The Role of Predictions in Human-Prosthesis Joint Action

Patrick M. Pilarski

Canada Research Chair in Machine Intelligence for Rehabilitation
Division of Physical Medicine and Rehabilitation, Dept. of Medicine

Fellow, Alberta Machine Intelligence Institute (Amii)

UNIVERSITY OF ALBERTA
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BLINC
BIONIC LIMBS FOR IMPROVED NATURAL CONTROL

SMART NETWORK
Sensory Motor Adaptive Rehabilitation Technology

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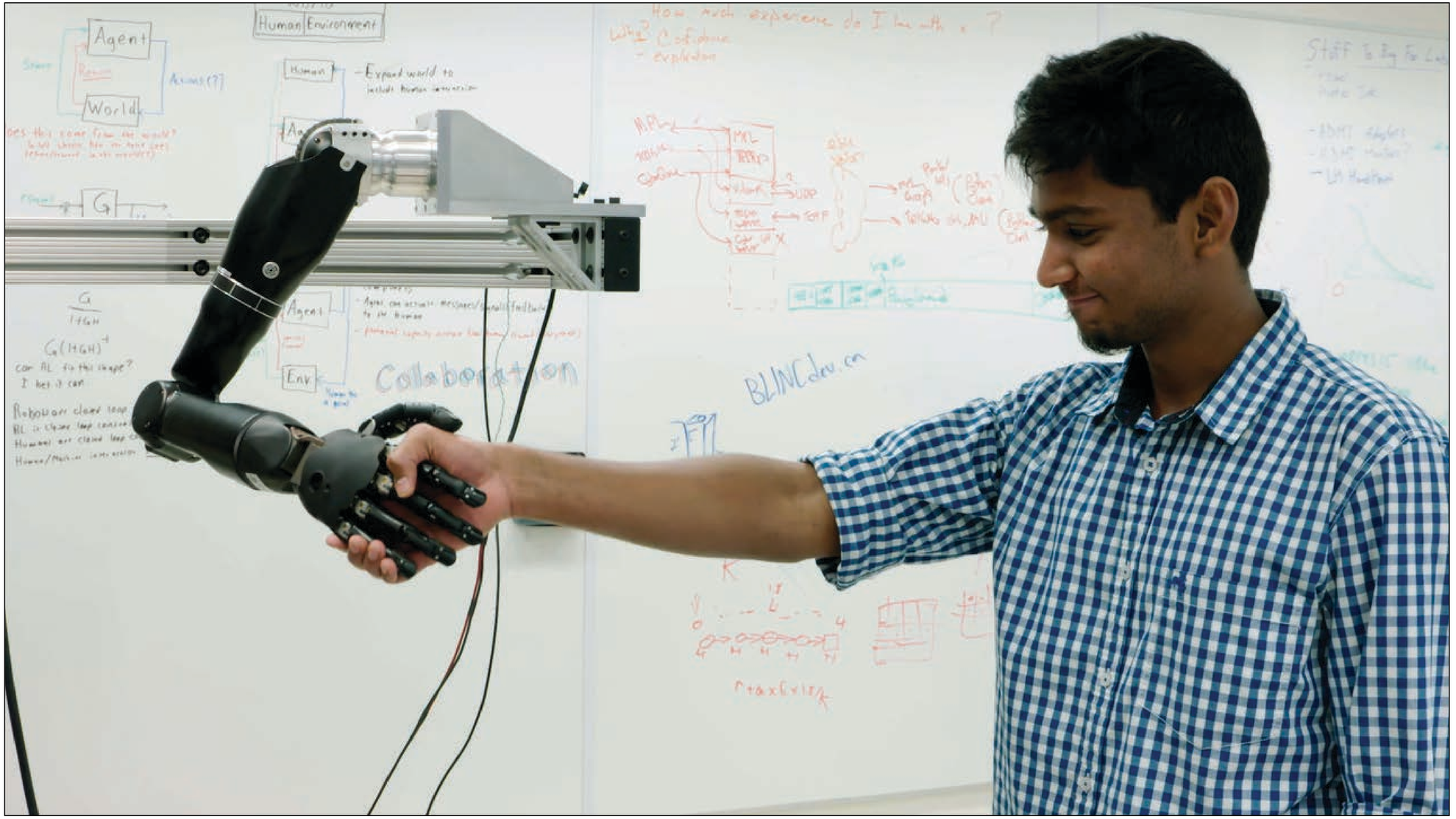

Joint Action?

Joint Action

Pesquita, Whitwell, and Enns, *Psychon Bull Rev* 25, 2018: “Predictive joint-action model: A hierarchical predictive approach to human cooperation”

JOINT ACTION

"a social interaction whereby two or more individuals coordinate their actions in space and time to bring about change in the environment"

Sebanz et al. (2006). Joint action: Bodies and minds moving together. *Trends. Cogn. Sci.* 10(2), 70–76.

Representation of shared **goal** and individual contributions to the shared goal.

Pesquita, Whitwell, and Enns, *Psychon Bull Rev* 25, 2018: “Predictive joint-action model: A hierarchical predictive approach to human cooperation”
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Monitoring and prediction of partner actions.

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Representation of shared **goal** and individual contributions to the shared goal.

Monitoring and prediction of partner actions.

Continual coordination via **continual improvement of predictions** about a partner's actions.

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PREDICTIONS

Momentary.
(e.g., classification decision)

S. Micera, J. Carpaneto, and S. Raspopovic, "Control of hand prostheses using peripheral information," *IEEE Rev. Biomed. Eng.*, 2010.

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Sutton et al., "Horde: A Scalable Real-time Architecture for Learning Knowledge from Unsupervised Sensorimotor Interaction," *Proc. of 10th International Conference on Autonomous Agents and Multiagent Systems (AAMAS)*, 2011.

PREDICTIONS

Momentary.
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Temporally extended.
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Can be acquired or updated in batches or in real time.

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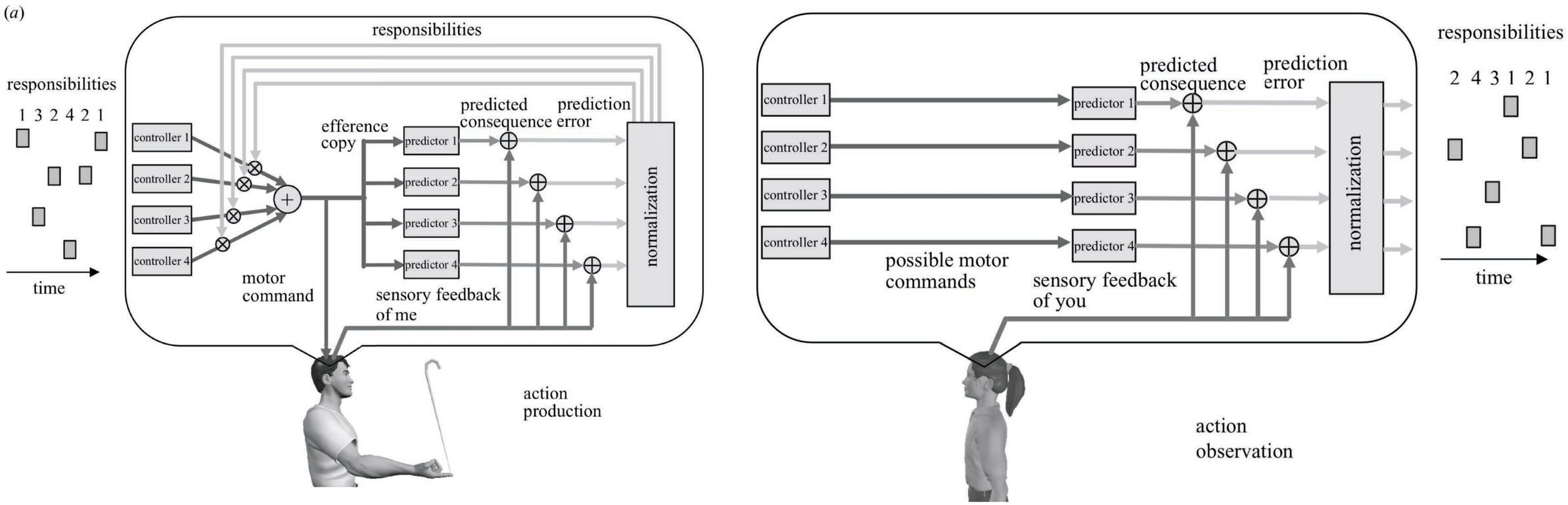
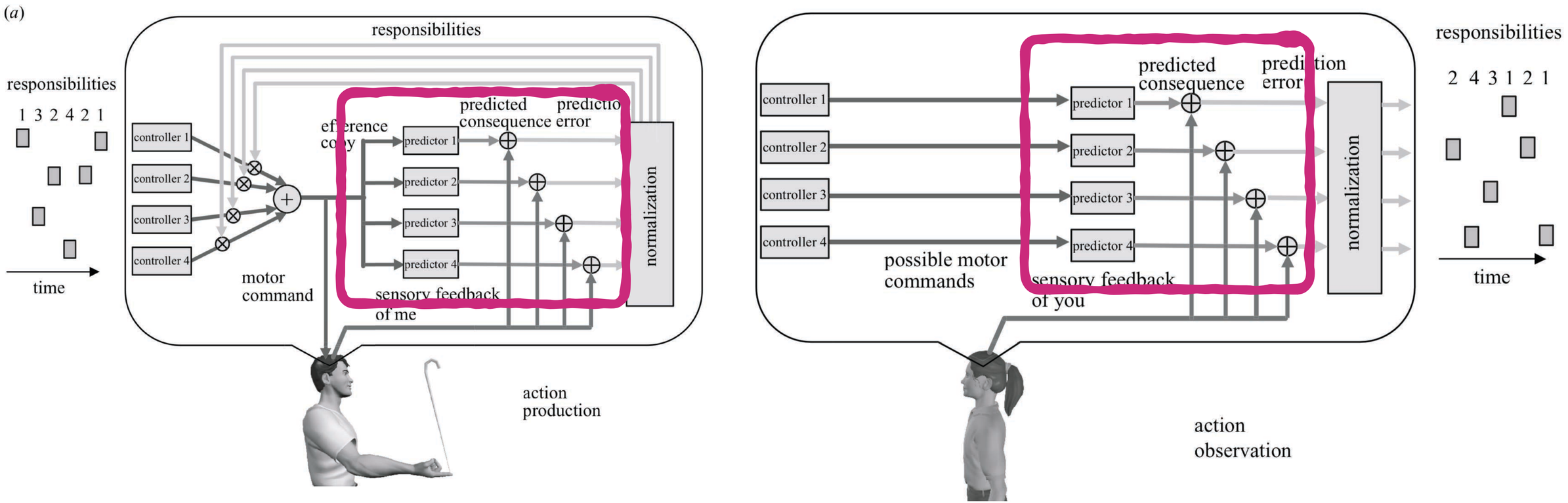
Sutton et al., "Horde: A Scalable Real-time Architecture for Learning Knowledge from Unsupervised Sensorimotor Interaction," *Proc. of 10th International Conference on Autonomous Agents and Multiagent Systems (AAMAS)*, 2011.

Wolpert et al., *Trends Cog Sci* 5(11), 2001: “Perspectives and problems in motor learning”
Flanagan et al., *Current Biology* 13(2), 2003: “Prediction precedes control in motor learning”
Desmurget et al., *Science* 324(5928), 2009: “Movement intention after parietal cortex stimulation in humans”



MOSAIC

Wolpert, Doya, and Kawato, *Phil Trans Royal Soc London B*, 358(1431), 2003: “[Motor control and social interaction]”



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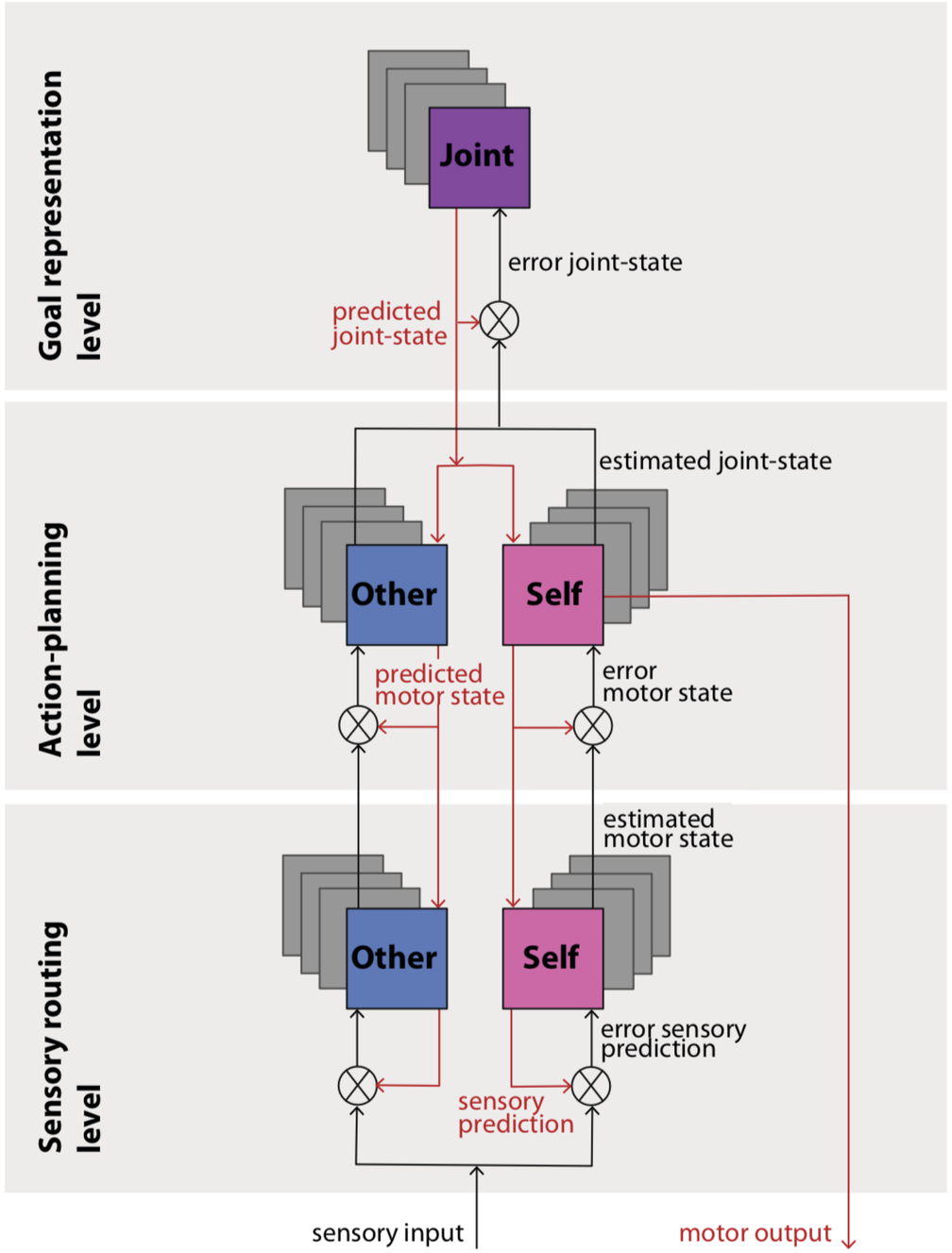

Predictive Joint-Action Model (PJAM)

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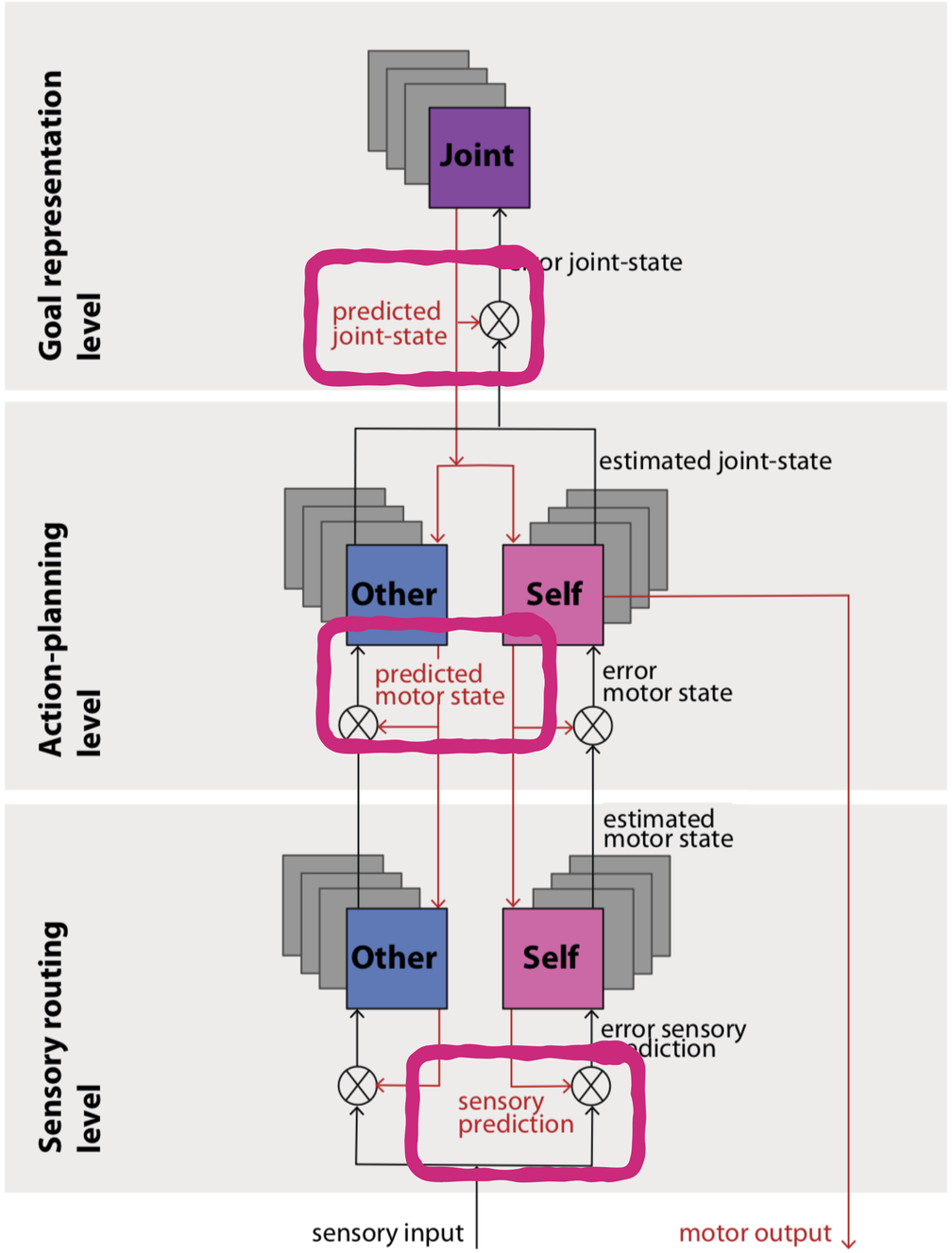

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“Hey! Look! (It’s not just for human-human dyads)

The Legend of Zelda: Ocarina of Time (1998)

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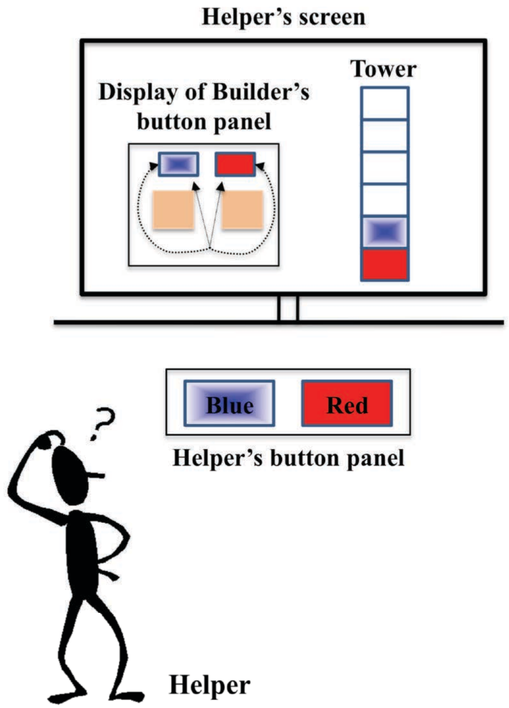

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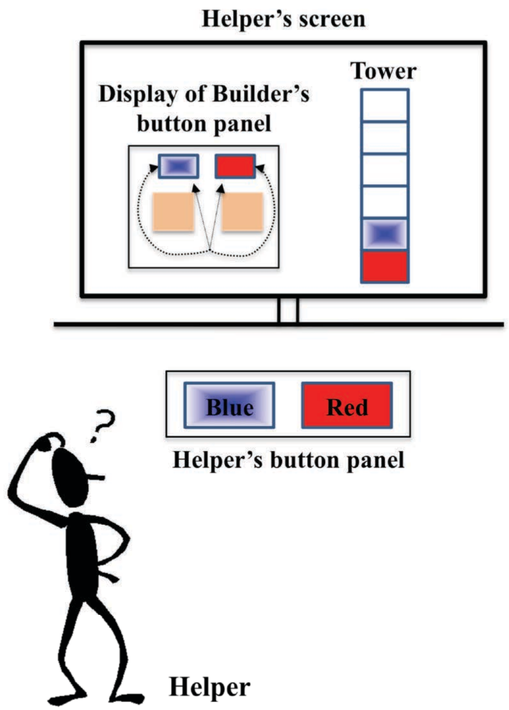

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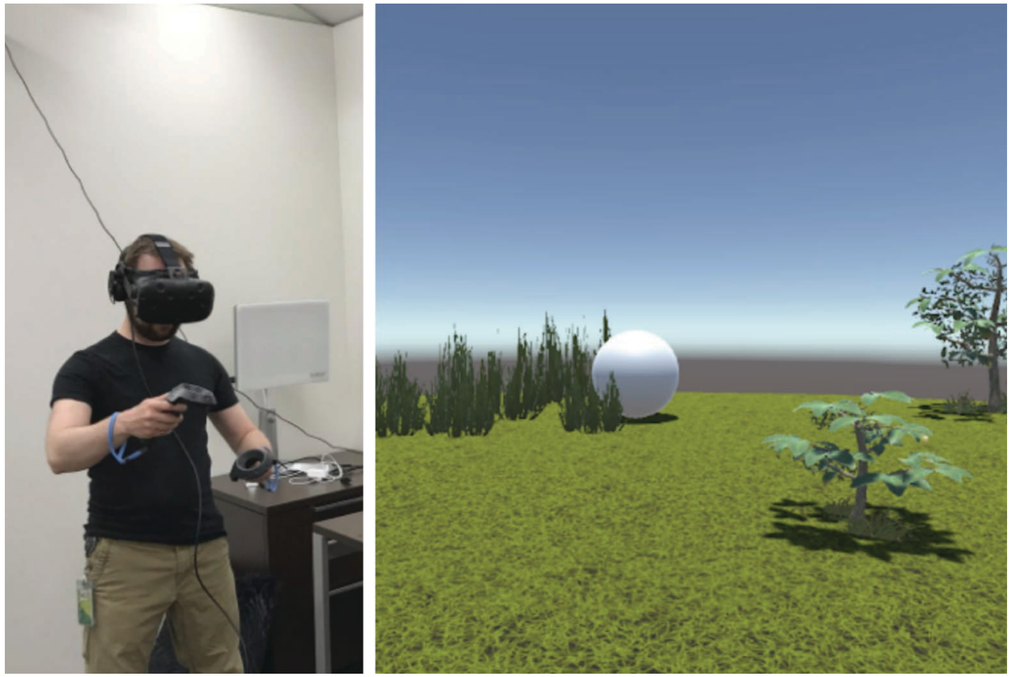
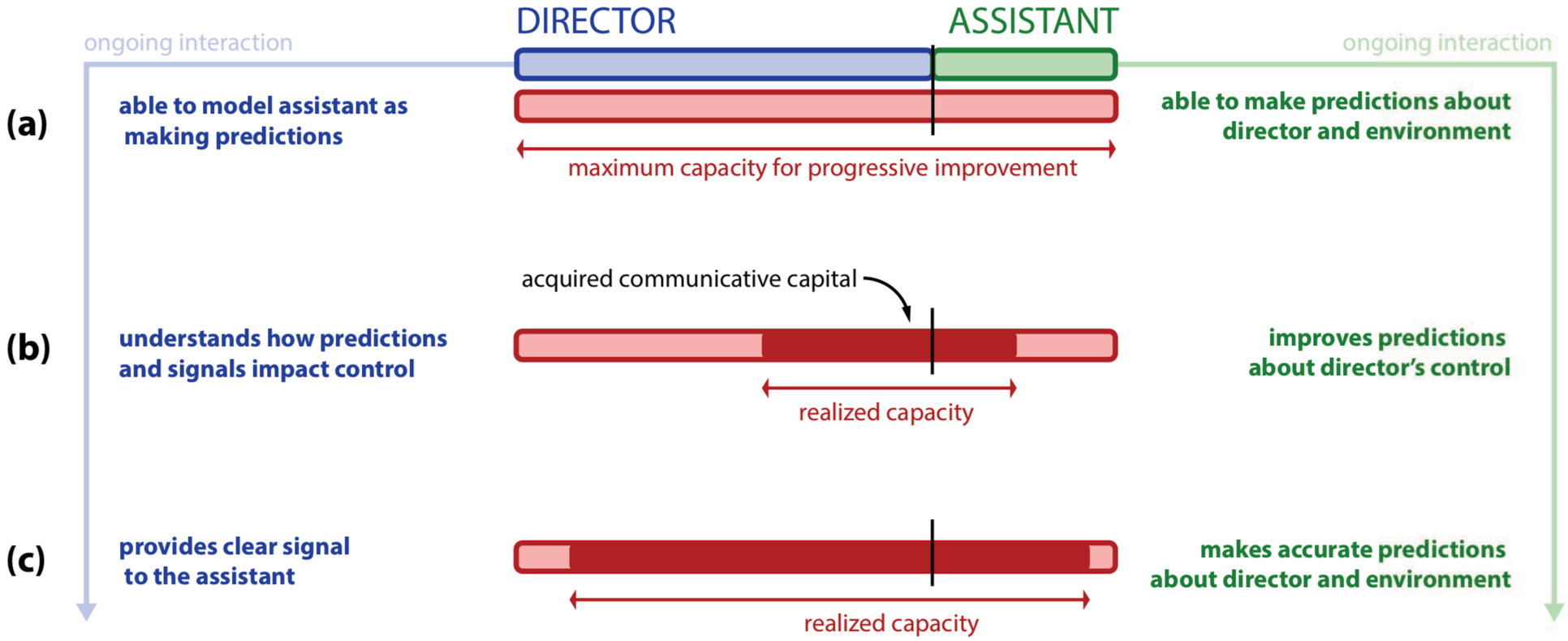


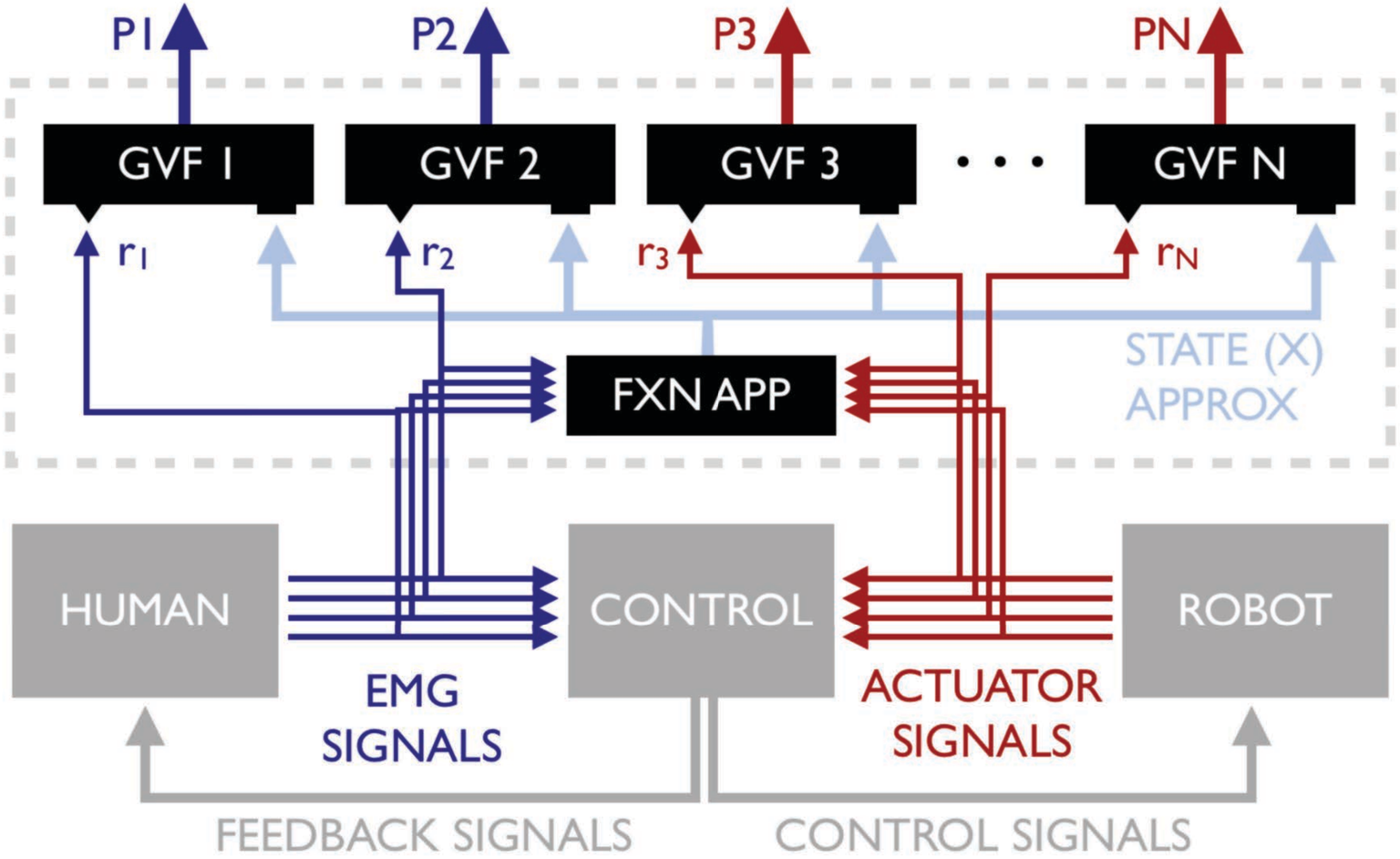
P. M. Pilarski, A. Butcher, M. Johanson, M. M. Botvinick, A. Bolt, A. S. R. Parker, “Learned human-agent decision-making, communication and joint action in a virtual reality environment,” *RLDM 2019 / arXiv:1905.02691* [cs.AI], 5 pages, 2019.

Predictions as *Communicative Capital*



P. M. Pilarski, R. S. Sutton, K. W. Mathewson, C. Sherstan, A. S. R. Parker, A. L. Edwards, "Communicative Capital for Prosthetic Agents," arXiv:1711.03676 [cs.AI] (arXiv): 33 pages, 2017.

Commercially Deployed
Pattern Recognition for Prostheses



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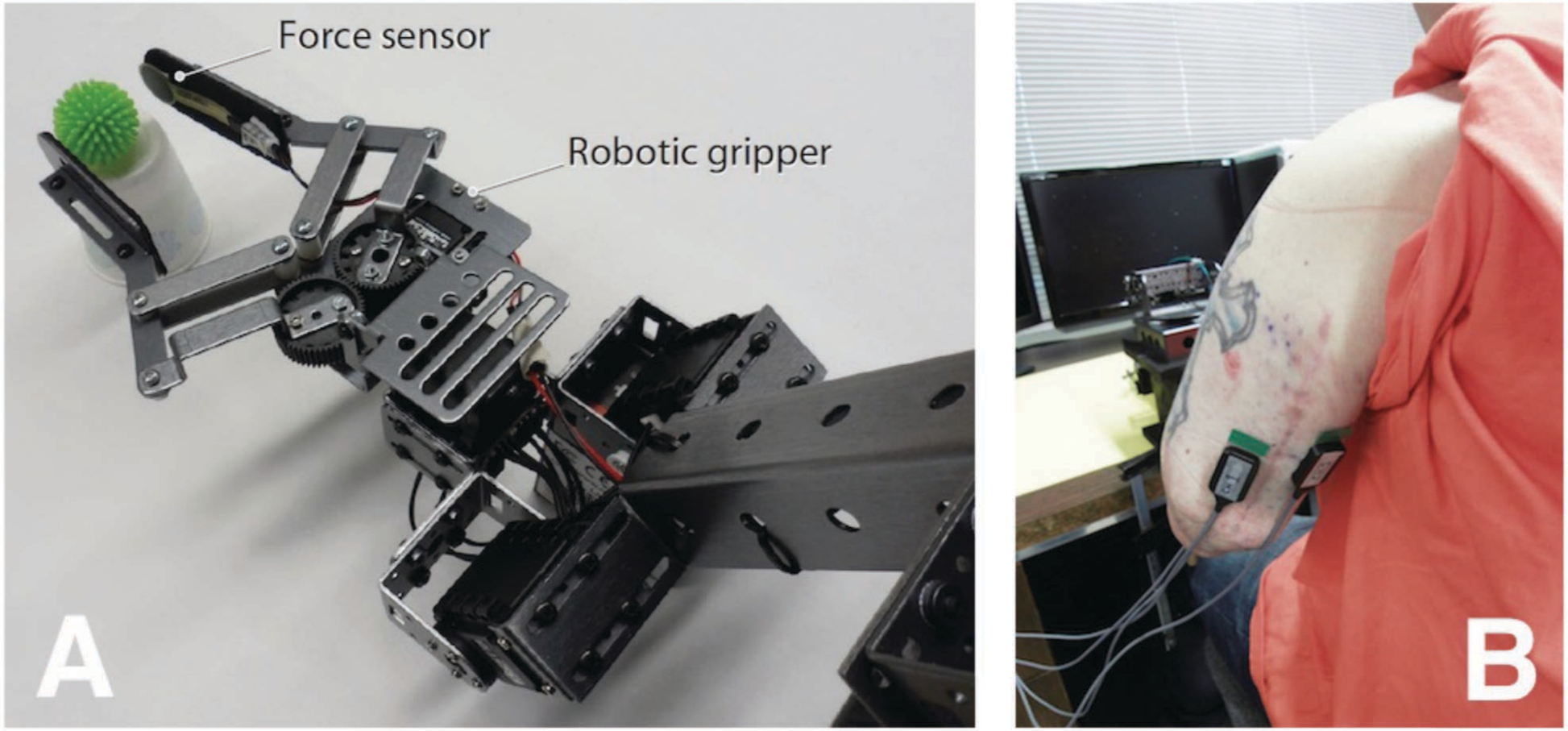

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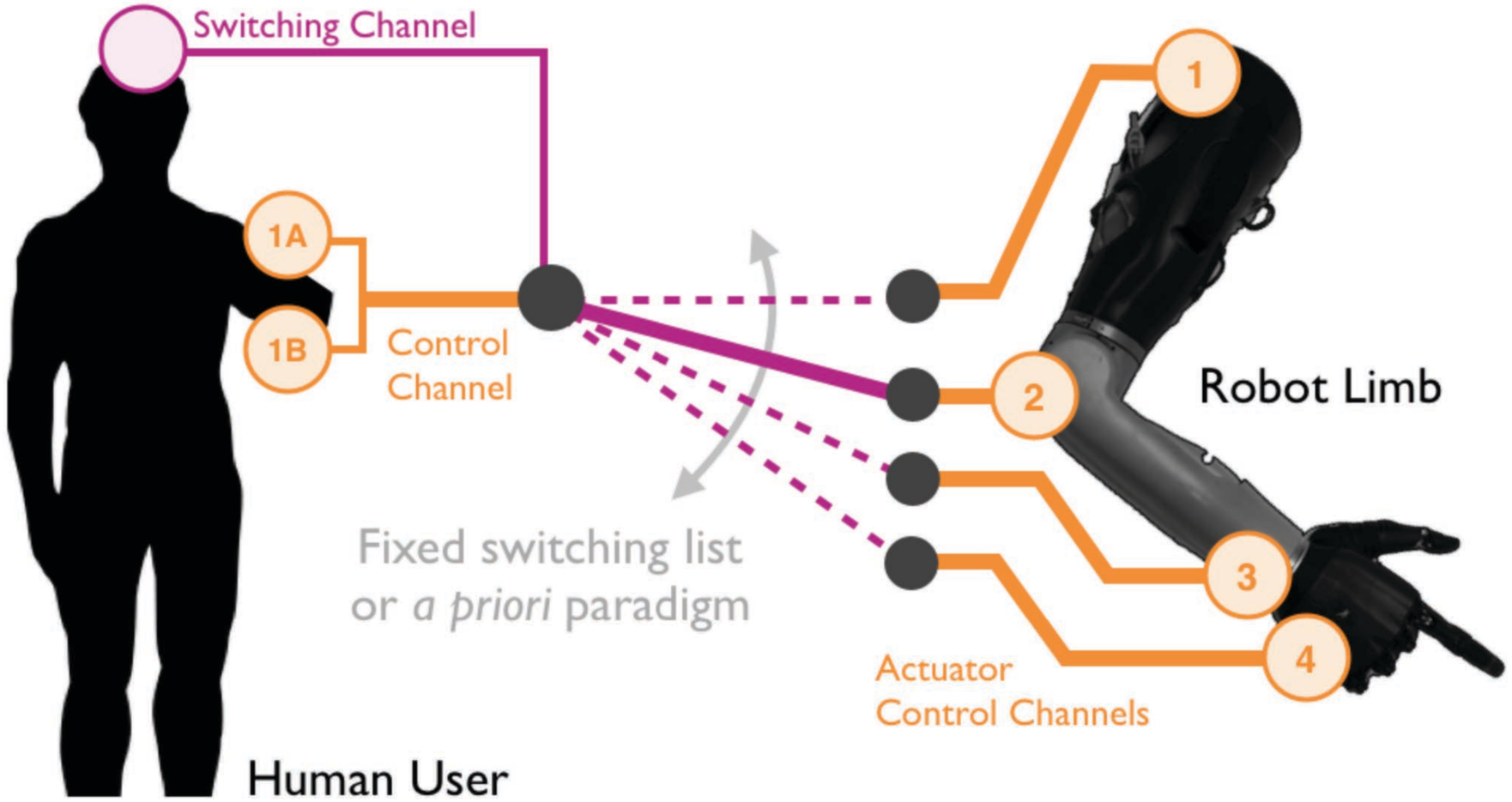

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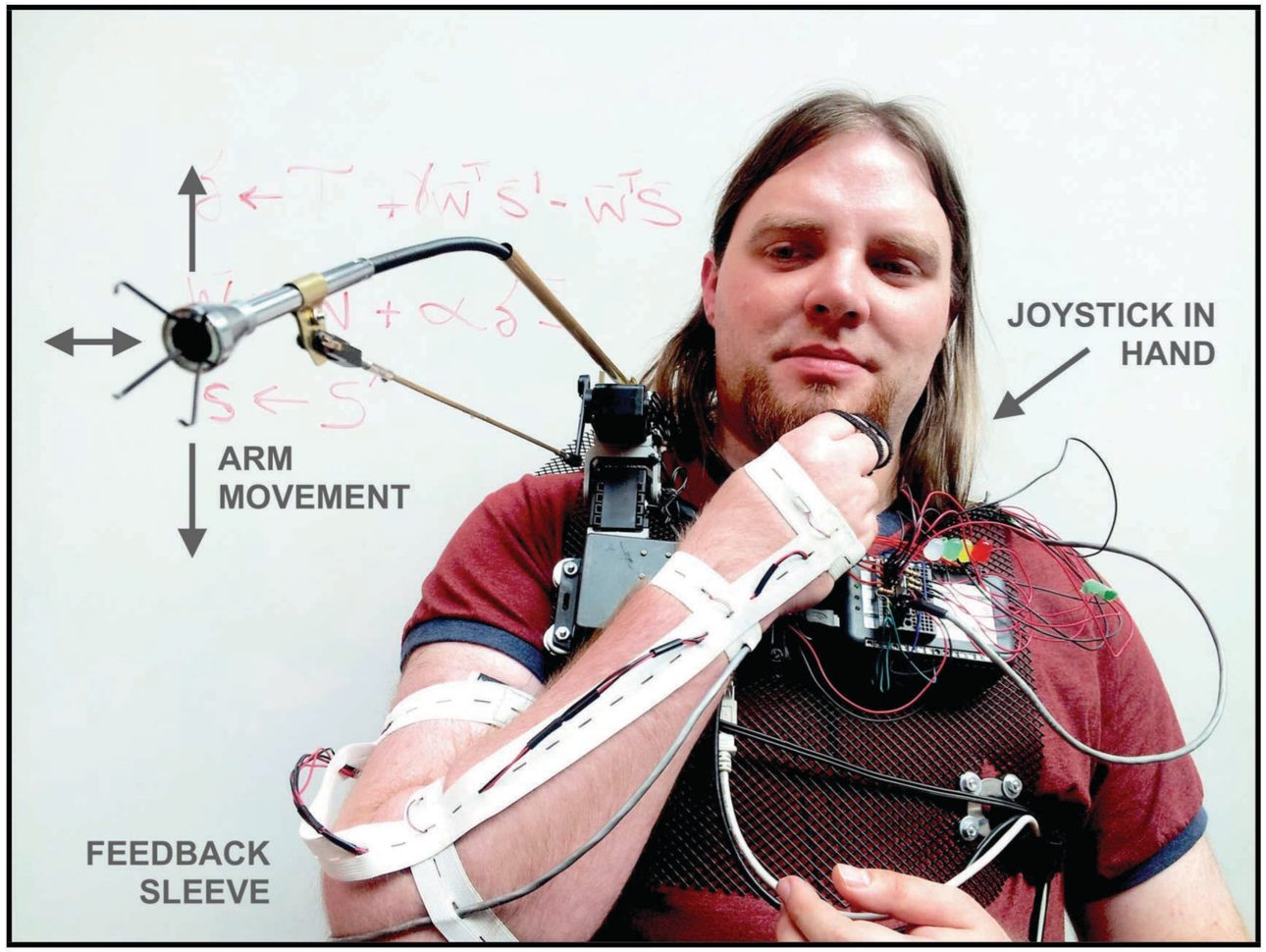
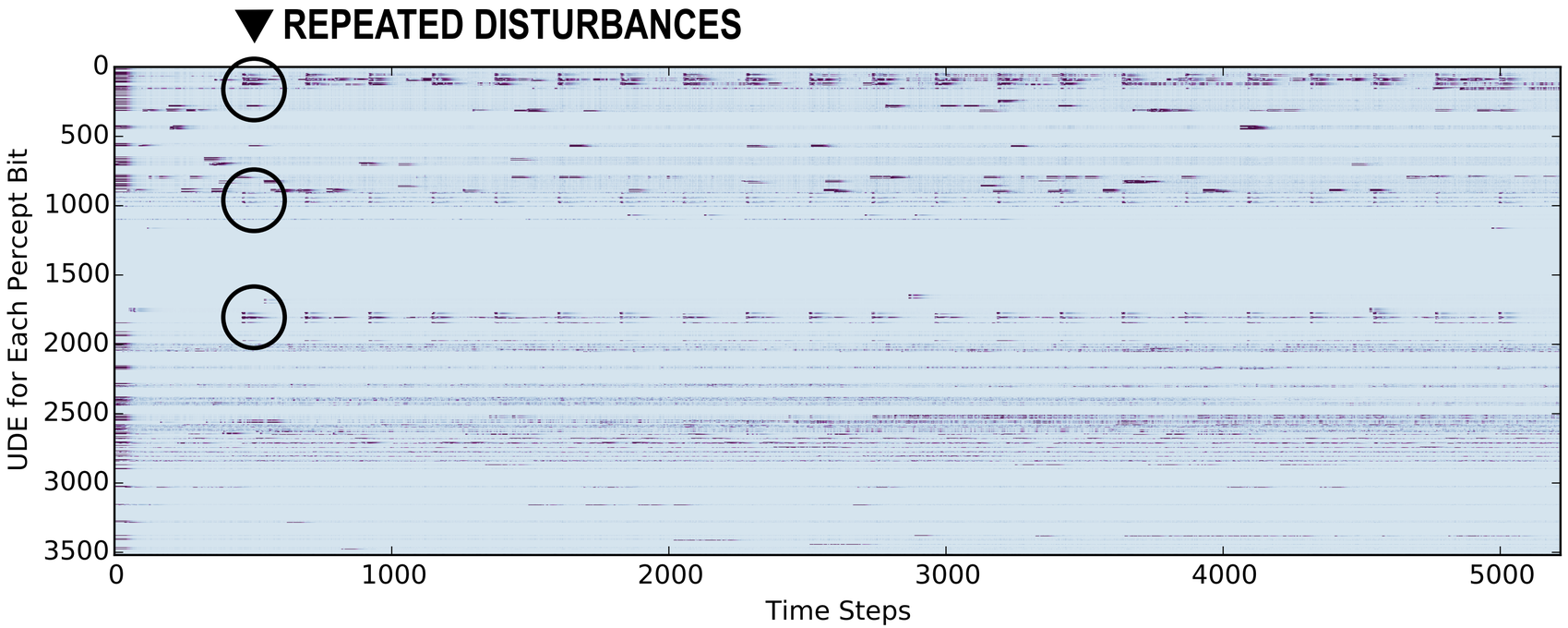


A. S. R. Parker, A. L. Edwards, P. M. Pilarski, “Exploring the Impact of Machine-Learned Predictions on Feedback from an Artificial Limb,” *2019 IEEE-RAS-EMBS International Conference on Rehabilitation Robotics (ICORR)*, 24-28 June, 2019, Toronto, 8 pages.



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We have both the technology and model systems to study human-machine coordination as joint action.

C. Castellini at al., “Proceedings of the First Workshop on Peripheral Machine Interfaces: going beyond traditional surface electromyography,” *Frontiers in Neurorobotics*, vol. 8, no. 22, Aug. 2014.

finally!

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Real-time machine learning

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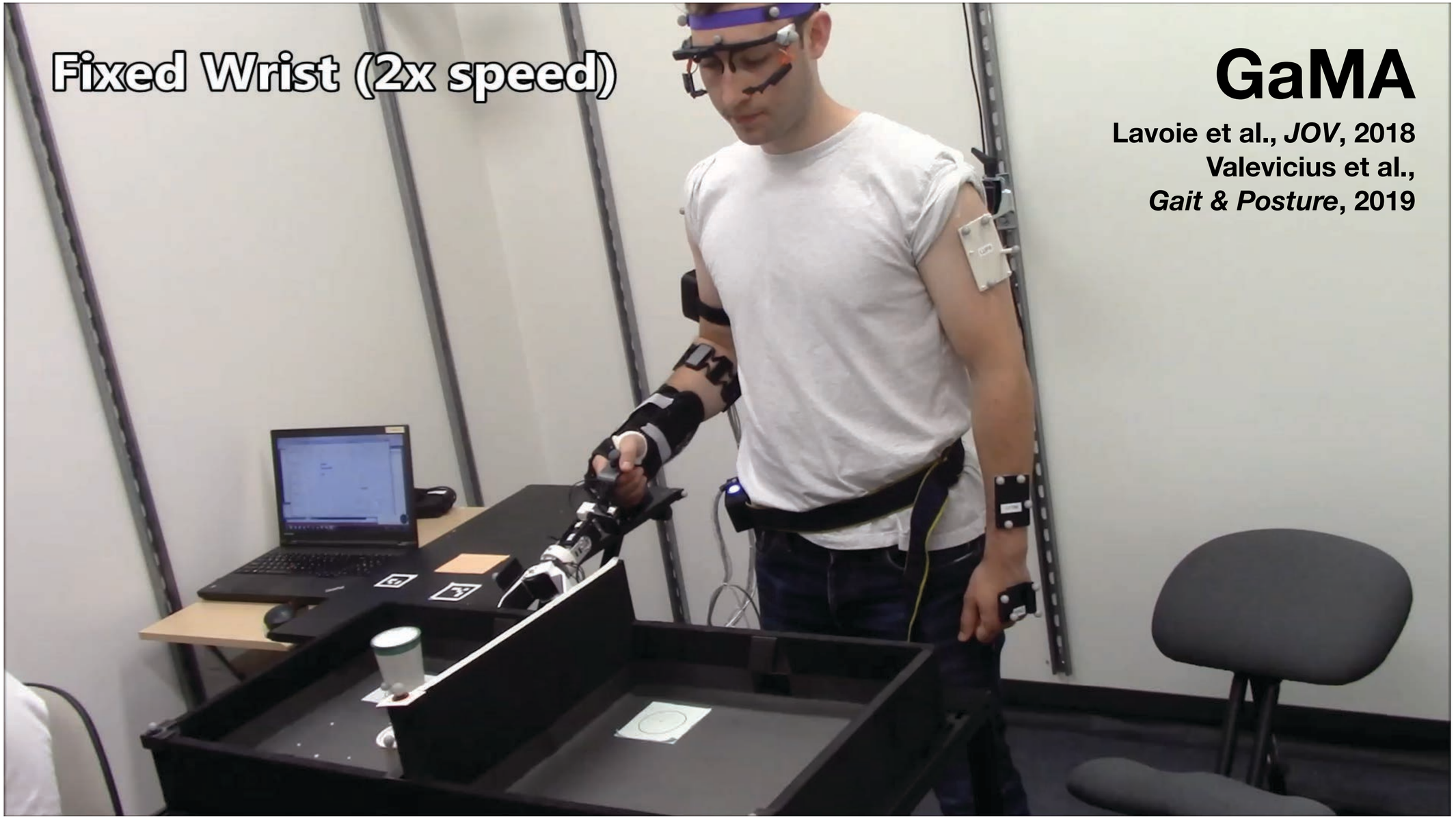

Brenneis et al., "The Effect of an Automatically Levelling Wrist Control System," *2019 IEEE-RAS-EMBS International Conference on Rehabilitation Robotics (ICORR)*, 24-28 June, 2019, Toronto, Canada, 8 pages

Both humans and machines can now represent goals, make and maintain predictions...

... can we gain utility by viewing human-prosthesis action as joint action?

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(Let's find out!)

With thanks to many collaborators:

Dr. Richard Sutton
Dr. Jacqueline Hebert
Dr. Craig Chapman
Dr. Albert Vette
Michael Rory Dawson
Trainees past and present
Dept. CS and Dept. Medicine
Glenrose Rehabilitation Hospital

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