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mathematical thinking during collaborative problem-solving activity

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TEACHER'S GAZE BEHAVIOR WHEN SCAFFOLDING PEER INTERACTION AND MATHEMATICAL THINKING DURING COLLABORATIVE PROBLEM-SOLVING ACTIVITY

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Scaffolding is an important teaching action that can target either at student cognitive or socio-emotional processes. The details of these scaffolding events can be examined through teacher visual attention, which interacts with his pedagogical decisions. In this study we use mobile gaze tracking device to investigate the different types of teacher's gaze behavior while he is scaffolding collaborative problem solving on mathematics lesson. Teacher's attentional focus during scaffolding events was found to relate to the purpose of the scaffolding event and thus to reflect teacher's objectives for the interaction with students. This situational nature of teacher gaze implicates the need of contextual use of gaze tracking analysis in the field of education.

INTRODUCTION

Teacher's experience, values, and pedagogical views affect their attention towards various students and targets in the classroom (McIntyre, Mainhard, & Klassen, 2017). Teacher's ability to notice situations that are crucial for mathematical or interactional learning is an essential skill that develops through practice (Stockero, 2014). The nature of social interaction affects teacher's gaze behavior (Prieto, Sharma, Kidzinski, & Dillenbourg, 2017). Teacher makes decisions on the direction of his attention. By offering adequate attention to students according to their needs, the teacher can foster their engagement to learning (Nizielski, Hallum, Lopes, & Schütz, 2012) and nurture the teacher-student relationship (Dessus, Cosnefroy, & Luengo, 2016). The learning and the social interaction during problem solving are influenced by the content of teacher feedback and guiding as well. Many teachers offer mostly guidance on mathematical contents and procedures, sometimes even neglecting the importance of peer interaction (Ding, Li, Piccolo, & Kulm, 2007). Teacher has the possibility to support interaction between students, which is often the least appearing form of interaction in mathematics lessons (Akkus & Hand, 2011).

Human eyes work as receiver and provider of information (Csibra, 2010). Recent research has shown the unevenness of teacher's gaze attention among students (Dessus et al., 2016), and the connection between teacher expertise and student-orientation of gaze behavior (McIntyre et al., 2017). Teacher's actions and visual perceptions interact and cooperate continuously as she targets her gaze towards relevant areas (Tatler, Kirtley, Macdonald, Mitchell, & Savage, 2014). As the eyes do not participate in action, investigating human gaze with mobile gaze tracking cameras offers valuable

information on cognitive processes during activities (Shayan, Bakker, Abrahamson, Duijzer & van der Schaaf, 2017). Gaze consist of fixations on targets and brief eye movements called saccades between fixations. A sequence of fixations on a defined area of interest constitutes a "dwell", whose duration is referred as "dwell time" (Holmqvist et al., 2011). A person's characteristics emerge in the proportion, duration, and frequency of the dwell times on separate targets (Yamamoto & Imai-Matsumura, 2013) and thus form the gaze behavior of the subject (Lappi, 2016). In this research, concept gaze behavior refers to the pattern of teacher's dwell times.

This study examines teacher's gaze behavior during scaffolding events with collaboration groups of students. Our research question is:

How does the content of scaffolding event (either mathematical or interaction-oriented) affect a teacher's visual attention?

METHODS

The researchers collected the data during a mathematics lesson of a 9th grade class in Southern Finland. The participating class included nineteen 15– and 16–year-old students (11 boys, 8 girls) and a teacher. Students were sitting in five collaboration groups of two to four students. In this article, we examine three groups which we here call A, B, and C. The teacher was a 30-year-old male who had three years of experience teaching mathematics. We chose this class for our study because of the teacher's wish to participate, and all students were asked to express their willingness to participate in a consent form. The participants received small donations as an acknowledgement of their contribution.

We recorded actions and whole-class conversations during the problem-solving session using three stationary video cameras in the classroom. In addition, eye movements of four students and the teacher were recorded using our self-made gaze tracking devices (Toivanen, Lukander & Puolamäki, 2017). The devices consist of two eye cameras and a scene camera and simple electronics, attached to 3D-printed eyeglasses-like frames. Software computes the gaze target coordinates on the scene video.

The collaborative problem-solving session examined in this study is an 18-minute episode in a 45-minute lesson. The objective of the collaboration in groups of two or four students was to find out the optimal solution to a geometry problem. The teacher encouraged the students to share their ideas both verbally and visually, and to select the solution they preferred. The lesson task was to find the shortest possible way to connect four imaginary cities with electrical cable, located at the vertices of a square. The teacher's role was to support students in the problem-solving process through encouragement and questions without giving hints for solving the task. During the session, the teacher roamed in the classroom and stopped to help one group at a time. These short scaffolding sessions are called 'events' in this research.

In this study, our coding unit is a dwell time. We coded gazes with ELAN software using distinctive codes, and annotated each dwell that was at least 80 milliseconds (two frames) long. The basic principle in the coding system was to code those targets that contained information on teacher-student interaction and teacher's pedagogy precisely. Less informative targets, such as classroom furniture, were coded with less attention to accuracy.

After the coding, we exported all the dwell times to a spreadsheet for further analysis. We compare distributions of targets of teacher's visual attention in several guiding events quantitatively. To cover the explorative and descriptive research questions, the analysis includes both a statistical representation and a qualitative description of the interaction during the session. The qualitative analysis is based on the verbal teacher-student interaction on video data.

RESULTS

This research compares teacher's gaze behavior during scaffolding events that either included mathematical conversation and advice, or focused on interaction and collaboration. This chapter presents teacher's gaze targets during six events with three student groups. The following graph (Figure 1) shows the overall distribution of gaze targets in all these events.
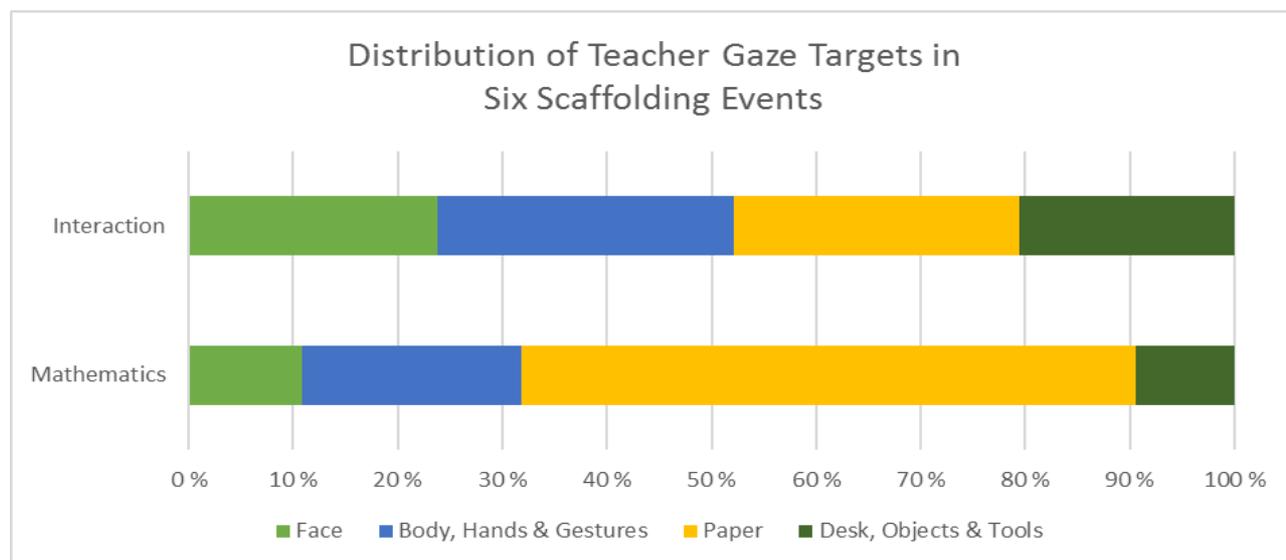

Figure 1 The average of the student-related targets of teacher gaze in groups A, B and C during Interactional and mathematical event

Teacher gazed at students more as persons during interactional events and at their papers in mathematical events. During mathematical scaffolding, 59 % of teacher's dwell times were directed to students' solutions, while during interactional events the percentage was 27 %. Accordingly, the percentages of gaze at student's face, hands and bodies were 25 % in mathematical and 50 % in interactional events.

In interactional events, the teacher focused more on multiple objects on students' desks. On one hand, he looked at the surface of the desks and school accessories while he was considering the interaction or listening to students. On the other hand, he

scanned students' irrelevant objects such as phones and headphones, especially in those groups where students expressed lack of motivation.

Despite these general tendencies, interesting differences emerged between separate collaboration groups (Figure 2).
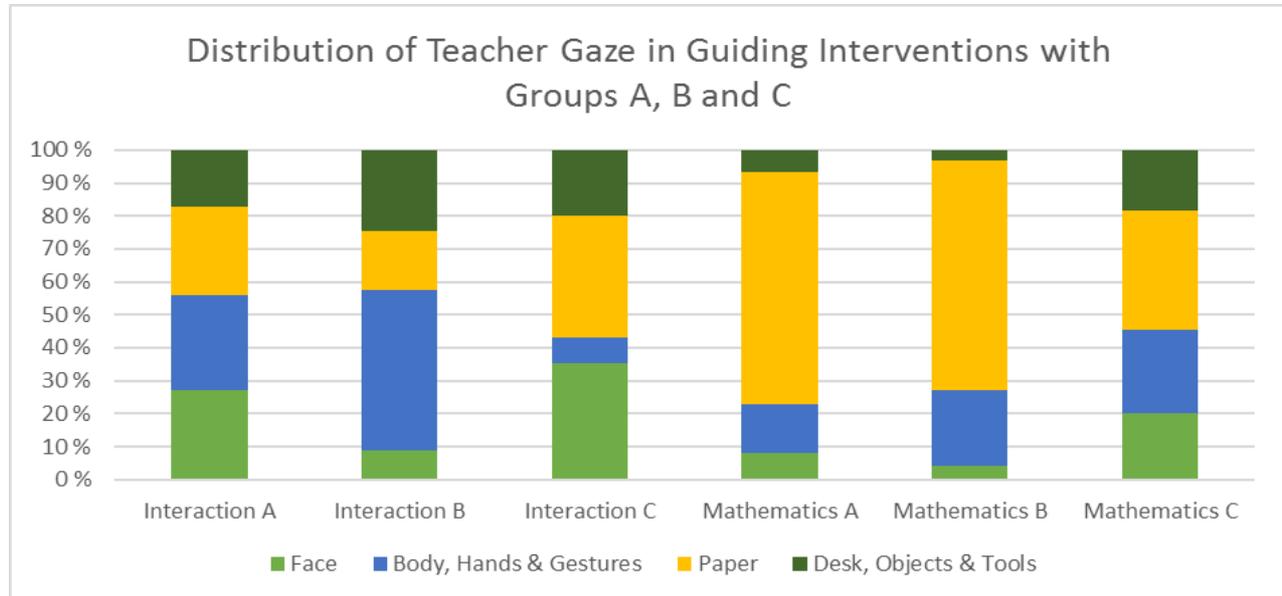

Figure 2 Student-related targets of teacher gaze in collaboration groups A, B and C during Interactional and Mathematical scaffolding events.

Group A consisted of four boys, Konsta, Daniel, Unto, and Henrik. Their interaction-oriented event (50 seconds) started when the teacher noticed them sitting quietly and intervened to encourage them to share the ideas. The group was divided into two pairs, as Konsta and Daniel in the front row focused on solving the problem together while Unto and Henrik behind them were drawing comic solutions. The teacher requested Konsta and Daniel to turn to Unto and Henrik and present the solutions to them. Konsta wanted to continue his efficient collaboration with Daniel, and disagreed with the teacher. During this event, the teacher's gaze distributed quite evenly between different targets. When students focused on their solutions, the teacher also looked at the papers or students' hands. Face-targeted gazes occurred with those students who responded to teacher initiatives of eye-contact.

The mathematical event with group A took place at the end of the collaboration session. The students had drawn several solutions on their papers and wanted teacher feedback. The teacher gazed at students' papers with long dwell times to observe the solutions and while he listened to students' description of the solutions. These gazes lasted 2.4 seconds on average, while the mean of all gazes in collaboration session was 0.5 seconds. As Konsta presented a specific question on the comparison of measurement and calculation of the solution they assumed optimal, the teacher took the paper and re-measured it. During this measuring, he naturally looked strictly on the paper. Also, while he discussed the calculation with Konsta and Daniel, his gaze was mostly directed to boys' papers. In this event, the students wished for confirmation to their solution, and the teacher wanted to help them finishing the problem solving

process as the first group in lesson. Reflecting teacher's instructional objectives to this event, these paper-targeted gazes formed 70 % of teacher's dwell times.

Group B consisted of one girl, Ingrid, and three boys, Tauno, Aarne, and Jani. In the interactional event (30 seconds), the teacher instructed them to turn towards each other and share their solution ideas by discussing. At the end of the event, Jani turned to others and started to describe his solution to them. In this event, the teacher focused a large amount of his gaze at student's bodies, hands and desks. On her desk, Ingrid had her pencil case, headphones and a phone. Bodies, however, were in the teacher's focus as he tried to capture the students' attention. Despite this, Tauno and Aarne ignored the teacher's initiatives and continued drawing, and the teacher directed his gaze at their hands. Only Jani made eye contact with the teacher by turning to him for a short while. Other students had their gaze targeted downwards during the whole event.

In the end of the collaborative phase, Tauno asked the teacher to intervene. This mathematical event (110 seconds) included mainly conversation on the task, as Tauno had managed to find out the optimal solution, and wanted teacher's confirmation of it. The teacher spent time focusing on Tauno's solution, and asked clarifying questions to help Tauno to develop it further. Teacher's gaze was 84 % of the time directed to Tauno during this event, and 94 % of the Tauno-oriented gazes targeted at his paper, the ruler pointing the solution, or hands starting to calculate. The teacher did not try to have eye contact with him, and looked at his face only when Tauno already had started re-measuring the solution.

In **group C** (two girls), the distribution of teacher gaze was more complex than in the two other example groups. The essence of the interaction event (38 seconds) was the teacher's attempt to motivate Aino and Annikki to work on the problem task. The students responded to the teacher's initiatives of eye contact, and the teacher directed his gaze at their faces while talking to them. When Annikki described her opinion about the task and its solutions, the teacher took turns looking at her paper and her face. After that, the teacher's focus turned back to the girls' faces. This event included a strong emotional component, as the students expressed their frustration and refused obeying the teacher's instructions. The teacher seemed to focus on the students' faces to better interpret their emotions and attitude. The teacher also paid attention to the phones on the table, which were not used for calculating.

The teacher returned to group C 2.5 minutes later when he noticed that Aino and Annikki were still sitting passively. This event (37 seconds) was mathematical, and teacher opened the conversation by telling the students that their solution was not the optimal. The solution papers received same proportion of teacher's gaze in this event (36 %) as in the earlier (37 %), probably because the solutions did not represent the girls' expected achievement level. However, the teacher focused less on girls' faces and more on their hands because Aino showed her solutions and concentrated in handling her headphones. The students also had several objects on their desk that captured the teacher's attention occasionally. Despite the mathematical content of the

conversation, its actual purpose was motivating students. This explains the similarities in teacher's gaze behavior in both events with group C.

DISCUSSION

This research indicates that teacher's gaze behavior is situational nature. As in Yamamoto and Imai-Matsumura's (2013) results, our informant teacher focused his gaze on those areas of interest that were relevant for his objectives. Generally, he gazed at students' solution papers during mathematical scaffolding, and at student faces, bodies, and belongings during events that included motivating and instruction on collaboration skills. During this lesson, the teacher offered guidance on two important aspects of mathematical problem solving: procedural and interactional objectives (Ding et al., 2007). In the beginning of the collaboration phase, he stressed peer interaction and shared reflection of the solution ideas. Towards the end of the phase, the emphasis of instruction moved towards mathematical goals. Thus, also his gaze behavior varied during different scaffolding events, and comparison of six individual events revealed the relation between the interaction and visual attention. To discuss the results, we will first examine face targets and secondly paper and hand targeted teacher gazes.

Gazes towards students' faces were probably the most difficult component of teacher's gaze behavior to analyze, as it seemed to be affected by the social characteristics of the scaffolding event. As Prieto et al. (2017) found out, looking at students' desks and back decreased teacher's cognitive load, while looking at their faces increased it. Our research indicates similar result. Face-targeted gazes include a great amount of information on student's emotional state, and the teacher used these gazes to either receive or give relevant information on the collaboration. Another aspect of face-directed gazes is eye contact. In the analysis of the six events, the teacher either initiated eye contact without students' response, where he did not seek eye contact at all, or where he established successful eye contact with students. The amount of eye contact carries with it high dwell times of face-targeted gazes. Nevertheless, this study does not explain the reasons for the small amount of eye contact. However, we can suggest that it relates to an already established teacher-student relationship and/or the novelty brought about by the gaze tracking glasses on the teacher's face.

The goal of teacher gazes at students' hands and papers seems to be receiving information on the problem-solving process and students' engagement. The teacher looked at students' hands to follow their actions. During these events, hand-targeted gazes occurred mostly while the teacher directed his attention to students drawing or presenting their solutions. Similarly, the gazes at papers offered a survey of a group's progress on the problem-solving task. Elegant and relevant solutions captured the teacher's attention resulting in longer dwell times than during the explanation of intuitive solution drafts. Groups A and B had proceeded with their problem solving between the scaffolding events, and teacher was interested in focusing on the solutions

in latter ones. Group C, however, presented same undeveloped solutions in both events, and also the amount of teacher's attention to those solutions remained similar.

Mathematical problem solving involves both interactional and mathematical objectives. To reach these goals, the teacher is supposed to pay attention to relevant events in the classroom (Stockero, 2014). This research indicates that the objectives alternate during a collaborative problem-solving lesson, and this variation directs the teacher's visual attention. Thus, he targets his gaze to interpret the phase and plane of student collaboration but also to affect it by focusing on those targets, which he sees relevant for the goals given a certain situation. The teacher can orchestrate the class not only by noticing some events but also by ignoring others.

As a limitation to the study, the method of mobile gaze tracking as well as the teacher's inclination to help create high quality research data may have influenced his attention. Some students may have felt it difficult to look at the teacher's face, and he might have been less task-oriented without this research setting. Gaze tracking is a largely used method for researching cognitive processes (Shayan et al., 2017). Using this method, we were able to examine a teacher's attention in detail. According to our case study, the teacher's gaze behavior is situational by its nature and reflects on his objectives on ever-changing situations. Whether these gaze patterns appear in other teachers and circumstances is a question for future research.

According to this analysis, different stages of interaction would be an interesting aim for future gaze tracking research. As interaction affects the interpretation of objects, this implies a need of flexible areas of interest. First, it is important to classify students' belongings according to their effect on learning process. Phones, for instance, represent completely different goals depending on whether they are used for amusement or calculating. Secondly, students' faces can express e.g. emotional rejection or shared interest regarding to the expression and eye contact. In this research, some students avoided eye contact with the teacher. This raises a further research question on the importance of eye contact to both collaborative and mathematical learning goals in the lesson.

Acknowledgement

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