(Gaze) Analytics: where do we stand ?

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http://cede.epfl.ch
http://www.dualeyetracking.org

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

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Headquarter
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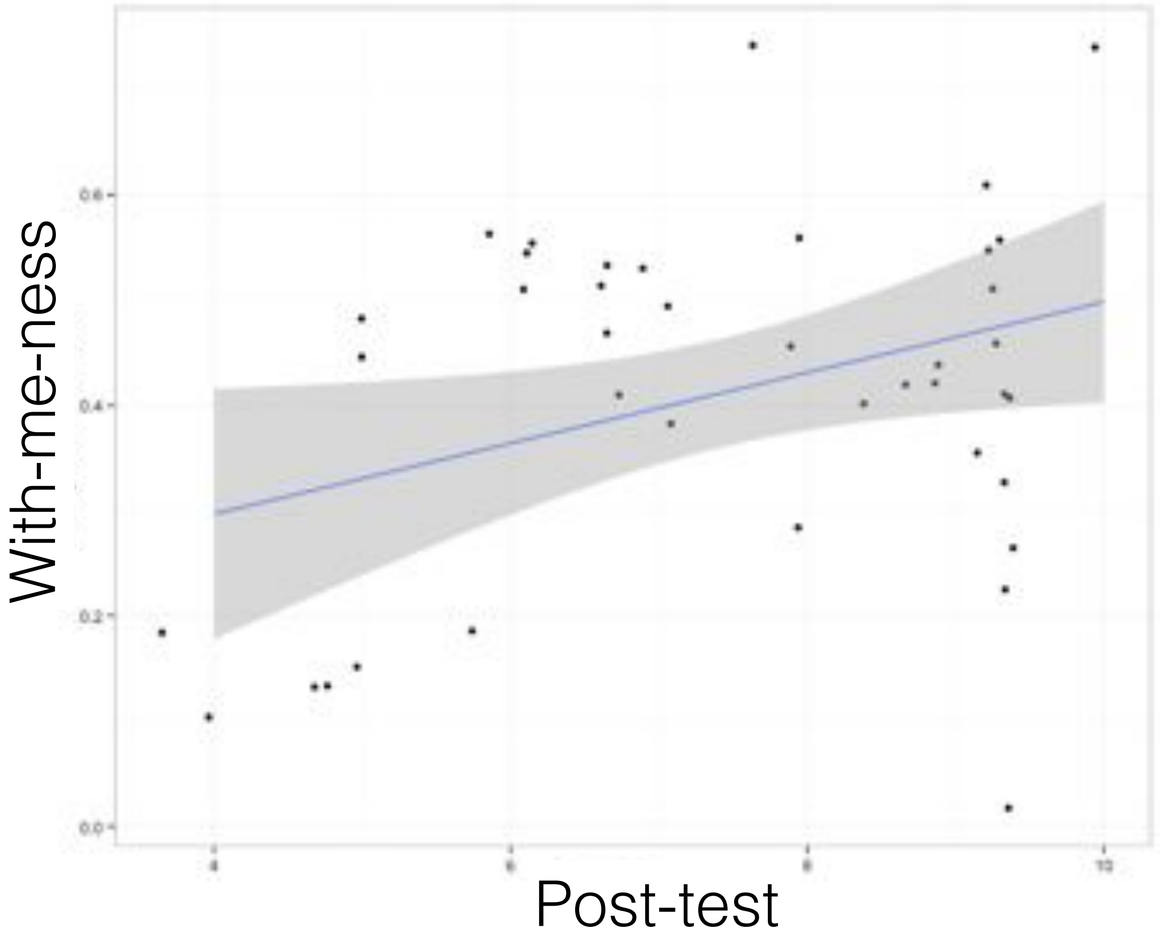
Eye track you

Eye tracking experiment on MOOC Video

Following teacher's references

Gaze of students' watching Scala course by Prof. Martin Odersky (EPFL, Switzerland)

K. Sharma, P. Jermann, P. Dillenbourg
@ CHILI – http://chili.epfl.ch
Supported by the Swiss National Science Foundation
(Grants CR1211_132996 and PZ00P2_126611)

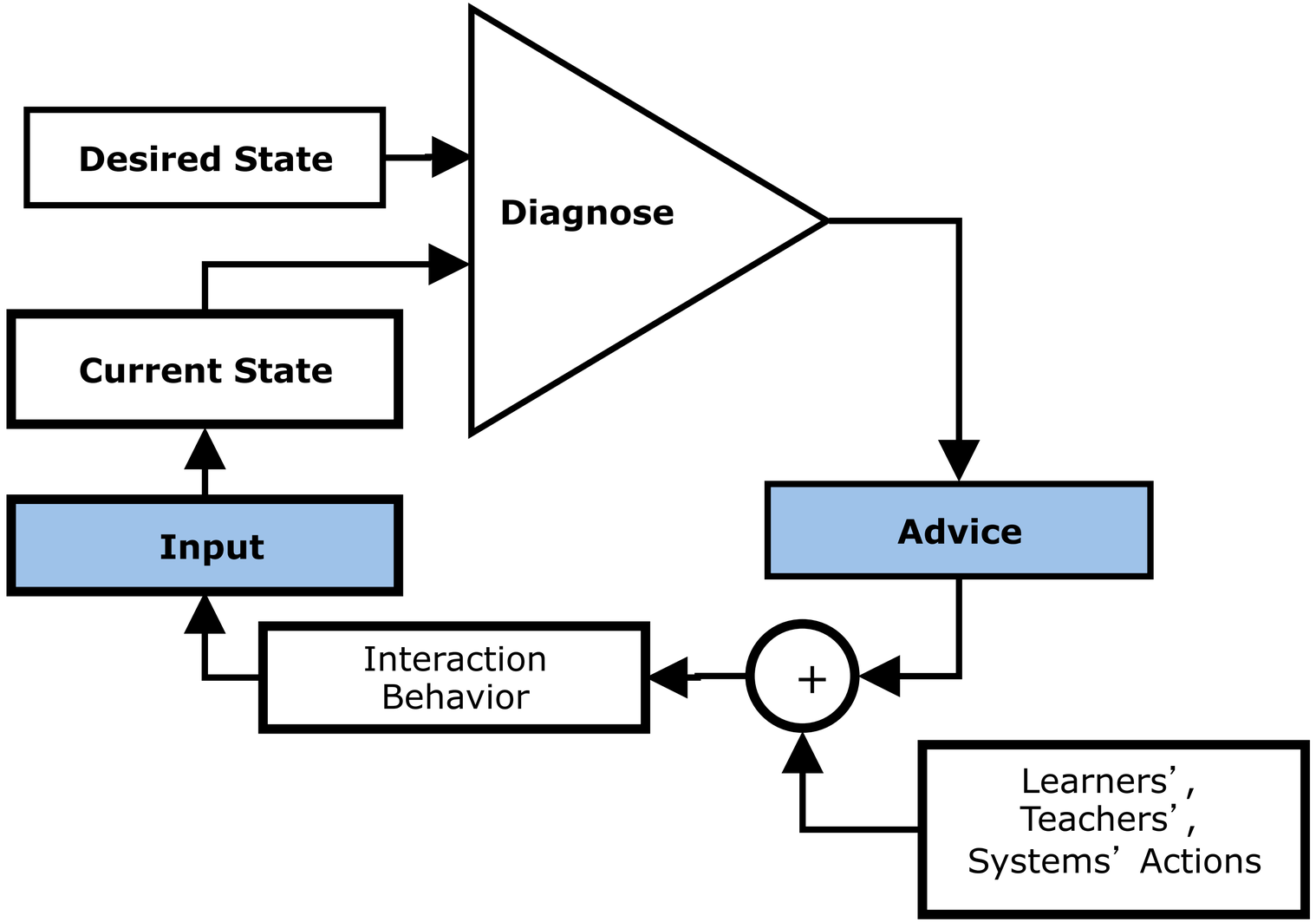


- Perceptual With-me-ness
  - Entry-time delay
  - First visit duration
  - Re-visits
- Conceptual with-me-ness
  - Textual references

Outline

Regulation Framework
Example 1: Gaze
Example 2: Clickstream
Analytics Rationale

Analytics = real-time “research” for action control



Jermann, P., Soller, A., & Muehlenbrock, M. (2001). - From mirroring to guiding: A review of the state of art technology for supporting collaborative learning

TABLE 1
Time Scale of Human Action

Scale (sec)	*Time Units*	*System*	*World (theory)*
10^{7}	months		SOCIAL BAND
10^{6}	weeks		
10^{5}	days		
10^{4}	hours	Task	RATIONAL BAND
10^{3}	10min	Task	
10^{2}	minutes	Task	
10^{1}	10sec	Unit task	COGNITIVE BAND
10^{0}	1sec	Operations	
10^{-1}	100ms	Deliberate act	
10^{-2}	10ms	Neural circuit	BIOLOGICAL BAND
10^{-3}	1ms	Neuron	
10^{-4}	100μs	Organelle	

From *Unified Theories of Cognition* by A.N. Newell, 1990, Ch. 3, p.122.

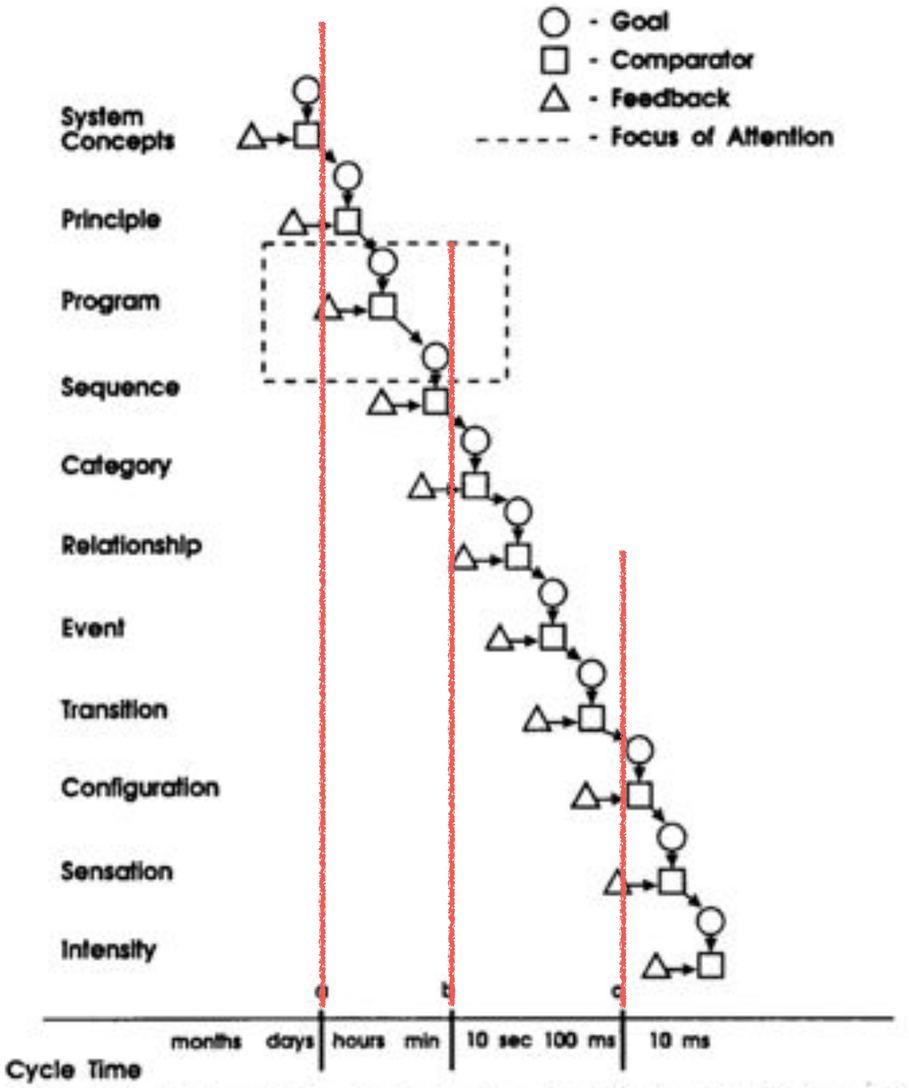


FIG. 2. Hierarchical organisation of control systems with shifting band signifying focus of attention. Note: The hash marks labelled a, b, and c correspond to the boundaries between social, rational, cognitive, and biological levels respectively.

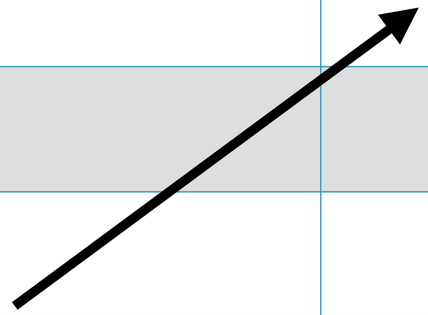
Lord, R. G., & Levy, P. E. (1994). Moving from Cognition to Action: A Control Theory Perspective. Applied Psychology: An International Review, 43(3), 335- 398.

Time scales

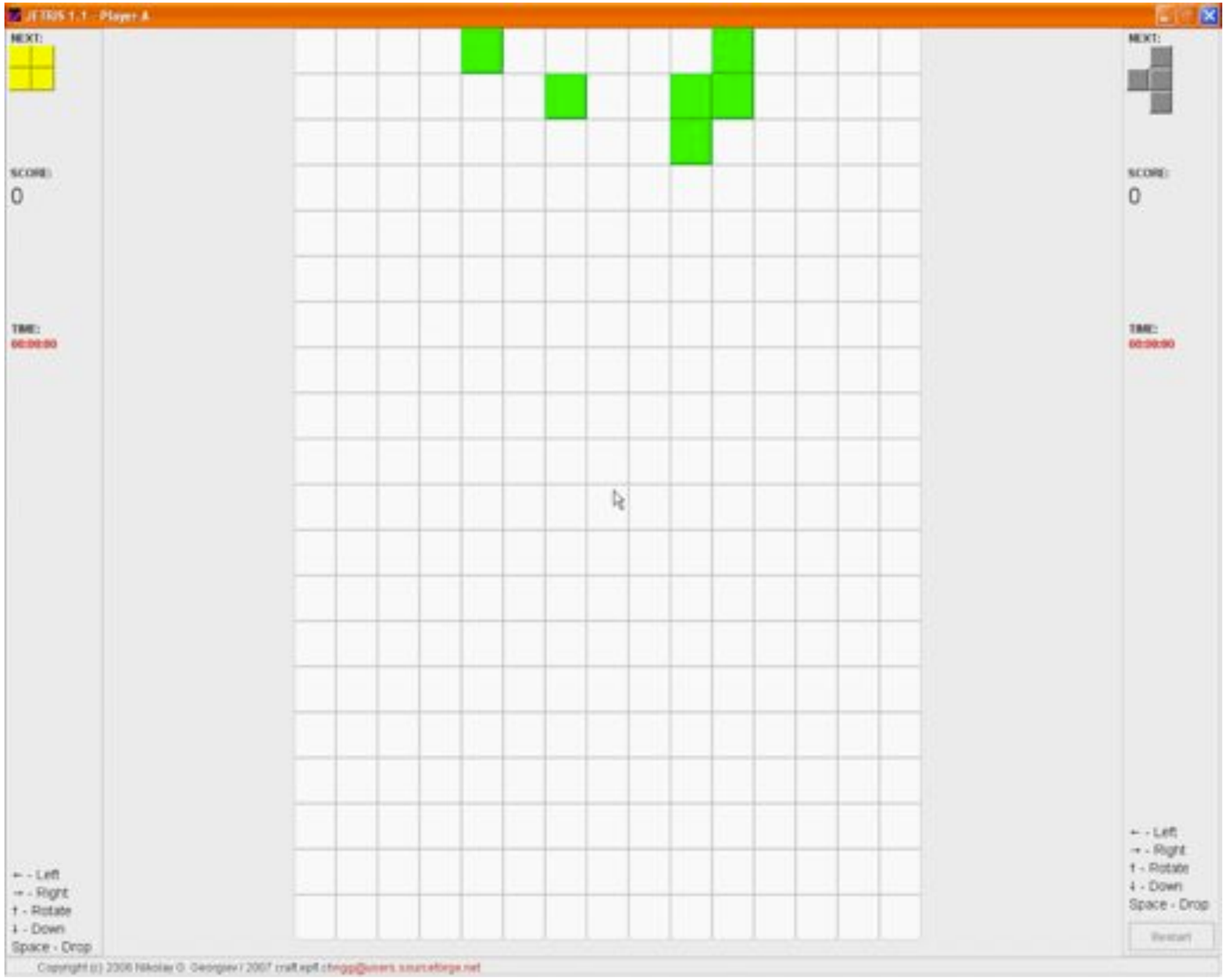
Time	Collaboration / CSCL	MOOCs
10 days [1'000'000 sec]		Completing the course
1 day [100'000 sec]		Completing a week
3 hours [10'000 sec]		Doing assignments
15 minutes [1'000 sec]	Building a concept map	Watching a video Doing a quizz
100 sec [1000 fixations]	Understanding Interaction quality	Writing a message
10 sec [100 fixations]	Dialogue	Reading a message
1sec [10 fixations]	Grounding Referring	

The challenge

Time	Gaze	Collaboration / CSCL
3 hours [10'000 sec]		
15 minutes [1'000 sec]		Building a concept map
100 sec [1000 fixations]		Understanding Interaction quality
10 sec [100 fixations]		Dialogue
1sec [10 fixations]		Grounding Referring
100 ms [250 samples]	fixation	
4ms [1 sample]	raw data	

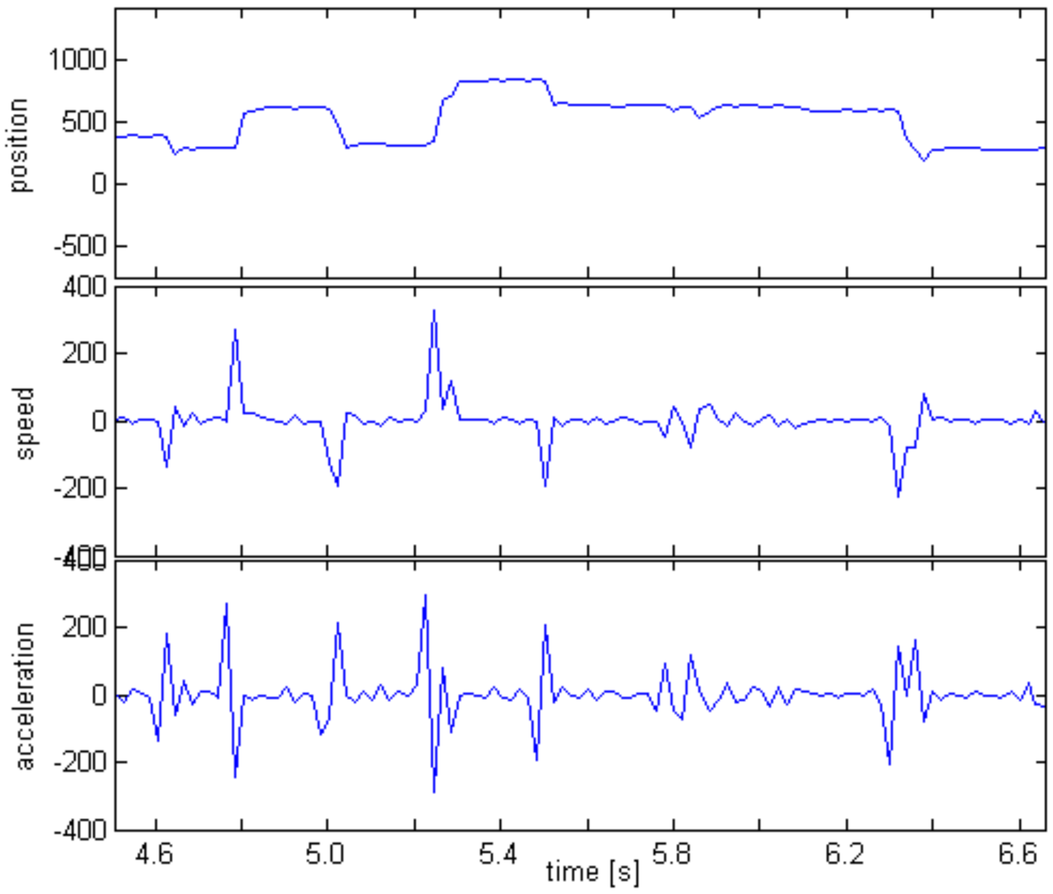


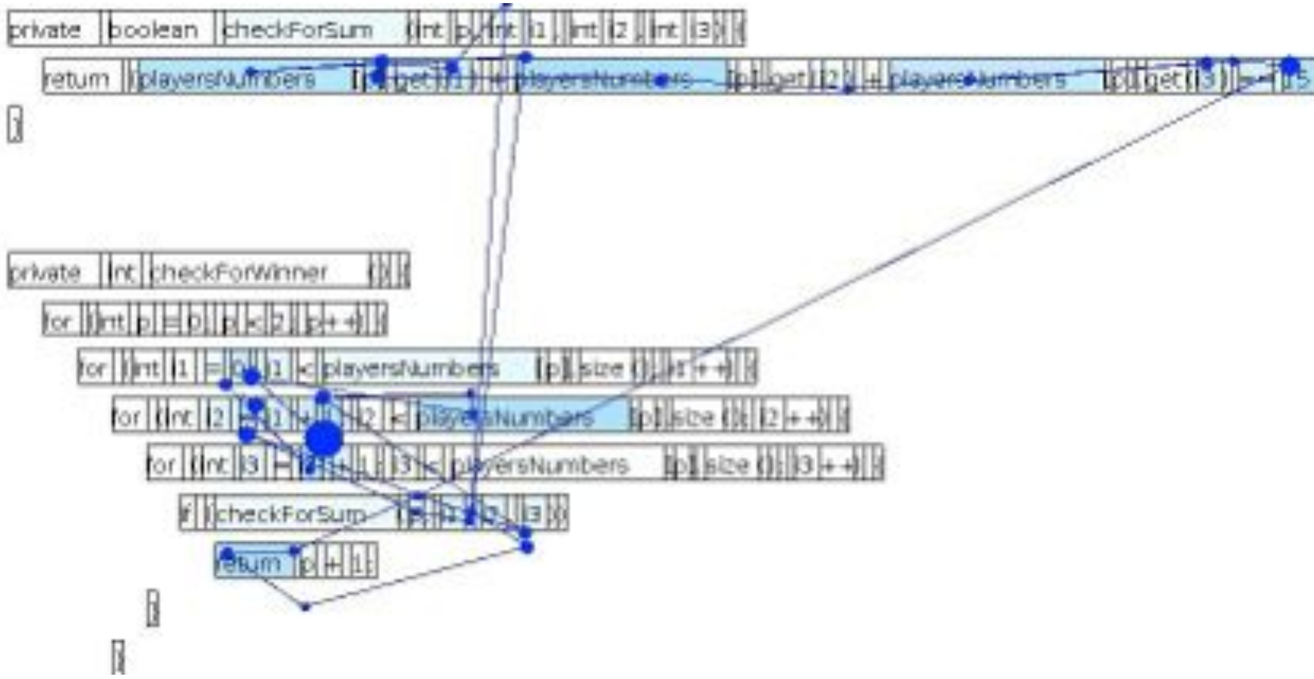
Dual Eye-Tracking [2008-2013]



Kirsh & Maglio, 1994; Underwood, 2005; Jermann, P., Nüssli, M.-A., & Li, W. (2010)

Fixations, Saccades and Areas of Interest





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1sec [10 fixations]	eye-voice span voice-eye span	Grounding Referring
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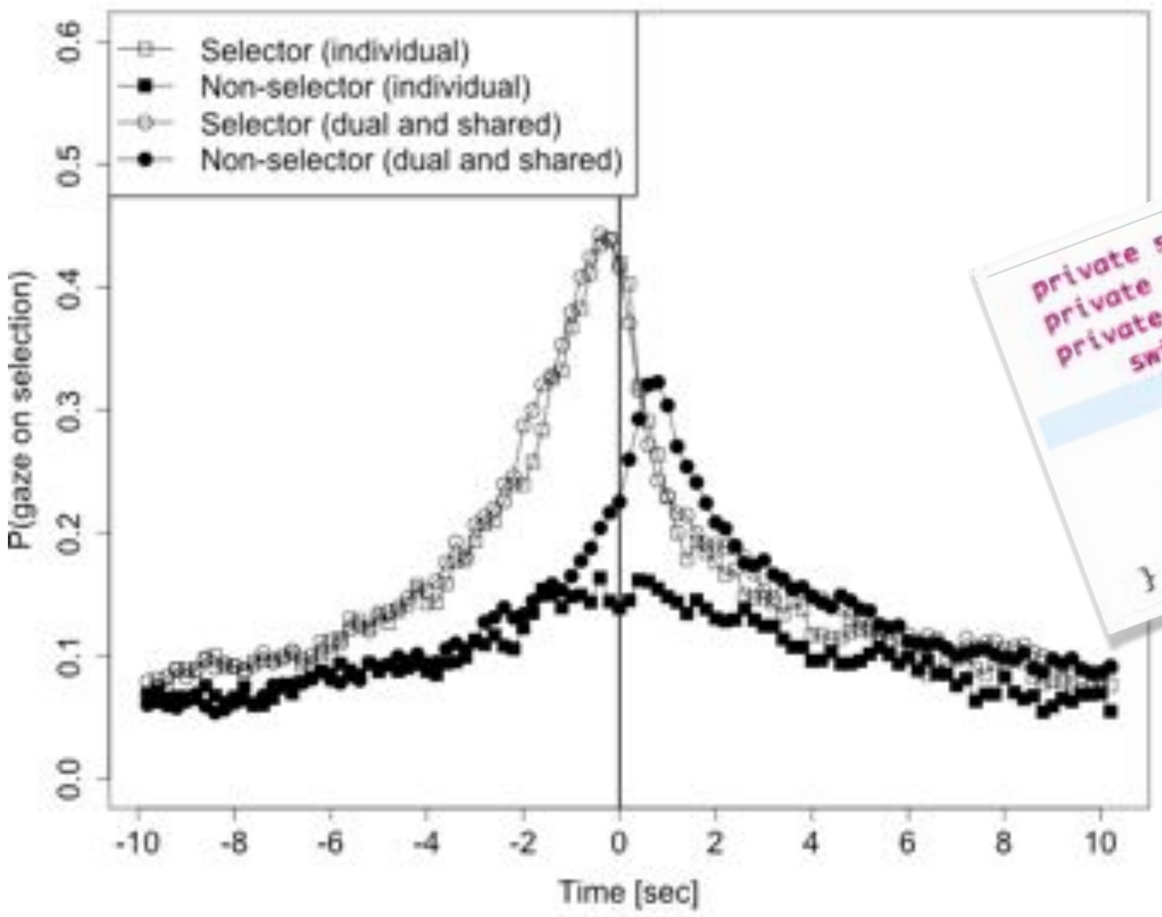
4ms [1 sample]	raw data	

1sec [10 fixations]	eye-voice span voice-eye span	Grounding Referring

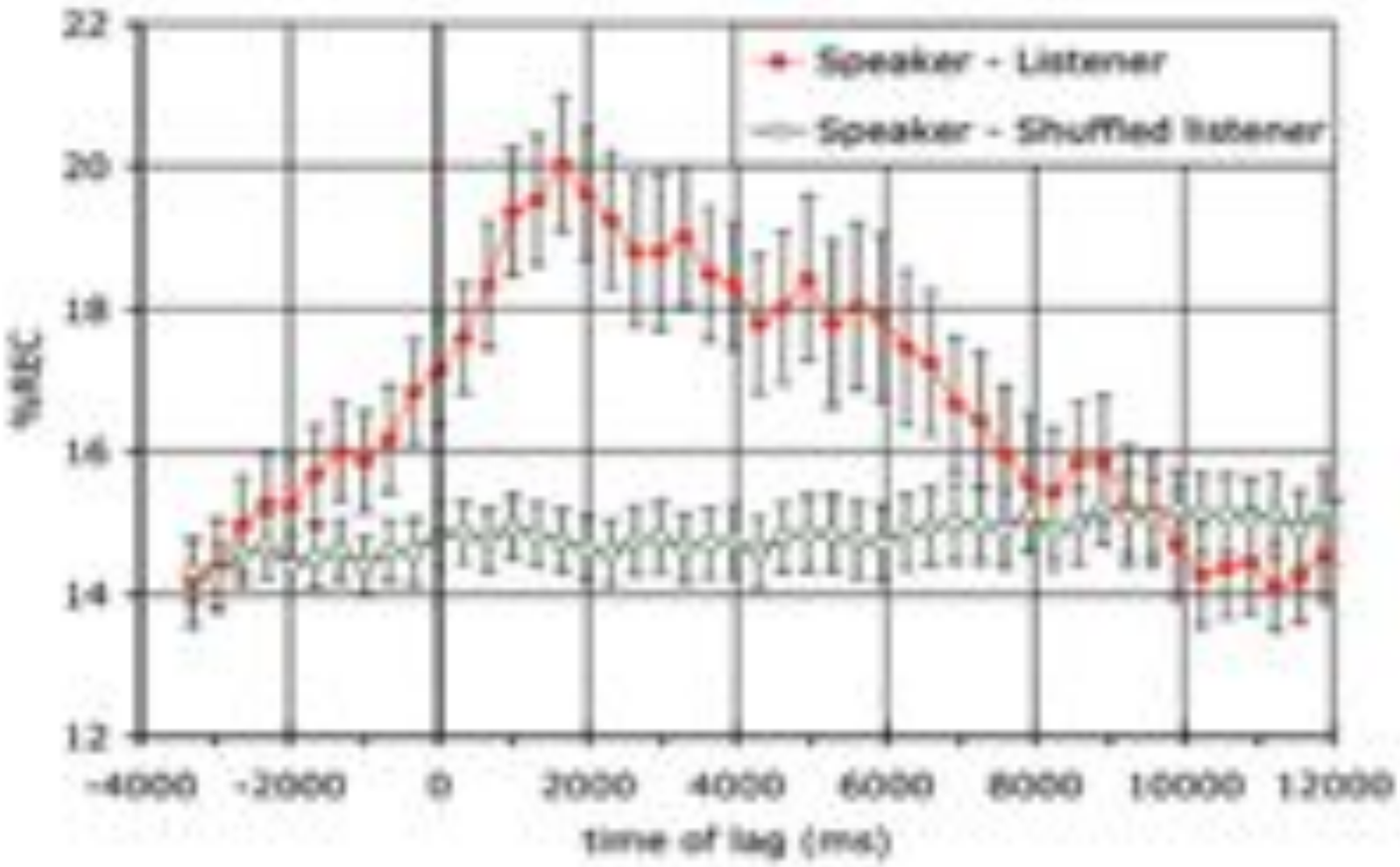



```
private static final Rectangle BEFORE_START_RECORDING_TEXT_SOLO = new Rectang
private static final Rectangle BEFORE_START_RECORDING_TEXT_DUO = new Rectang
private static final Rectangle BEFORE_START_RECORDING_TEXT(int expTypeId) {
    switch (expTypeId) {
        case GlobalConstants.SOLO_EXPERIMENT_TYPE_ID:return BEFORE_START_R
        case GlobalConstants.CSCW_EXPERIMENT_TYPE_ID:return BEFORE_START_
        case GlobalConstants.DUO_TEST_EXPERIMENT_TYPE_ID:return BEFORE_ST
    }
    return null;
}
```

Griffin and Bock (2000); Allopenna et al., 2000; **Jermann & Nüssli (2012)**

Cross-recurrence

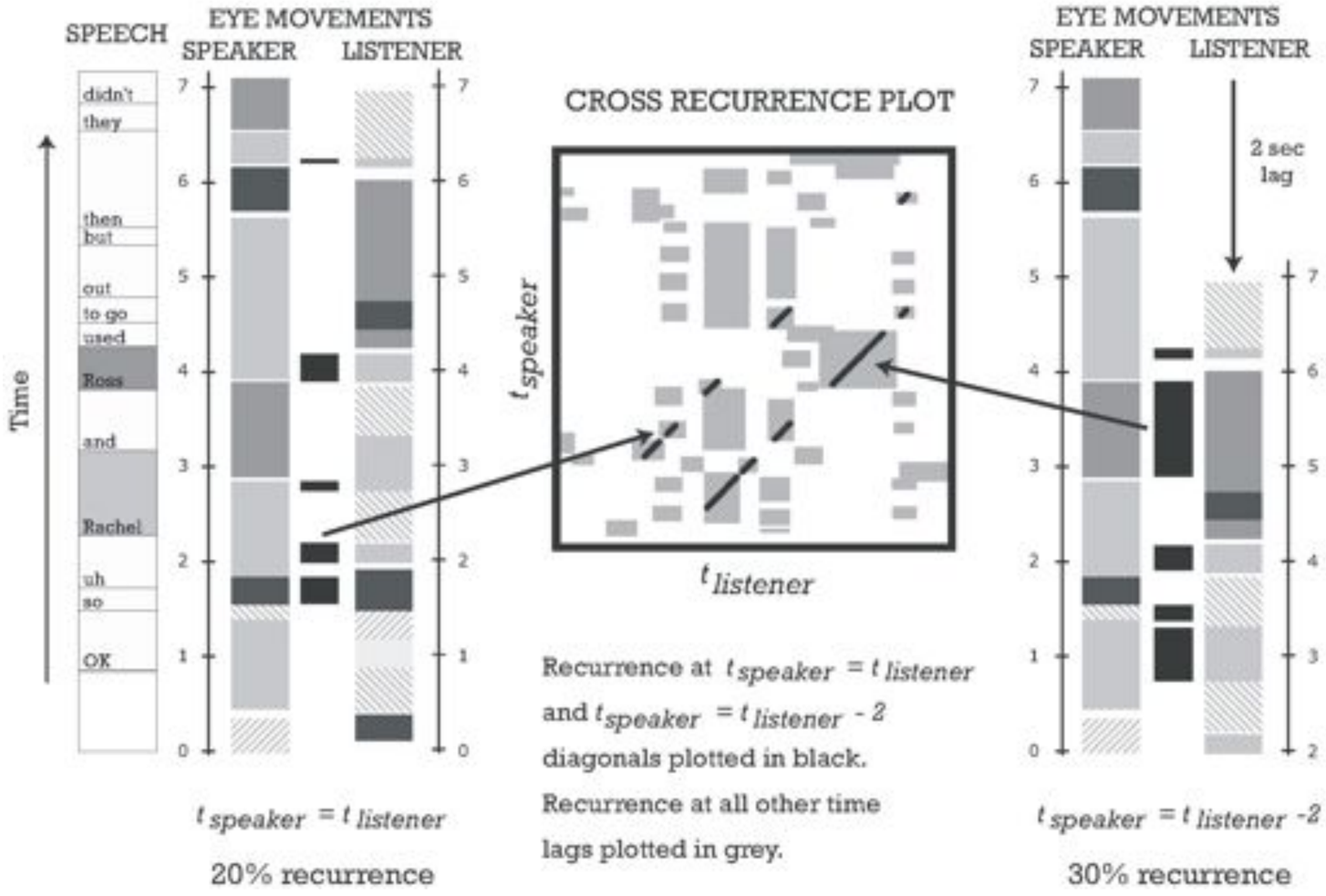
Daniel Richardson and Rick Dale (2005)



http://www.eyethink.org/eye-chat.html

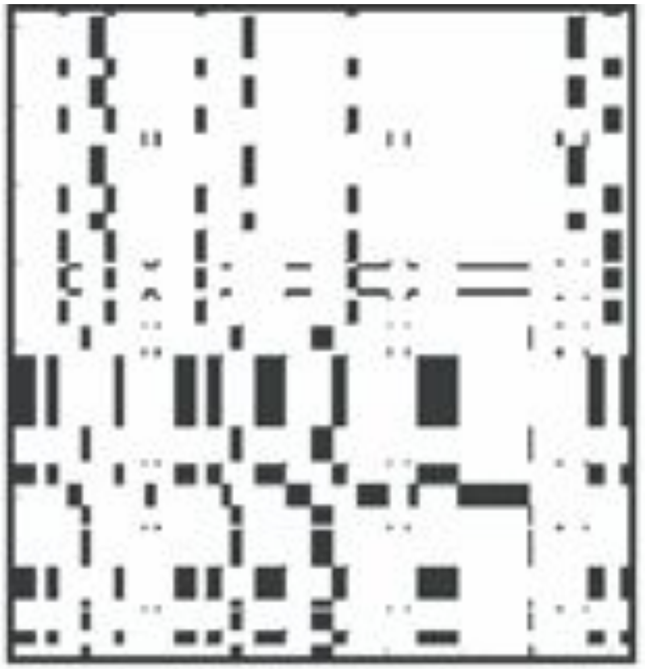
http://www.eyethink.org/resources/movies/coordination/friends_example.mp4

Cross-recurrence

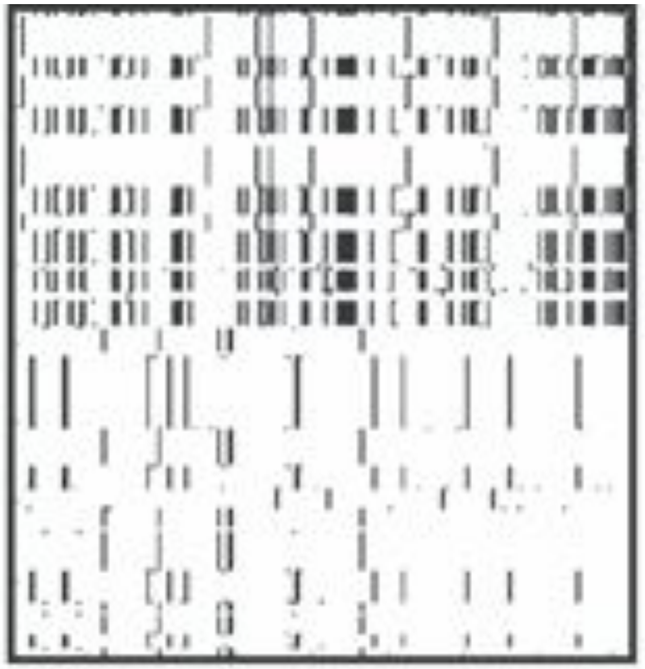


Cross-recurrence

Good Listener

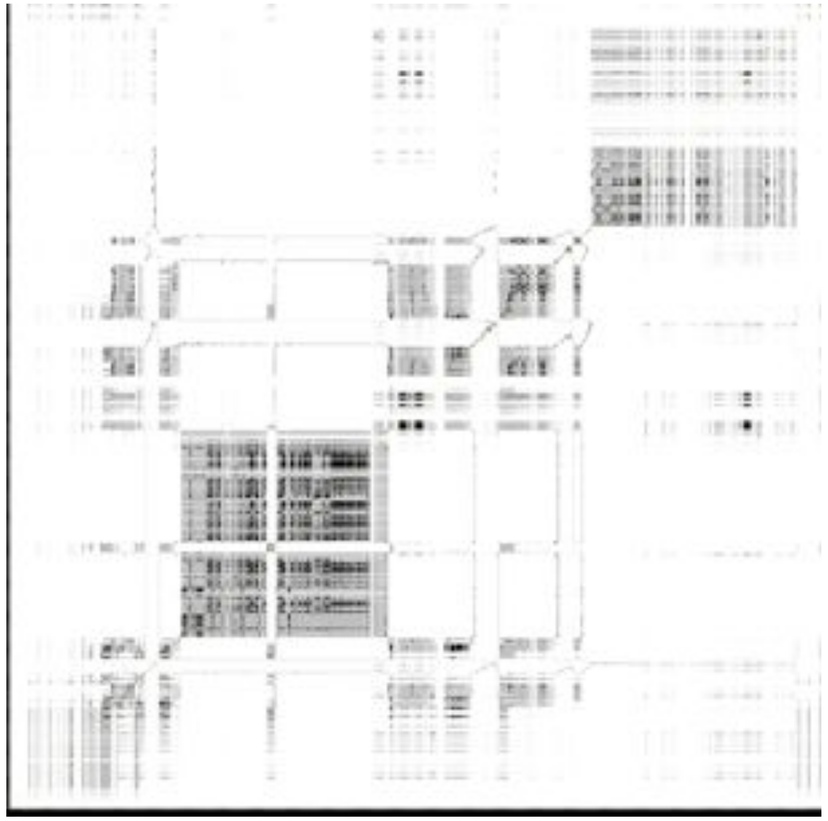


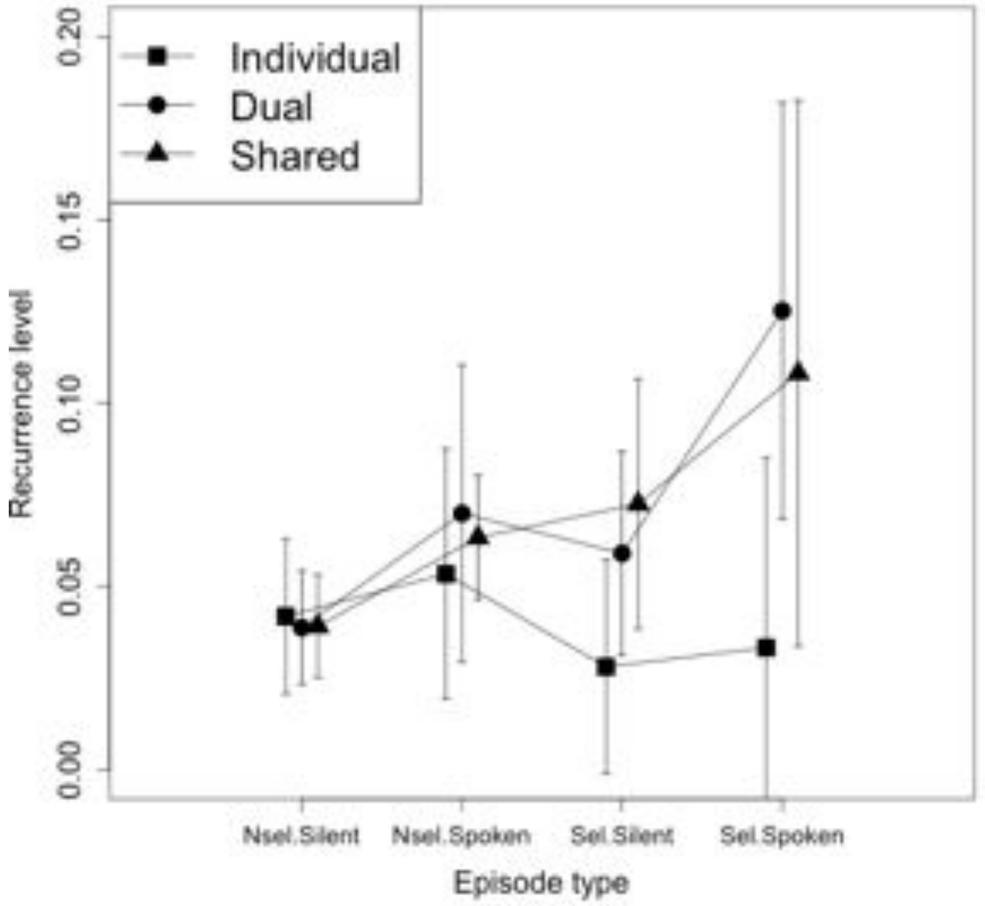
Bad Listener



Randomized Listener

Cross-recurrence in pair program understanding





Richardson & Dale (2005); Richardson, Dale, & Kirkham (2007); Jermann & Nüssli (2012)

Time scales

Time	Gaze	Collaboration / CSCL
3 hours [10'000 sec]		
15 minutes [1'000 sec]		Building a concept map
100 sec [1000 fixations]	recurrence	Understanding Interaction quality
10 sec [100 fixations]		Dialogue
1sec [10 fixations]	eye-voice span voice-eye span	Grounding Referring
100 ms [250 samples]	fixation	
4ms [1 sample]	raw data	

100 sec [1000 fixations]	recurrence	Understanding Interaction quality

DUET - Dual Eye-Tracking
Pair programming experiment

Low gaze recurrence

P. Jermann, M.-A. Nüssli & P. Dillenbourg
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Supported by the Swiss National Science Foundation
(grants #K-12K1-117909 and #PZ00P_126611)

http://www.youtube.com/watch?v=38qxsyNoAsI

DUET - Dual Eye-Tracking
Pair programming experiment

High gaze recurrence

P. Jermann, M.-A. Nüssli & P. Dillenbourg
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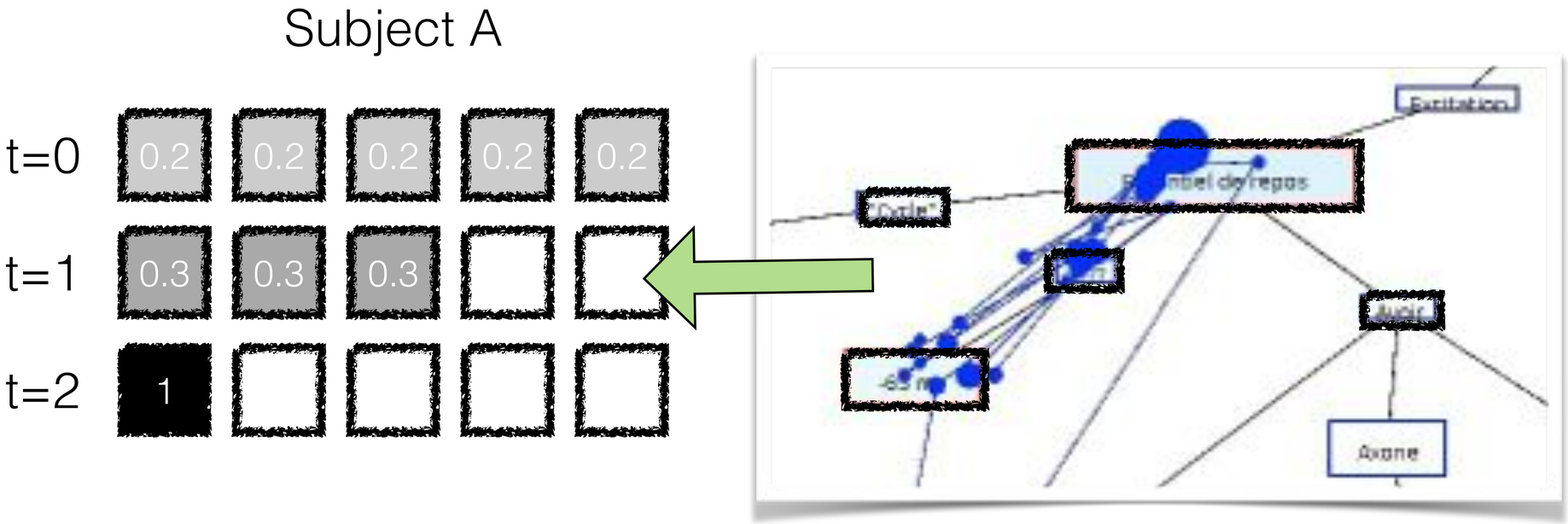
Supported by the Swiss National Science Foundation
(grants #K-12K1-117909 and #PZ00P_126611)

http://www.youtube.com/watch?v=dumgo3gPM78

Time scales

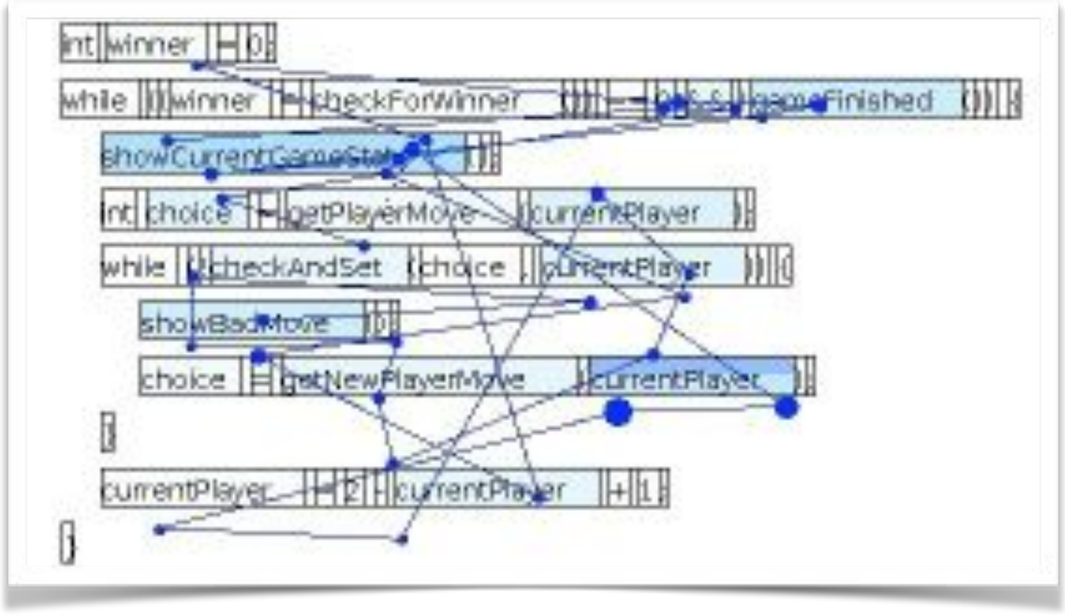
Time	Gaze	Collaboration / CSCL
3 hours [10'000 sec]		
15 minutes [1'000 sec]		Building a concept map
100 sec [1000 fixations]	recurrence	Understanding Interaction quality
10 sec [100 fixations]	**focus** **similarity**	**Dialogue**
1sec [10 fixations]	eye-voice span voice-eye span	Grounding Referring
100 ms [250 samples]	fixation	
4ms [1 sample]	raw data	

Attentional map

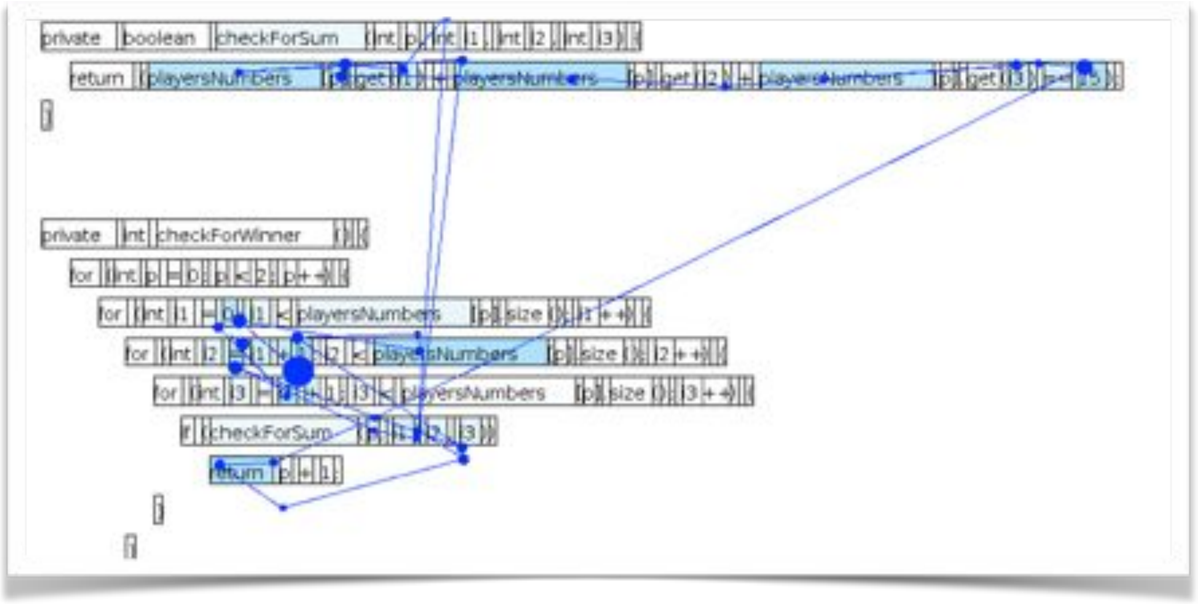


Attentional focus

entropy = Σ p log(p)



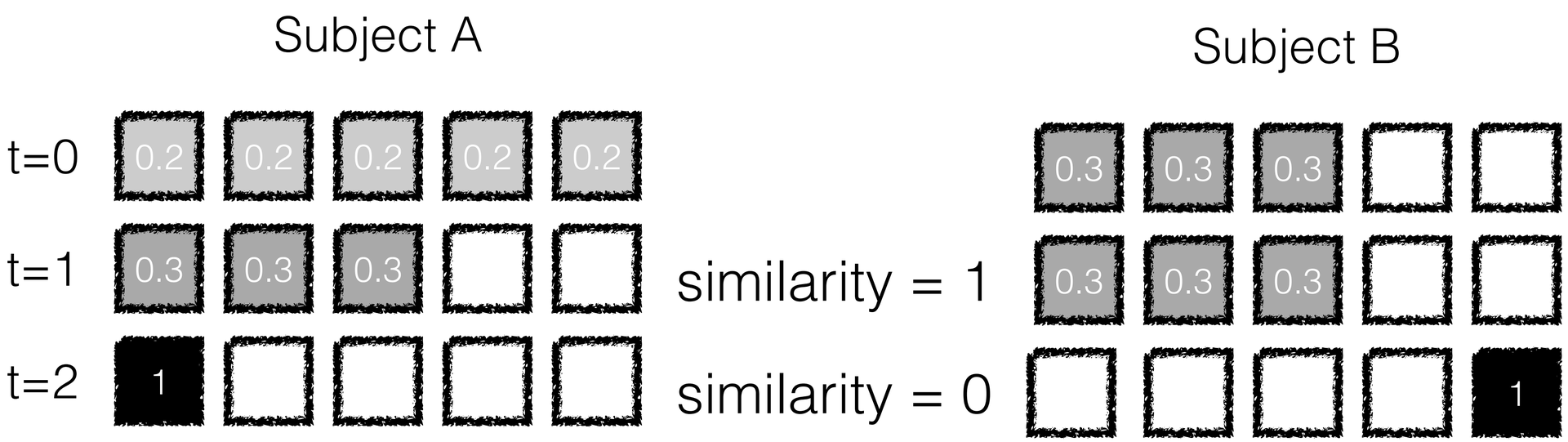
Low focus = high entropy



High focus = low entropy

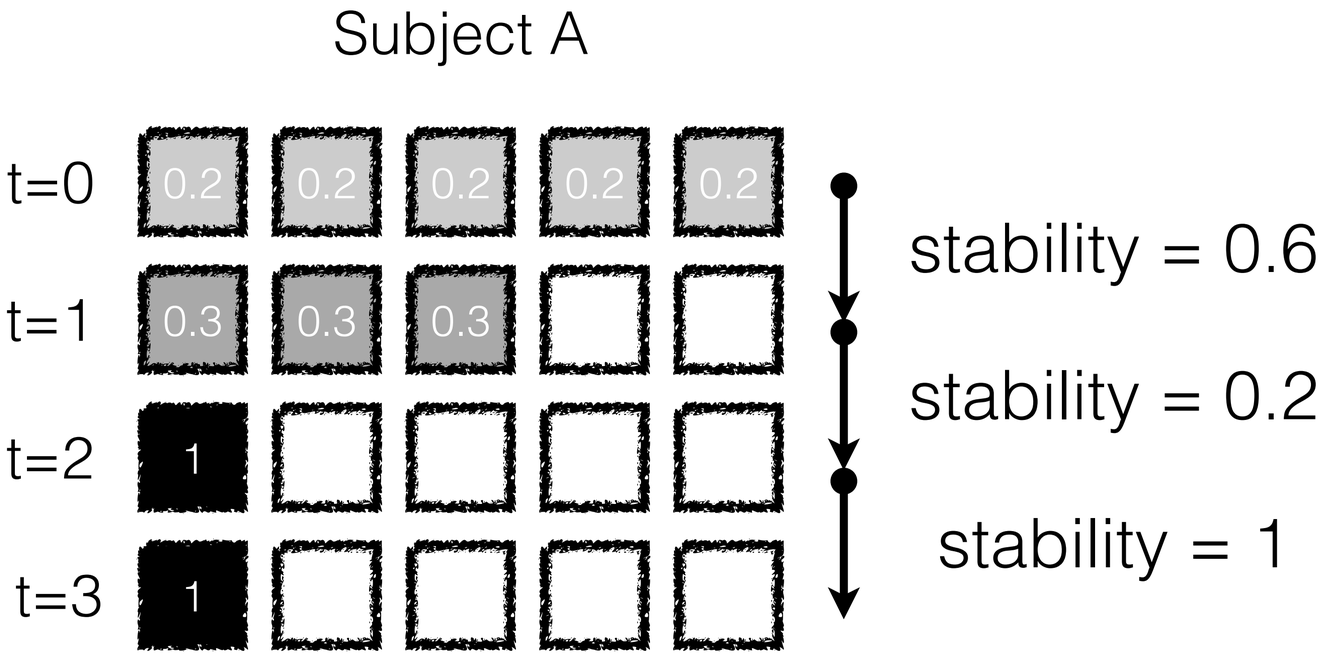
Attentional similarity

similarity => $\cos\theta = \frac{\langle \mathbf{a}, \mathbf{b} \rangle}{\|\mathbf{a}\| \, \|\mathbf{b}\|}.$



Attentional stability

stability => $\cos\theta = \frac{\langle \mathbf{a}, \mathbf{b} \rangle}{\|\mathbf{a}\| \, \|\mathbf{b}\|}.$

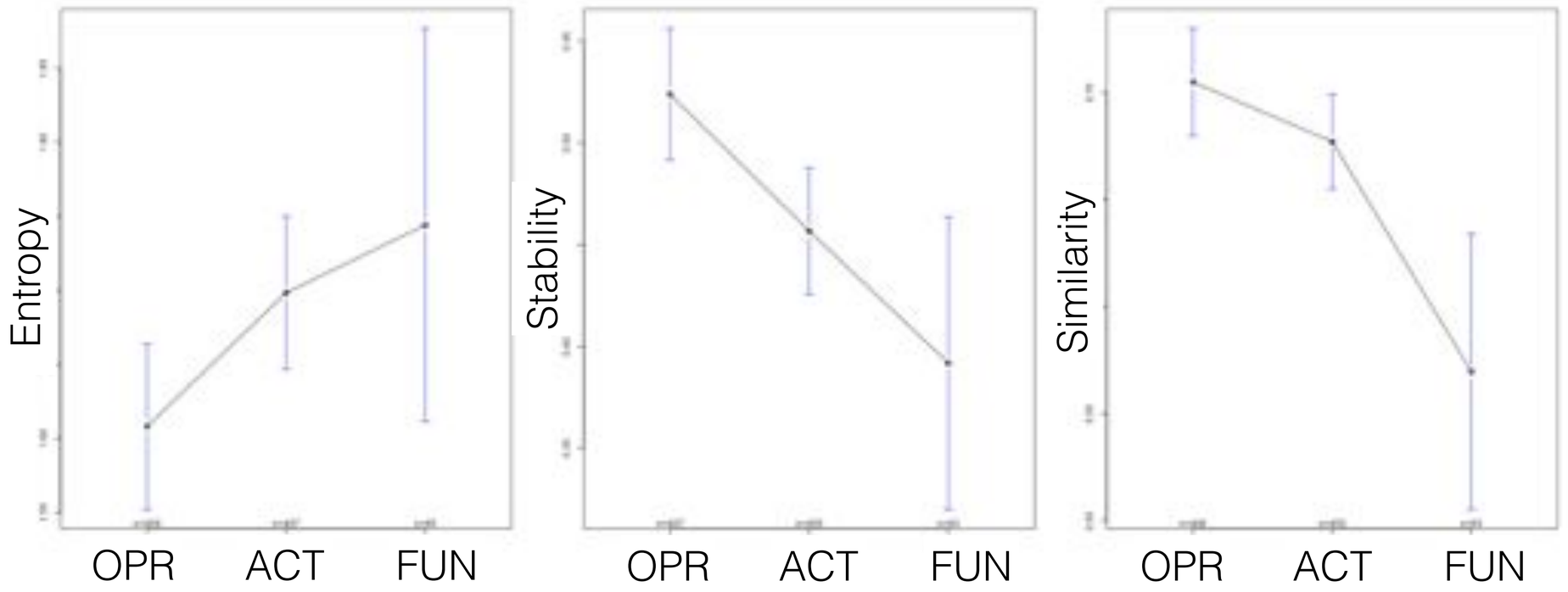


Dialogue coding

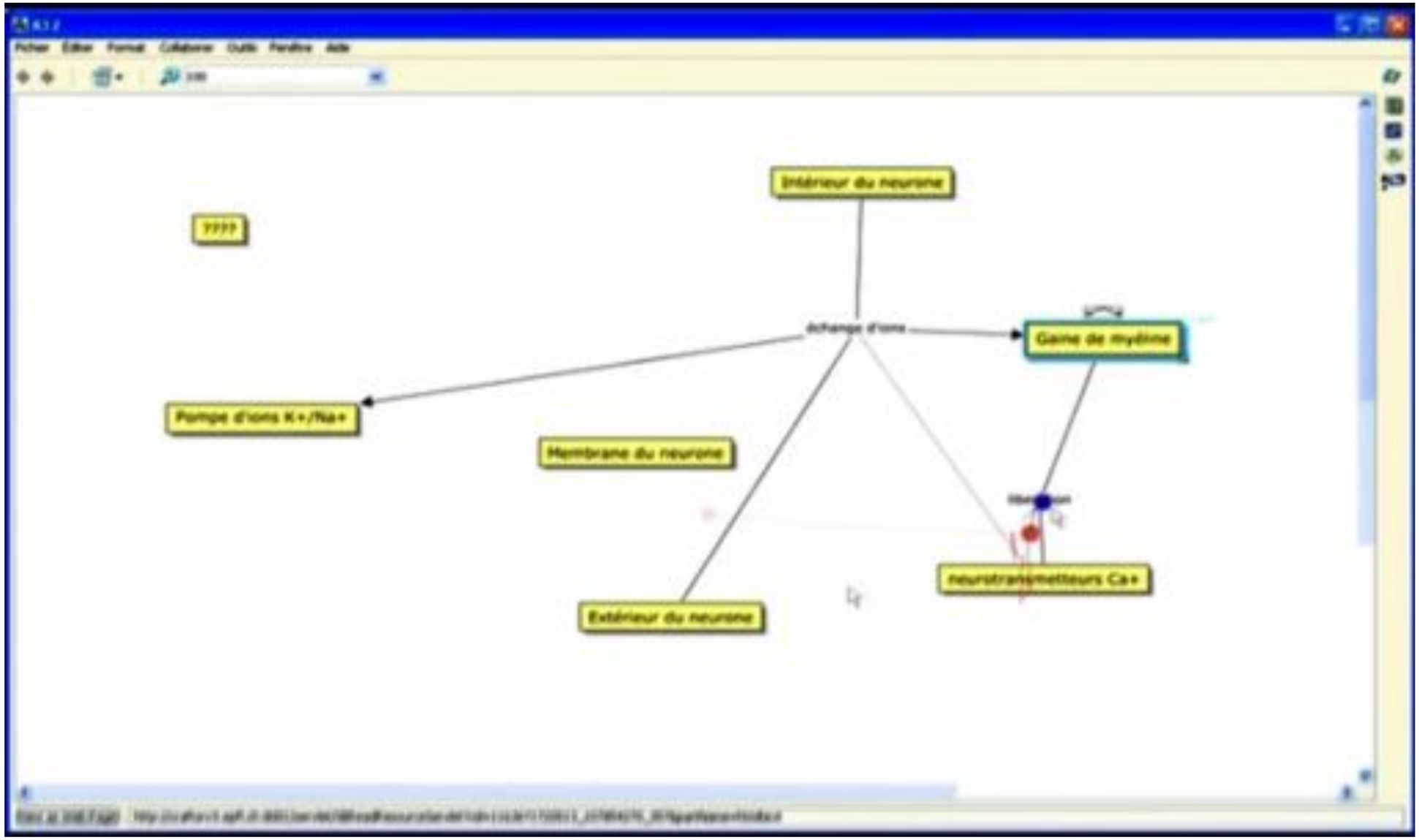
[Program understanding]

	Level of abstraction		
	Syntactic level (OPR)	Abstract code (ACT)	World model (FUN)

10 sec [100 fixations]	**focus similarity**	**Dialogue**



Do people speak about concrete operations (OPR) or general functionalities (FUN) ?



Mirweis Sangin, Gaëlle Molinari, Marc-Antoine Nüssli

Dialogue Coding

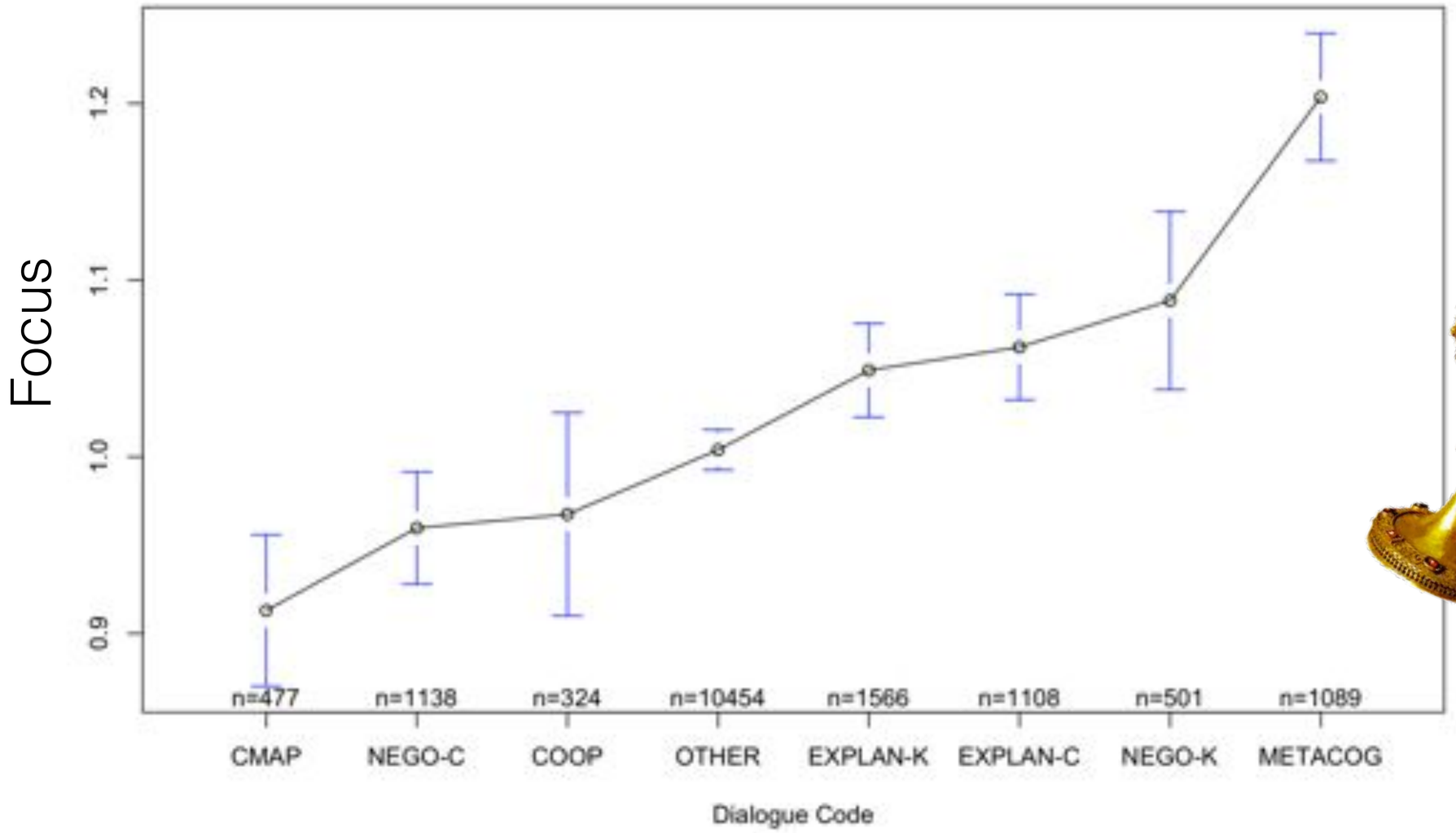
[Concept Mapping]

CMAP	Tool functionality
COOP	Organization
EXPLAN-C	Giving explanations [C=ref to concept map]
EXPLAN-K	
NEGO-C	Negociate knowledge [C=ref to concept map]
NEGO-K	
METACOG	Evaluate process

M. Sangin. Peer Knowledge Modeling in Computer Supported Collaborative Learning. PhD thesis, Ecole Polytechnique Federale de Lausanne, 2009.

Sangin, M., Dillenbourg, P., NüssliMarc-Antoine, & MolinariGaëlle. (2008). How learners use awareness cues about their peer's knowledge?: insights from synchronized eye-tracking data. In Proceedings of the 8th international conference on International conference for the learning sciences-Volume 2 (287–294).

10 sec [100 fixations]	**focus similarity**	**Dialogue**



Moving up the ladder

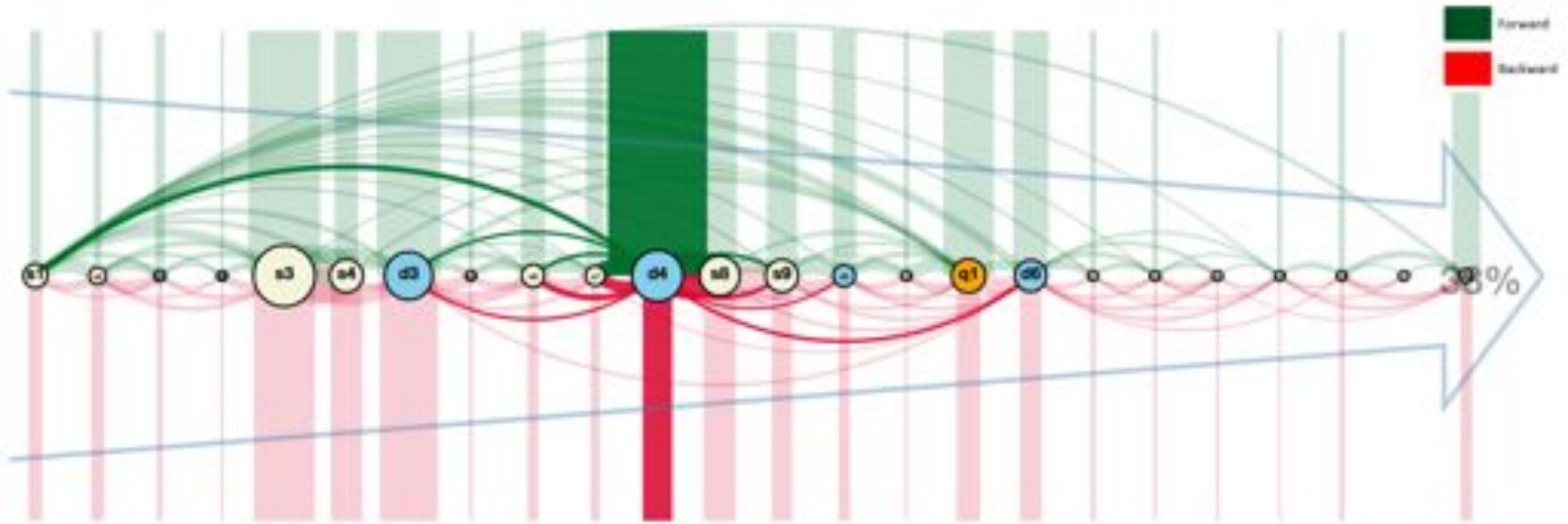
- **Referencing** as a basic mechanism of interaction
  => Attending to references as a perceptual mechanism
  => Linked to understanding and grounding
  => Referencing reflects abstraction

- **Representation**
  => spanning across levels of psychological functioning (operation / action / activity).

- **Abstraction**
  => attentional maps and cross-recurrence are content independent

MOOC Clickstreams

http://cedegesrv2.epfl.ch:9000/



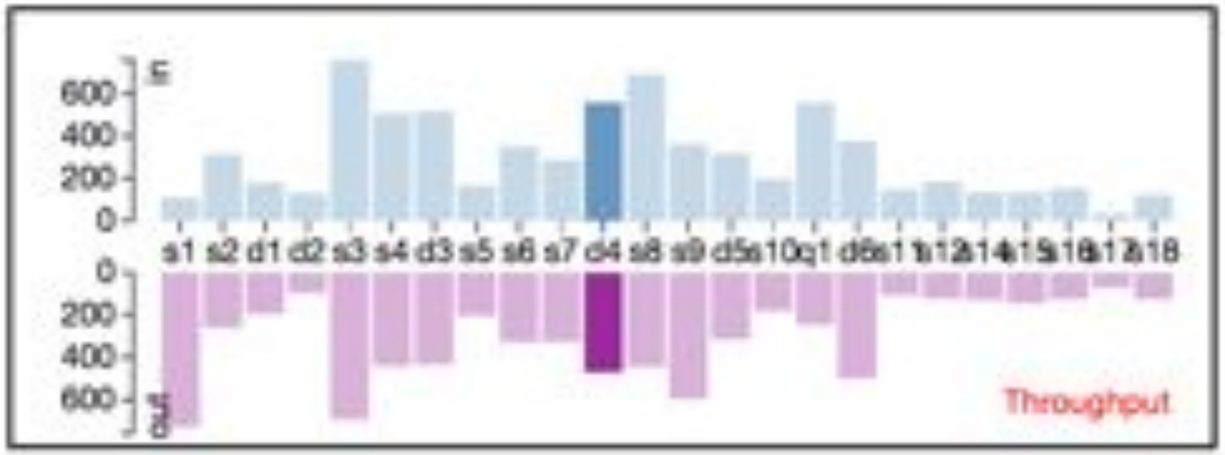
demo 4

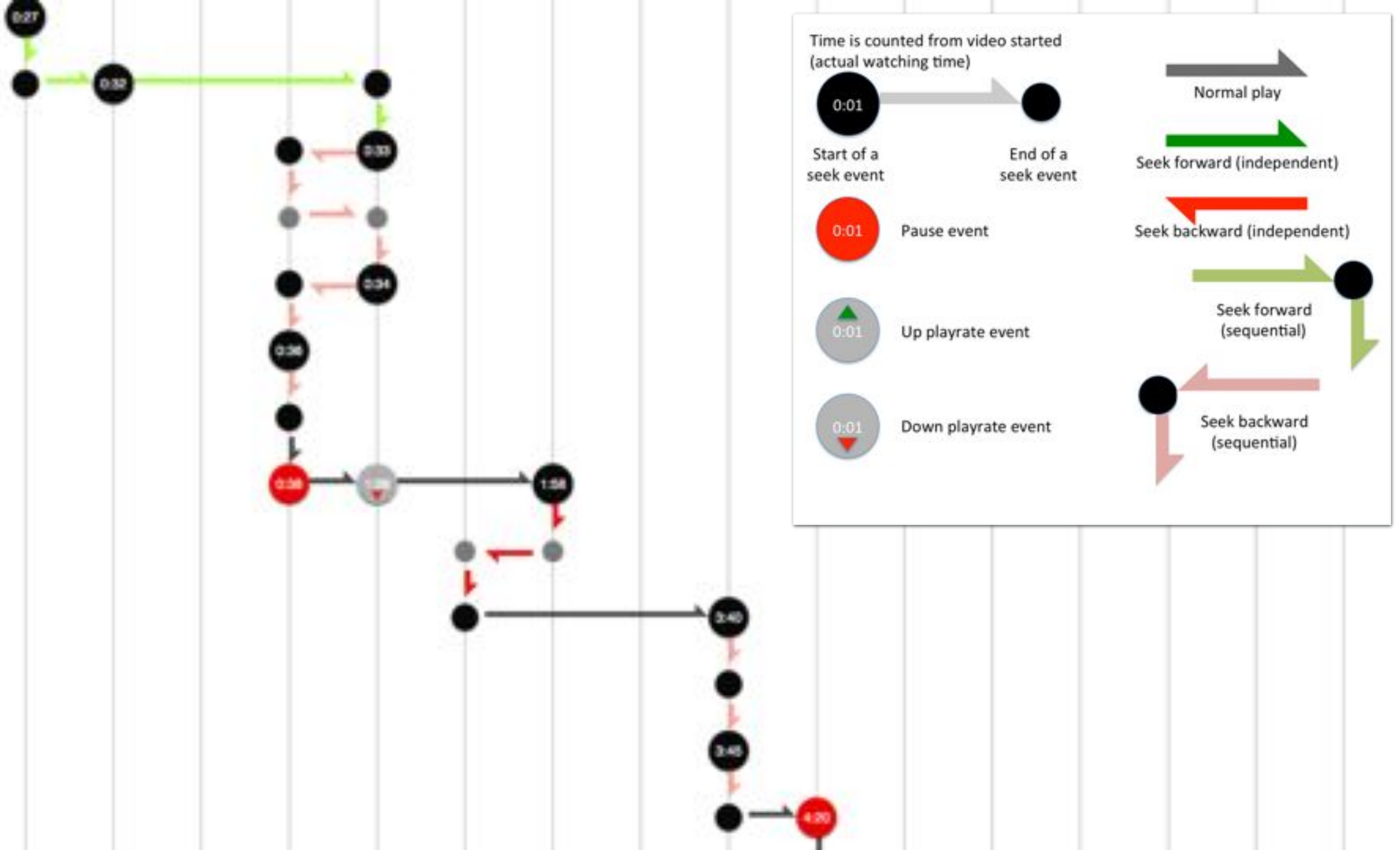
total = 2205 seeks

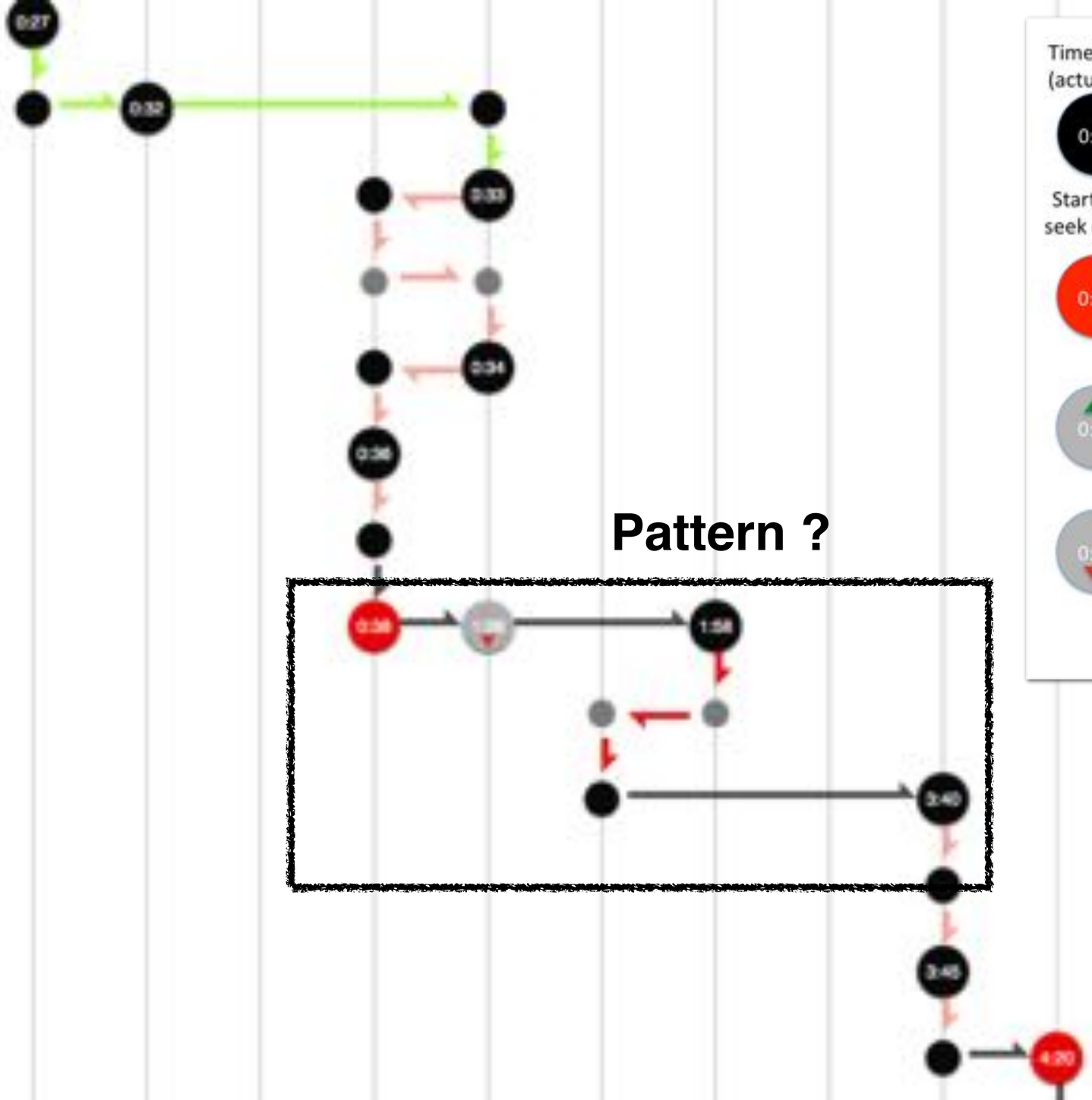
in = 558 seeks

out = 470 seeks

internal = 1177 seeks




Time is counted from video started
(actual watching time)
0:01
Start of a
seek event
End of a
seek event
Normal play
Seek forward (independent)
Seek backward (independent)
0:01
Pause event
Seek forward
(sequential)
0:01
Up playrate event
Seek backward
(sequential)
0:01
Down playrate event



Pattern ?

Time is counted from video started
(actual watching time)

0:01

Start of a seek event

End of a seek event

Normal play

Seek forward (independent)

Seek backward (independent)

0:01 Pause event

0:01 Up playrate event

0:01 Down playrate event

Seek forward (sequential)

Seek backward (sequential)

Can we obtain with clicks what we get with gaze ?

Time	Clickstream	MOOCs
10 days [1'000'000 sec]		Completing the course
1 day [100'000 sec]		Completing a week
3 hours [10'000 sec]		Doing assignments
15 minutes [1'000 sec]		Watching a video Doing a quizz
100 sec [1000 fixations]		Writing a message
10 sec [100 fixations]		Reading a message
1sec [10 fixations]	click	

Moving up the ladder …

Play

Forward

Pause

Play

PlPaSfSfPaSbPaPlSfSfSfaSbPa

PlPaSfSf

PaSfSfPa

SfSfPaSb

….

- **Rewatch**: PlPaSbPl, PlSbPaPl, PaSbPlSb, SbSbPaPl, SbPaPlPa, PaPlSbPa
- **Skipping**:SfSfSfSf, PaPlSfSf, PlSfSfSf, SfSfSfPa, SfSfPaPl, SfSfSfSSf, SfSfSSfSf, SfPaPlPa, PlPaPlSf
- **Clear Concept**: PaSbPlSSb, SSbSbPaPl, PaPlSSbSb, PlSSbSbPa (a combination of SeekBw and ScrollBw clicks, indicating high tussle with the video lecture content)
- **Checkback Reference**: SbSbSbSb, PlSbSbSb, SbSbSbPa, SbSbSbSf, SfSbSbSb, SbPlSbSb, SSbSbSbSb (a wave of SeekBw clicks)

Machine Learning Experiments

Research Question	Condition	Accuracy Kappa	False Negative Rate	Most representative (weighted) features that characterize classes
1. Engagement Prediction	A)Raw Clicks	0.81 0.63	**0.24**	**High** (skipping=low, playrate transition=low, rewatch=high, slow watching=low, checkback reference=low, clear concept=high)
	B)Summarized Behavioral Action Vectors	0.75 0.49	**0.15**	**Low** (skipping=high, playrate transition=high, rewatch=low, slow watching=high, checkback reference=high, clear concept=low)
2. Next Click Prediction	A)Raw Clicks	0.68 0.57	-	**SeekFw** (playratetransition=low, skipping=low, fast watching=high, clearconcept=low) **SeekBw** (checkbackreference=high, rewatch=low, playratetransition=low, propSeekBw, clearconcept=high)
	B)Summarized Behavioral Action Vectors	0.66 0.54	-	**Ratechangefast** (playratetransition=high, rewatch=low, checkbackreference=low) **Ratechangeslow** (playratetransition=high, clearconcept=high)
3. In-video dropout Prediction	A)Raw Clicks	0.90 0.69	**0.19**	**Non dropouts** (skipping=low, clearconcept=high, slow watching=high, Checkbackreference=low, rewatch=high, engagementfromStart=low, engagementlastClick=high)
	B)Summarized Behavioral Action Vectors	0.90 0.70	**0.15**	**Dropouts** (skipping=high, clearconcept=low, slow watching=low, engagementfromStart=high, rewatch=low, engagementlastClick=low, checkbackreference=high)
4. Complete Course dropout Prediction	Operationalized trajectories	0.80 0.57	**0.143**	**Non dropouts** (trajectory_IPI=H H H H, trajectory_eng=H H H VL H, trajectory_vpp=H H H L H) **Dropouts** (trajectory_IPI=H H VL VL VL, trajectory_eng=H L H L L, trajectory_vpp=H H H H VL)

Moving up the ladder …

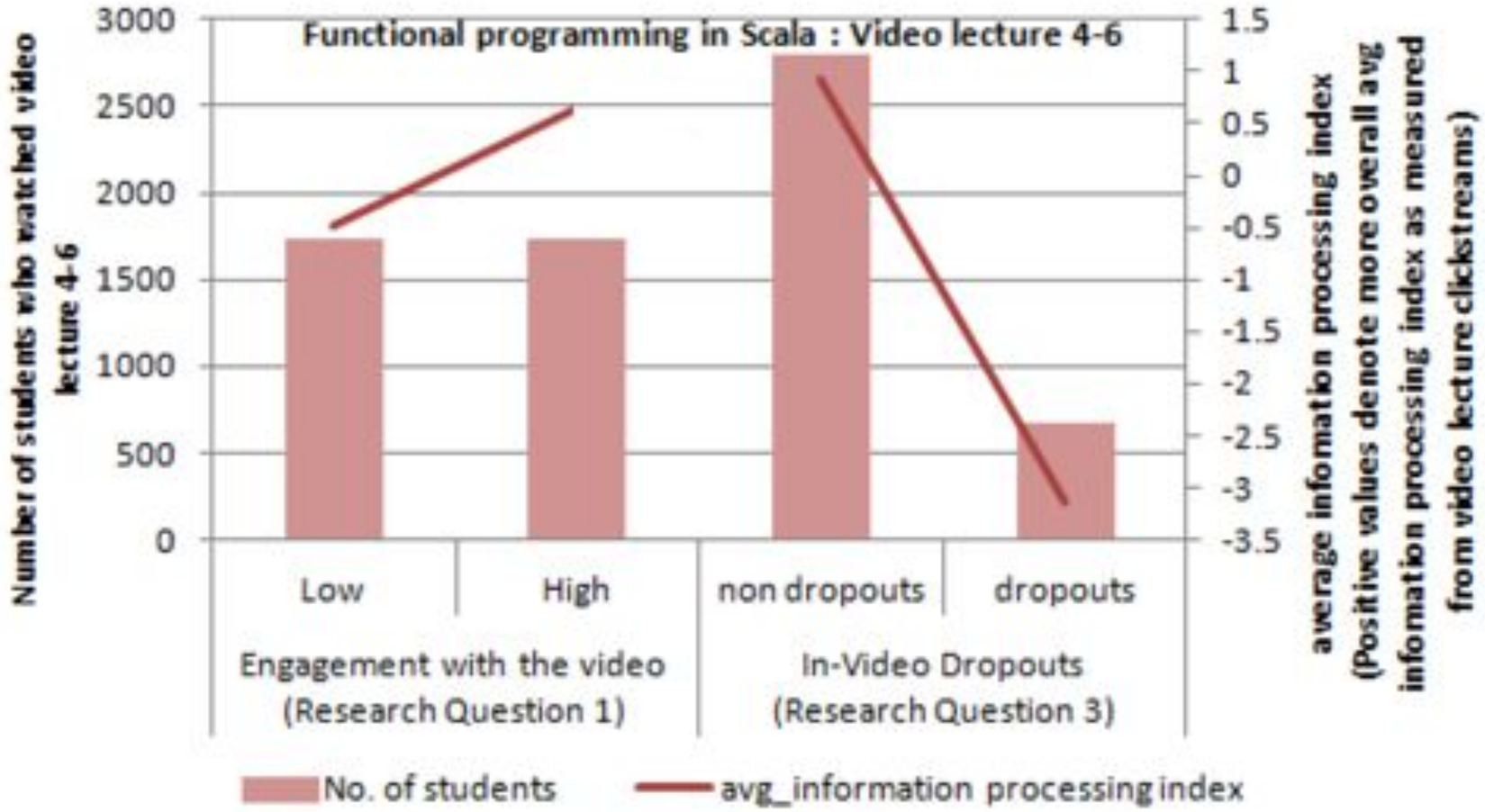
- **Rewatch**: PlPaSbPl, PlSbPaPl, PaSbPlSb, SbSbPaPl, SbPaPlPa, PaPlSbPa
- **Skipping**:SfSfSfSf, PaPlSfSf, PlSfSfSf, SfSfSfPa, SfSfPaPl, SfSfSfSSf, SfSfSSfSf, SfPaPlPa, PlPaPlSf
- **Clear Concept**: PaSbPlSSb, SSbSbPaPl, PaPlSSbSb, PlSSbSbPa (a combination of SeekBw and ScrollBw clicks, indicating high tussle with the video lecture content)
- **Checkback Reference**: SbSbSbSb, PlSbSbSb, SbSbSbPa, SbSbSbSf, SfSbSbSb, SbPlSbSb, SSbSbSbSb (a wave of SeekBw clicks)

Behavioral Actions	WeightAssign
Clear Concept	3
Slow Watching	2
Rewatch	1
Playrate Transition	0
Checkback Reference	-1
Fast Watching	-2
Skipping	-3

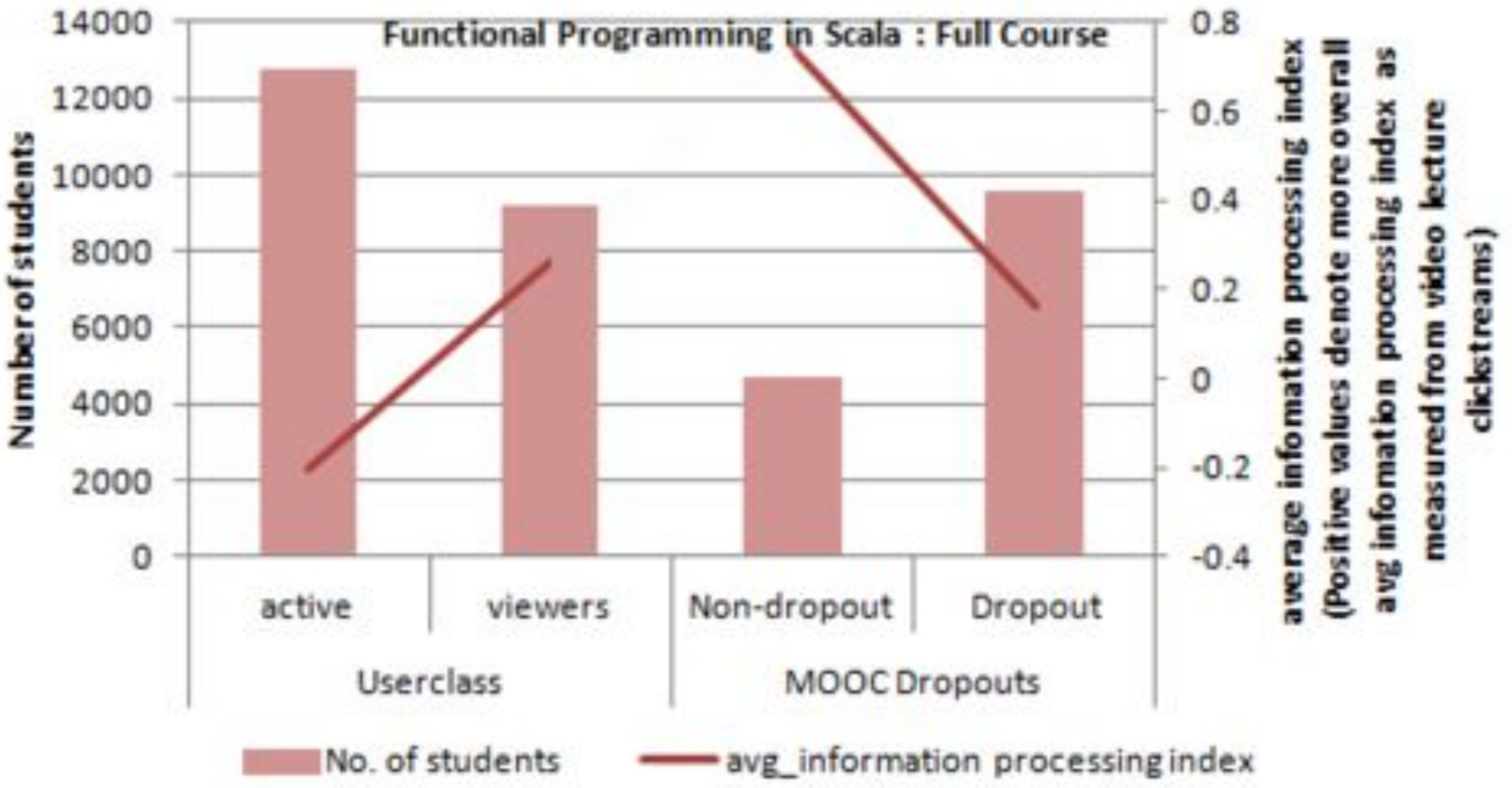
High Information Processing

Low Information Processing

Video Dropout



Course dropout



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3 hours [10'000 sec]		Doing assignments
15 minutes [1'000 sec]	information processing index	Watching a video Doing a quizz
100 sec [1000 fixations]	patterns	Writing a message
10 sec [100 fixations]	n-gram	Reading a message
1sec [10 fixations]	click	

Real-time “research” for action control

Time	Gaze	CSCL		Clickstream	MOOCs
10 days [1’000’000 sec]					Completing the course
1 day [100’000 sec]				action graph	
3 hours [10’000 sec]					Completing a week Doing assignments
15 minutes [1’000 sec]		Building a concept map		**information processing index**	Watching a video
100 sec [1000 fixations]	recurrence	Understanding Interaction		actions	Reading a message
10 sec [100 fixations]	**focus similarity**	Dialogue		n-gram	
1sec [10 fixations]	eye-voice span voice-eye span	Grounding Referring		click	Click

coursera | Content Send Emails Setup Grading Advanced | Analytics

Functional Programming Principles in Scala
by Martin Odersky

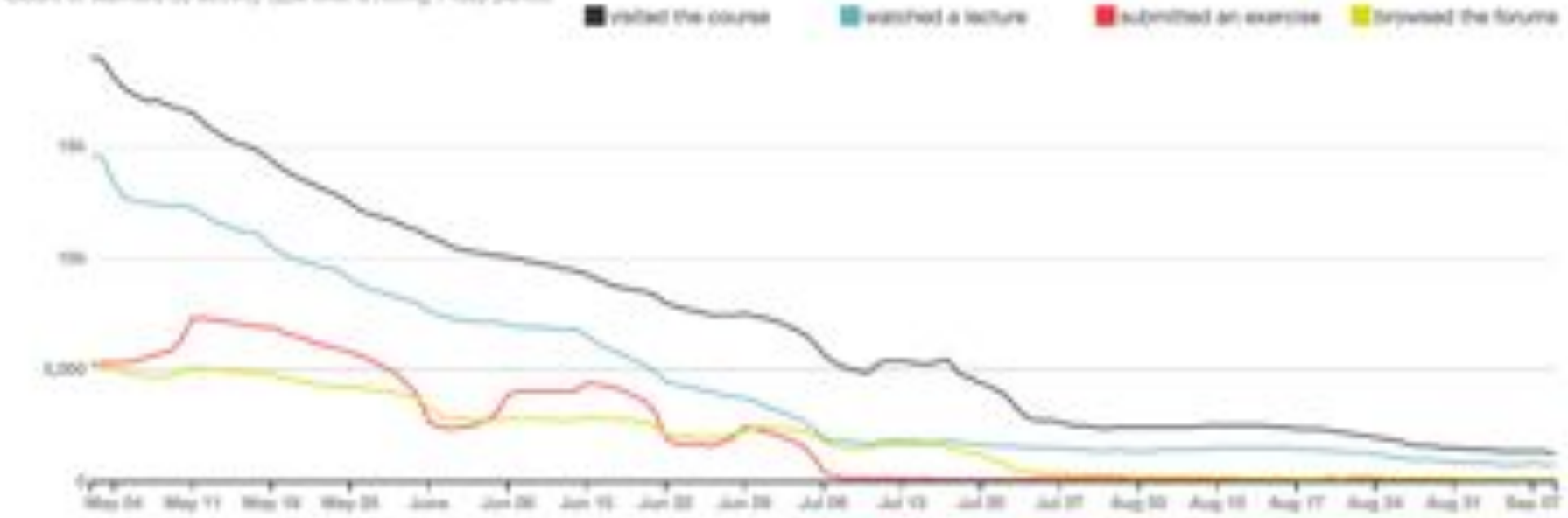
Overview Reach **Engagement** Content Polls Classic Tools Exports

Learner Activity
This Week

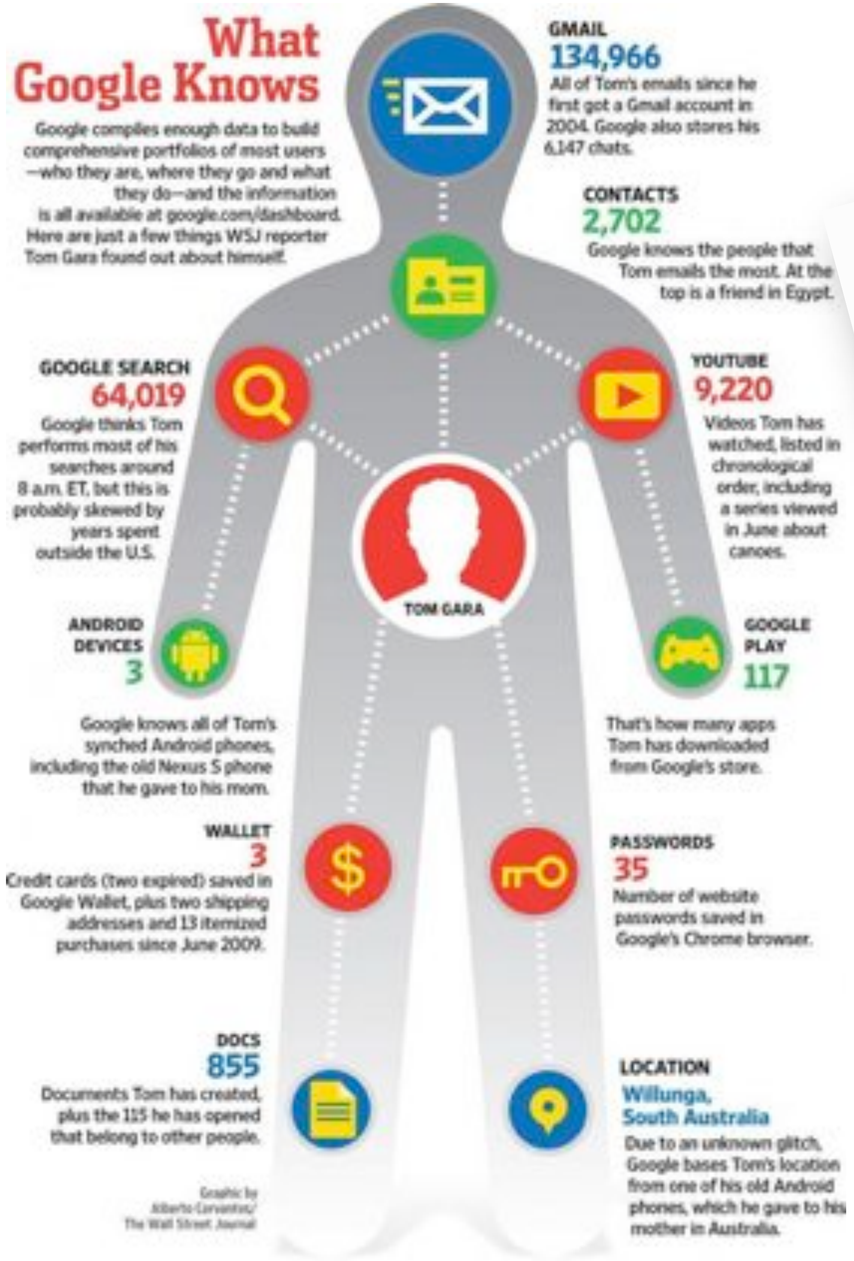
1,223 visited the course
748 watched a lecture
48 submitted an exercise
100 browsed the forums

Types of Activity

Count of learners by activity type over a rolling 7-day period



Physiological Measures



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