Coordination versus dis-coordination in student-tutor collaboration during an embodied activity

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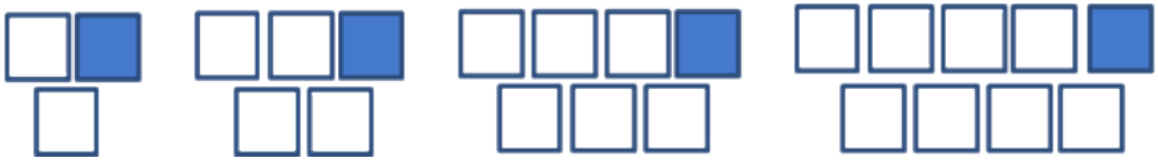
The presentation plan

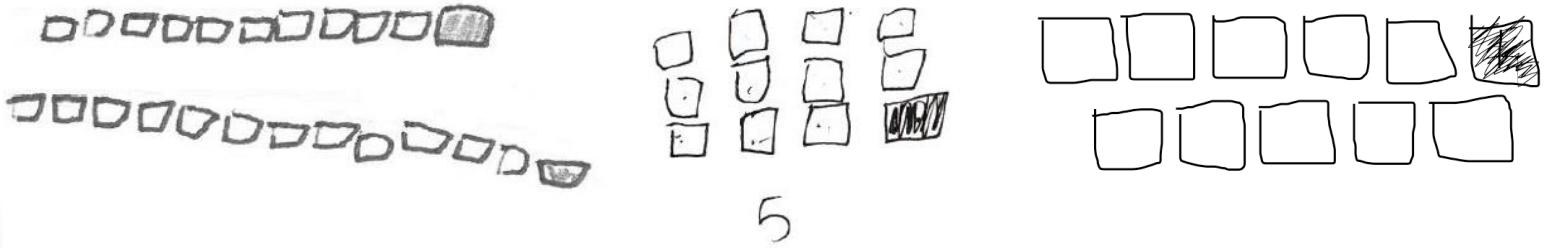
- Theoretical background
  - Vygotsky's cultural-historical approach to education: theorizing embodied collaboration
  - Cognitive science and educational research findings on the embodied collaboration under the lens of Vygotsky's approach
  - Complex dynamical systems theory as contemporary clarification of some cultural-historical approach claims
- Methodology
  - Dual eye-tracking technical solution
  - Embodied educational design
- Micro-ethnographical analysis of the teaching-learning episodes
  - Dual eye-tracking, video and audio data sources
  - Theoretical conclusions and educational applications

Vygotsky's approach: 'Real' (naïve, initial) and 'Ideal' (cultural, final) forms

A second grade student

An adult



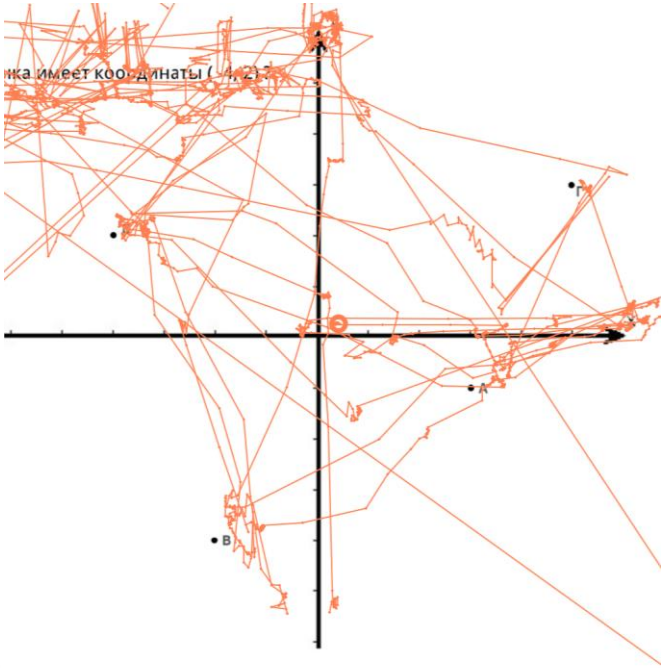


(Radford, 2010)

Vygotsky's approach: 'Real' (naïve, initial) and 'Ideal' (cultural, final) forms

A first grade student

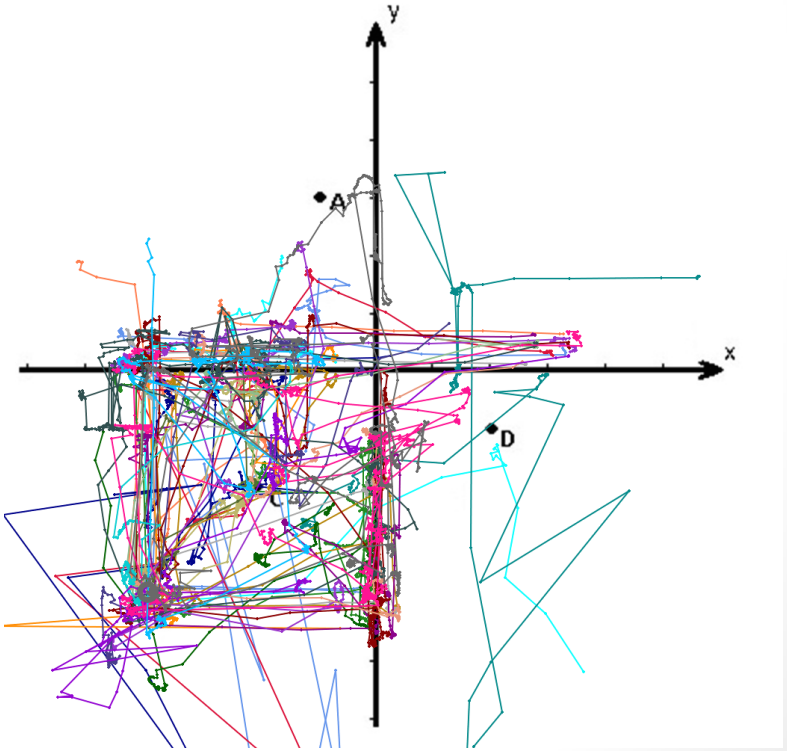
Which point has coordinates *(-4, 2)?*



Shvarts, 2017

The university students

Which point has coordinates *(-4, -4)?*



Krichevets, Shvarts, Chumachenko, 2014

Vygotsky's approach: 'Real' (naïve, initial) and 'Ideal' (cultural, final) forms

- "Ideal forms" are particular cultural ways of how [educated] adults do perceive reality and perform actions.
- These "ideal forms" of knowledge or 'how-to-do' abilities surround a child in her social environment and co-exist with her "initial forms" or "real" forms of perception and action.
- The greatest distinctiveness of a child's development in comparison with any natural evolutional processes is the pre-existence of "ideal forms" or "final" forms of development (Vygotsky 1934/2001).

‘Real’ and ‘Ideal’ forms of perception: contemporary data

- Different names of this phenomenon:
  - professional perception (Goodwin, 1994),
  - disciplined perception (Stevens & Hall, 1988),
  - educated perception (Goldstone, Landy, & Son, 2010),
  - theoretical perception (Radford, 2010) regarding the Marxist idea of social practice that transforms human senses.
- Eye-tracking data (Gegenfurtner, Lehtinen, & Säljö, 2011 for a review):
  - An ability of experts to distinguish relevant information much easier and faster then novices do (e.g. Haider & Frensch, 1996; Jarodzka, Scheiter, Gerjets, & van Gog, 2010; Krichevets, Shvarts, & Chumachenko, 2014).
- The objects themselves are distinguished differently following their cultural meaning.

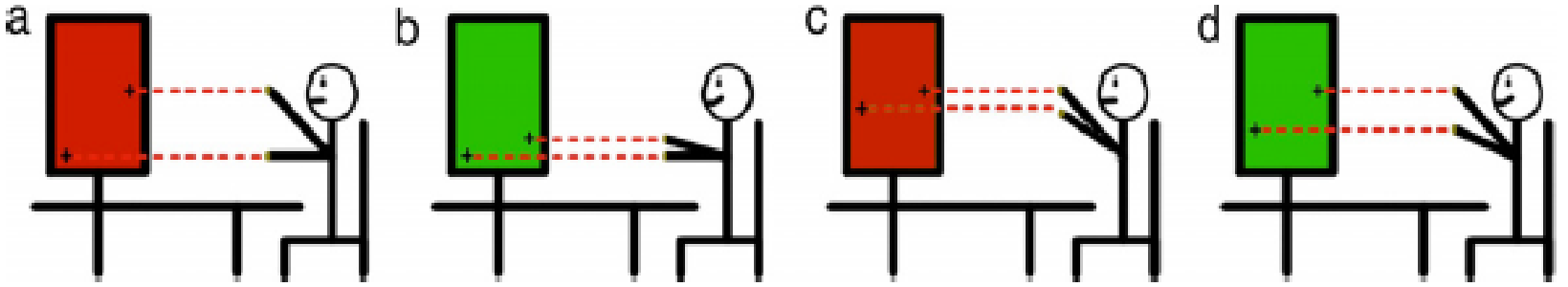
Vygotsky's approach: the role of social environment and student's personal activity

- Vygotsky, Educational psychology (1926):

- "Just as the gardener would be acting foolishly if he were trying to affect the growth of a plant by directly tugging at its roots with his hands from underneath the plant, so is the teacher in contradiction with the essential nature of education if he bends all his efforts at directly influencing the student. But the gardener affects the germination of his flowers by increasing the temperature, regulating the moisture, varying the relative position of neighboring plants, and selecting and mixing soils and fertilizer, <…> Thus it is that the teacher educates the student by varying the environment."

Social environment: An educational design construction

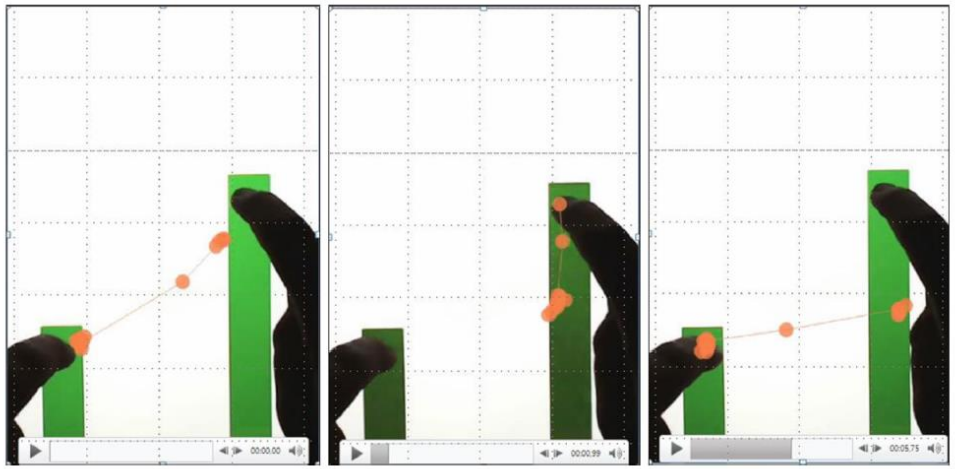
- Providing cultural environment as it provokes goal-oriented actions that lead to new mathematical concepts emergence through student's activity.
- Embodied manipulations guarantee multimodal nature of emerging mathematics.



(Abrahamson, 2014)

Personal activity: the variety of student's strategies

- *Attentional anchors*: unique mathematically meaningful sensory-motor coordination (Abrahamson & Sanchez-Garcia, 2016).



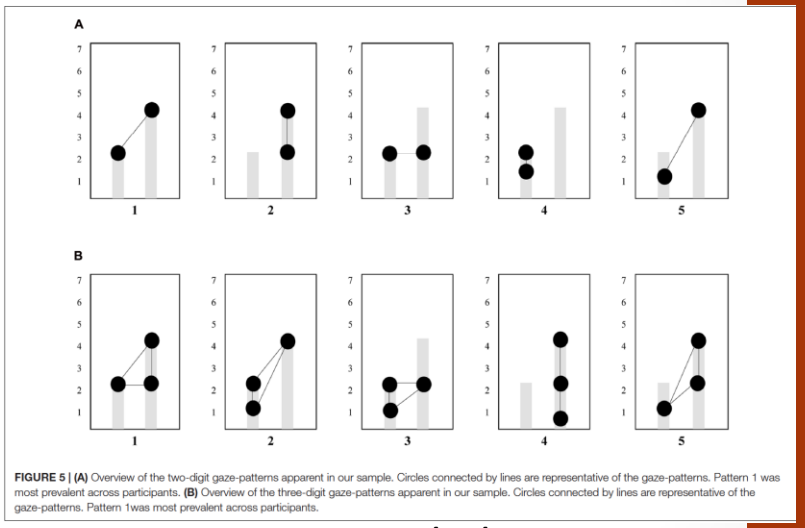


FIGURE 5 | (A) Overview of the two-digit gaze-patterns apparent in our sample. Circles connected by lines are representative of the gaze-patterns. Pattern 1 was most prevalent across participants. **(B)** Overview of the three-digit gaze-patterns apparent in our sample. Circles connected by lines are representative of the gaze-patterns. Pattern 1was most prevalent across participants.

Duijzer, Shayan, Bakker, Van der Schaaf, & Abrahamson, *Frontiers in Psychology,* 2017.

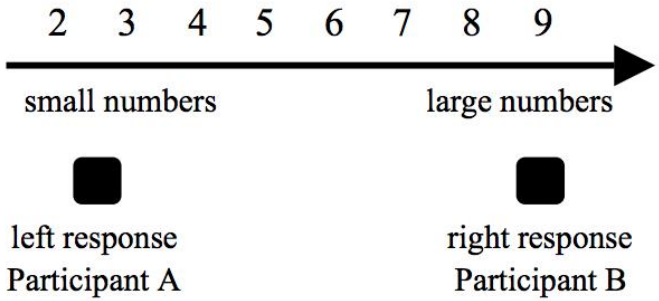
- These coordinations might be disclosed as specific repetitive patterns of the students' eye-movements.
- The patterns vary from student to student, although all of them lead to conceptualization of rational relations – evidence towards complex dynamical systems theory

Vygotsky's approach: student-tutor collaboration within the zone of proximal development

- The cultural forms are at first acquired in "a form of collective behavior of a child, forms of collaboration with others" (Vygotsky, 1935/2001) and then they are transformed into individual functions.
- Zone of proximal development (ZDP) is the range of tasks that are affordable for the child in collaboration with others but not alone.
  - Collaboration within the zone of proximal development "awakens a variety of internal developmental processes that are able to operate only when the child is interacting with people in his environment" (Vygotsky, 1978)
- Symmetrical ZPD:
  - both, an adult and a child, need to be moved by the other one; they both need to become a learner to be perceptive to meanings of the other (Roth & Radford, 2010).

Joint action: dyadic embodied coordination

- Spontaneous synchronization of iterative movements such as rocking chairs or typing



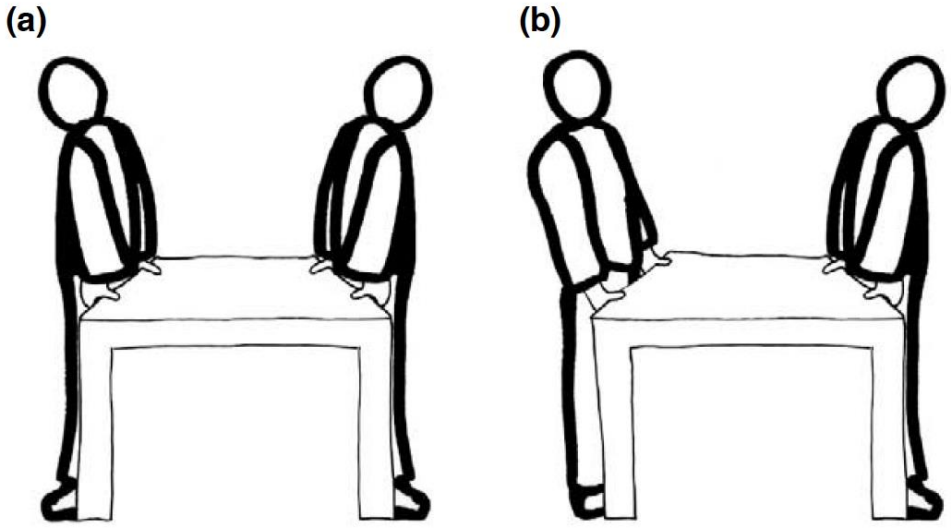
- "Co-representation" of the problem space that means the representation of task-relevant aspects of the other one's action.
- Motor adjustment to the situation of the other (Schmitz, Vesper, Sebanz & Knoblich, 2017)

(Atmaca, Sebanz, Prinz, & Knoblich, 2008)

Intersubjective coupling of perception-action systems
(Spivey et al., 2009, Dale et al., 2014)

Joint action in the teaching context: asymmetrical positions

- The common goal that requires different actions: to teach and to learn

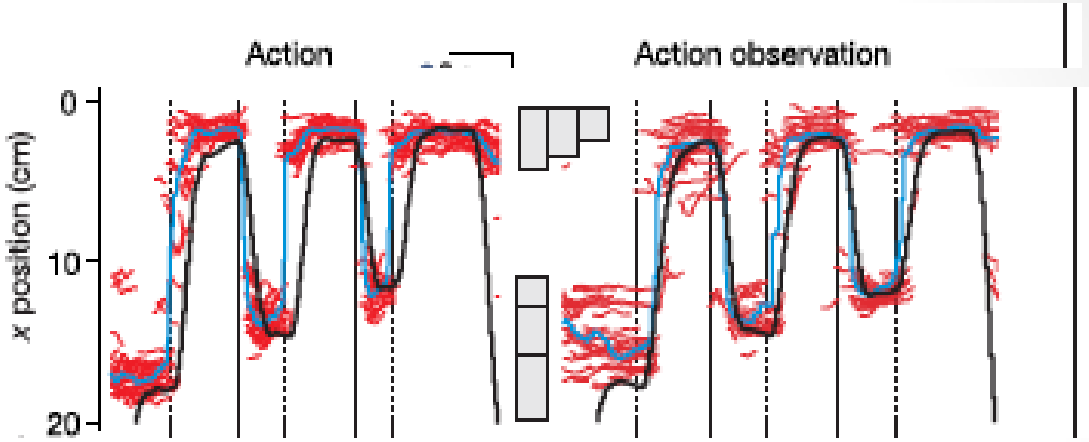


Sebanz, Bekkering & Knoblich, 2006

- Our ability to synchronously coordinate with each other is insufficient; we need to coordinate with the others in accordance with their positions and aims.

Action observation as an utter form of joint action

- Anticipatory perception: predicting the next move



Flanagan & Johansson, 2003

Vaziri-Pashkam et al. *Cognition*, 2017

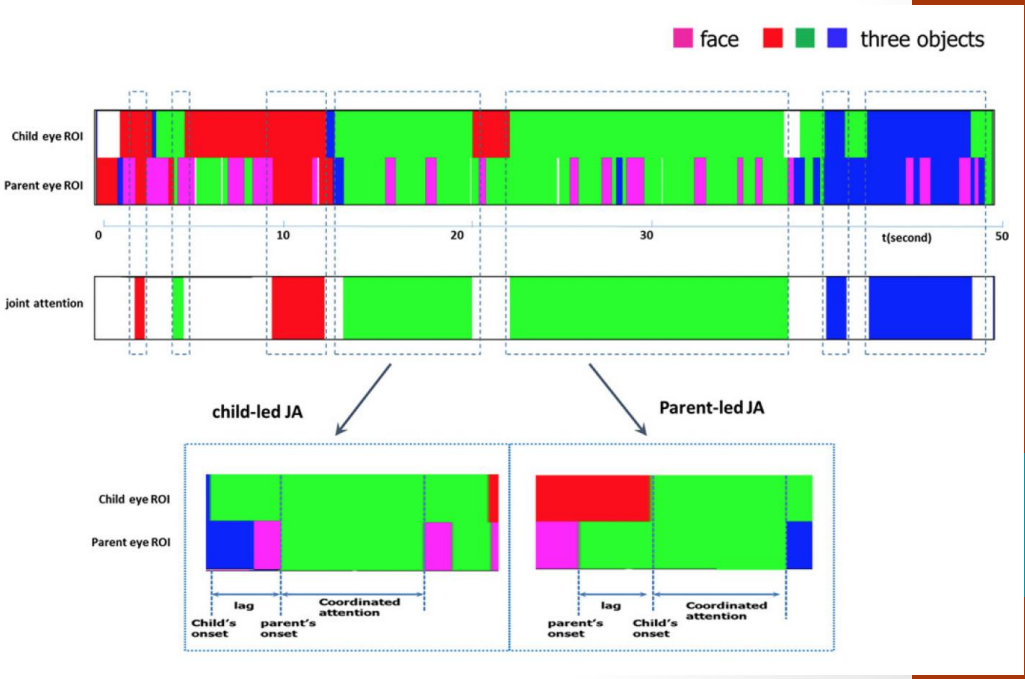
- Preparatory cues from all parts of the body are essential for the action prediction

- Mirror neurons system: motor simulation of observed action and intentions recognition at the neuronal level (e.g. Rizzolatti, Fadiga, Gallese, & Fogassi, 1996)

Joint attention: triadic embodied coordination between a student, a tutor, and an object

Joint attention is an episode when two people are focused on the same object and are aware of another one's focus of attention.

- Follow-in strategy is more effective than redirection strategy in both natural and experimental word learning (Tomasello & Farrar, 1986).
- The same results for face recognition memory task (Kim & Mundy, 2012)
- There are child-led and adult-led episodes in natural communication between an 12-18 month infant and an adult (Yu & Smith, 2016)
- Equal proportion of Initiating and Responding to joint attention episodes between two partners correlate with high learning gains (Schneider et al., 2016)



Main aspects of Vygotsky's approach

- Co-existence of a 'real' and an 'ideal' forms of perception and action
  - Professional, disciplined, educated, theoretical perception
- The role of social environment and personal students' activity
  - Embodied design and emerging cognitive sensory-motor coordination (attentional anchors)
- Teaching-learning collaboration
  - Zone of proximal development: each one needs to be ready for a transformations
  - Dyadic student-teacher relations: joint actions
    - Intersubjective coupling of perception-action systems, anticipation in perception.
  - Triadic student-teacher-object relations: joint attention.
    - Student-led versus tutor-led JA

Dual eye-tracking research questions

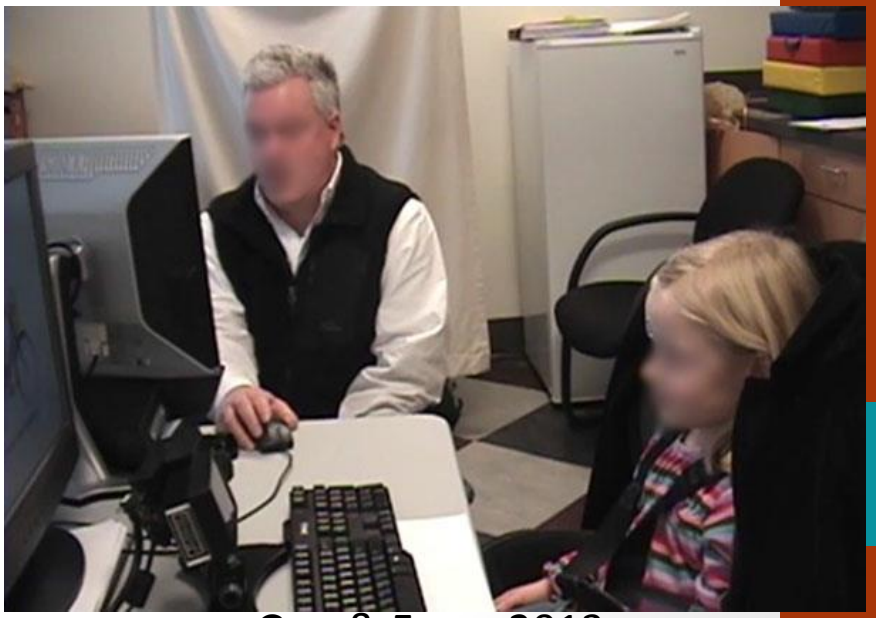
- **Cognitive linguistics:**
  - referential behavior (Richardson, Dale, & Kirkham, 2007; Gergle & Clark, 2011; Sandgren, Andersson, Weijer, Hansson, & Sahlén, 2012)
  - dialogue communication (Ho, Foulsham, & Kingstone, 2015; Fedorova, 2017)
- **Developmental psychology:**
  - joint attention emergence (Yu & Smith, 2013, 2016, 2017)
- **Cognitive psychology**:
  - collaboration and co-construction (Jermann, Nüssli, & Li, 2010; Carletta et al., 2010, Schneider et al., 2016;)
- **Education/learning:**
  - Computer-supported collaborative learning (Sangin, Molinari, Nüssli, Dillenbourg, 2008; Belenky, Ringenberg, & Olsen, 2014; Sharma, Caballero, Verma, Jermann, & Dillenbourg, 2015; Uzunosmanoğ lu & Çakir, 2014; Molinary, 2015)
  - effects of gaze sharing (Brennan, Chen, Dickinson, Neider & Zelinsky, 2008; Bremann & Hanna, 2012; Shneider, & Pea 2013; Sarah & Begel, 2017)

Dual eye-tracking technology: remote trackers

Recording of two people, while each one is sitting in front of her monitor and the synchronized pictures are presented (Sharma, et al., 2013; Guo & Feng, 2013; Belenky et al., 2014).

- **Advantages:**
  - Natural overlap of the gazes and simple further analysis
  - Accuracy as good as individual remote eye-tracking
  - Implementation of gaze sharing
- **Limitation:**
  - The communication is limited to the verbal channel
  - Gestures are not recorded and are not analyzed.

Sharma, et. al., 2013



Guo & Feng, 2013

Dual eye-tracking technology: head mounted trackers

- **Advantages:**
  - the freedom of movements in shared space,
  - interaction beyond the screen
  - variety of communicative channels

The main **limitation** appears at the level of data analysis: each eye-movement track is presented within the video scene of the particular participant.

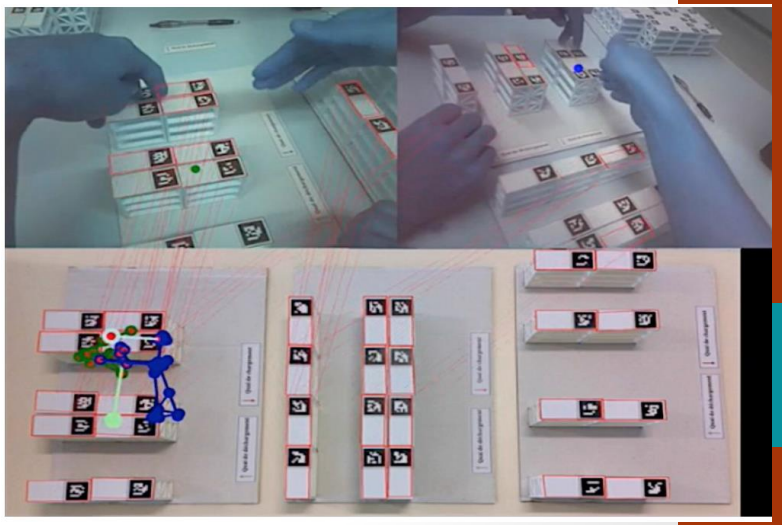
Manual solution: The data is manually coded according to areas of interest

(Yu, Smith, 2016)

Dual eye-tracking technology: head mounted trackers

- **Automatized solutions:**
  - Objects of interest identification
    - (Gergle & Clark, 2011; Pfeiffer & Renner, 2014)
    - **Limitations:** we need to identify the objects beforehand
  - Convergence of eye-data on the common ground truth
    - (Schneider et al., 2016; Lilienthal & Schindler, 2017)
    - **Limitations:** transformation of common space are not reflected on the ground truth
- **Limitation:**
  - worse space accuracy

Gergle & Clark, 2011



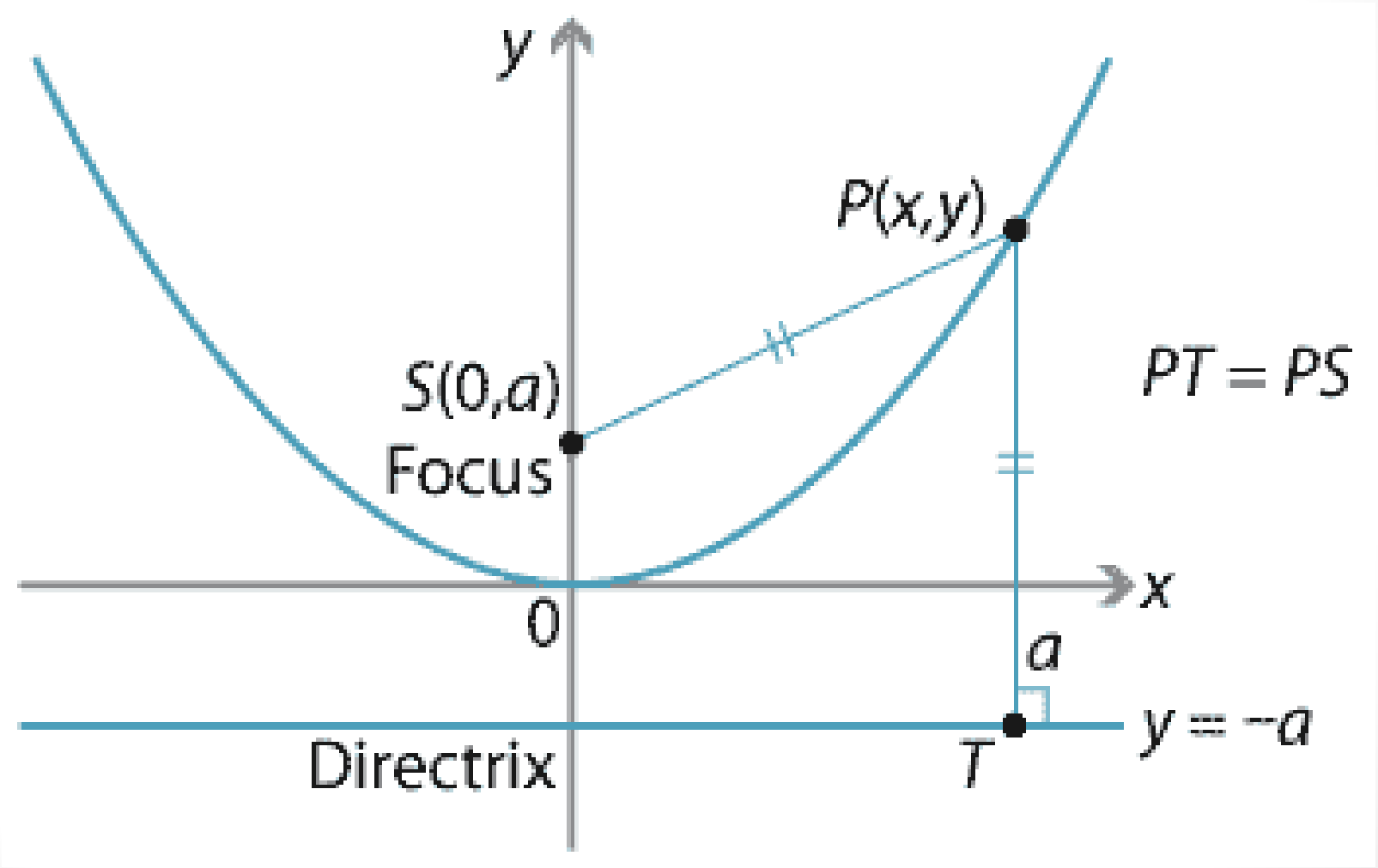
Schneider et al., 2016

Our technological solution and analysis

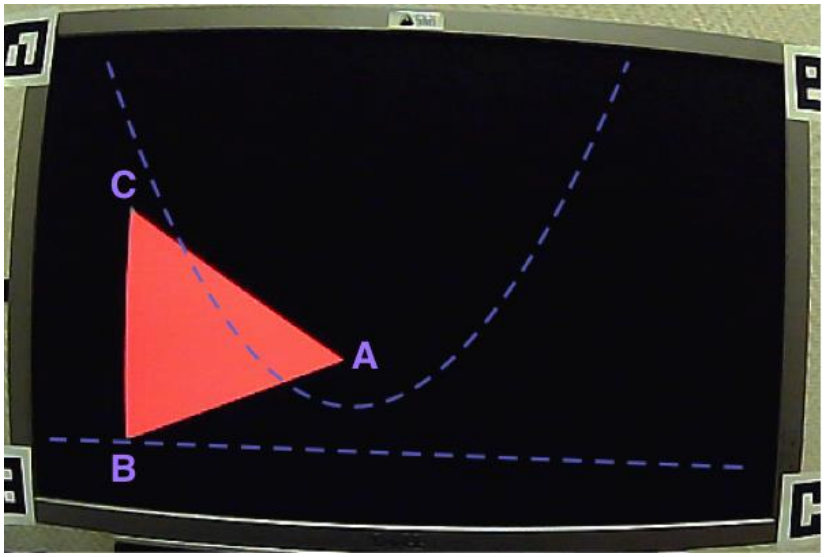
- Two Pupil-labs eye trackers (60hz) were calibrated at the same monitor.
- Special markers were attached to the monitor for automatic recognition of the surface.
- Pupil-labs software was improved to produce a video from a screen surface overlaid by eye paths from two eye-trackers.

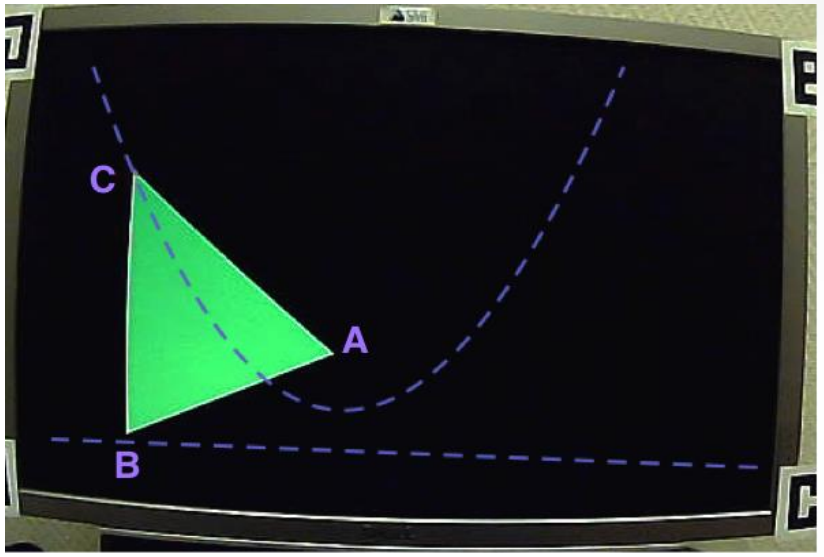
Micro-ethnological qualitative analysis of video and audio material with additional frame by frame analysis.

Educational embodied design: Mathematical Imagery Trainer for…



Educational embodied design: Mathematical Imagery Trainer for Parabola

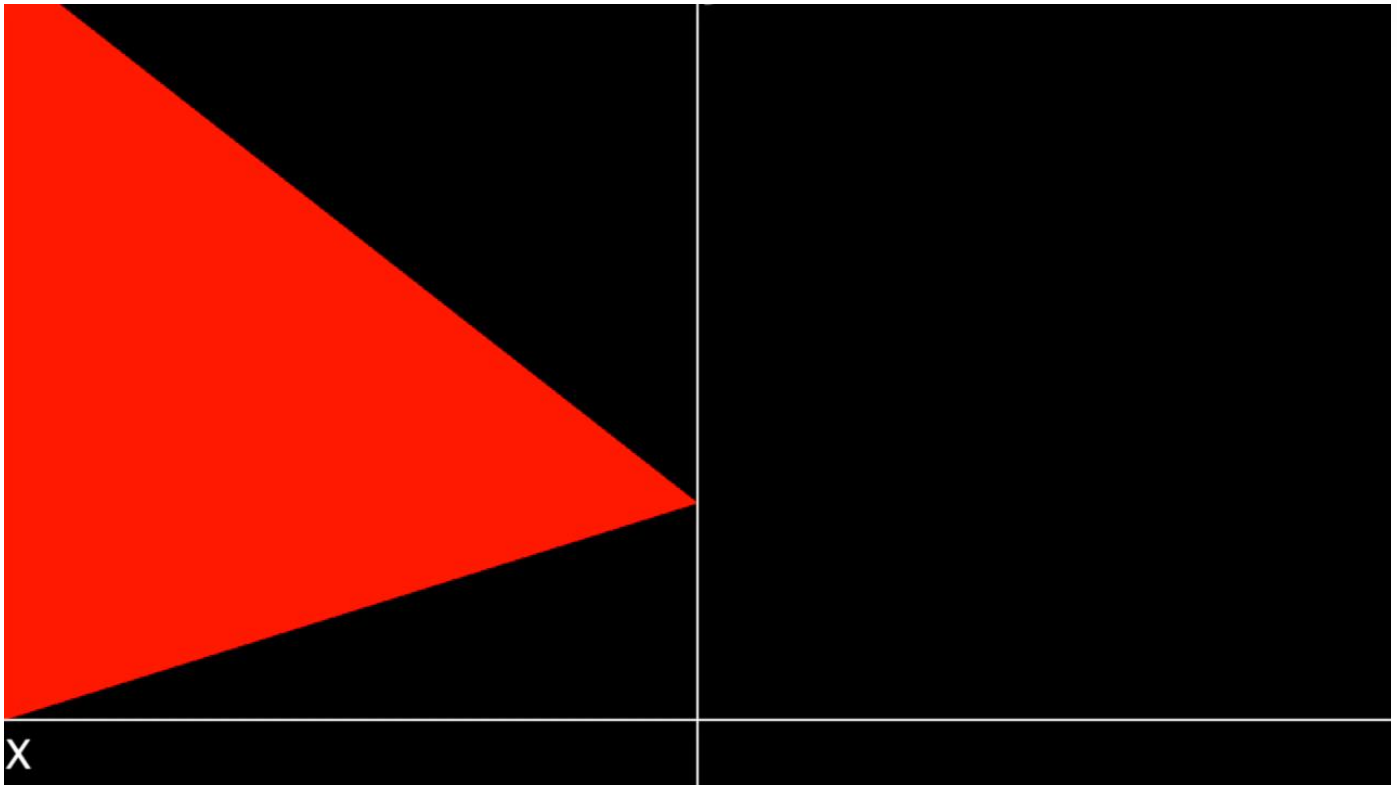




Level 1

- The student manipulates Vertex C.
- The triangle is green when BC=AC, where B runs along the horizontal dashed line, A is the parabola's focus.
- By keeping the triangle green while moving Vertex C, the student would effectively be inscribing a parabola.

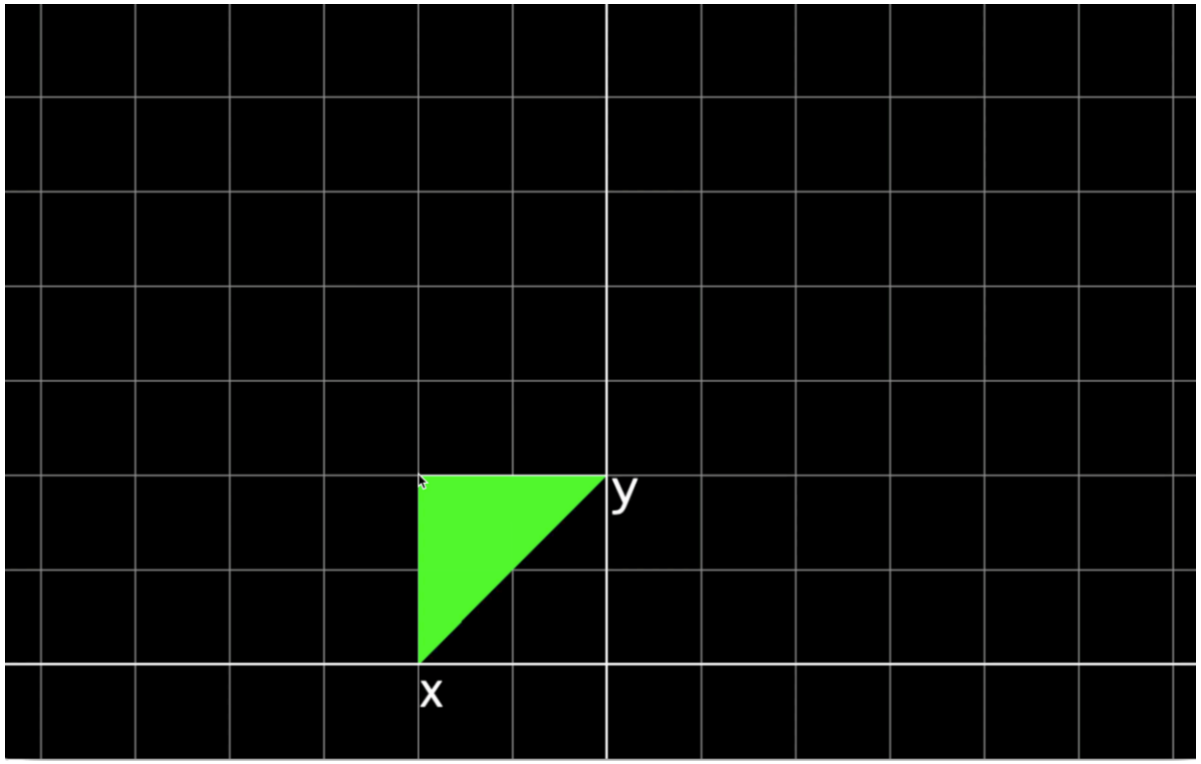
Educational embodied design: Mathematical Imagery Trainer for Parabola



Level 2

- The axes and the projections of Vertex C appear on a screen. The student needs to figure out the formula.

Educational embodied design: Mathematical Imagery Trainer for Parabola



Level 3

- A grid appears on a screen. The student needs to apply the formula and to answer prior the movement of the Vertex C, at which grid points the triangle is green.

In the current presentation, I analyze only Level 1.

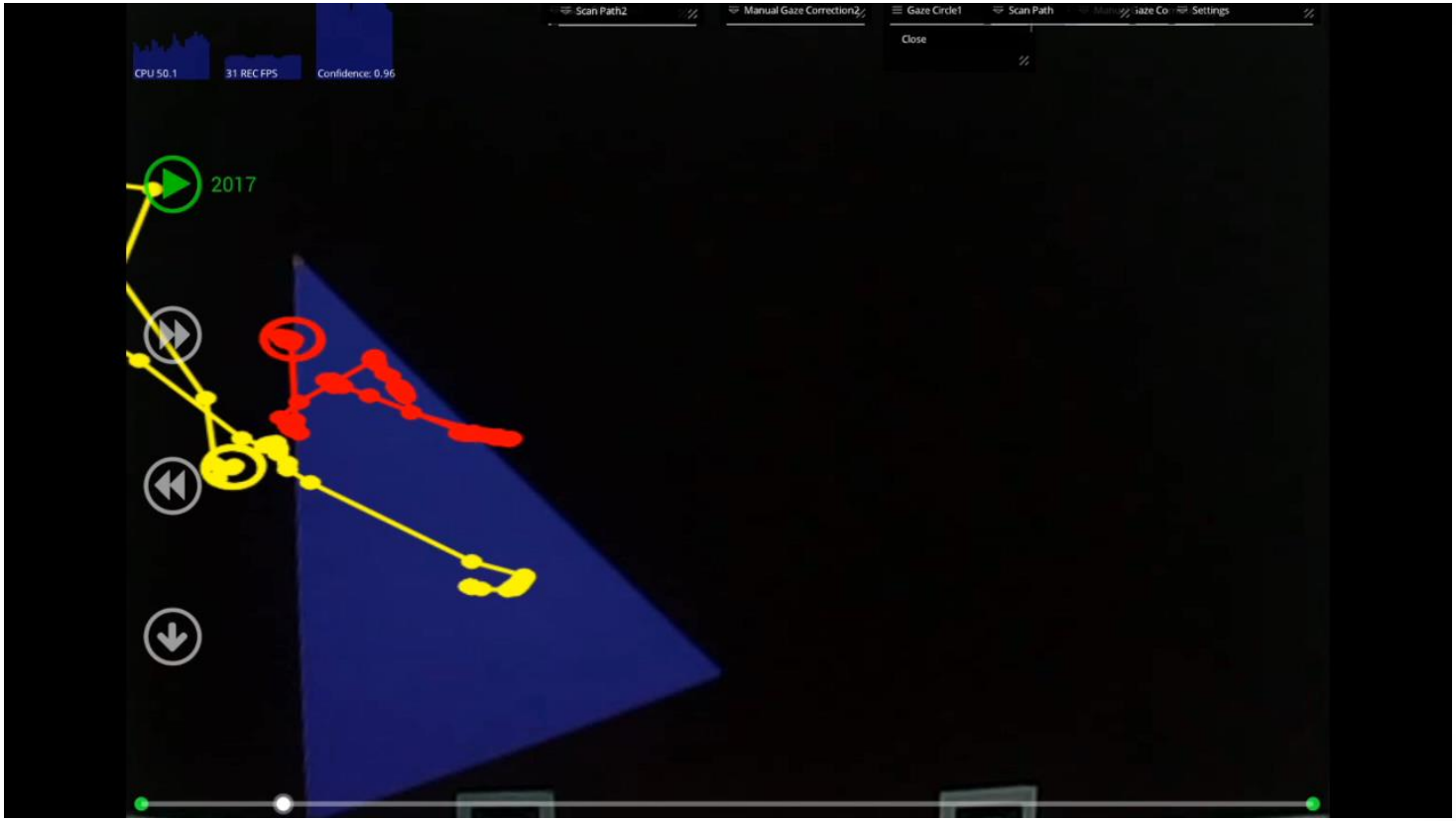
Experimental design and participants

- Two pairs of university students (department of psychology) Experimental design and participants.
  - **Episode 1:** The experimenter takes the role of the tutor. The first participant takes the role of the student.
  - **Episode 2:** The first participant takes the role of the tutor. The second participant takes the role of the student.
  - **Instruction for the participant-tutor:** “Now you will be the tutor. Follow the same procedure as I did”
- Two pairs of participants provided four tutor-student pairs. The provided analysis summaries data from all the pairs.

The research questions:

- Is it possible to trace intersubjective coupling between a student and a tutor perception-action systems that that would make the embodied level of collaboration evident?
- Does a tutor expose the ideal form of her enculturated perception during collaboration with a student? Does the tutors take into account the particular emerging attentional anchors of the students?
- How is the students' activity involved in student-tutor collaboration? Do tutors follow or guide student's attention?

Stage 1.
Coordination of the student's and the tutor's perception-action systems



- The delay between the tutor and the student vary from 17 ms (the technically minimal delay that we can track) to 300-600 mc in the cases of unpredictable student's movements.

Stage 1.
Coordination of the student's and the tutor's perception-action systems

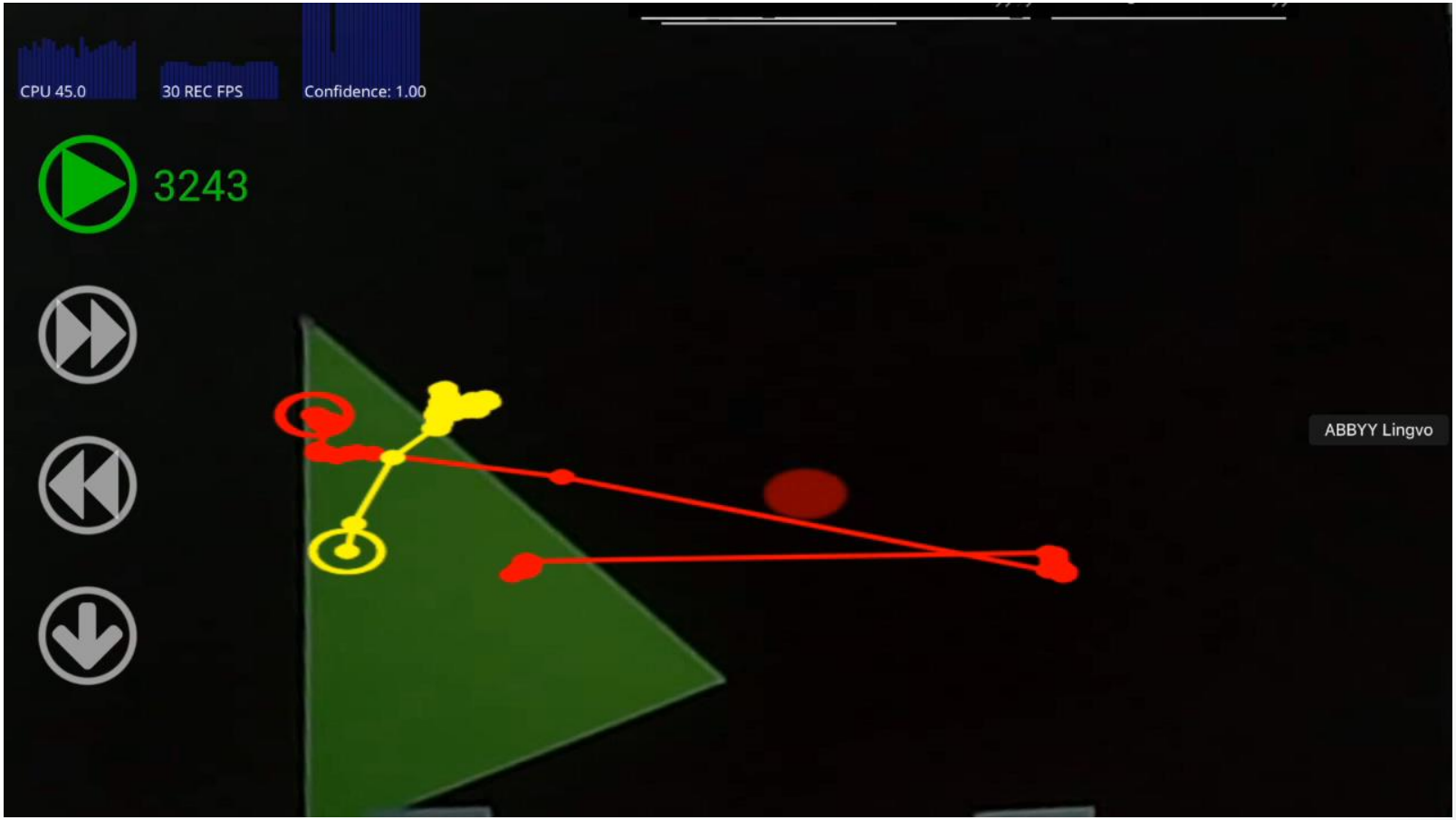
Theoretical background:

- Intersubjective coupling of two perception-action systems (Dale et al., 2014; Spivey et al., 2009)
- An anticipation of observed movement (Flanagan & Johansson, 2003; Gredebäck & Falck-Ytter, 2015)
- The joint attention is initiated by the student (Kim & Mundy, 2012; Tomasello & Farrar, 1986)

Educational significance:

- The tutor experiences the student's embodied experience.
- Let tutor be "on a wave" with the student, to be aware of her tactics, probes, and mistakes.

Stage 2.
Dis-coordination of the tutor and the student.
A ‘real’ and an ‘ideal’ forms



Stage 2.
Dis-coordination of the tutor and the student. A 'real' and an 'ideal' forms

Theoretical background:

- Co-existence of an 'ideal' and a 'real' forms (Vygotsky, 1934/2001)
- Subtle intersubjective coupling of two perception-action systems: the tutor's perception is coordinated with the student's actions but not with the student's perception.
- A new kind of Attentional Anchors: AA without actual action regulation.

Educational significance:

- The tutor is 'rooting for' the student.
- Letting the student explore the problem on her own and supporting her.
- Evaluating the student's progress and detecting the moment to intervene.

Stage 3.
The role of environment/design: discovering an ideal form

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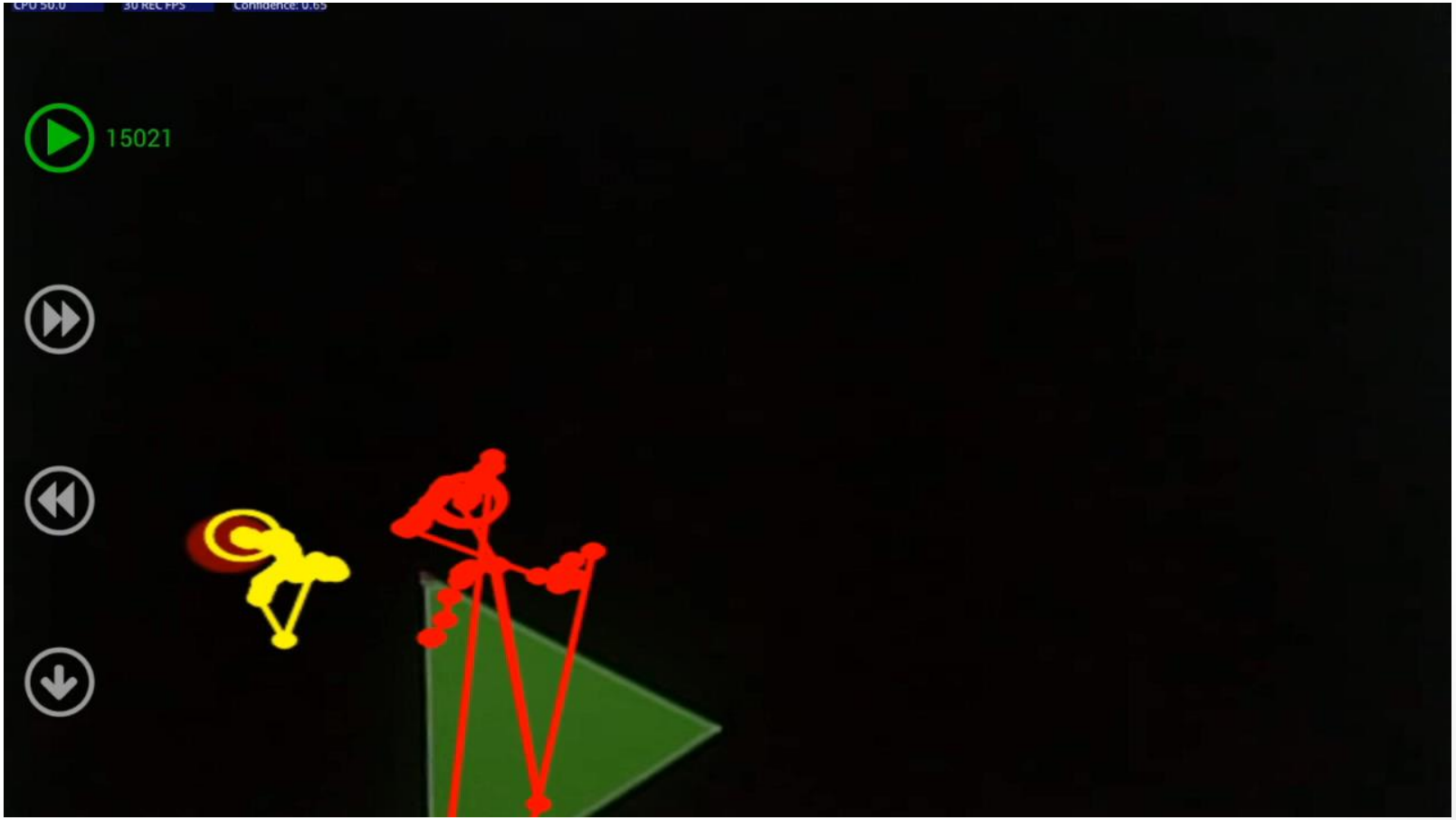
The role of environment/design: discovering an ideal form



Stage 3.
The role of environment/design: discovering an ideal form

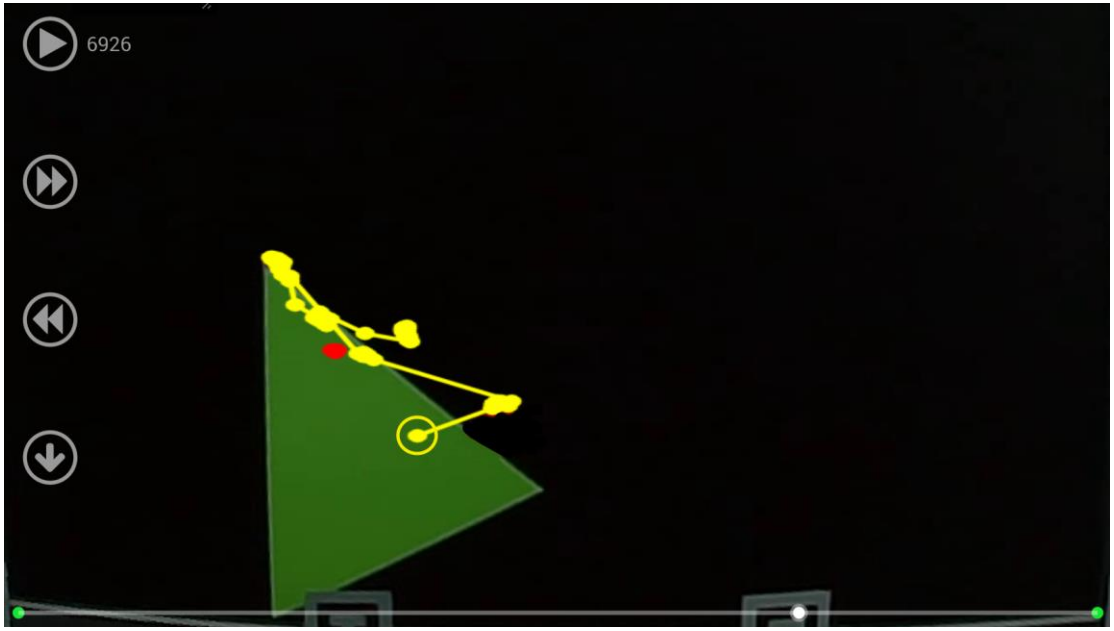
Theoretical background:

- Modulation of social environment provides an opportunity to acquire a new cultural meaning (Vygotsky, 1926)
- Spontaneous discovery of a new mathematically meaningful sensory-motor coordination (Abrahamson & Sanchez-Garcia, 2016, Duijzer et al., 2017)

Educational significance:

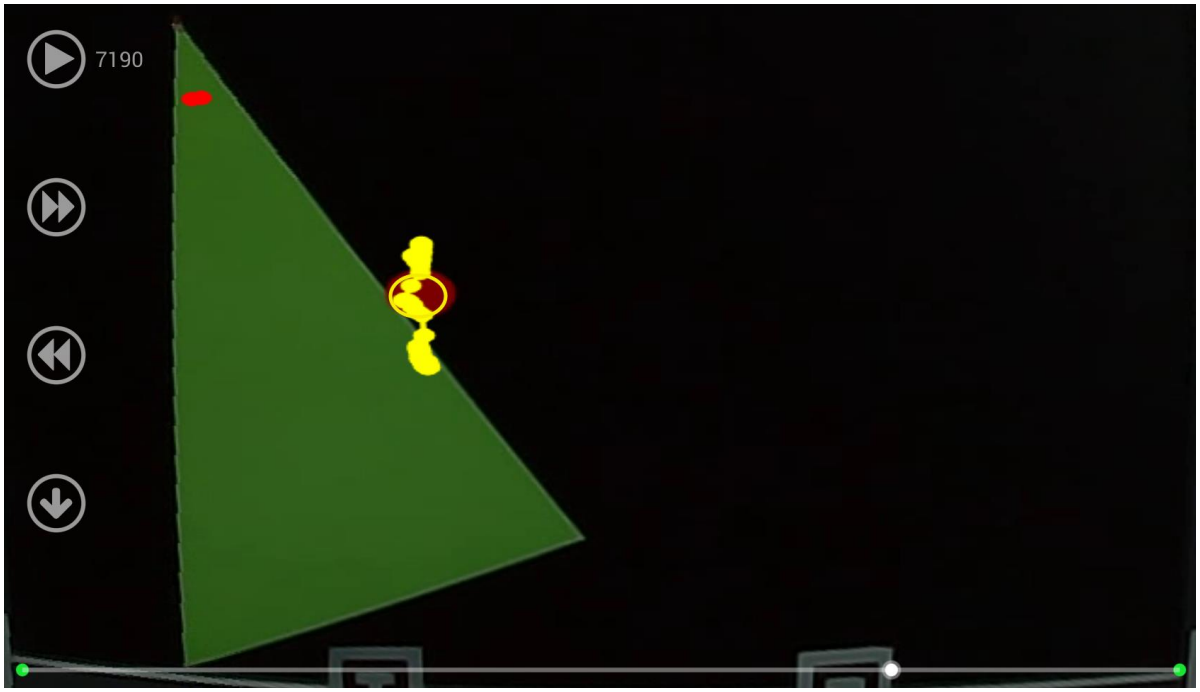
- Educational design provides an opportunity for the student to develop a new attentional anchor. Apparently, the student's AA does not necessarily repeat the tutor's AA.
- The role of the tutor is limited to facilitation of the student's motor activity and to distinguishing of the zone of proximal development that becomes a place for the further student-tutor collaboration.

Stage 4. Case 1. The tutor's intervention: coordinating the ideal forms



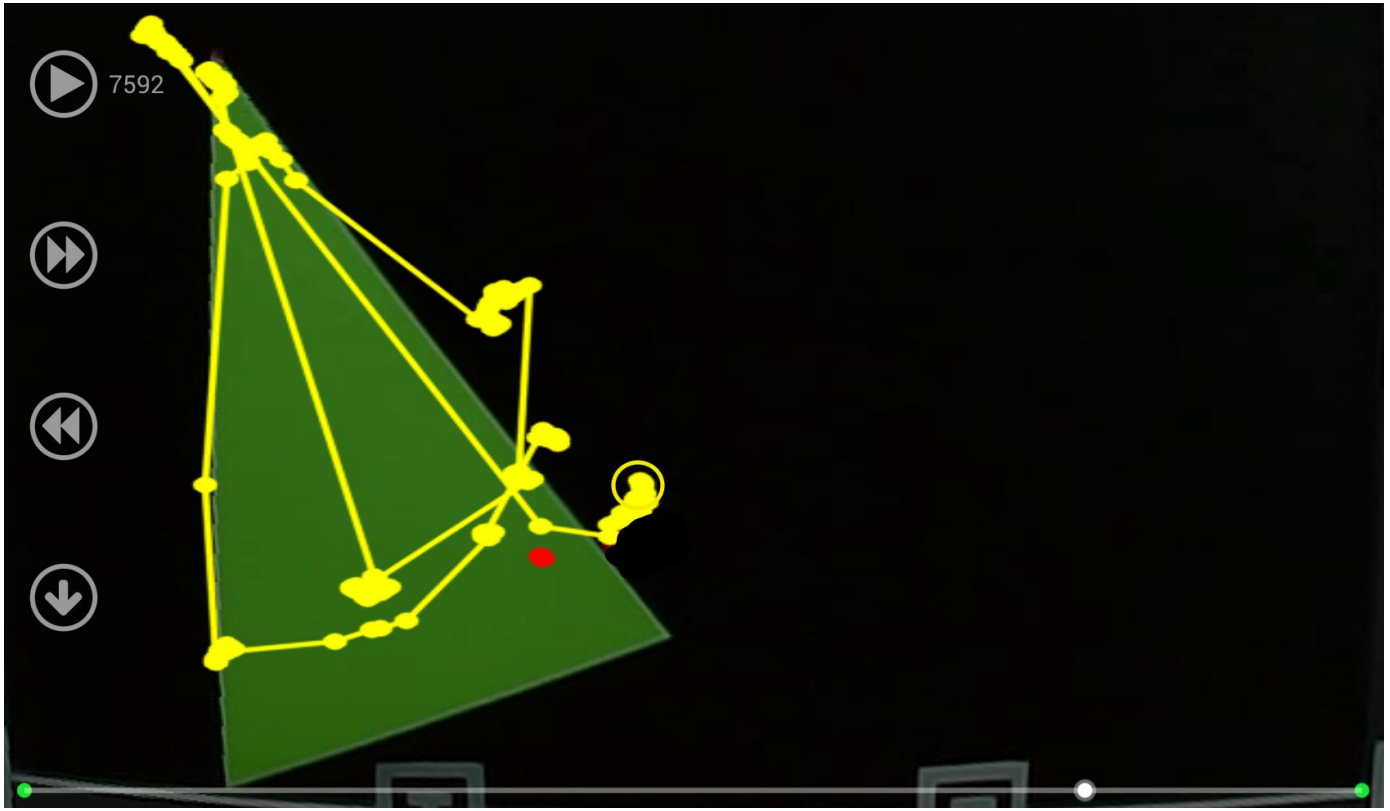
- T1: Could you think about the triangle? How do you manage to keep it green?
- S1: Alright… The triangle is obviously… (She explores only the right side of the triangle Fig 12 a) Oh, I am bad with geometrical terminology…

Stage 4. Case 1.
The tutor's intervention: coordinating the ideal forms



- T1: It's alright, you can explain, I will help you with the word.
- S1: It is not equilateral… but isosceles. I think it is how it is called.

Stage 4. Case 1.
The tutor's intervention: coordinating the ideal forms



- T1: Yes, what does it mean?
- S1: It means… that it has two sides of equal length (Fig 12 c).

Stage 4. Case 2. The tutor's intervention: coordinating the ideal forms

T2: Can you think of a rule that keeps it green?

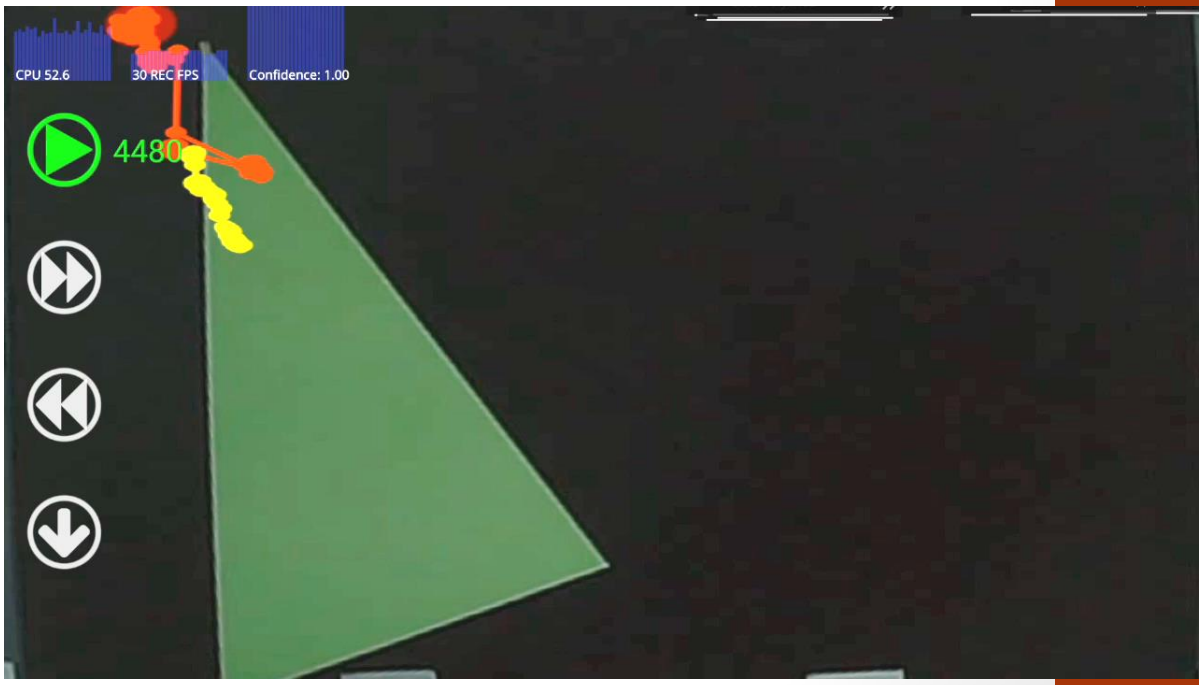
S2: I think it is a relation of this angle… Here, this angle will be the the same

T2: Which angle?

S2: I mean, the vertical… , the relation of vertical side to the diagonal side, the one which is long. The angle is the same all the time

T2: Even when it is like a line at the bottom [of the screen]?

S2: Yes… One moment… Let me check it!



Stage 4. Case 2.

T2: Do you think **the mystery is hidden here**? In this part?
S2: It starts from some determined [position]. That is if it is so… This length then blue, this length is also blue, and only at this particular length in becomes green.
T2: **The length of what**? What are you altering?
S2: The length of…. A-a-a… [pause about 6 seconds**] the length of one of triangle's sides**?
T2: **Only one side**?
S2: No… **the interrelation** [between two sides].
T2: Yes… and what is the interrelation when it is green?
S2: 50 to 50.
T2: Equal?
S2: Yes… Yes-yes!!
T2: Try it once more now.
S2: Wow… funny, indeed, they are equal!

Stage 4.
The tutor's intervention: coordinating the ideal forms

Theoretical interpretation and educational significance

- Effective collaboration is happening within the student's ZDP: the tutor's intervention is helpful in case of sufficient personal experience.
- The dichotomy of
  - initiating versus responding to joint attention (Hecke et al., 2007; Schneider et al., 2016), student versus tutor led joint attention (Yu & Smith, 2016)

  appears to be misleading.
  - The tutor re-orients student's attention to her 'operational point' by additional semiotic means without spatial re-direction of attention.
- Two ideal forms, as they are separately elaborated in a personal embodied activity, are coordinated at the level of social communication.

Concluding highlights

1. There is intersubjective coupling between perception-action systems of a tutor and a student. However, the coupling does not mean exact coordination of perceptive strategies: a 'real' and an 'ideal' forms of perception may co-exist in one co-action.
2. Attentional anchors are activated not only by active performance but also by participatory action observation.
3. Attentional guidance might happen not only through spatial re-direction of attention but also through re-orientation within visual joint attention. This re-orientation provides an opportunity for the students' to acquire a new meaning of their focal entities and to *see* new objects.
4. The diversity of attentional anchors, as they are elaborated in personal embodied activity, is coordinated by the constitution of shared meaning in multiple semiotic means of social communication.

General conclusions

- Vygotsky's cultural-historical approach provides a helpful theoretical framework that might be enriched by contemporary data and enhanced by complex dynamical systems paradigm.
- Dual eye-tracking is an indispensable instrument for interaction in embodied design investigations. The quality of the data provided by the Pupil-labs eye-trackers dictate limitations for educational design and data analysis.
- All findings should be considered as preliminary due to the small sample size.

Thank you
for our joint attention