A Multimodal Approach to Coding Discourse:

Cooperation, Distributed Cognition, and Geometric Problem Solving

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A Collaborative Project

between Virginia Tech and University of Chicago researchers and undergraduate RA's

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Theoretical Frame

Two overriding principles: "*constructionism*: we should put learners in situations where they can construct and revise their own models...*collaboration*: if our concern is that students come to understand what is significant about models from a specifically mathematical point of view, then learning environments should foster discussion and and reflection upon these models." (Noss & Hoyles, p.389)

Artifact Mediation

"Explicit mediation involves the intentional introduction of signs into an ongoing flow of activity. In this case, the signs tend to be designed and introduced by an external agent, such as a tutor, who can help reorganize an activity in some way" (Wertsch, p.185)

Our Research

- Facilitate informal geometry via innovative learning strategies and technologies
- Focus on early elementary (PreK-3) education, an increasingly important demographic for theory and design
- Emphasize co-located interactions, sliding (unencumbered) between physical and virtual artifacts

Analyzing cooperation in group problem solving

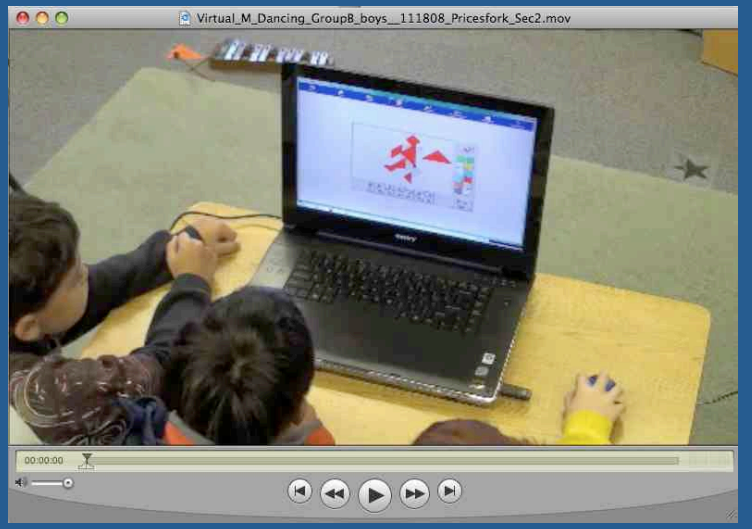
- “How does cooperation operate differently in virtual and non-virtual settings?”

- “How do children appropriate geometric principles differently in virtual/non-virtual settings?”

- Our research aims to identify children´s communicative strategies in a puzzle-solving setting and their potential for creating “distributed cognition” in mathematics learning context.

Solving puzzles in a group

- We selected two groups of 8 year old children: a group of three girls and a group of three boys.
- Each group was given a tangram puzzle to solve in two settings.
  - Physical: plastic pieces and board
  - Virtual: computer and mouse
- Video footage recorded from three angles to capture gestures.
- Although students were similar in age, they differed in their TEMA-tested math competency, grade level, gender, experience, etc.



Multimodal analysis of group interaction

- Cooperation is a difficult phenomenon to categorize and quantify. Why? Because interactive behavior takes place in many ways
  - in different modes of discourse-verbal, gestural, postural
  - on different levels of discourse-object, meta, and para.

- We found it more useful to identify intervals of heightened interaction, where we looked at an array of indices for cooperative behavior.

- We developed a system of coding that would allow us to track multiple verbal and nonverbal variables that index collaboration and cooperation, such as gaze, gesture, verbal utterances, physical manipulations of objects, etc.

Coreferences: units of discursive cohesion

Our basic tenant is that discursive cohesion is necessary for successful group activity, and furthermore that interlocutors establish discursive cohesion via references to the same thing—objects, ideas, and other speakers.

- **Object** : reference to object or place in the physical world
  - e.g., “this triangle” or “here”
- **Meta** : refers to the discourse itself, or to the problem solving process
  - e.g., “*that* wouldn´t work” (where *that* represents a previous utterance) or “this triangle goes *next*” or “we need to start over”
- **Para**: refers to the participants themselves, or emphasizes a speaker’s viewpoint
  - e.g., “it´s *your* turn,” or “I think” or “I got you”

- Coreferences tend to build upon one another, forming coreferential chains. These chains of cohesion comprise topics in the discourse.

Coalitions

Generally speaking, a coalition is a period in the discourse where the participants´ focuses are aligned on a single task, and where they seem especially responsive to one another.

M:	"I think this triangle goes right there"	V Obj/Para
M:	(tries to place small triangle in space created from the last move)	NV Obj
R:	(slides parallelogram back into place)	
M:	"um"	
L:	"no turn it this way"	V Obj/Meta
L:	(turns small triangle)	NV Obj
R:	(picks up other large triangle and holds it)	
M:	"I know this way"	V Meta/Para
M :	(slides triangle from under L's fingers and fits it in)	NV Obj/Para

Coalitions

- A given coreferential chain can span different speakers and can weave across different levels of discourse. We term this phenomenon a coalition.

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M :	(slides triangle from under L's fingers and fits it in)	NV Obj/Para

Patterns that identify coalitions

- In most cases, a coalition is marked by para-level comments bracketing at least one meta-level comment.
- This makes sense since participants in a new coalition first indicate their allegiance to the theme (para-level) and then indicate its significance in the discourse (meta-level).
- Such a pattern may be a signature of temporary coalitions that form around specific discourse themes.
- Why coalitions matter: we may be able to better understand pivotal moments in group collaboration

Temporality and methods of analysis for transcribing & coding discourse

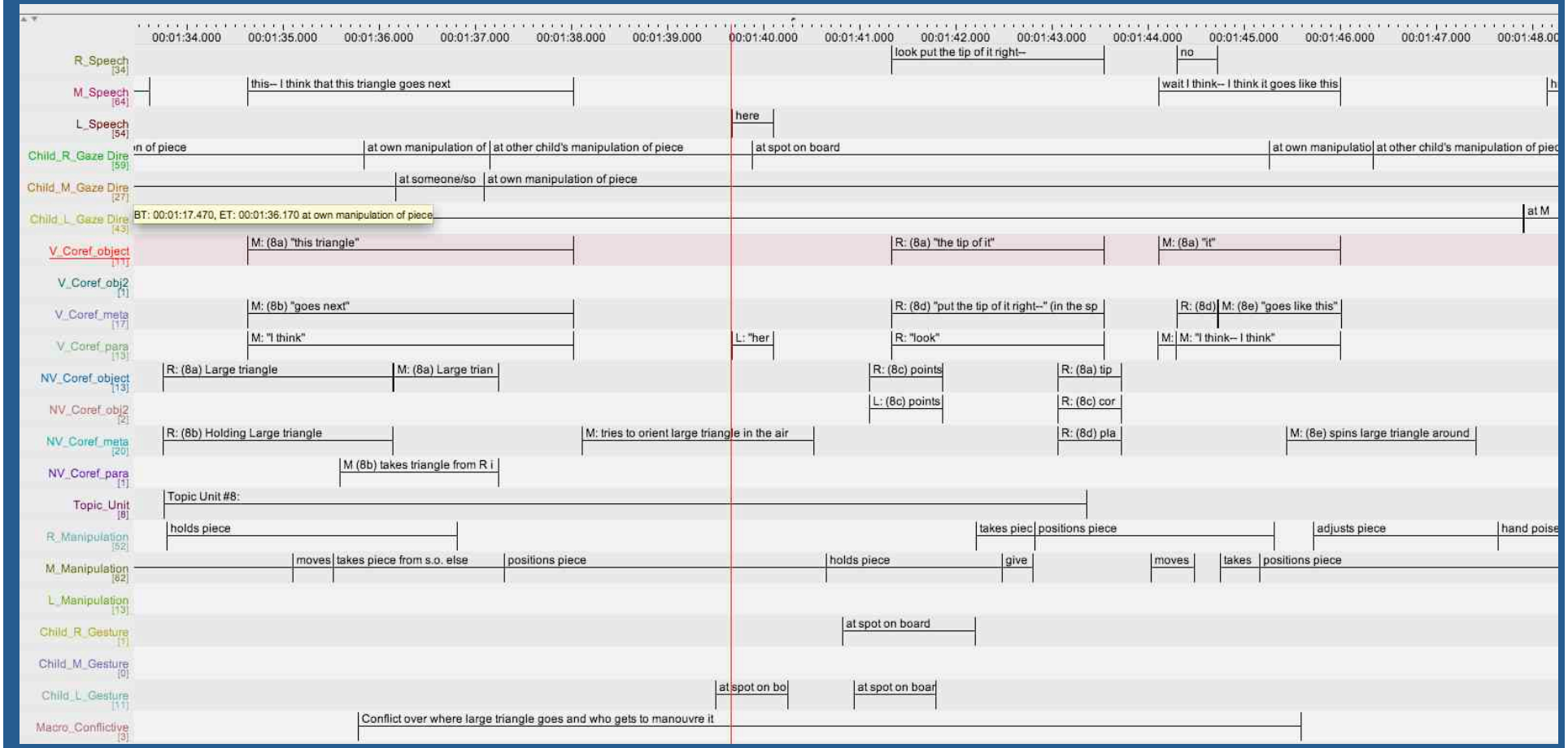
- Understanding temporality in an interaction is largely a function of how it is represented in the transcript
- Traditional [linear] transcript
  - distorts the sequence of events and interactions
  - cannot easily represent non-verbal behavior

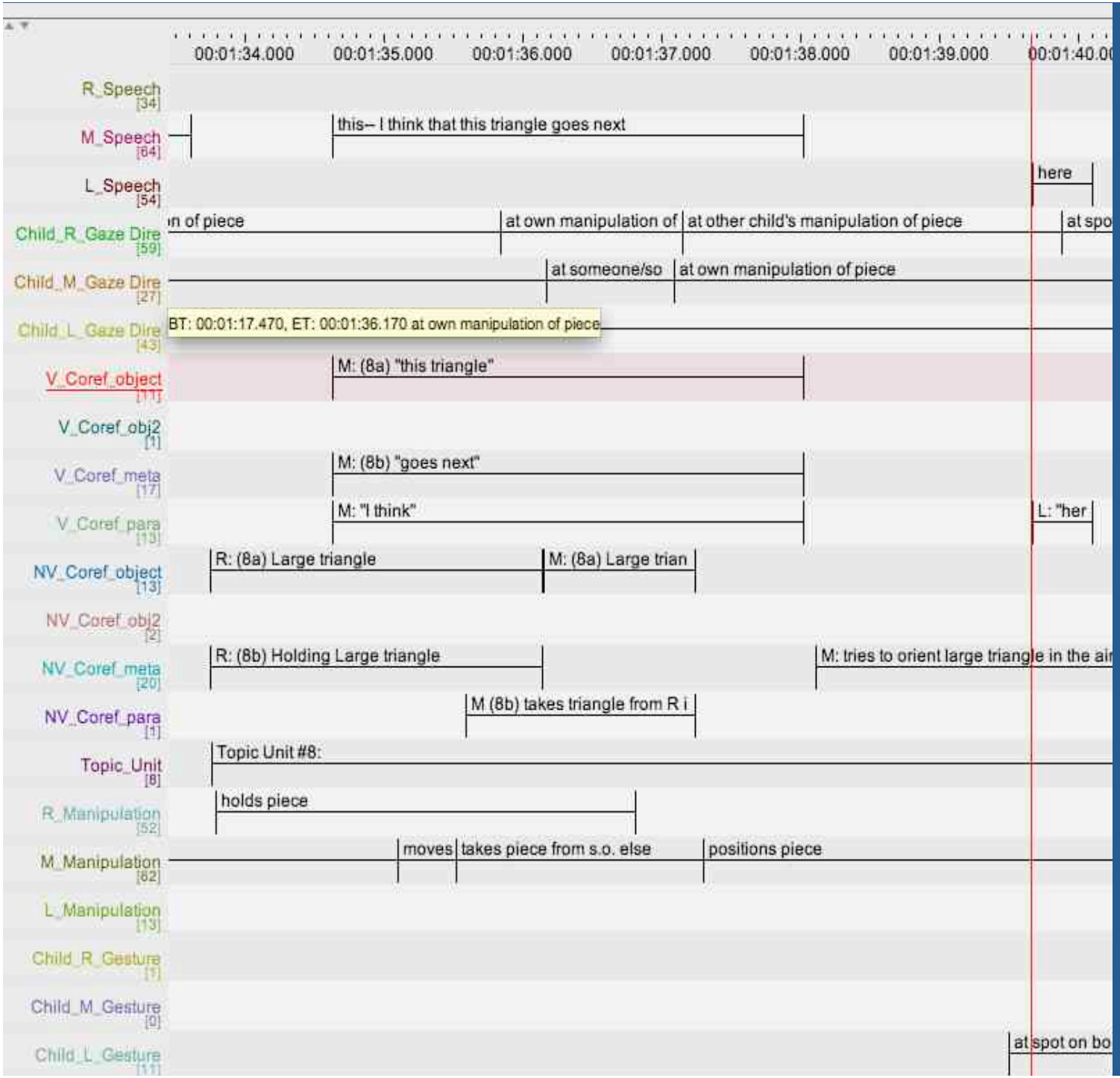
→ Elan allows us to capture sustained activity and overlapping events/levels.

Forming a Coalition: Transcript in Elan Interface

Girls' Physical, 1:35-1:49

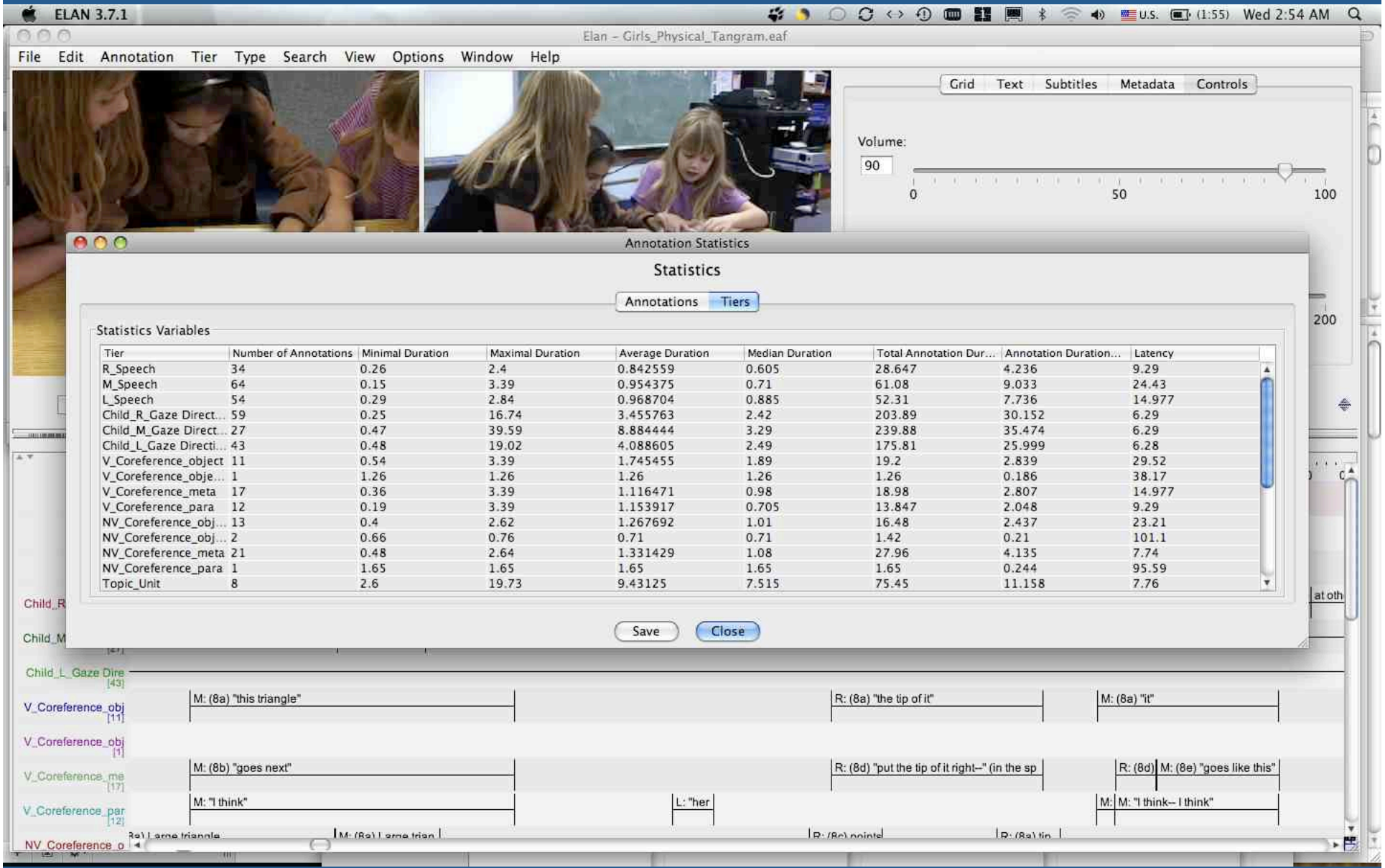
Brief Description of coalition: M takes large triangle from R and tries to fit it into the center. Both L and R point to a spot and advise M to put the tip of the triangle into a corner. R takes the piece from M and tries to fit it in. R realizes it won't fit and M takes it back from her. L looks on.





Elan Tiers

Speech
Gaze
Verbal Obj Coreference
Verbal Meta Coreference
Verbal Para Coreference
Non-verbal Obj. Coref.
Non-verval Meta Coref.
Non-verbal Para Coref.
Topic Unit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Statistics
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Statistics Variables
Tier | Number of Annotations | Minimal Duration | Maximal Duration | Average Duration | Median Duration | Total Annotation Dur... | Annotation Duration... | Latency
R_Speech | 34 | 0.26 | 2.4 | 0.842559 | 0.605 | 28.647 | 4.236 | 9.29
M_Speech | 64 | 0.15 | 3.39 | 0.954375 | 0.71 | 61.08 | 9.033 | 24.43
L_Speech | 54 | 0.29 | 2.84 | 0.968704 | 0.885 | 52.31 | 7.736 | 14.977
Child_R_Gaze Direct... | 59 | 0.25 | 16.74 | 3.455763 | 2.42 | 203.89 | 30.152 | 6.29
Child_M_Gaze Direct... | 27 | 0.47 | 39.59 | 8.884444 | 3.29 | 239.88 | 35.474 | 6.29
Child_L_Gaze Directi... | 43 | 0.48 | 19.02 | 4.088605 | 2.49 | 175.81 | 25.999 | 6.28
V_Coreference_object | 11 | 0.54 | 3.39 | 1.745455 | 1.89 | 19.2 | 2.839 | 29.52
V_Coreference_obje... | 1 | 1.26 | 1.26 | 1.26 | 1.26 | 1.26 | 0.186 | 38.17
V_Coreference_meta | 17 | 0.36 | 3.39 | 1.116471 | 0.98 | 18.98 | 2.807 | 14.977
V_Coreference_para | 12 | 0.19 | 3.39 | 1.153917 | 0.705 | 13.847 | 2.048 | 9.29
NV_Coreference_obj... | 13 | 0.4 | 2.62 | 1.267692 | 1.01 | 16.48 | 2.437 | 23.21
NV_Coreference_obj... | 2 | 0.66 | 0.76 | 0.71 | 0.71 | 1.42 | 0.21 | 101.1
NV_Coreference_meta | 21 | 0.48 | 2.64 | 1.331429 | 1.08 | 27.96 | 4.135 | 7.74
NV_Coreference_para | 1 | 1.65 | 1.65 | 1.65 | 1.65 | 1.65 | 0.244 | 95.59
Topic_Unit | 8 | 2.6 | 19.73 | 9.43125 | 7.515 | 75.45 | 11.158 | 7.76
Save
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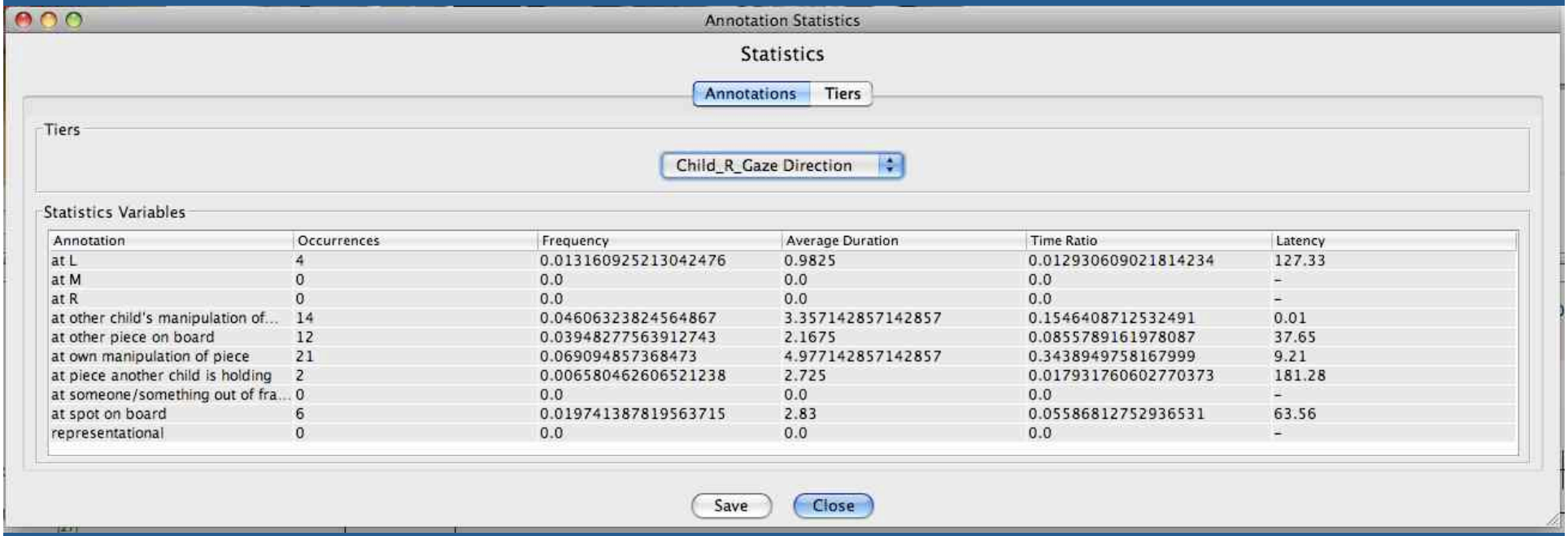
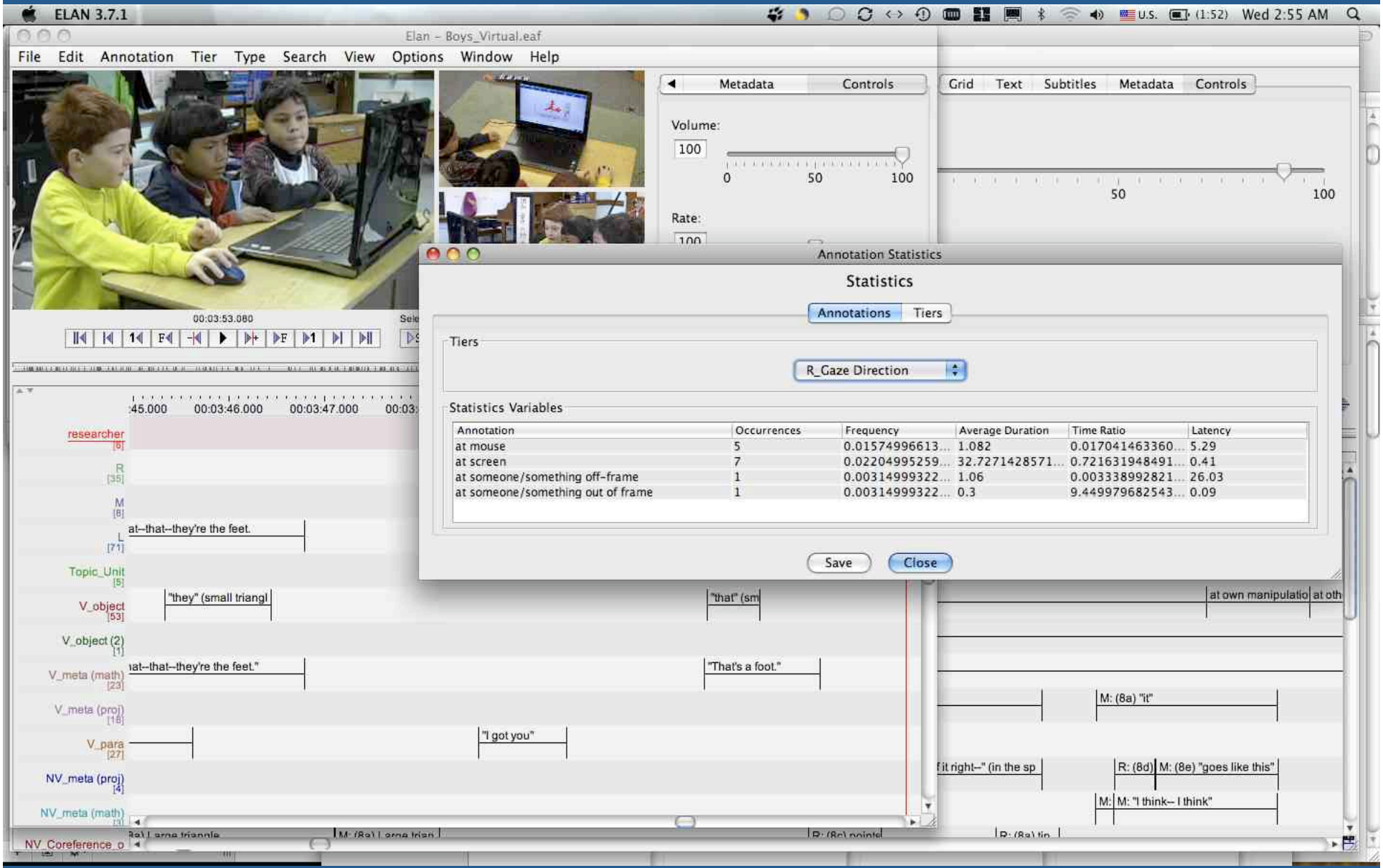
Child_L_Gaze Dire
V_Coreference_obj
V_Coreference_obj
V_Coreference_me
V_Coreference_par
NV_Coreference_o
M: (8a) "this triangle"
R: (8a) "the tip of it"
M: (8a) "it"
M: (8b) "goes next"
R: (8d) "put the tip of it right–" (in the sp
R: (8d)
M: (8e) "goes like this"
M: "I think"
L: "her
M: "I think– I think"



Annotation	Occurrences	Frequency	Average Duration	Time Ratio	Latency
at L	4	0.013160925213042476	0.9825	0.012930609021814234	127.33
at M	0	0.0	0.0	0.0	-
at R	0	0.0	0.0	0.0	-
at other child's manipulation of...	14	0.04606323824564867	3.357142857142857	0.1546408712532491	0.01
at other piece on board	12	0.03948277563912743	2.1675	0.0855789161978087	37.65
at own manipulation of piece	21	0.069094857368473	4.977142857142857	0.3438949758167999	9.21
at piece another child is holding	2	0.006580462606521238	2.725	0.017931760602770373	181.28
at someone/something out of fra...	0	0.0	0.0	0.0	-
at spot on board	6	0.019741387819563715	2.83	0.05586812752936531	63.56
representational	0	0.0	0.0	0.0	-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at mouse | 5 | 0.01574996613... | 1.082 | 0.017041463360... | 5.29
at screen | 7 | 0.02204995259... | 32.7271428571... | 0.721631948491... | 0.41
at someone/something off-frame | 1 | 0.00314999322... | 1.06 | 0.003338992821... | 26.03
at someone/something out of frame | 1 | 0.00314999322... | 0.3 | 9.449979682543... | 0.09
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researcher
R
M
L
Topic_Unit
V_object
V_object (2)
V_meta (math)
V_meta (proj)
V_para
NV_meta (proj)
NV_meta (math)
NV_Coreference_o
at--that--they're the feet.
"they" (small triangl
"that" (sm
at own manipulatio
at oth
at--that--they're the feet."
"That's a foot."
M: (8a) "it"
"I got you"
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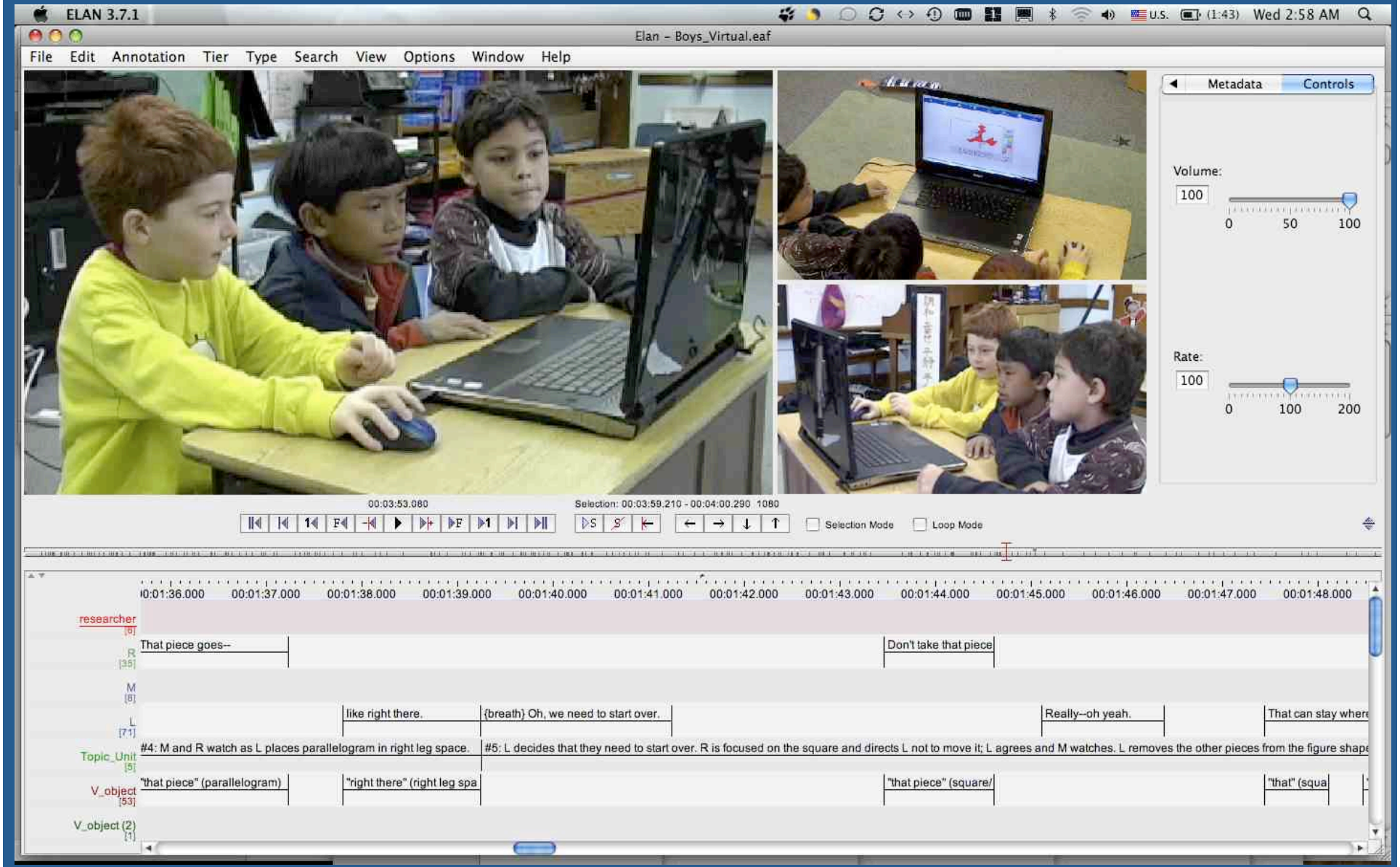
R: (8d)
M: (8e) "goes like this"
M: "I think-- I think"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researcher [6]
R [35]
That piece goes--
Don't take that piece
M [8]
L [71]
like right there.
{breath} Oh, we need to start over.
Really--oh yeah.
That can stay where
Topic_Unit [5]
#4: M and R watch as L places parallelogram in right leg space.
#5: L decides that they need to start over. R is focused on the square and directs L not to move it; L agrees and M watches. L removes the other pieces from the figure shape
V_object [53]
"that piece" (parallelogram)
"right there" (right leg spa
"that piece" (square/
"that" (squa
V_object (2) [1]

Limitations of Elan

- Elan interface is unwieldy and hard to read!
- Difficult to see the linkage between verbal and nonverbal activity, even with the View Statistics feature.
- Need a “linear” transcript to serve as a sequential map of the interaction.
  - Structural features
- How can we visually represent both structural features and temporality?

Extended Transcript: Physical Setting, Girls (0:00-1:35)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
	Time (mm:ss)	Participant	Speech/Action	Gaze			Medium of cohesion	Focus (M, L, R)			Topic Unit	Number of participants with common focus	Initiator of topic unit	Initiator of coalition
				L	M	R								
		R/M/L	(try to open the bag)	M/m	M/m	M/m	NV obj (mani)					3		
		M	(whisks bag away)	M/m	M/m	M/m	NV obj (mani)					3		
	0:09	R	"Taliah"	M	M/m	M/m	V para					3		
	0:14	M	(dumps pieces on table)	M/m	M/m	M/m	NV obj (mani)				TU 1 (R,M,L) = opening bag	3		
	0:15	L	"good job"	L/m	M/m	M/m	V para/meta	Opening the bag (				3		
	0:17-0:19	M	(slides triangle around vigorously)	M/m	M/m	R/m	NV obj (mani)	M is playing with the piece and L signals that it is time to start the puzzle		R focuses on small triangle in foot space	TU 2 (M,L) = M's playing with the	2		
	0:19	R	(takes small triangle from M)	M/m	M/m	R/m	NV obj para					2		
	0:21	L	"okay"	M/m	M/m	M/m	V meta/para					2	M	L
		L	"(())"	B	M/m	R/m						2		
		R	(tries to fit small triangle in a protruding place in outline)	R/m	M/m	R/m	NV obj (mani)	M is concentrating on placing the large triangle in the center.	L turns her attention to R's small triangle in the foot space and suggests putting the parallelogram there instead. When she sees that the small triangle fits, she withdraws her suggestion.			2		
		L	(shows R the parallelogram)	R/m	M/m	R/m	NV obj/meta (gest)					2		
		L	"hey what about that one"	B	M/m	R/m	V obj/meta					2		
		M	"(())go here"	R/m	B	R/m	V obj					2		
		M	(places large triangle in space)	R/m	M/m	R/m	NV obj (mani)					2		
		L	"what about that one"	R/m	M/m	R/m	V obj/meta					2		
		M	"um"	R/m	M/m	R/m					TU 3 (R,L) = small triangle/parallelogram	2		
		M	(places square in space)	R/m	M/m	R/m	NV obj (mani)					2		
		M	"square here"	B	M/m		V obj	M focuses on the square in the head space				2		
		R	(fits small triangle in space)	B	M/m		NV obj (mani)					2	R	L
		L	"oh no that fits"	B	B	R/m	V meta					0		
		M	"um"	L/m	B	R/m		L focuses on small triangle she is holding, and places it on side space. M watches. M moves L's piece out of the way, placing the parallellogram there instead. L		R concentrates on fitting the medium triangle into the leg space	TU 4 (L,M) = small triangle 2 and parallelogram	2		
		R	(tries to fit medium triangle in space)	L/m	L/m	R/m	NV obj (mani)					2		
		M	"oopsy"	L/m	L/m	R/m						2		
		L	(places small triangle in space on left)	L/m	L/m	R/m	NV obj (mani)					2		
		M	(moves triangle L just placed and places parallelogram instead)	M/m	M/m	R/m	NV obj/meta (mani)					2	L	M
		M	"I think this goes here"	M/m	M/m	M/m	V obj/para					3		
		M	(slides large triangle slightly out of place to fit parallelogram)	M/m	M/m	M/m						3		
		M	"I think"	M/m	M/m	B						3		
		R	(slides large triangle back in place, parallelogram slides out)	M/m	R/m	R/m						3		
		M	"okay"	M/m	M/m	R/m	V meta					3		
		L	"no"	M/m	M/m	R/m	V meta					3		
		L	(points at space in outline)	B	L/g	R/m	NV obj/meta (gest)					3		
		M	"wait"	M/m	M/m	R/m	V para					3		
		M	(slides parallelogram down, large triangle slides out)	M/m	M/m	R/m						3		
		M	"this way"	M/m	M/m	R/m	V obj	R looks at what M is doing briefly, and then tries to correct the large triangle that M keeps sliding out in order to fit in the parallelogram. L looks on. Then L points out the impossibility of M's placement.				3		
		L	"see the white piece"	M/m	M/m	R/m	V meta					3		
		M	"what"	B	B	R/m	V para					3		
		R	(slides large triangle back in place, parallelogram slides out)	R/m	R/m	R/m	NV obj (mani)					3		
		R	"(()) goes there" (whispered)	M/m	M/m	R/m	V obj			R shifts her focus from parallelogram/ large triangle issue to the	TU 5 (M,L and R) = where to place the parallelogram	2		
		R	(slides square back in place)	M/m	M/m	R/m						2		
		M	(slides parallelogram back so it fits into another space)	M/m	M/m	R/m	NV obj (mani)					2		
		M	"(()) yeah right there"	M/m	M/m	R/m	V obj/meta	M moves parallelogram further back. L watches.				2		
		L	(reaches for parallelogram, but withdraws)	B	B	R/m						2	M	L
		R	(places medium triangle in space)	B	B	R/m				R places medium		2		
		M	"I think this triangle goes right there"	M/m	M/m	R/m	V obj					2		

Distinguishing between two types of meta-level coreferences

- "**Mathematic**" coreferences– alludes to geometric/ mathematic principles and properties of puzzle pieces
  - ex. "that fits" or "it keeps leaving that white space"

- "**Project**" coreferences – adheres to collaborative problem-solving strategies or cooperation
  - ex. "let´s start over" or "my turn goes next"

- Why this matters: differentiating between types of metacognition is useful in understanding development of collaborative and problem-solving skills.
- Both types are key to organization of distributed cognition.

Time as an explicit topic of discourse

- Children often produced meta-commentary on time itself
  - Ex. “We´ve only got three minutes left” or “Taliah´s had the mouse for a long time”
- In the virtual setting, turn taking was largely dependent on time
  - Mouse sharing
  - Timed activity

Initial Findings of our Research

- Suggests that children communicate more overall in virtual setting than in the physical setting.
- Focus (gaze, verbal & nonverbal coreference) is aligned more often in virtual setting than physical setting.
- Concentration of meta and para-level coreferences at beginning and ending of topic unit. (“sandwich” theory)

Initial Findings of our Research

- More meta coreferences (mathematic and project-oriented) overall in virtual setting

- Explore patterned dynamics reflective of
  - gender differences?
  - math competency?
  - preexisting friendships among participants?

Going further

- Larger data pool
- Gaze tracking
- Identifying recurring patterns over time
  - "modes of use"?
  - Using Elan software
- Lag sequential analysis
- Markov models
- Understanding play/freeform/"off task" activity as part of collaborative trajectory

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