Interpersonal Synergies in Social Interactions: From Parent-Child Play to Dance Improvisation

Julian Zubek

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Human Interactivity and Language Lab, Faculty of Psychology, University of Warsaw

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An interdisciplinary research group (cognitive science, psychology, philosophy) led by prof. Joanna Rączaszek-Leonardi.

"HILL gathers people interested in the importance of interactivity for human cognition. We study **physical, situated, embodied and value-laden interactions** seeking in them both sources and motivations for cognitive processes and structures."

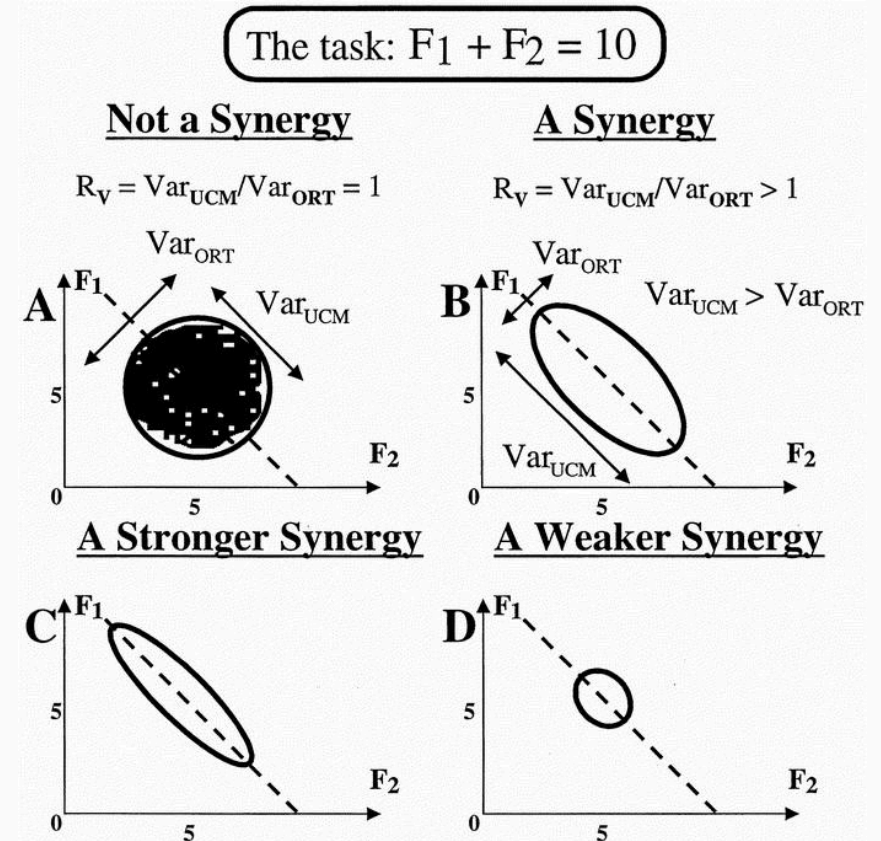Central question: relation between **form** and **dynamics.**
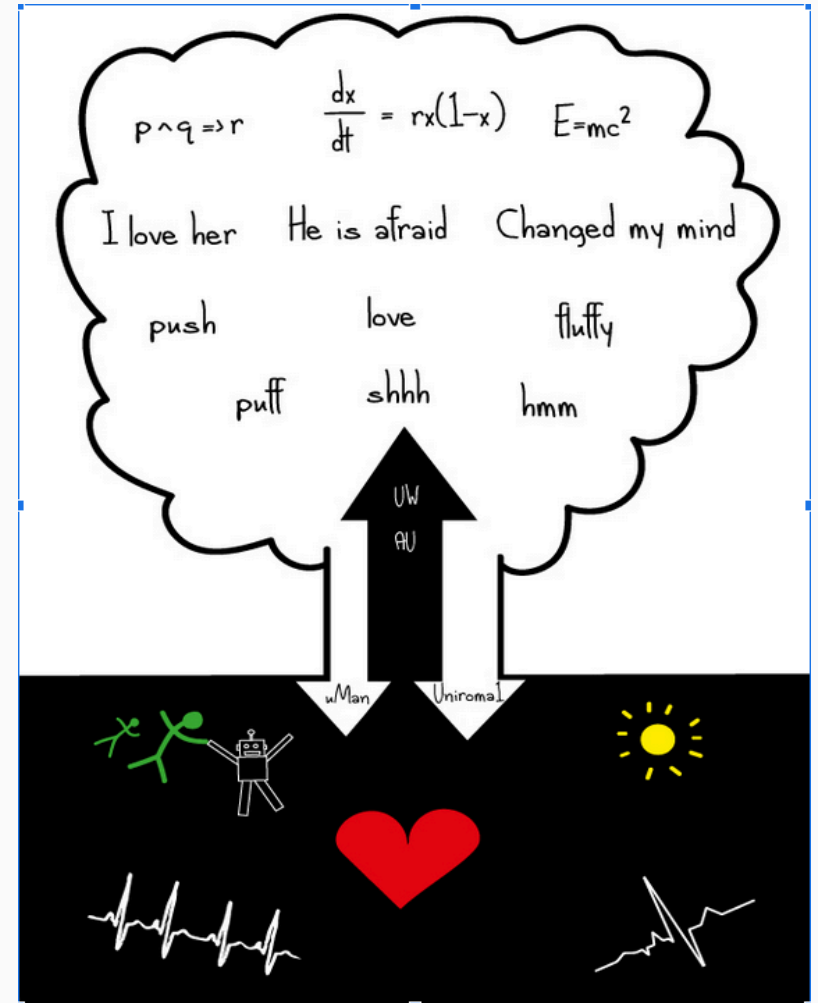
Interpersonal synergies are higher-order control systems formed by coupling movement system degrees of freedom of two (or more) actors.

— Riley, Richardson, Shockley, Ramenzoni (2011). Interpersonal synergies

A synergy is characterized by:
- dimensionality compression (functional reduction of degrees of freedom),
- reciprocal compensation (components react to each other).

The task: $F_1 + F_2 = 10$

Not a Synergy

$R_V = Var_{UCM}/Var_{ORT} = 1$

Var_{ORT}

A F_1 Var_{UCM}

5

F_2

A Synergy

$R_V = Var_{UCM}/Var_{ORT} > 1$

Var_{ORT}

B F_1 $Var_{UCM} > Var_{ORT}$

5

Var_{UCM} F_2

A Stronger Synergy

C F_1

5

F_2

A Weaker Synergy

D F_1

5

F_2

Latash, Scholz & Schöner (2002). Motor Control Strategies Revealed in the Structure of Motor Variability.
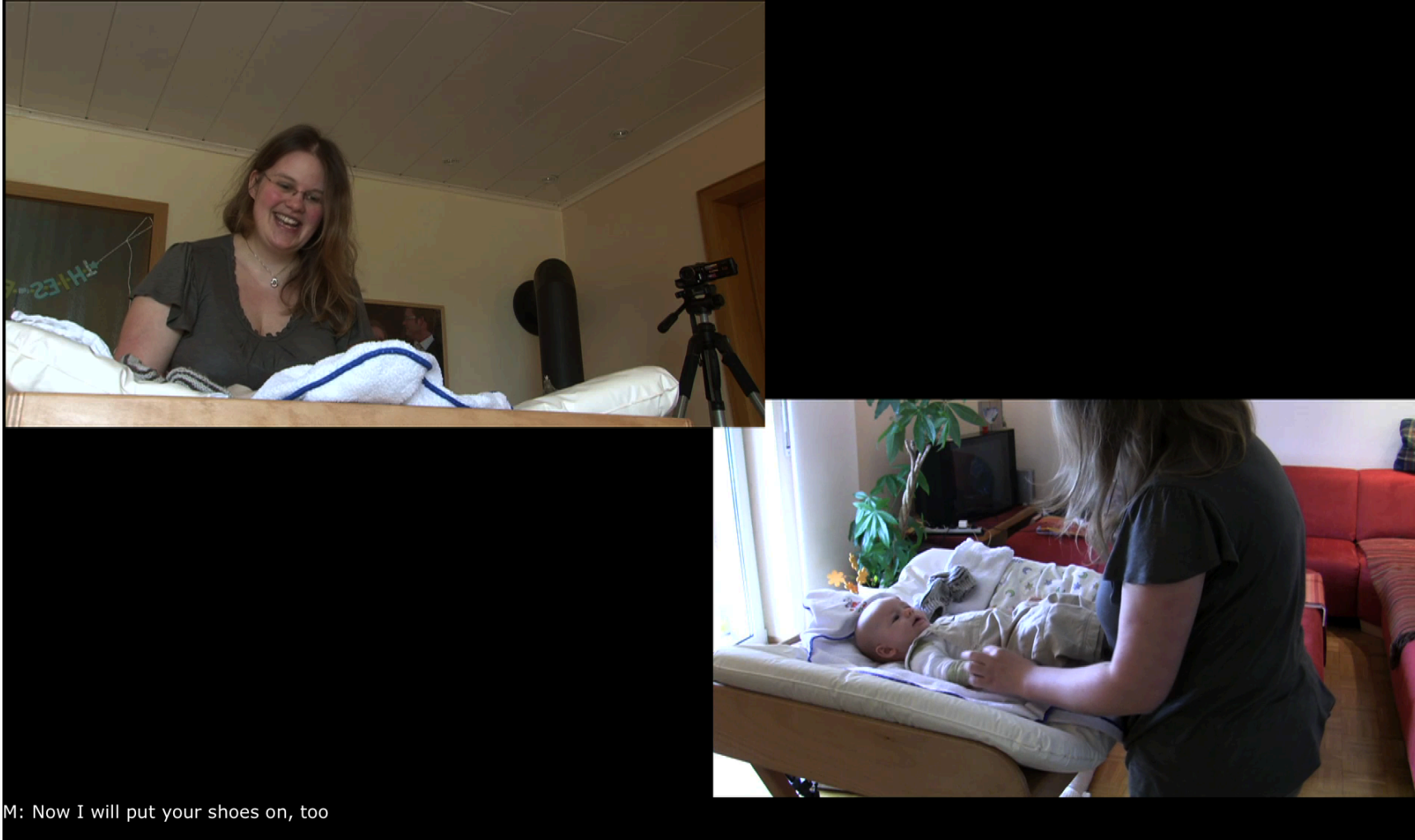
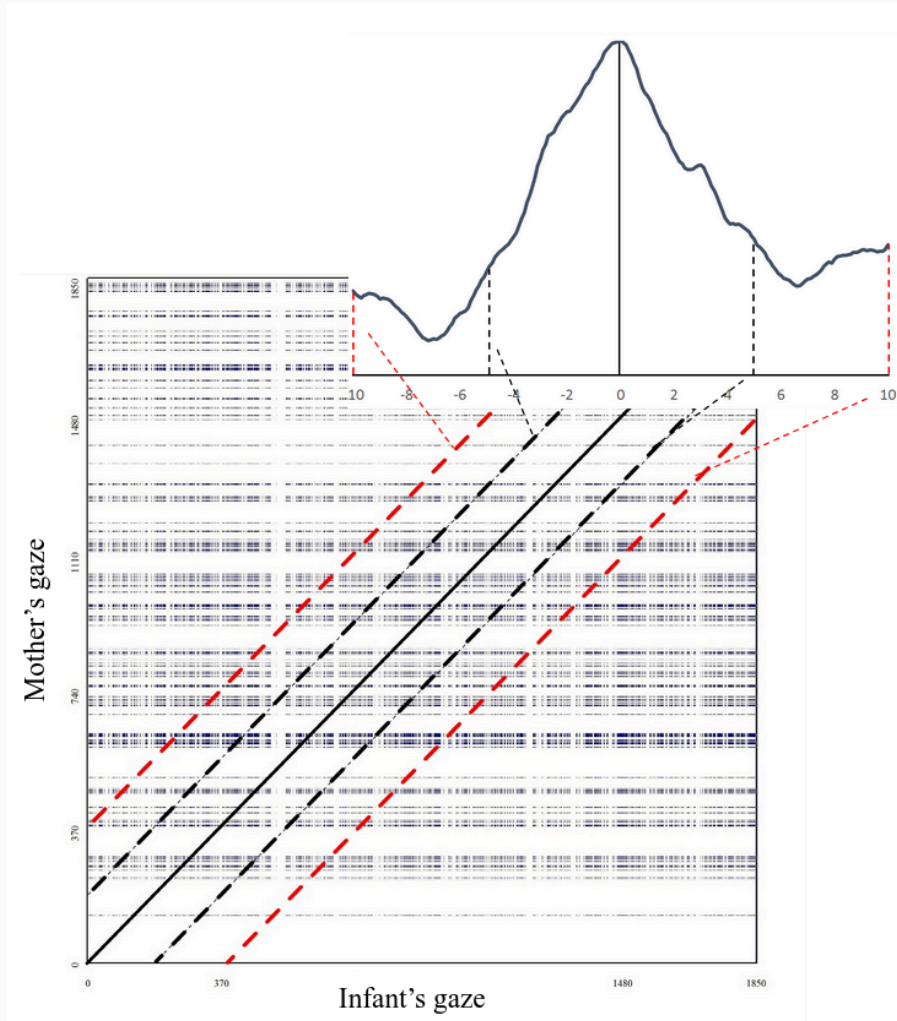Interpersonal synergies are ubiquitous in social interactions!

Assumptions:
1. Movement coordination in social interactions arises from interpersonal synergies.
2. Synergistic description naturally extends to verbal exchanges.
3. Interpersonal synergies form the scaffolding for social development.

M: Now I will put your shoes on, too

- Videos manually coded for gaze and vocalization.
- Cross-recurrence plot: recurrent point marked if at time t_1 mother performs the same behavior as child at time t_2 (for all pairs of t_1, t_2).
- Diagonal profile: average number of recurrent points corresponding to specific time lag.
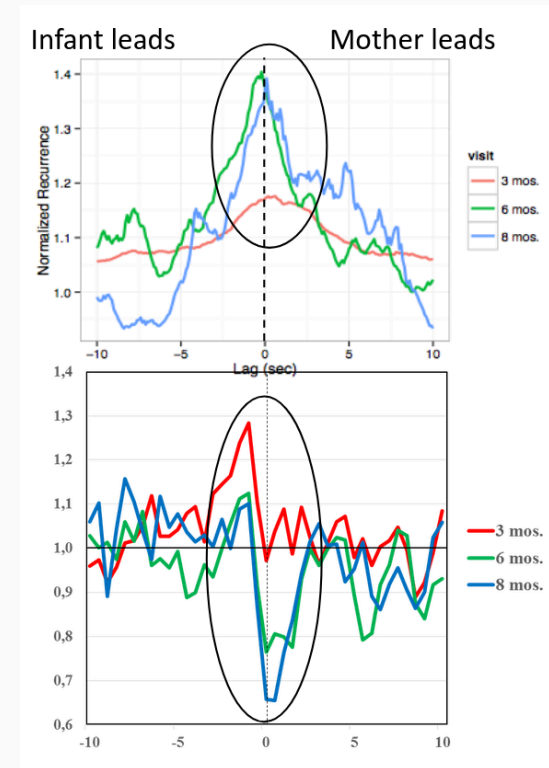
3 months $\rightarrow$ 8 months

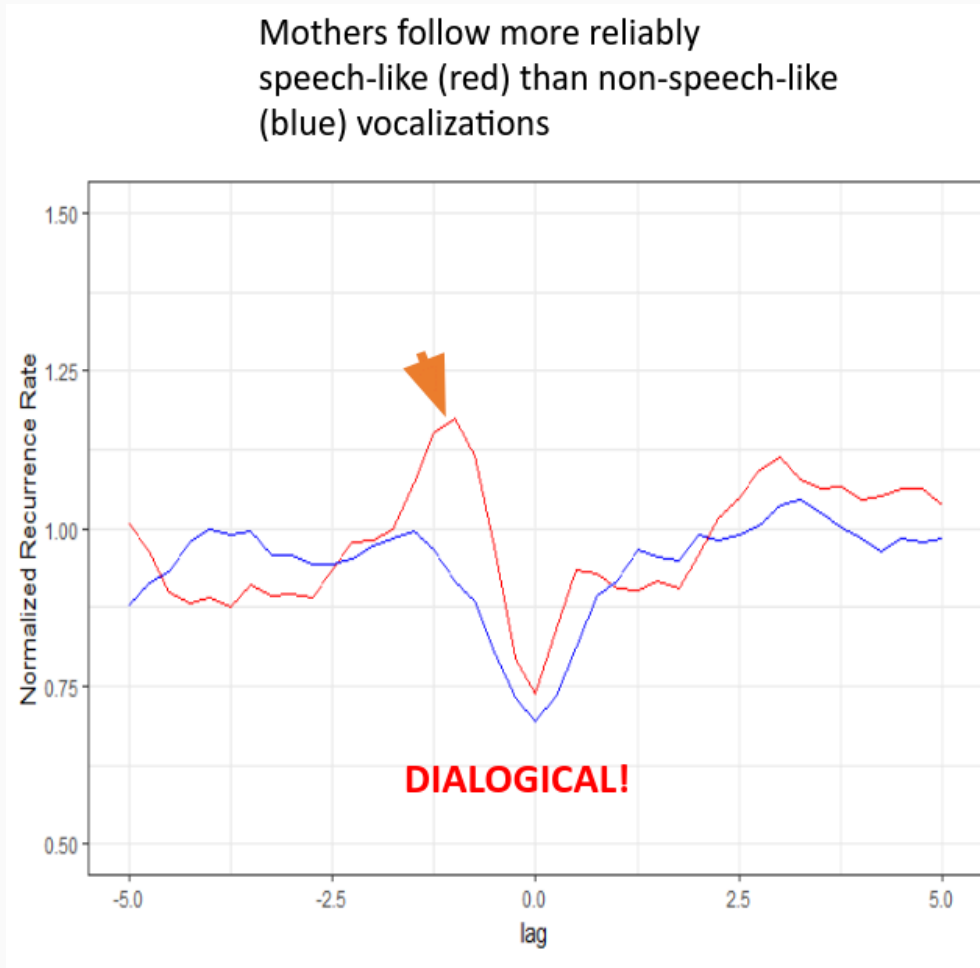Emergent dynamics of mother-infant dyad: **mutual constraining.**

Coupling of gaze (synchrony)

Complementarity of vocalizations (turn-taking)

Nomikou, I., Leonardi G., Rohlfing K., Rączaszek-Leonardi, J. (2016). Constructing interaction: the development of gaze dynamics.
Leonardi, G; Nomikou, I., Rohlfing K., Rączaszek-Leonardi, J. (2016) Vocal Interactions at the Dawn of Communication.

Mothers follow more reliably speech-like (red) than non-speech-like (blue) vocalizations

DIALOGICAL!

The Symbol Ungrounding problem (Rączaszek-Leonardi & Deacon, 2018): How arbitrary sounds become meaningful forms?

Differentiation/segregation of the vocal layer (**Timing!** Warlaumont, 2014).

Rączaszek-Leonardi, J. (2016). How does a word become a message? An illustration on a developmental time-scale.
Rączaszek-Leonardi, J., Nomikou, I., Rohlfing, K. J. & Deacon, T. W. (2018). Language Development From an Ecological Perspective: Ecologically Valid Ways to Abstract Symbols.

Assessing typical parent-child interaction patterns in joint action
$\rightarrow$ a potential scaffolding for social development.

Sample: 211 children, 5.5 years old.

ToM score: based on 5 false-beliefs tasks.

Parent and child movement estimated from video using frame-difference method. Coordination quantified using cRQA.

Children with high ToM:

- maintain **lower level of coordination**
- …but follow their parents **more reliably!**

Interpersonal synergies have to be functional, but not rigid.

Białek, A., Zubek, J., Jackiewicz-Kawka, M., Adamik, K., & Białecka-Pikul, M. (2022). Coordinating movements and beliefs: Different facets of doing things together.

	β	p	
Child's gender	.213	.022	
P_instruction	.120	.295	
P_presence	.063	.608	
Executive functions			
EF_flexibility	.176	.092	
EF_hot	−.162	.201	
EF_memory	.263	.012	↑
EF_inhibition	−.072	.614	
Movement coordination			
RR	−.442	.009	↓
RR_asymmetry	−.232	.047	↓
RR_max_delay	.209	.032	↑
ENTR_child	.603	.018	↑
LAM_child	−.369	.020	↓
ENTR_parent	−.431	.057	
LAM_parent	.289	.051	

Linear model predicting ToM score ($R^2 = .447$).

Does movement coordination reflect changes in an ongoing interaction?

Material: recordings of 7 improvised dance duets, level of "togetherness" rated continuously by 5 experts.

Position of individual body parts tracked using YOLOv8 model. Coordination analysis using moving window cRQA.
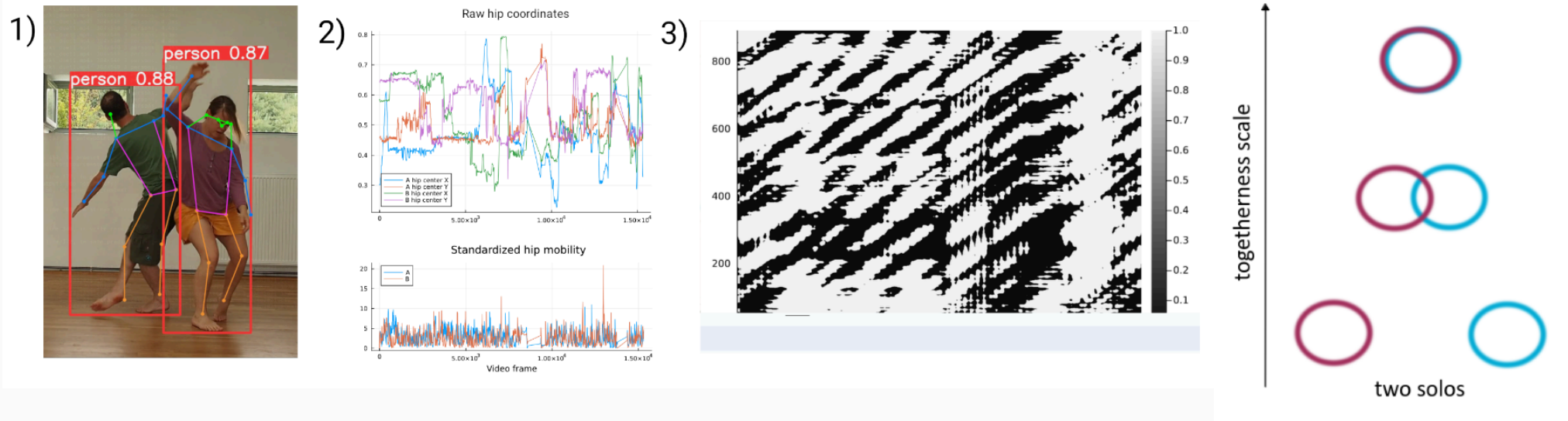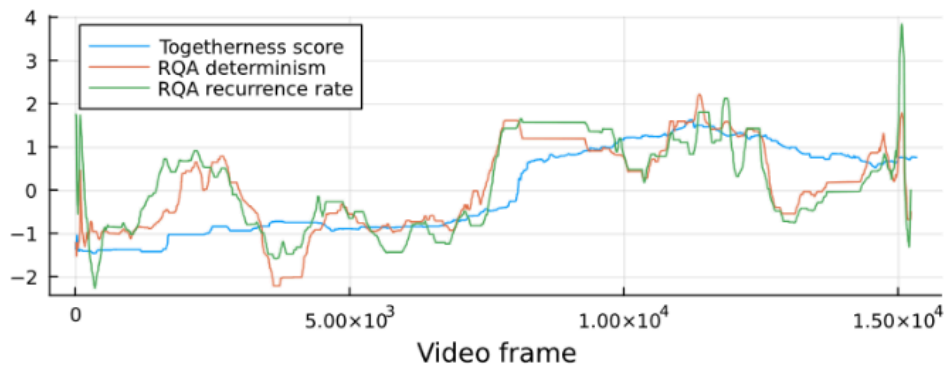
Study 3: Movement coordination and the togetherness in dance

a) Standardized hip mobility
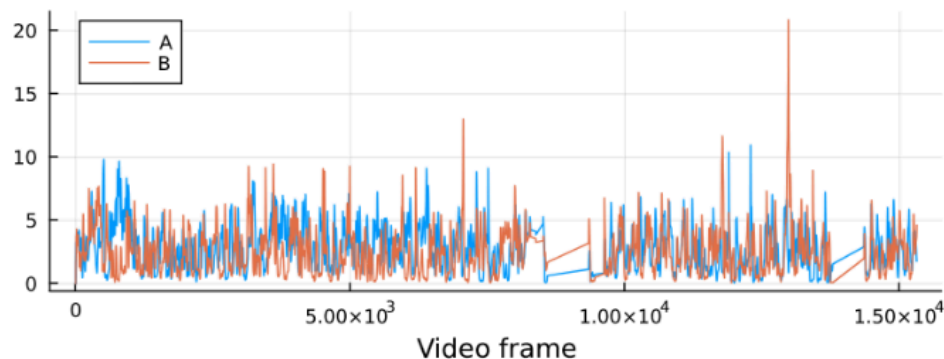
b) Togetherness and determinism

duet	N	r_{RR}	p_{RR}	r_{DET}	p_{DET}
1	4293	.01	.45	.08	< .024
2	3506	.46	< .024	.34	< .024
3	2425	-.01	.14	-.06	< .024
4	4540	.10	< .024	.09	< .024
5	4306	-.24	< .024	-.06	< .024
6	3245	.25	< .024	.17	< .024
7	3300	.53	< .024	.22	< .024

Correlations between fluctuations in togetherness and RR and DET compared against false pairs.

More stable coordination $\rightarrow$ better interpersonal connection.

Zubek, J., Łucznik, K. (2024). Movement coordination as a measure of togetherness in improvised dance duets.

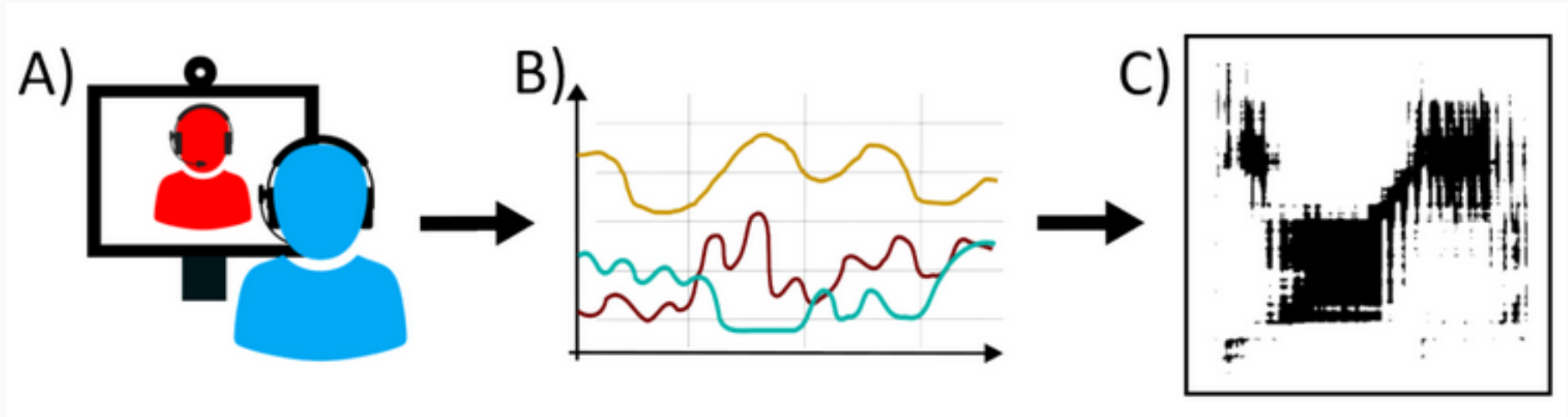# Study 4: Concepts in conversation

Coordination is helpful for understanding others in motion. What about verbal exchanges?

- Language as a carrier of **abstract concepts** – stepping away from the immediate environment.
- Words as Social Tools (Borghi & Binkofski, 2014): abstract meanings grounded in social interactions.
  - ‣ The more uncertain we are, the more we need to negotiate meaning with others.
 - ‣ Interpersonal synergies might support the negotiation process.

Study 4: Concepts in conversation

Data: recordings of 25 pairs negotiating definitions of concrete and abstract words on Zoom.

Movement extraction: body parts tracked with YOLOv8, registered shifts in the position of tip of the nose. Coordination quantified using cRQA.

Study 4: Concepts in conversation

Interpersonal coordination
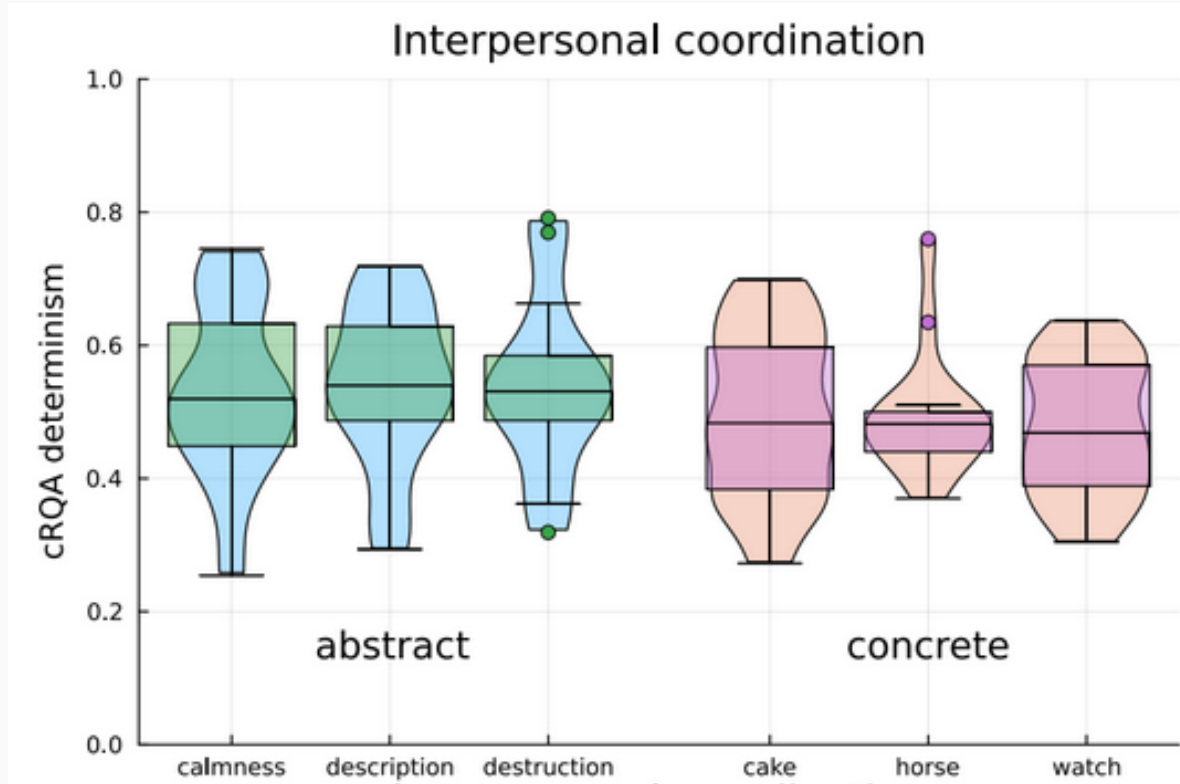
Abstract words elicit more stable coordination than concrete ones.

Understanding of abstraction is also embodied and reflected by real-time dynamics!

Zubek, Miecznikowski, Rossi, Fini, Borghi, Rączaszek-Leonardi (2024). Interactive basis for abstract concepts understanding (in preparation)

Thank you!

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https://hill.psych.uw.edu.pl

https://zubekj.github.io

We are grateful to all our collaborators and experiment participants.