The Emerging Role of Machine-Learned Feedback in Neuroprostheses

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C.O.I. Disclosure

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950BC - 700BC, The "Cairo Toe" (The University of Manchester),
Video courtesy:
Amii / Chris Onciul
Extension
Engelbart, 1962
Serino, 2019
Amplification
Ashby, 1956
Tightly Coupled
Licklider, 1960
the control pathway

Hallworth, et al.,
MEC, 2020
machine intelligence

the **feedback** path
(mechanical, auditory, visual)
engineered feedback

surgically enhanced feedback

Marasco, et al., Science Robotics, 2021
Hebert, et al., IEEE TNSRE, 2014
machine learned feedback

Parker, et al.,
ICORR, 2019
Expert-Designed
or Fixed Signalling

Emergent or Fully
Learned Signalling

scientific gap
Expert-Designed or Fixed Signalling


Emergent or Fully Learned Signalling
Expert-Designed or Fixed Signalling

Emergent or Fully Learned Signalling

a first, natural stepping stone
Pavlovian signalling

Butcher et al., 2022; Brenneis et al., 2022; Pilarski et al., 2022.
Pavlovian signalling is a process wherein learned, temporally extended predictions

Butcher et al., 2022; Brenneis et al., 2022; Pilarski et al., 2022.
Pavlovian signalling is a process wherein learned, temporally extended predictions are mapped in a defined way to signals intended for receipt by a decision-making agent.

Butcher et al., 2022; Brenneis et al., 2022; Pilarski et al., 2022.
Pavlovian signalling is a process wherein learned, temporally extended predictions are mapped in a defined way to signals intended for receipt by a decision-making agent, and where these signals are grounded for the sender in the definition of the predictive question and mapping approach that generated them.

Butcher et al., 2022; Brenneis et al., 2022; Pilarski et al., 2022.
Butcher et al., 2022; Brenneis et al., 2022; Pilarski et al., 2022.
Pavlovian Signalling Co-Agent

Thresholded GVF Prediction

Binary Signal

A/V State  

Reward  

Event

Action

Human

Butcher et al., 2022; Brenneis et al., 2022; Pilarski et al., 2022.
Waiting for wind to pass...

The Frost Hollow Experiments

Pavlovian signalling in **motor prediction**.
Parker et al., *IEEE SMC 2022* (submitted); Parker et al., *ICORR 2019*.

Switching-based **exoskeleton control**.
Faridi et al., *ICORR 2022*.

Emergent communication during navigation.
Kalinowska et al., *CogSci 2022*; Kalinowska et al., *ICLR EmeCom 2022*.

Pavlovian signalling in **mode switching**.
Edwards et al., *BioRob 2016*. 
Pavlovian signalling in **motor prediction**. Parker et al., IEEE SMC 2022 (submitted); Parker et al., ICORR 2019.


Switching-based **exoskeleton control**. Faridi et al., ICORR 2022.

**Emergent communication** during navigation. Kalinowska et al., CogSci 2022; Kalinowska et al., ICLR EmeCom 2022.
Pavlovian signalling in **motor prediction**. Parker et al., *IEEE SMC* 2022 (submitted); Parker et al., *ICORR* 2019.


Switching-based **exoskeleton control**. Faridi et al., *ICORR* 2022.

Pavlovian signalling in **motor prediction.** Parker et al., IEEE SMC 2022 (submitted); Parker et al., ICORR 2019.


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Switching-based **exoskeleton control.** Faridi et al., ICORR 2022.

**Emergent communication** during navigation. Kalinowska et al., CogSci 2022; Kalinowska et al., ICLR EmeCom 2022.

Emergent communication during navigation. Kalinowska et al., CogSci 2022; Kalinowska et al., ICLR EmeCom 2022.
Context


Video courtesy:
Amii / Chris Onciul
Interpretation


Assessment


Video courtesy: Amii / Chris Onciul
Pavlovian signalling

Expert-Designed or Fixed Signalling

Emergent or Fully Learned Signalling
Expert-Designed or Fixed Signalling

Pavlovian Signalling

context

assessment

policy learning

frameworks

model learning

Emergent or Fully Learned Signalling
Ostensive-inferential Communication

Expert-Designed
or Fixed Signalling

Joint Action
Sebanz, et al., 2006.

Emergent or Fully
Learned Signalling
machine learned bidirectional coordination
Continually learning tightly coupled intelligent systems
Post-surgery Osseointegration Rehabilitation conducted at the Glenrose Rehabilitation Hospital
Thank you and questions!

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