

Which (task) contexts promote sensorimotor communication in human joint action?

- Asymmetric task knowledge: Providing information by exaggerating movement amplitude
- Choosing when to communicate: Switching coordination mechanisms in symmetric joint action
- Means versus goals: Communicating with movement duration

Asymmetric task knowledge

- **Providing information by exaggerating movement amplitude**

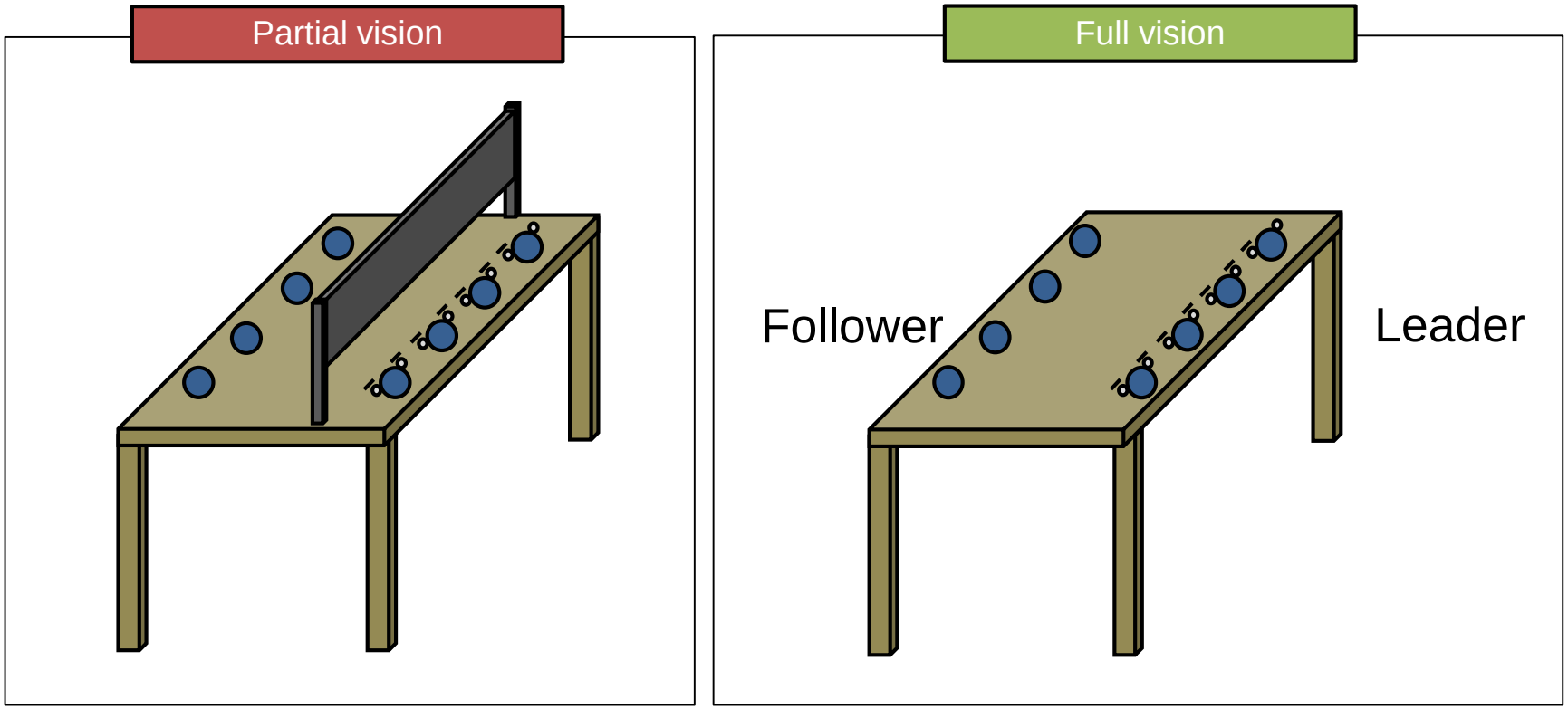
In many joint actions, a co-actor who has relevant task knowledge can support coordination by exaggerating movement kinematics, facilitating action prediction.

This is especially useful in tasks with high real-time constraints which require fast and reliable processing of a co-actor's actions.

How do more knowledgable co-actors provide information about their action goals?

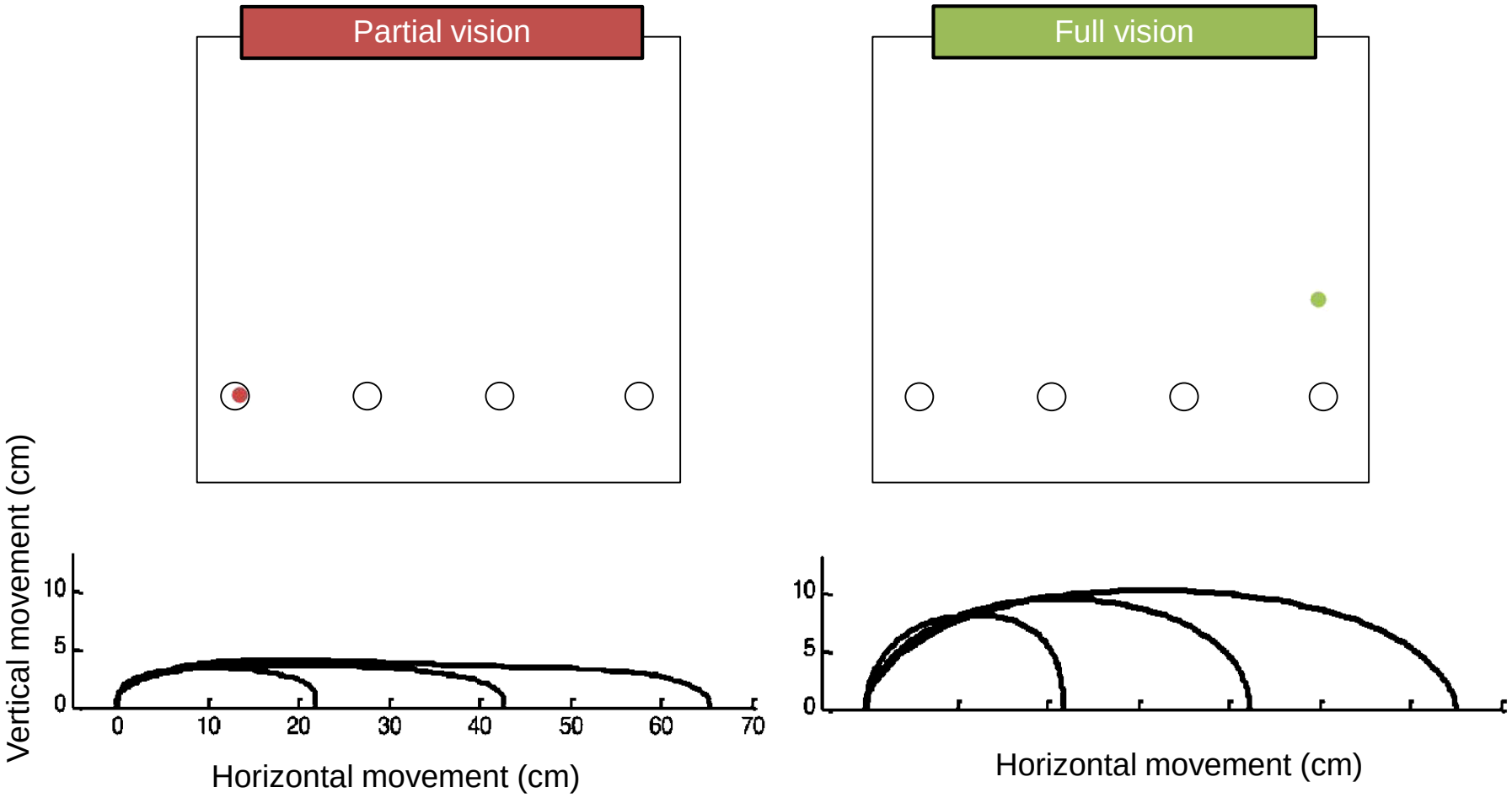
Synchronizing actions (target arrival times)

Task: “Tap on the targets at the same time while only the Leader knows the subsequent target!”



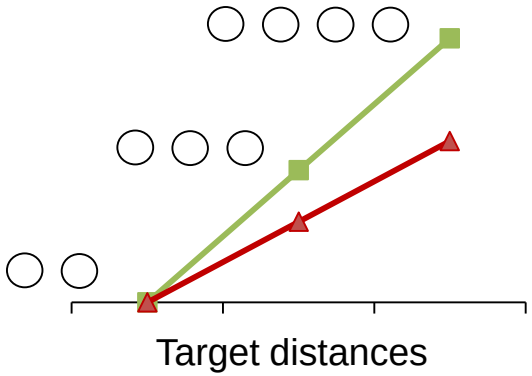
Vesper & Richardson, 2014

Hypothesis: When the Leader‘s action can be seen by the Follower, the Leader will exaggerate movement amplitude to facilitate predicting which is the next target.

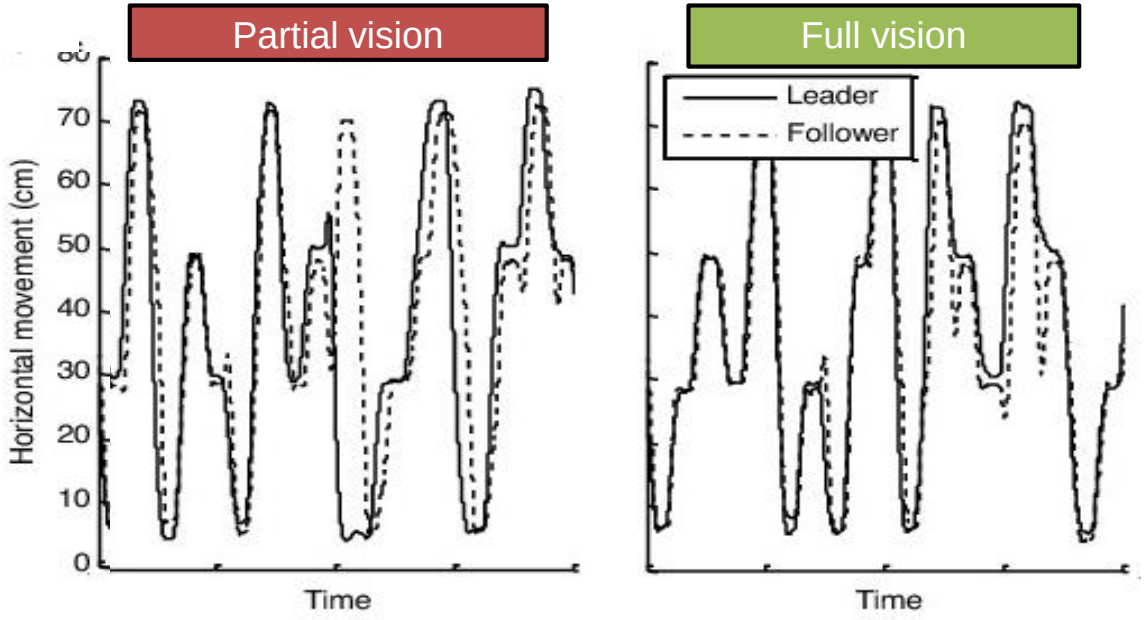


Providing and using information

- Leaders move with overall higher amplitude.
- Movement amplitude predicts target distance.



- Followers benefit from Leaders‘ amplitude exaggeration, allowing fast synchronous joint action performance.



Vesper & Richardson, 2014

Choosing when to communicate

- **Switching coordination mechanisms in symmetric joint action**

Is sensorimotor communication only useful if task knowledge is distributed asymmetrically?

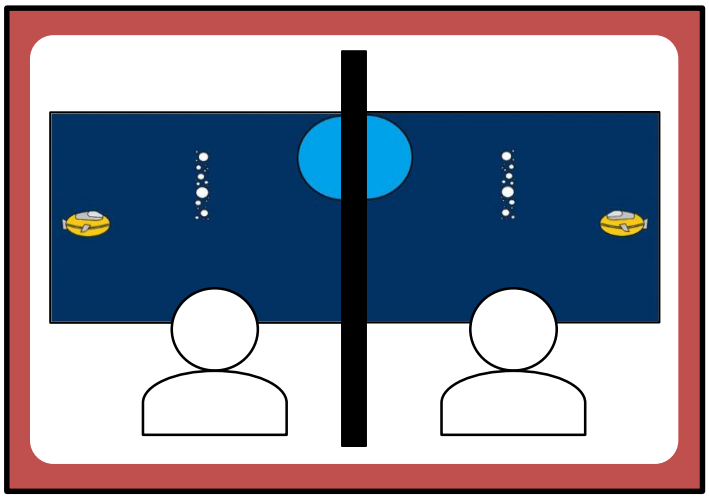
Exaggerating movement kinematics is costly and redundancy might be avoided. Candidi et al., 2015

Sensorimotor communication may also generally support real-time coordination, e.g. helping synchronous action performance.

Would co-actors choose to exaggerate movement kinematics to support coordination even if there is no ambiguitiy about action goals?

A preference for communicative actions?

Task: “Arrive at the planet at the same time as your partner without hitting the asteroid belt!”



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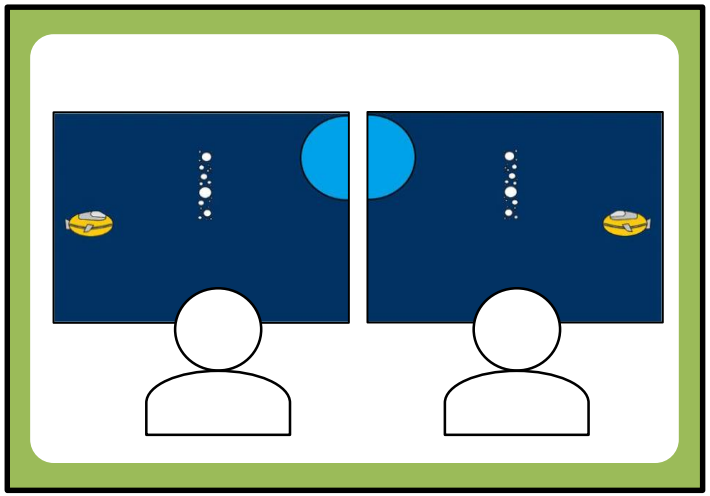

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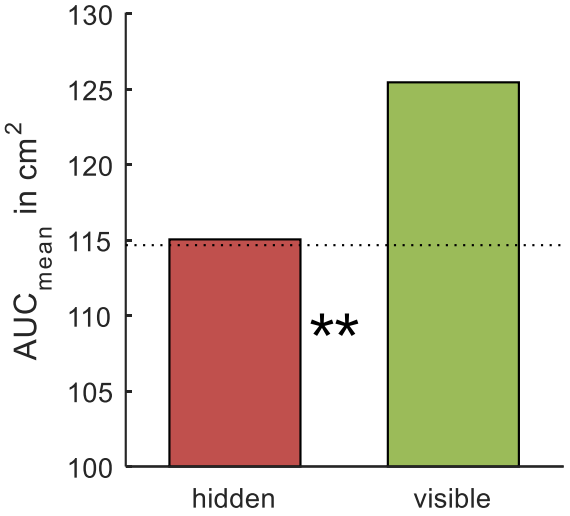
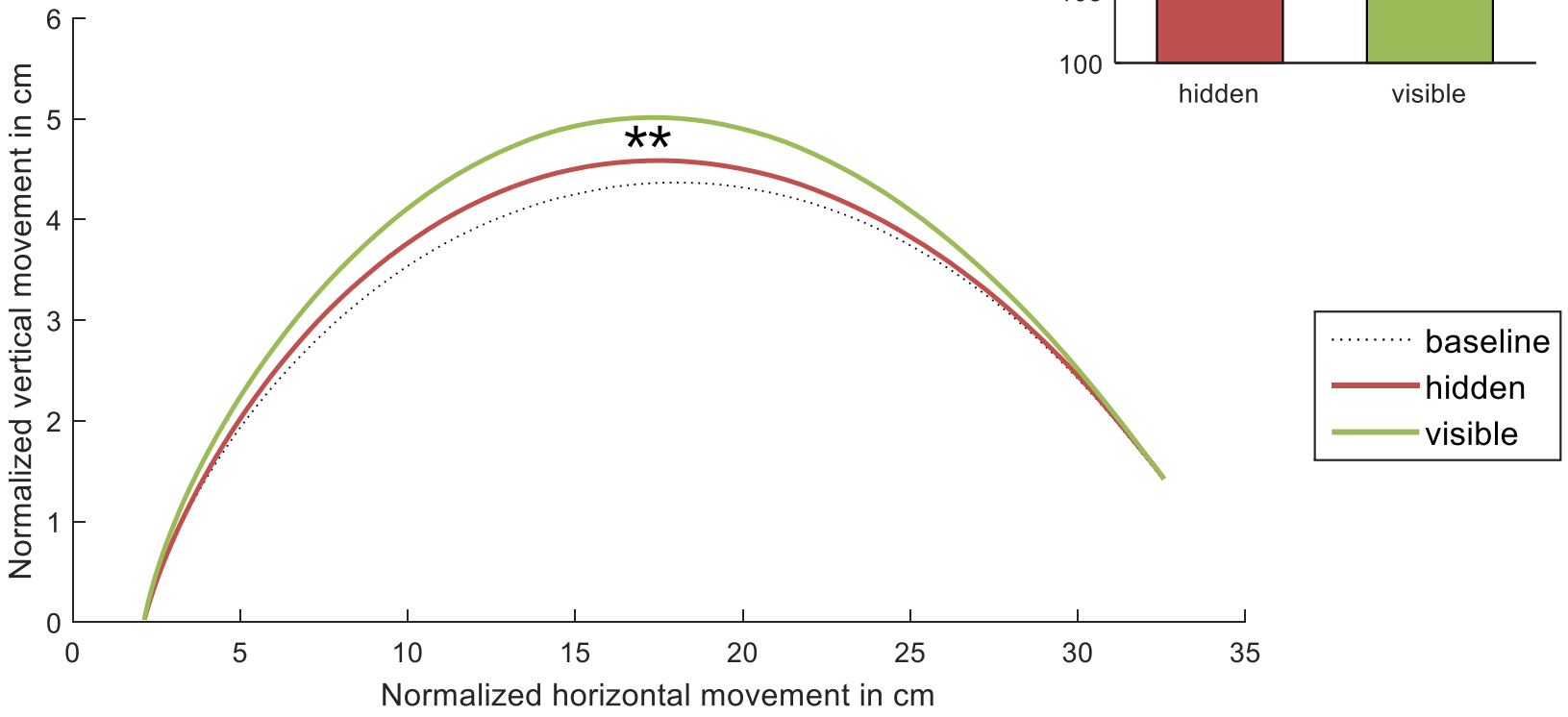
Hypothesis: As task knowledge is distributed equally and communication is therefore not necessary, exaggerations of movement kinematics indicate a preference for sensorimotor communication.

Vesper, Schmitz, Safra, Sebanz, & Knoblich, under review

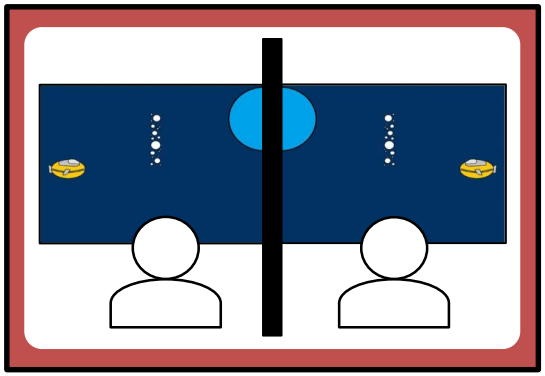
- Larger trajectory curvature when shared visual information is available.





Vesper, Schmitz, Safra, Sebanz, & Knoblich, under review

- When co-actors <u>cannot see</u> each other, the variability of their action timing influences how well coordinated co-actors are. Vesper et al., 2011



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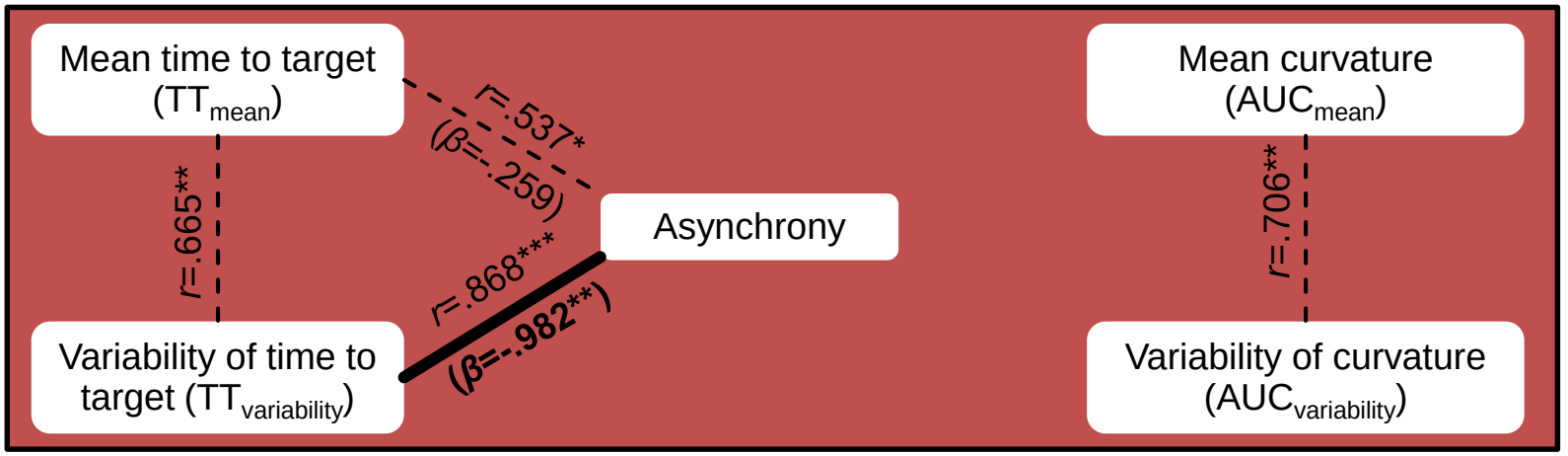
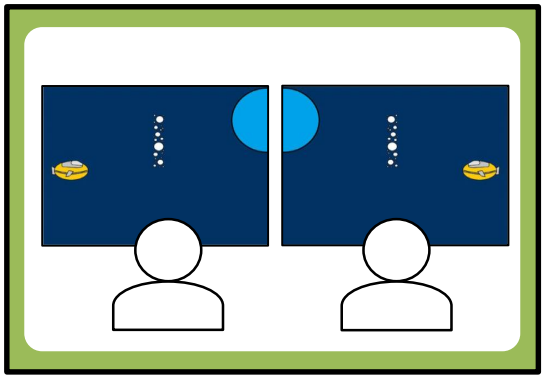


- In contrast, when co-actors <u>can see</u> each other, movement curvature predicts coordination success – even though reduction of timing variability is a feasible coordination mechanism.



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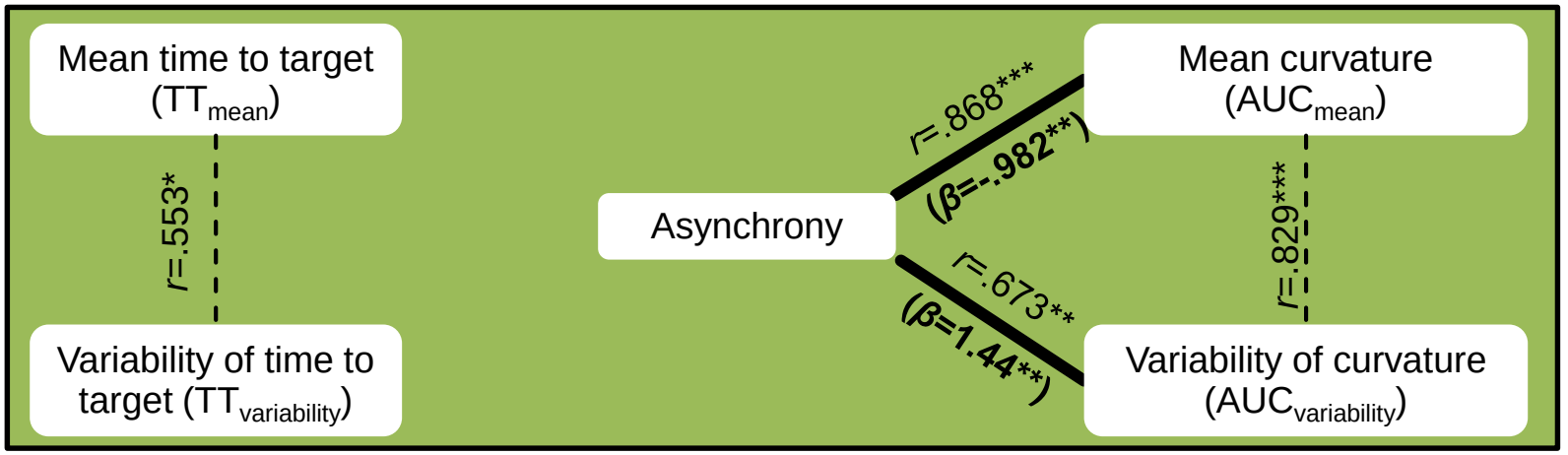
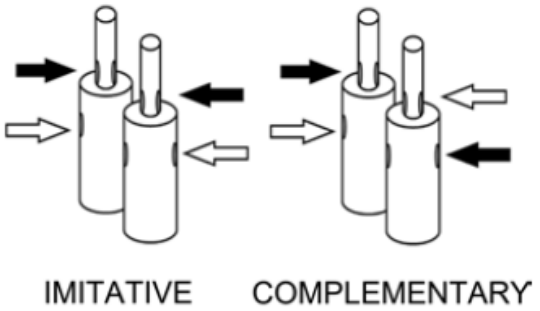


Different action kinematics are exaggerated to provide information to another person and thereby facilitate online interaction.

- Movement amplitude Goebl & Palmer, 2009; Sacheli et al., 2013; Vesper & Richardson, 2014; Vesper et al., under review
- Grasp aperture Sacheli et al., 2013
- Movement direction Pezzulo et al., 2011



Sensorimotor communication might be most needed under asymmetric knowledge conditions but can also generally support coordination, especially under high real-time constraints.

Means versus goals

- **Communicating with movement duration**

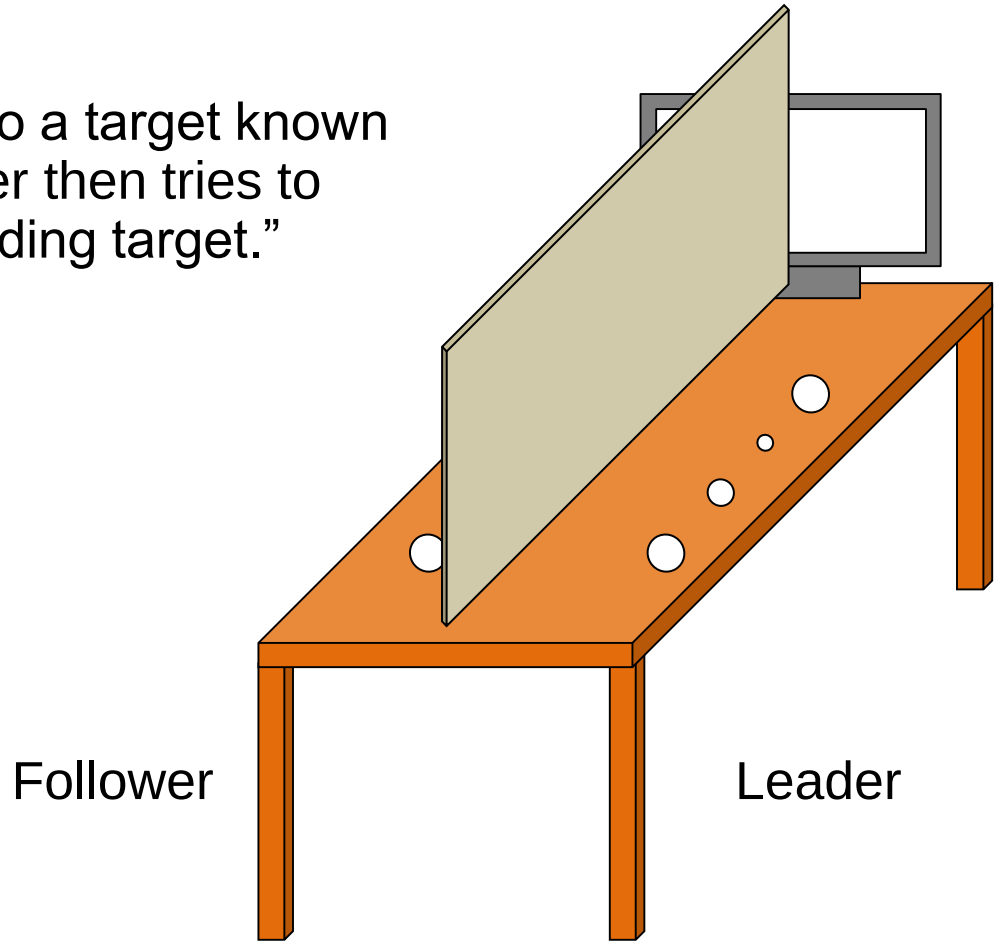
Sensorimotor communication should not be restricted to kinematic properties that are visually accessible.

Joint actions should also benefit from communicative exaggerations of action timing such as movement duration.

Would Leaders modulate the duration of their actions to communicate to a co-actor if visual information is unavailable?

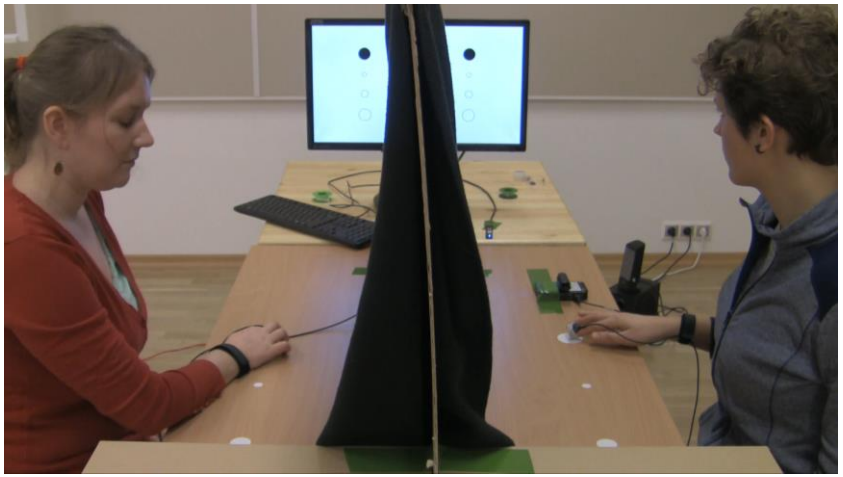
Asymmetric joint action without visual information

Task: “The Leader moves to a target known only to herself. The Follower then tries to quickly go to the corresponding target.”

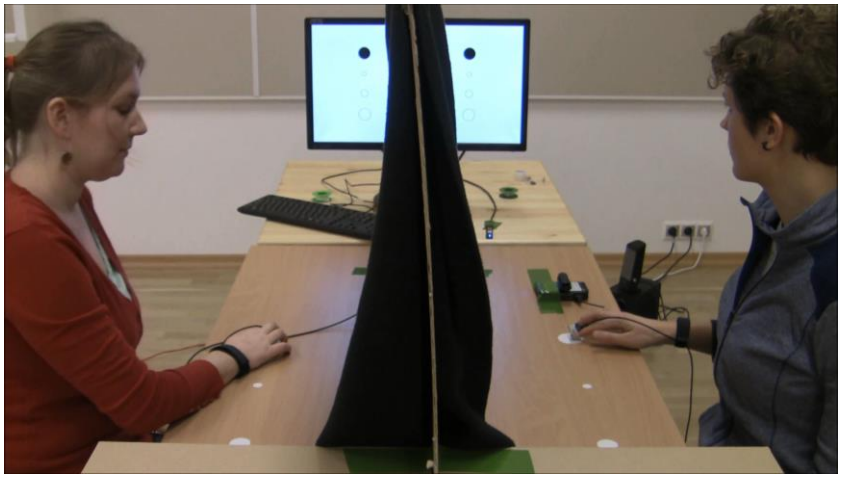


Vesper, Schmitz, & Knoblich, under review; in preparation

Pitch

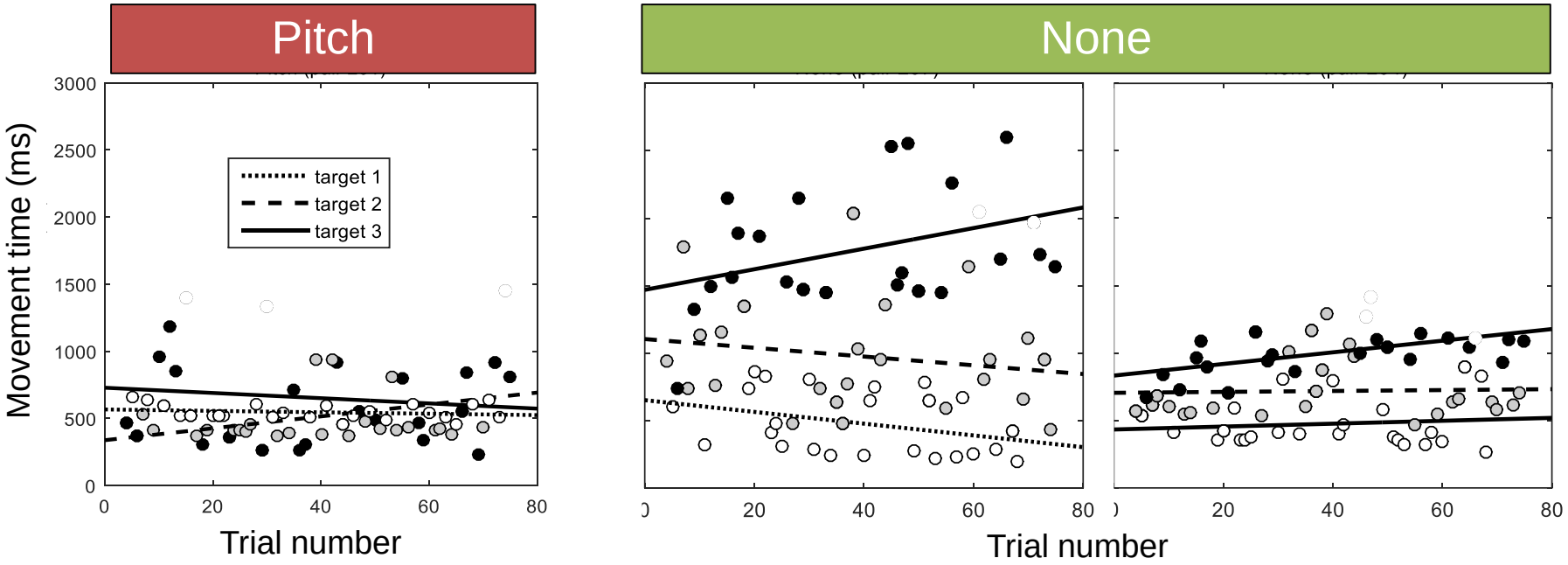


None

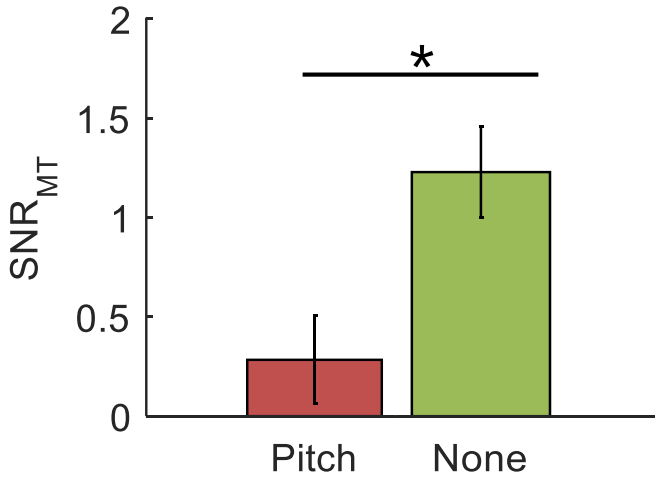


Hypothesis: Leaders modulate the duration of their actions when it is helping Followers to perform the task.

Vesper, Schmitz, & Knoblich, under review; in preparation

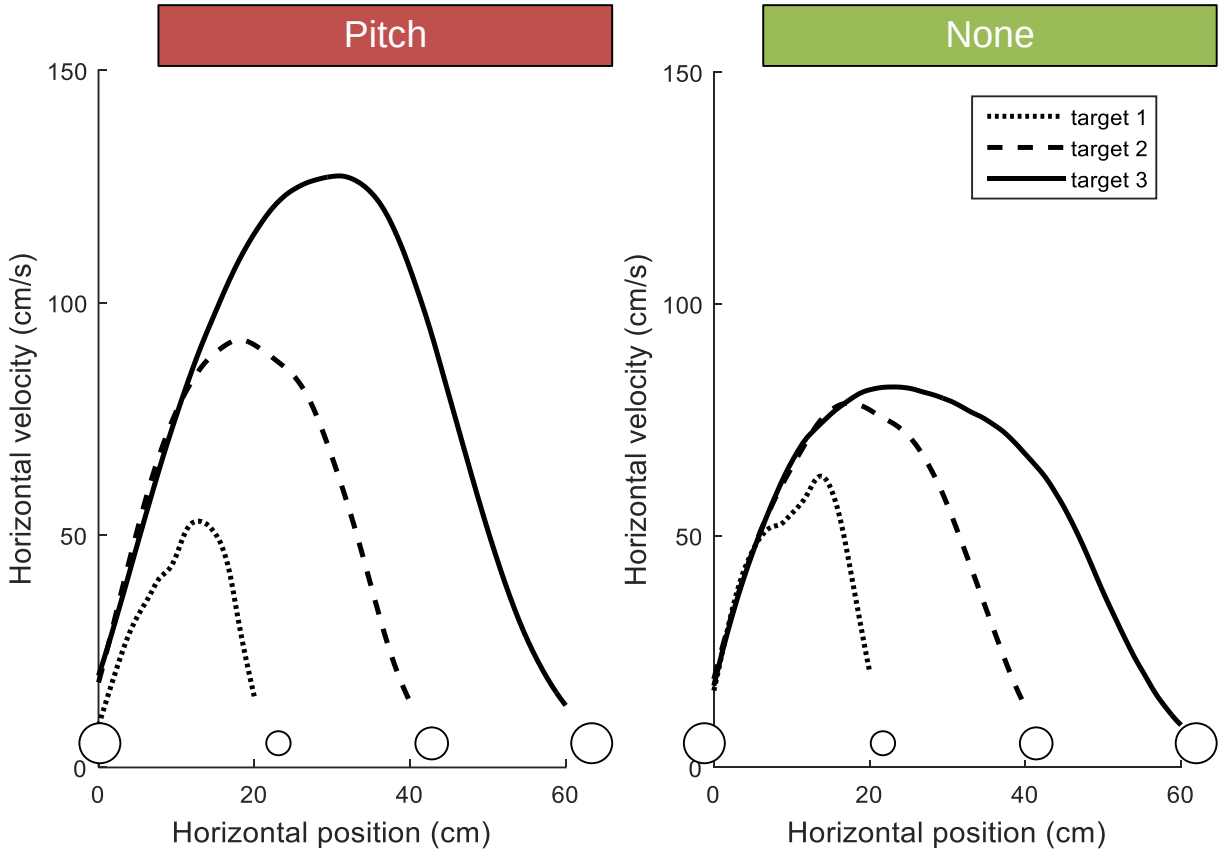


$$\text{Signal-to-noise ratio} = \frac{\text{Duration difference}}{\text{Variability of duration}}$$



- Leaders change their movement duration to differentiate targets and thereby provide communicative signals to Followers.

Vesper, Schmitz, & Knoblich, under review; in preparation



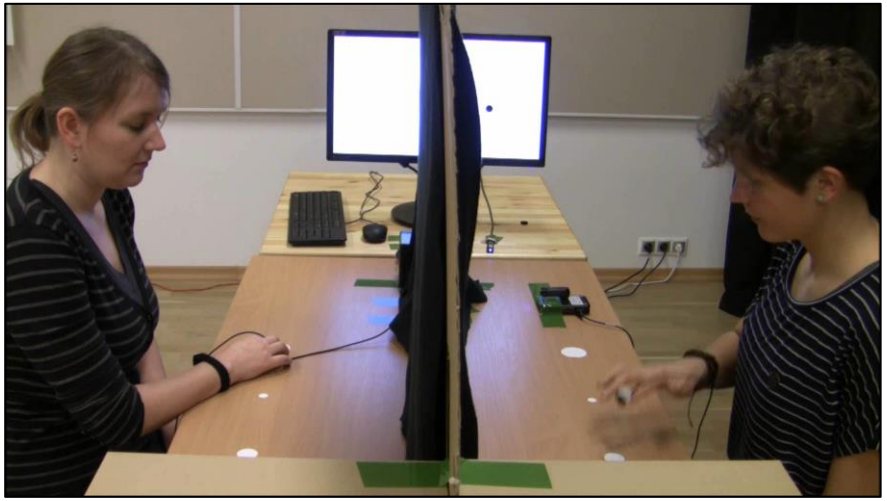
- To make targets distinct, Leaders change their movement time by keeping velocity more constant across targets. See Fitts, 1954

Vesper, Schmitz, & Knoblich, under review; in preparation

Scaling-up communication

If given the choice, would co-actors switch to a more symbolic form of communication, i.e. modulating the action end-state (*action goal*) instead of the movement itself (*action means*)?

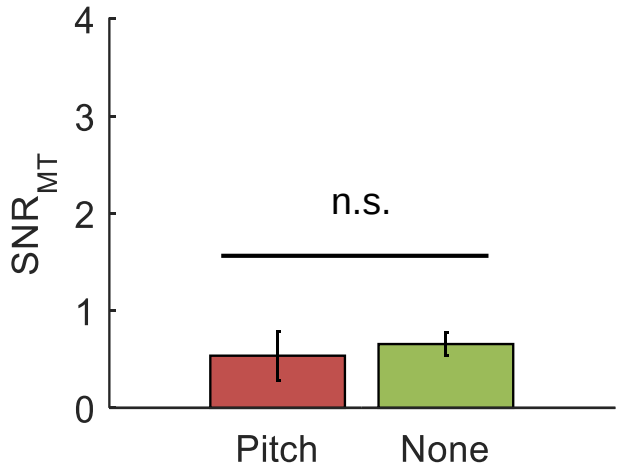
None



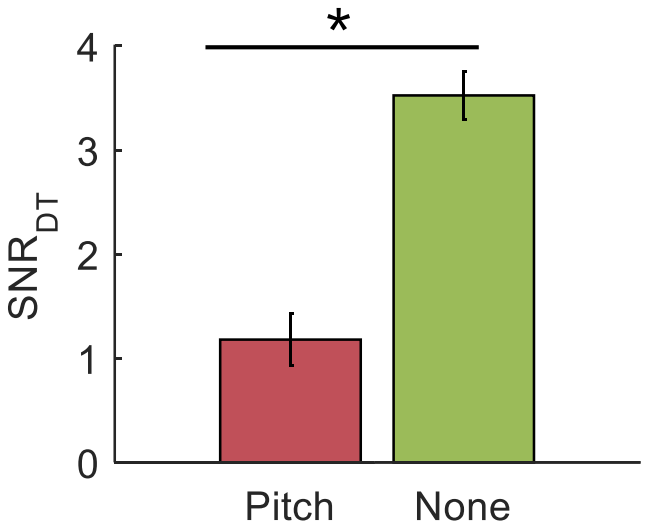
Follow-up experiment:

Vesper, Schmitz, & Knoblich, under review; in preparation

Modulation of movement time?



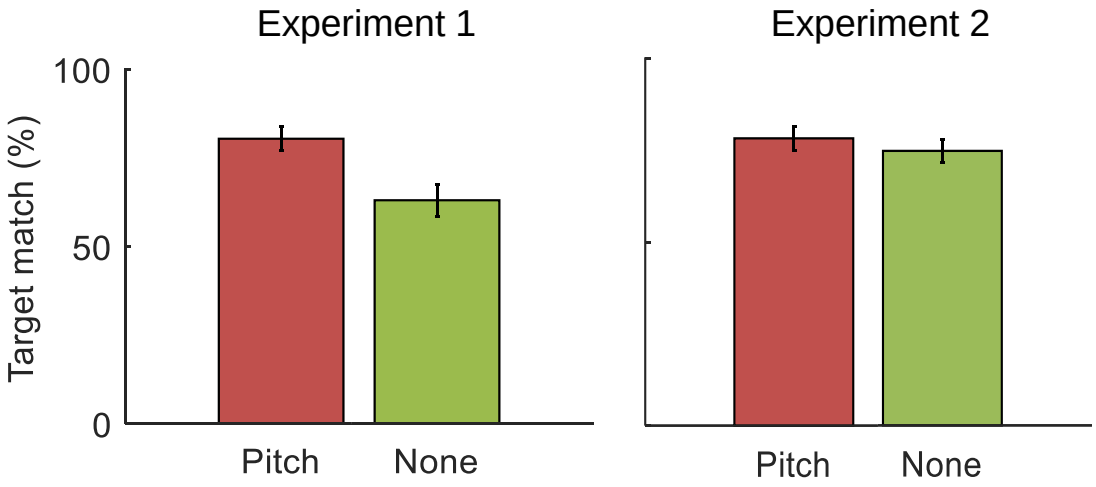
Or modulation of endstate?



- If given the option, Leaders shift from exaggerating movement execution towards a communicative signal based on the action end-state.

From sensorimotor communication to symbolic communication

Exaggerating action end-state might be more easily interpreted as having a communicative intention and might therefore be more efficient in supporting joint action.



- Followers in the online interaction perform better if Leaders communicate with modulations of the end-state.

Vesper, Schmitz, & Knoblich, under review; in preparation



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Conclusions

Research on human-human interaction shows that the "burden" of understanding another's action is not only on the perceiver's side – performers help the perceiver (when needed), e.g. by making their action goal easier to discriminate. Communication is bidirectional!

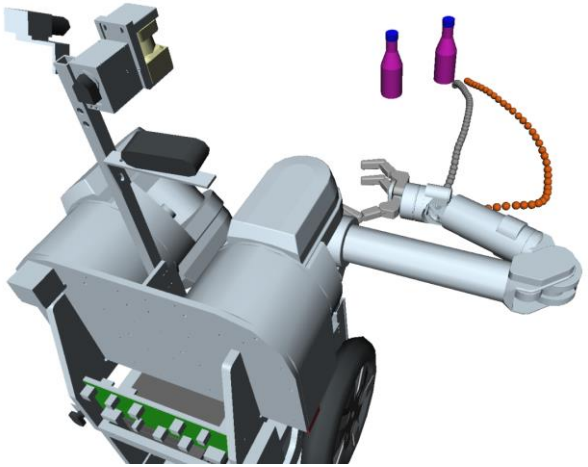
Thus, robots should be able to produce and understand sensorimotor communication in different contexts and using different forms. This requires a mechanism that realizes what *efficient performance* of an action is and how that is distinct from inefficient performance.

In human-robot interaction, *efficiency* needs to be guided by human standards. To implement sensorimotor communication, robot movements need to reflect human action constraints, even if the robot has other capabilities.

Conclusions

Sensorimotor communication might be implemented

- As specific exaggerations from direct movement paths such as movement amplitude or specific grasp parameters such as aperture
  See Dragan et al., 2013
- As modulations of movement duration
- Dependent on the robot‘s interactional role



Joint action between humans and robots will benefit from establishing common ground, for which sensorimotor communication can be helpful.

Thanks for your attention!

Sensorimotor communication

Francesco Donnarumma
ISTC-CNR

Haris Dindo
University of Palermo

Matteo Candidi
Arianna Curioni
Lucia Sacheli
University of Rome La Sapienza

HUMAN FRONTIER SCIENCE PROGRAM
FUNDING FRONTIER RESEARCH INTO COMPLEX BIOLOGICAL SYSTEMS

Laura Schmitz
Natalie Sebanz
Günther Knoblich
Central European University

Lou Safra
LNC/ENS

Michael J. Richardson
University of Cincinnati