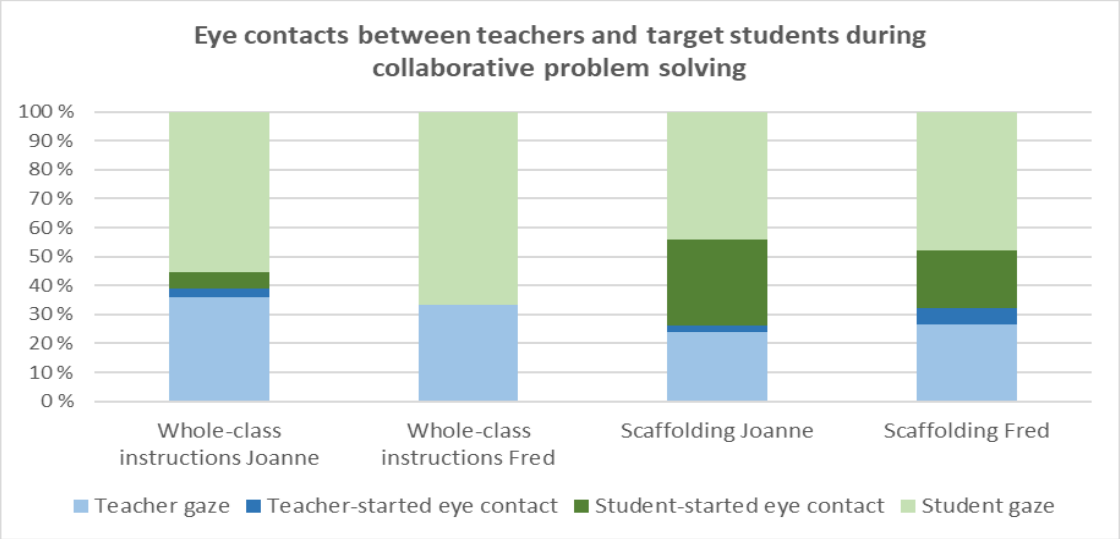

Figure 2 The distribution of teacher and student face-targeted gazes during two collaborative problem solving session with teachers called Joanne and Fred.

During scaffolding the target group, the eye contacts distributed similarly with both teachers. The observed four girls in Joanne's class and three boys in Fred's class gazed at their teachers more than other way around. While the teachers focused on one student's solutions or face at the time, the other three or two students often gazed at the teacher. Student gazes at teacher faces covered 44% (n = 22) of face-targeted gazes during scaffolding interaction in Joanne's class and 48% (n = 60) in Fred's class. The teachers seemed to have different intentions for the scaffolding interaction than the students. While the teachers' intention in the group varied between the problem-solving process and the motivational and emotional states of the students, students were willing to focus on the teachers as they arrived to the groups. The teachers' arriving to the group seemed to capture students' attention and pause their problem solving process. During verbal communication, the students often looked the teacher in the face even if the teacher was looking at and talking about the solutions.

While scaffolding other small-groups than the target group, Fred (74%, n = 131) scanned the students with one-way teacher gaze more often than Joanne (41%, n = 15) and Joanne had more dyadic eye contacts with students in other groups (54%, n = 20) than Fred did (23%, n = 41). In general, Joanne's students were more motivated and less frustrated that Fred's students and he had to be more critical in the interaction with them. In Joanne's classroom, the interaction throughout the problem solving process was warm and immediate, while Fred's lesson included also negatively loaded communication. However, Fred's class also included students who were concentrated in solving the challenging task, and hence not in need of the teacher's scaffolding.

In Fred's class, also the teacher's emotional state seemed to affect his gaze behavior. In the beginning of the collaborative phase, the target students joked at Fred, and they were not enthusiastic to solve the problem throughout the lesson. The uncertainty and pauses in Fred's speech in this moment

indicated that this event annoyed or embarrassed him and he avoided eye contacts with these students. After the confusion, Fred told the students to concentrate and continued scaffolding successfully. During scaffolding, three moments occurred, during which the target students tried to create an eye contact with Fred unsuccessfully. They directed several gazes (n = 14, 8, and 8) at Fred's face without receiving any response. During these moments, Fred guided them with verbal interaction but directed his gaze at student papers. Interview with him indicates that this aversion was more of pedagogical than purely emotional origin, as Fred wanted to calm the students and behave as an authority.

Discussion

Orchestrating collaborative instruction and classroom interaction is a complex and challenging task that is affected by various different factors (Prieto et al., 2017). The educational research field has rapidly adopted mobile gaze tracking as a method of data collection in real learning contexts. The use of multiple gaze tracking opens unexplored aspects of micro-level teacher-student interaction. In this paper, we have moved towards capturing the social nature of teaching and learning by using multiple gaze trackers simultaneously.

To summarize the results, the teachers' gaze behavior seemed to vary more depending the interactional state than the students' did. The students looked their teacher in the face both during whole-class instruction, and when the teachers were scaffolding the small-groups. This seems to be a result of teachers' social status and high agency in the classroom (Mehrabian, 1972). Even though collaborative problem solving is a student-centered learning method, the teacher's contribution in orchestrating the learning process is essential (Cross, 2009). The students need teacher's guidance, advice, and confirmation, which she can offer through eye contact and verbal instruction.

However, the teachers, especially Joanne, focused on her students' faces during whole-class instruction moments. In these moments, she looked at her students with numeral, short gazes. This finding is in line with the literature on teacher orchestration load (Prieto et al., 2017) and expertise (McIntyre et al., 2018). When speaking in front of the class, regardless of the content of the instructions, Joanne concentrated in addressing her message through direct gazes at student faces.

In Joanne's class, the target group was located closer to the front of the classroom, while in Fred's class the target students were seated in the back. As Cardellino et al. (2017) suggest, this may affect to the count of eye contacts between the students and the teachers. In Fred's class, no dyadic eye contacts were formed between him and the target students when Fred was standing in the front. Additionally, Fred's target students were not as motivated in solving the task as Joanne's were, and he may have unconsciously directed his instructions to those students he knew were waiting for them.

When changing the interactional state from whole class to a collaboration group, we found general characteristics in the gaze behaviors of teachers and students. The teachers were in the locus of students' attention in all interactional moments. While in whole class interaction the teacher's attention distributes unevenly (Dessus et al., 2016), we interpret that in small-group scaffolding moments all kinds of students had an opportunity to be seen and heard. Despite their misbehavior, the target students in Fred's class pursued his attention. Fred seemed to avoid dyadic eye contact with them after the confusions to act as an authority and direct their attention to the learning task.

Naturally, this exploratory study has certain limitations. First, the missing data (one student gaze recording and one teacher interview) and the differences in the counts of gazes between the lessons hinder the comparative interpretations. However, this is a case study, and all the comparisons are qualitative by nature. Their purpose is to chart the phenomena for more statistical analysis in the future. For instance, in this report the student groups happened to be of same gender as their teachers. In this analysis, the attentional patterns were quite similar between the two lessons. In future, the effect of altering the gender structure of the participants might be relevant to investigate. The quality of the gaze and video data was very high, which helped us in making analysis and interpretations. Each recording was annotated by only one researcher. Nevertheless, the research group negotiated on controversial issues during the annotation and interpreted the data collaboratively.

This study shows that adding student gaze data to teacher gaze data reveals aspects that would not be possible to be explored with only one gaze tracker. For instance, students' unsuccessful attempts to create eye contacts with the teacher and vice versa are indicators of the complexity of teacher-student verbal and nonverbal interaction. In future, we wish to examine more how teacher-student eye contacts are affected by aspects emerging in this analysis: the teacher and student personalities, methods of teacher-student interaction, and the physical learning environment.

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