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Embodied Social Experiences in Hybrid Shared Spaces

HORIZON-CL4-2022-HUMAN-01-14

2023-2025

Funded by the European Union

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Why is it important?

1. European Context
2. The Science
3. Project implementation
4. Proofs-of-Principle
5. Three scenarios
6. Next activities

European context

CALL: HORIZON-CL4-2022-HUMAN-01-14

HUMAN-CENTRED AND ETHICAL DEVELOPMENT OF DIGITAL AND INDUSTRIAL TECHNOLOGIES 2022 (HORIZON-CL4-2022-HUMAN-01)

Extended Reality Technologies (XR)

Expected Outcome: Proposals are expected to contribute to the following outcomes: Innovative eXtended Reality industrial and **societal applications**, integrating technologies such as advanced visualisation, 3D, Augmented and Virtual Reality experiences, human-machine interaction and cooperation, with a focus on well designed and fully tested scenarios in real-world environment.

Research & Innovation Action (RIA)

ShareSpace: 14 partners + 2 affiliated partners

8 EU countries

36 months (kick off January 2023)

6,437,000€

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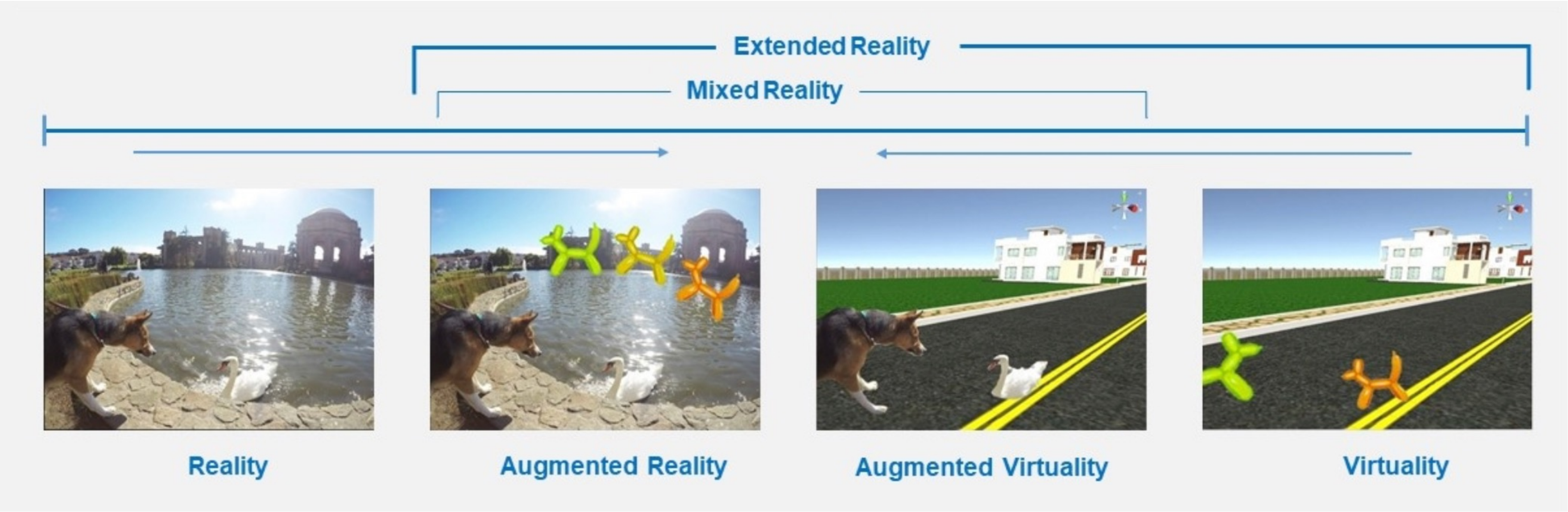
What is XR

It is the umbrella term used for Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), as well as future realities immersive technologies might create. XR covers the full spectrum of real and virtual environments.



A EUROpean Ecosystem: The European Commission is supporting research and innovation into a European XR ecosystem ensuring that our European values are upheld. The European Commission is encouraging **cross-fertilisation between disciplines** and domains.

XR applications are used in sectors such as manufacturing and construction, cultural heritage, tourism, training and education, **HEALTH**, advertisement, work processes, industrial processes, but also for entertainment, online commerce and construction. The European Commission Green Deal is another potential use area for XR applications with future virtual spaces for people to meet and work in a climate neutral society.

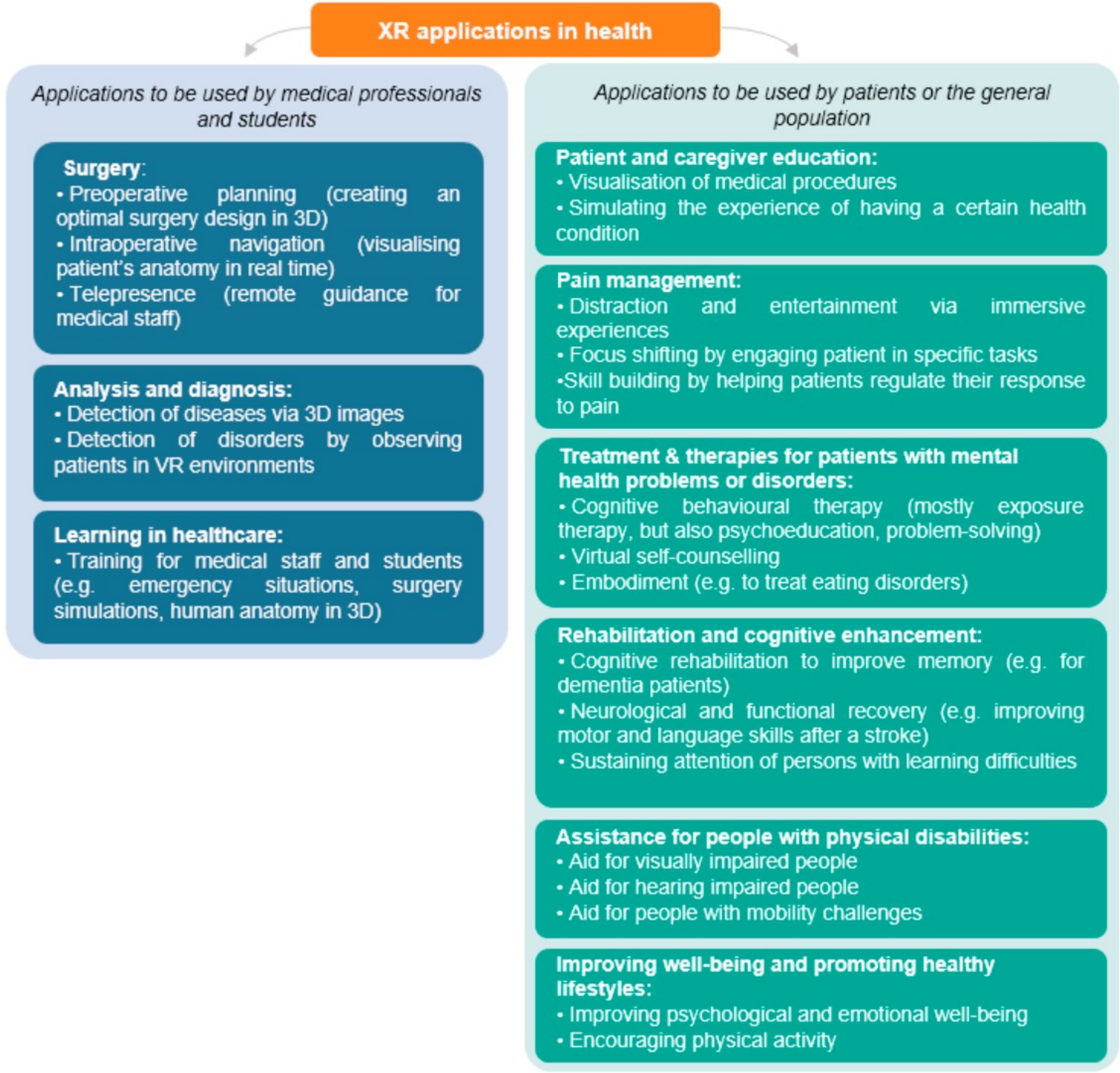
User experience with XR technology is becoming more and more immersive. Apart from re-creating realistic virtual environments, the current work involves improving the user experience even further by adding emotion, language technologies and better speech recognition, as well as human senses like smells and touch.

Virtual universes

A metaverse is a computer-generated universe with online 3D virtual environments in which the user can **MOVE** freely. It could be a **DIGITAL** world based on the real Earth, as well as a fictional environment where users can game, go shopping for virtual products and services or meet with other users through avatars in **MOTION**.

In such computerised virtual environments, **European core values are crucial for the take-up of the technology, including equality, non-discrimination and inclusion**.

Figure 1. Applications of XR technologies in the health sector



Source: Visionary Analytics, 2022

Embodied Social Experiences in Hybrid Shared Spaces

The vision of SHARESPACE is the creation of **future Social Hybrid Spaces (SHS)** shared by humans (5-7) and avatars (2-3) engaged in embodied collaborative tasks, where social sensorimotor primitives are transparently captured through mobile connected innovative sensors, and then reconstructed using novel extended reality (XR) technology. Our ambition is to **create a hybrid, multimodal-multisensory integrated platform which adapts to individual users and enables them to interact in an embodied shared space by learning, identifying, and reconstructing the core sensorimotor primitives of social interactions.**

Our vision

Partners

#	Participant organisation name	Country	Type
1	DFKI – German Research Centre For Artificial Intelligence	Germany	RES
2	UM - University of Montpellier, EuroMov DHM (+ IMT Mines Ales)	France	RES
3	CRdC - CRdC Nuove Tecnologie per le Attività Produttive Scarl	Italy	RES
4	UKE - University Medical Center Hamburg-Eppendorf	Germany	RES
5	ALE - Alcatel-Lucent Enterprise	France	IND
6	UJI - Universitat Jaume I De Castellon	Spain	RES
7	Golaem - Golaem S.A.	France	SME
8	LST - LightSpace Technologies SIA	Latvia	SME
9	CYENS - Center of Excellence	Cyprus	RES
10	Ricoh - Ricoh Europe	Germany	IND
11	DMU - De Montfort University	United Kingdom	RES
12	INRIA - Institut national de recherche en sciences et technologies du numérique (+ University Rennes 2)	France	RES
13	AE, Ars Electronica Linz GmbH & Co KG	Austria	RES
14	VHIR - Hospital Vall d'Hebron	Spain	RES

Example of sensorimotor primitive

Kinematic intersection information

Extended (by Becchio and Panzeri) to kinematics

Compute how and much information encoded in movement kinematics is actually read out by human perceivers

- ✓ Based on the trivariate relationship between kinematics, the actual internal state and the inferred internal state
- ✓ Based on observation of kinematics, encoded and perceived internal states
- ✓ Primary purpose: understand computations made by perceivers on kinematics
- ✓ Lead to design interventions on kinematics that can causally manipulate transmission of kinematic information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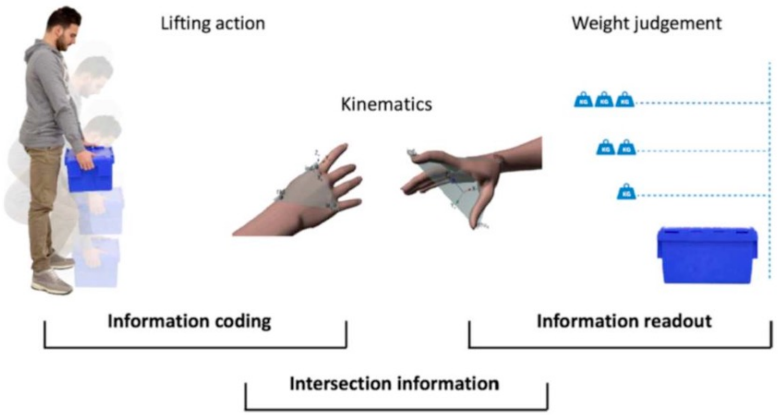
Comment

Sensorimotor communication at the intersection between kinematic coding and readout

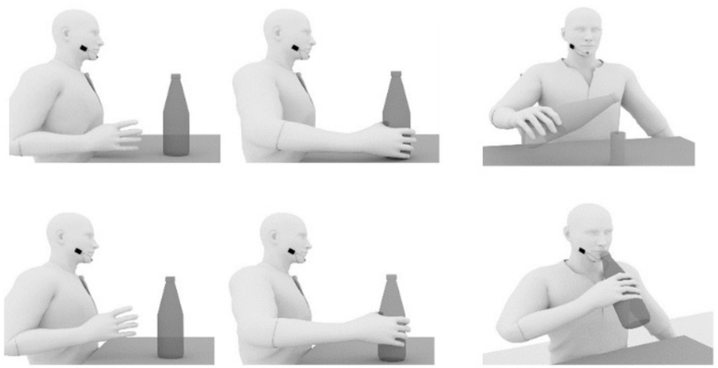
Comment on "The body talks: Sensorimotor communication and its brain and kinematic signatures" by Giovanni Pezzulo, Francesco Donnarumma, Haris Dindo, Alessandro D'Ausilio, Ivana Konvalinka, Cristiano Castelfranchi

Cristina Becchio [a], Stefano Panzeri [b,*]



Becchio and Panzeri, Behav Brain Sci 2018; Patri et al Curr Biol 220; Montobbio et al PNAS 2022

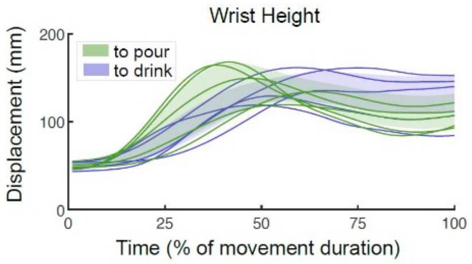
Kinematic **encoding** of intention information

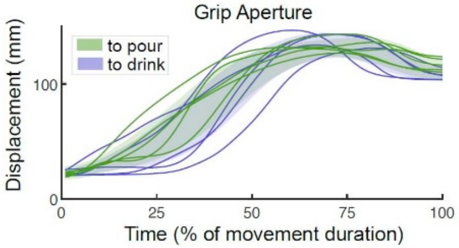


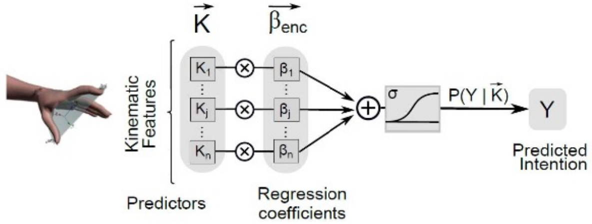
Grasp for an object with different intentions

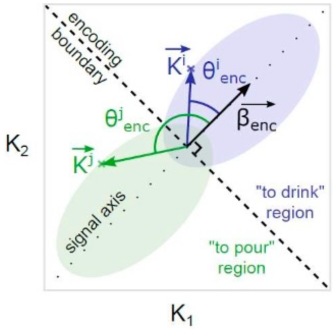
Identical physical constraints of reaching (e.g., initial arm configuration, size, shape and location of the bottle)

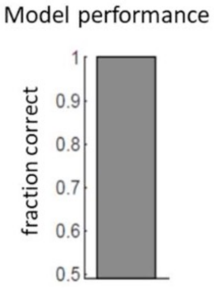
Variations in movement kinematics can be taken to reflect intention

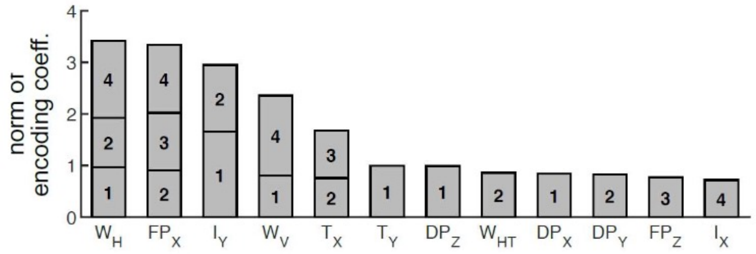






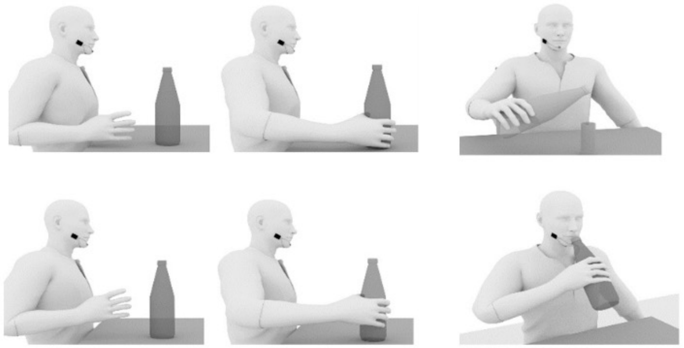


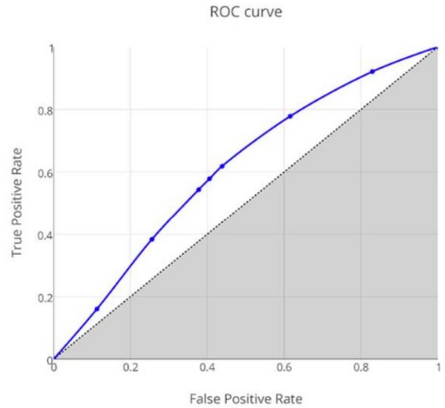


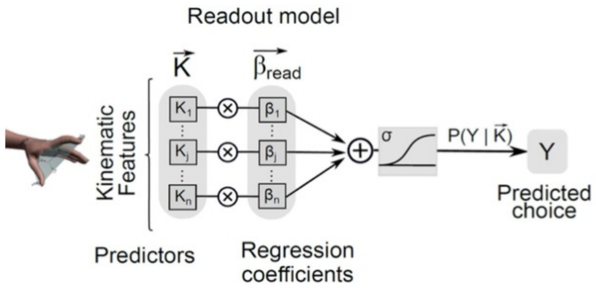


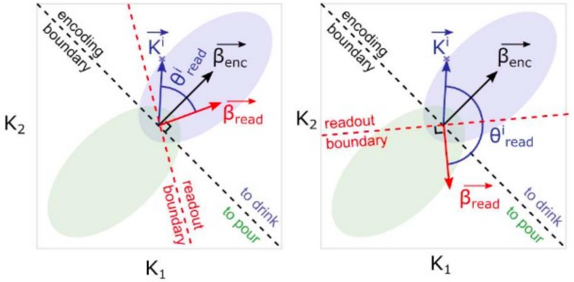
Patri et al., Curr Biol, 2020; Becchio et al., Behav Brain Sci, 2021; Montobbio et al., PNAS, 2022

Kinematic **readout** of intention information

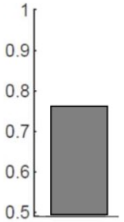




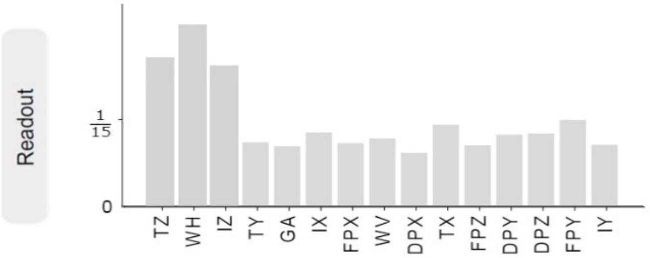




Model performance



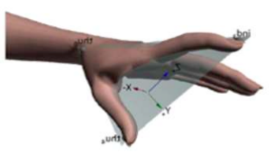
fraction of intention choices correctly predicted by the model



Amplification

The features that matter for social transmission are those at the intersection of kinematic encoding and readout of information

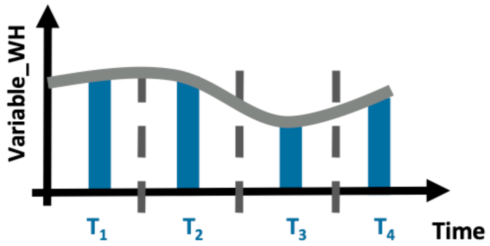
Track movement kinematics and extract kinematic variables



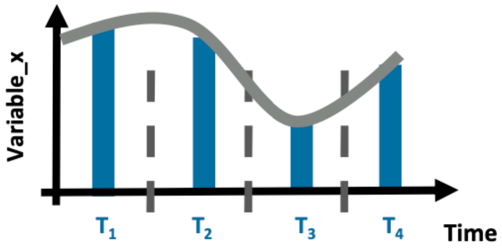
Kinematic variables

- Wrist velocity
- Wrist height
- Wrist horizontal trajectory
- Grip aperture
- …

Use the kinematic intersection information approach to identify features at the intersection of encoding and readout (i.e. features relevant for social transmission)



Time evolution discretized as averages within time-bins



Time evolution discretized as averages within time-bins

Reconstruct movement kinematics in XR amplifying features at the intersection of encoding and readout

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Synchronisation, Social Connectedness & Pain

Synchronization metrics

- Individual Sync Index

$$\rho_k := |\bar{\phi}'_k| \qquad \in [0,1]$$

- Group Sync Index

- Dyadic Sync Index

$$\rho_{d_{h,k}} := \left| \frac{1}{T} \int_0^T e^{\{j\phi_{d_{h,k}}(t)\}} \, dt \right| \simeq \left| \frac{1}{N_T} \sum_{i=1}^{N_T} e^{\{j\phi_{d_{h,k}}(t_i)\}} \right| \qquad \in [0,1]$$

Model

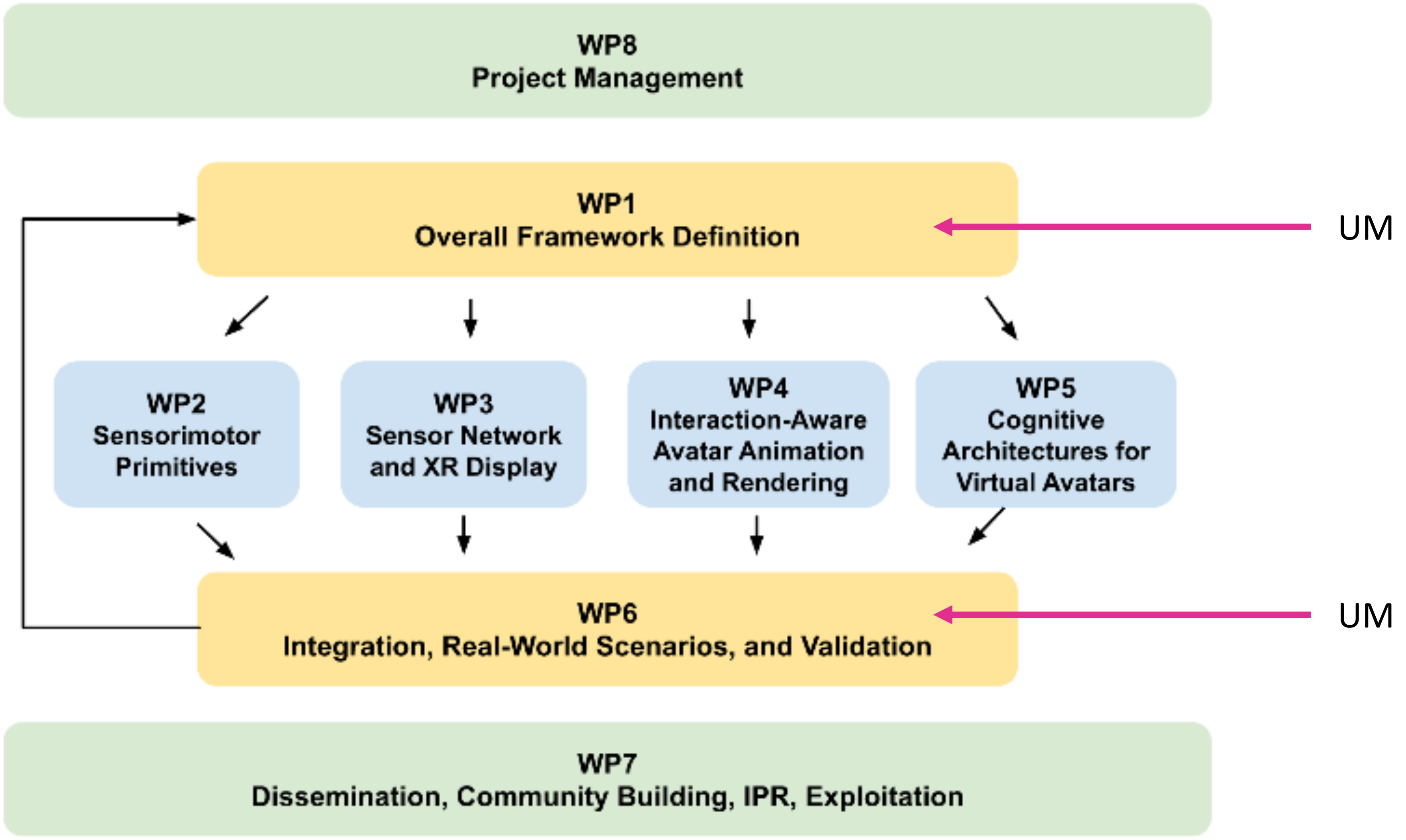
- Network of heterogeneous Kuramoto oscillators

$$\dot{\theta}_k = \omega_k + \frac{c}{N} \sum_{h=1}^{N} a_{kh} \sin(\theta_h - \theta_k), \qquad k = 1, 2, \ldots, N$$

- N = 7
- c = constant
- A_{kh} = 0 or 1

Alderisio et al., 2017; Bardy et al., 2020; Calabrese et al., 2021

Workplan



UM+IMT: Benoît, Ludovic, Christophe, Simon, Patrice
1 post-doc (2 or 3 years) – Marta
1 post-doc (2 years) – Summer-fall 2023

The ShareSpace Glossary

The ETHICAL

Ethics in XR
- Authenticity
- Plausibility
- Transparency
- Humanistic principles (freedom of speech/expression, movement, autonomy, right to privacy)

The SOCIAL

Social Shared Space in XR
- VR-AR-XR
- L0-L1-L2-L3
- Virtual group
- Hybrid group

Embodied Social Information in XR
- Motion primitives / Sensorimotor primitives
- Kinematic coding: Information encoding/Specification
- Kinematic coding: Information readout/detection
- Intersection information
- Amplification/Attenuation
- Multisensory perception
- Synchronization
- ~~Inter-agent topology~~

Embodied Social Propagation in XR
- Information transmission
- Empathy
- Mimicry
- Affiliation
- Connectedness
- Bounding
- Cohesion
- Contagion
- Leadership

Social and Biological Presence in XR
- Self-identity
- xBodiment
- Sense of agency
- Embodied intentionality
- Extended motivation
- Technostress
- Cybersickness
- Fatigue
- Addiction
- Demographics
- UX in Social Hybrid Space ?

The PHYSICAL

Capturing & Processing in XR
- Ego-centric visual-inertial tracking
- Multi-sensor multi-person localization and pose estimation
- Multimodal-multisensory system perception
- Representation for motion encoding / decoding
- Scene scanning and representation
- RGB spherical(360°) camera plus imaging
- Time-of-Flight RGBD (depth)
- 3D digitization
- Recording alignment
- Eye-tracking
- Fisheye image
- Occlusion
- Point cloud

XR System Architecture
- Platform initialization
- Distributed space synchronization (clocking)
- WebRTC sensorimotor channel
- Multi-modal multi-sensory real-time processing
- Multi-modal multi-sensory lossless transportation

Cognitive Architecture in XR
- Feedback control strategy
- Motor signal synchronization (*to differentiate with inter-agent sync/coordination***)
- ~~Virtual humans' levels of autonomy (L1, L2, L3)~~
- Autonomous Virtual Character perception

Rendering in XR
- Scene neural rendering
- Virtual human animation and style
  - Eyetracking and audio to facial expression mapping
  - Hyper-realistic representation
  - Posture/ human modelling
  - Biomechanics/kinematics
- Virtual human post-synchronization

The CULTURAL

Health in XR
- Social exercises
- Kinesiophobia
- Pain modulation
- Patient empowerment
- Virtual Pills

Sport in XR
- Performance
- Wellbeing
- Retention
- Transfer
- xx

Art in XR
- Cultural embodiment
- Artistic expression
- Artistic remote participation
- Collaborative aesthetics
- xx

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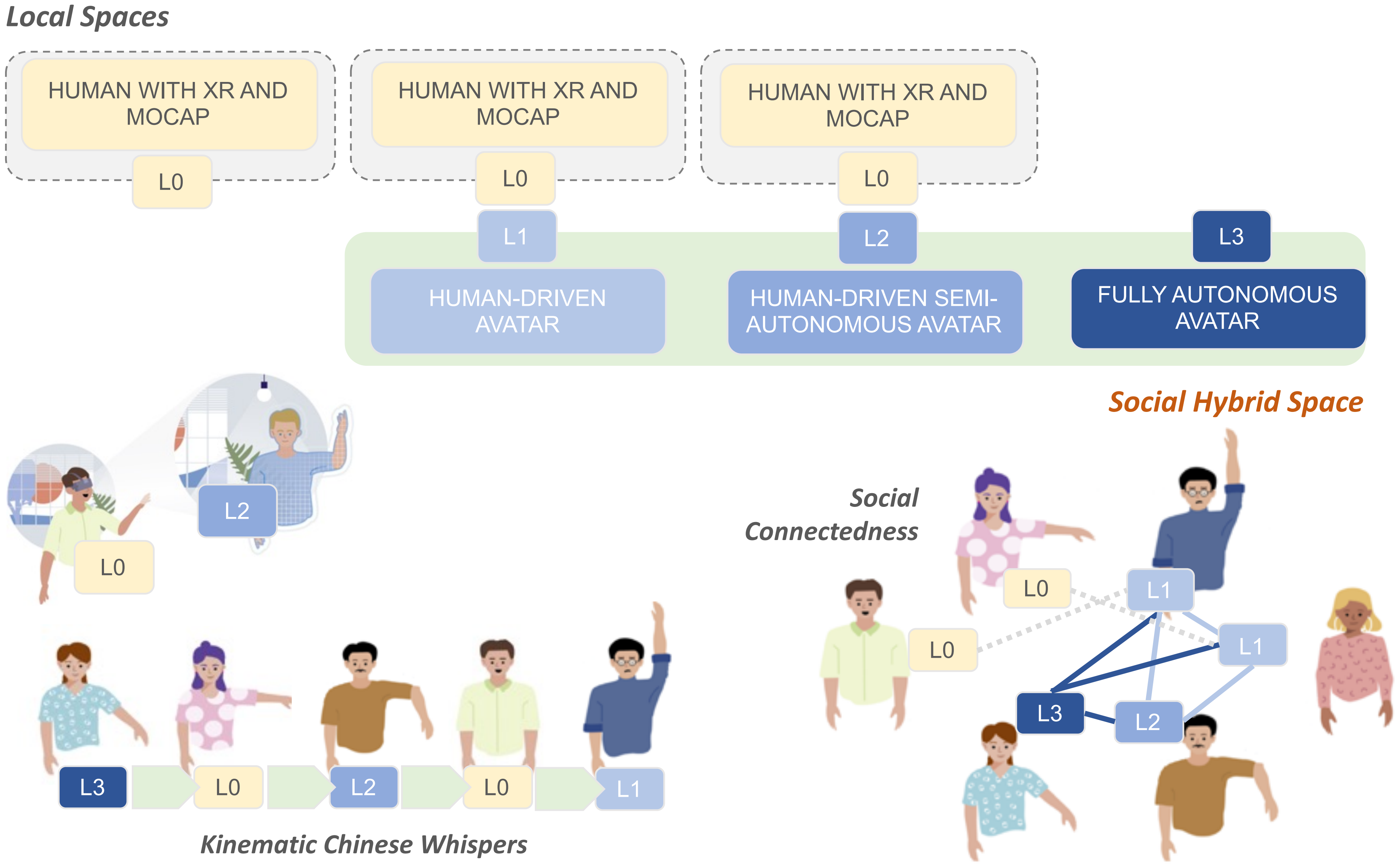
Levels of autonomy in human-agent interaction

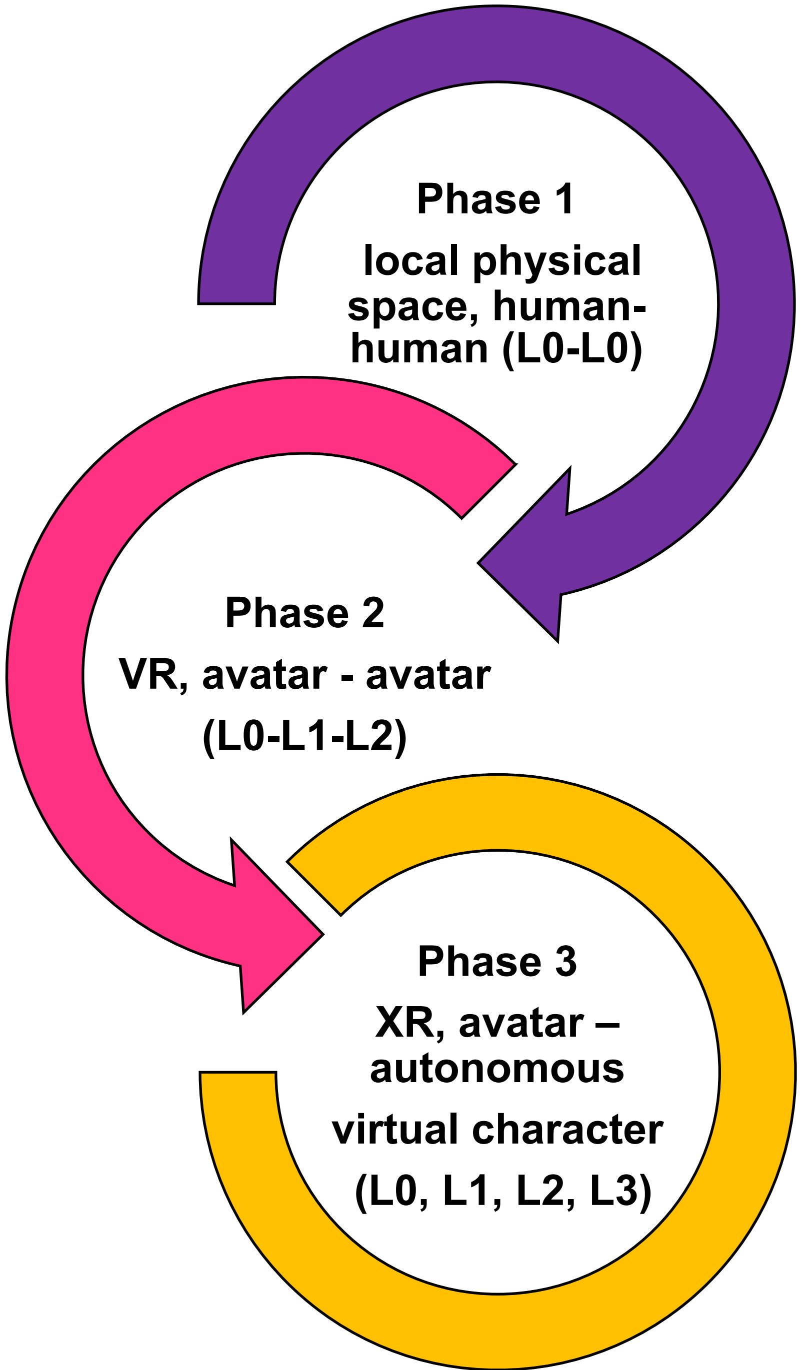


Proofs of Principle
PoPs

- Kinematic Chinese Whispers

- Social Connectedness

PoPs


Phase 1
local physical space, human-human (L0-L0)
Phase 2
VR, avatar - avatar
(L0-L1-L2)
Phase 3
XR, avatar – autonomous
virtual character
(L0, L1, L2, L3)

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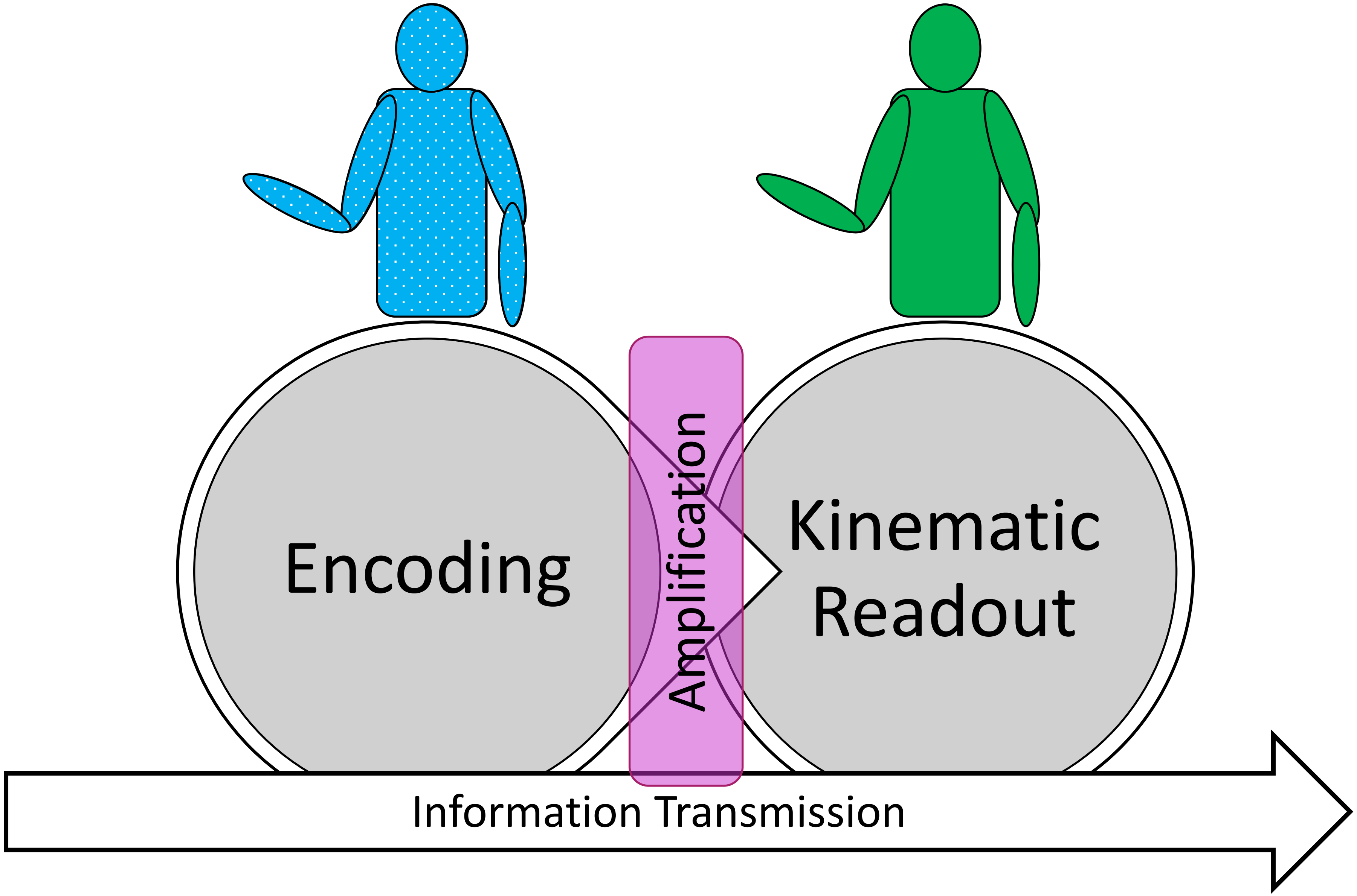
KINEMATIC CHINESE WHISPERS - AMPLIFICIATION

SHARESPACE Interactions

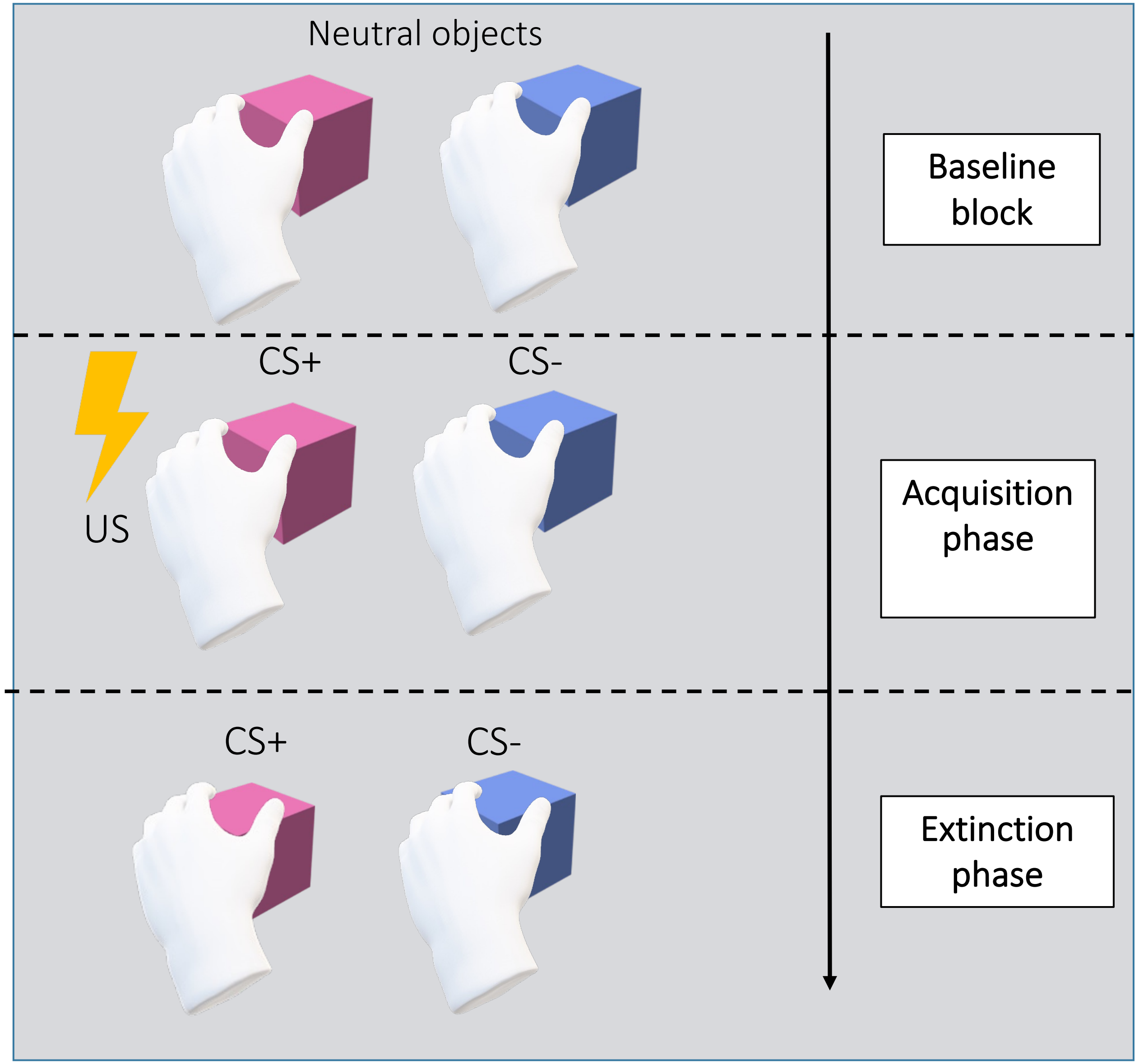


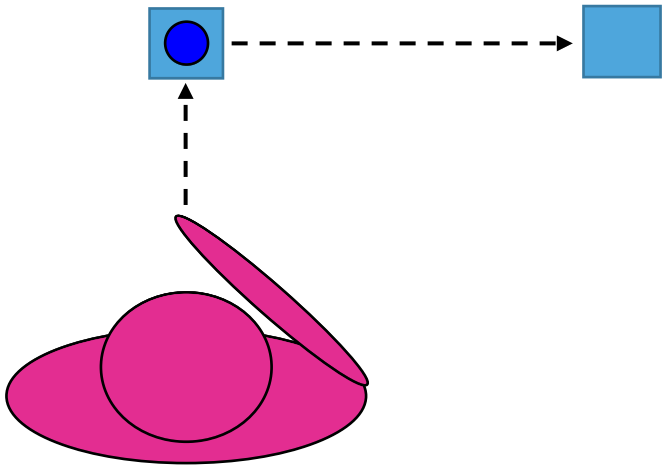
What information?

1) Fear in object passing

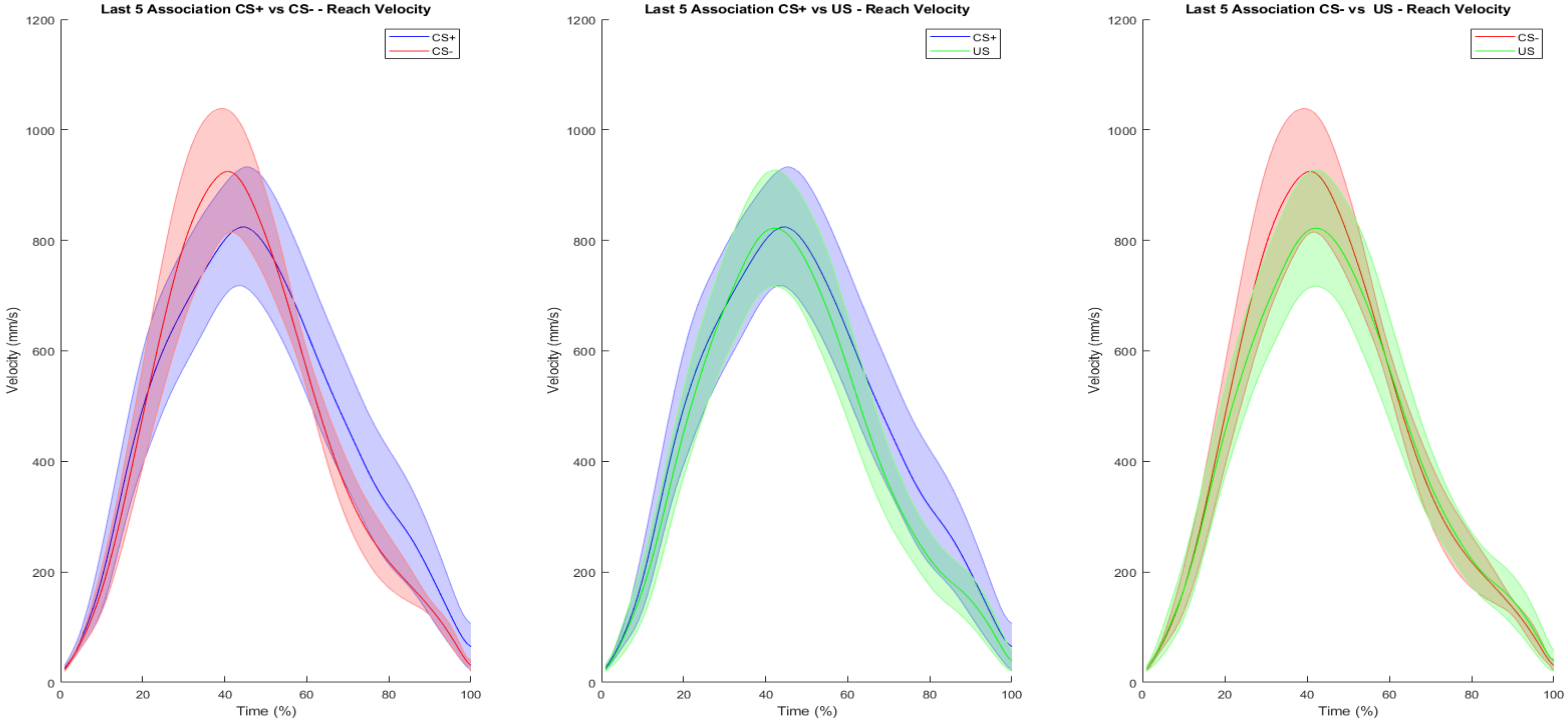
2) Ratio of distance to width in a movement sequence (Fitts’ Law)

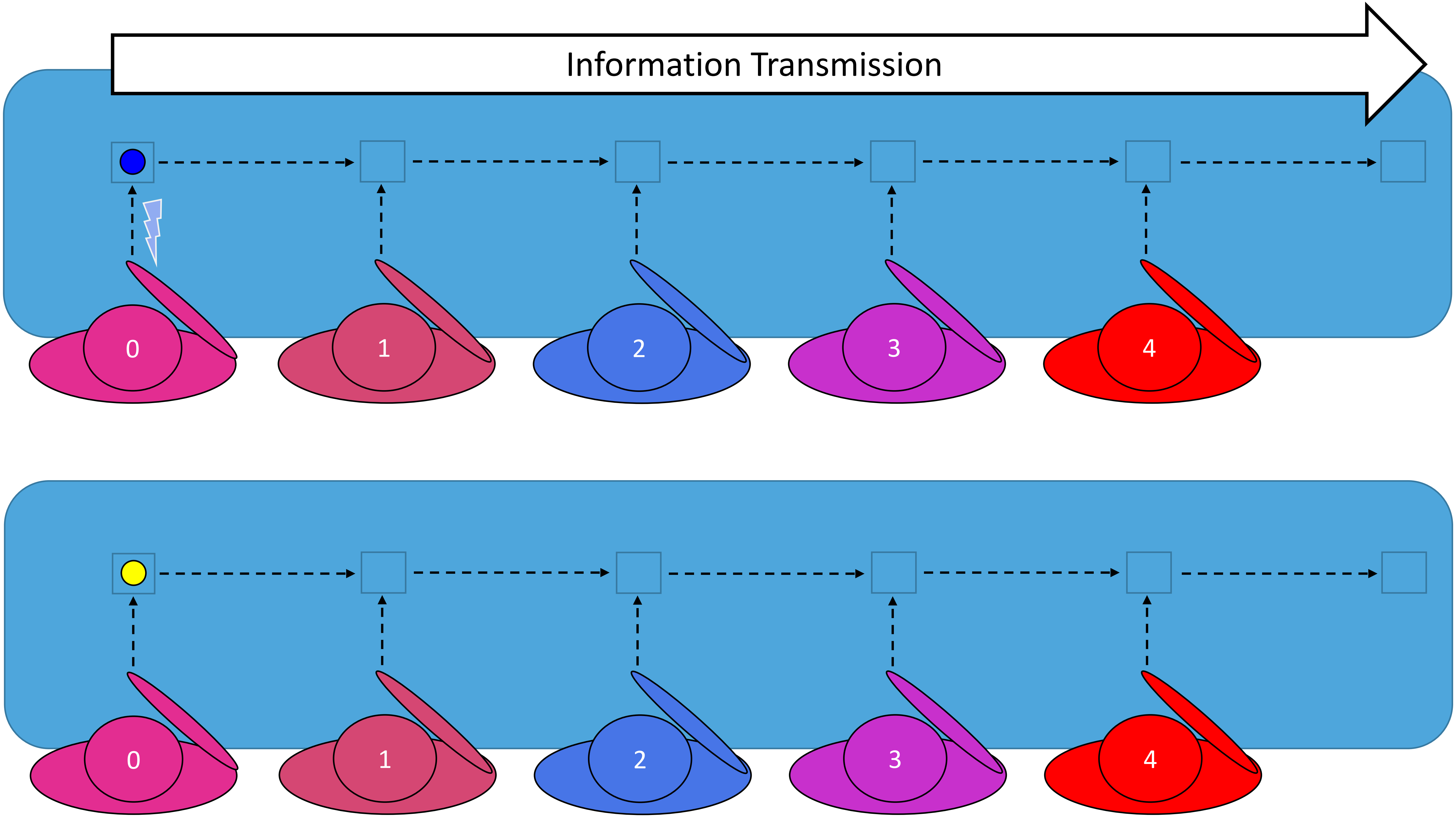
Transmission of Fear Information



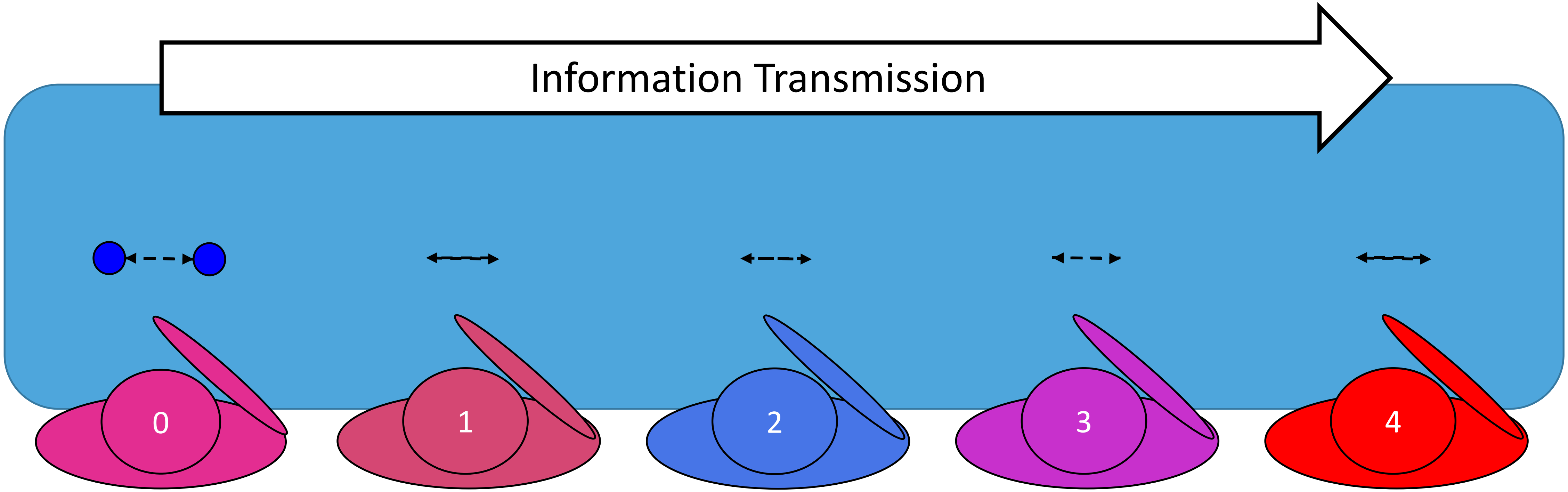


p001


Last 5 Association CS+ vs CS- - Reach Velocity
CS+
CS-
Velocity (mm/s)
Time (%)
Last 5 Association CS+ vs US - Reach Velocity
CS+
US
Velocity (mm/s)
Time (%)
Last 5 Association CS- vs US - Reach Velocity
CS-
US
Velocity (mm/s)
Time (%)



Information Transmission
0
1
2
3
4
0
1
2
3
4


Information Transmission
0
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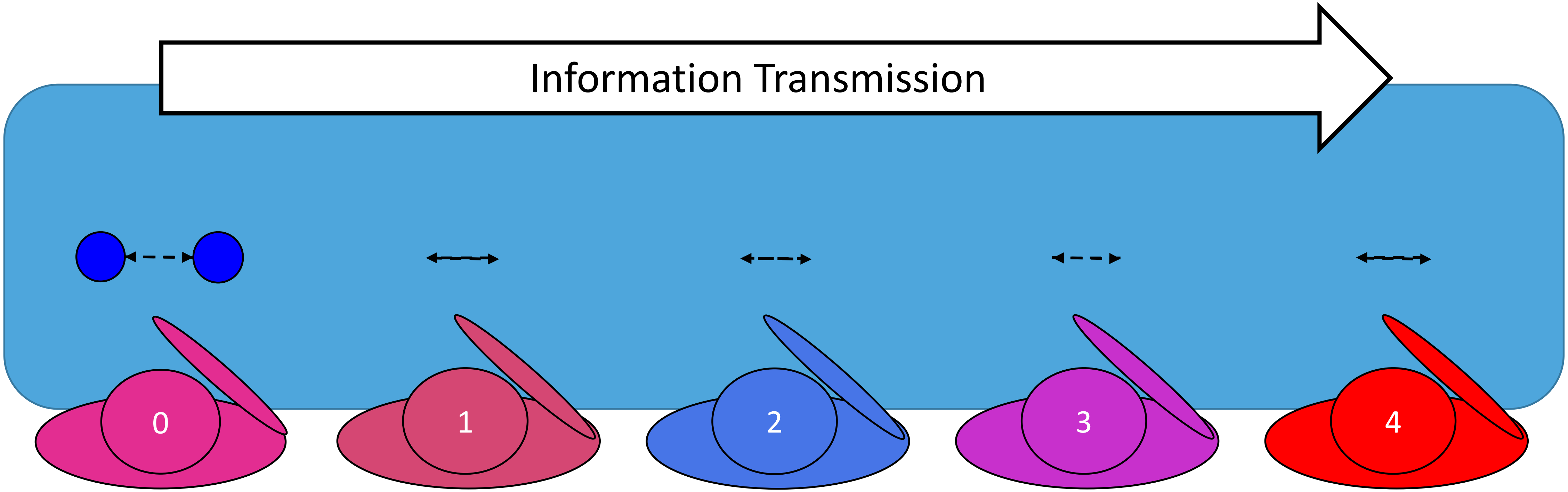
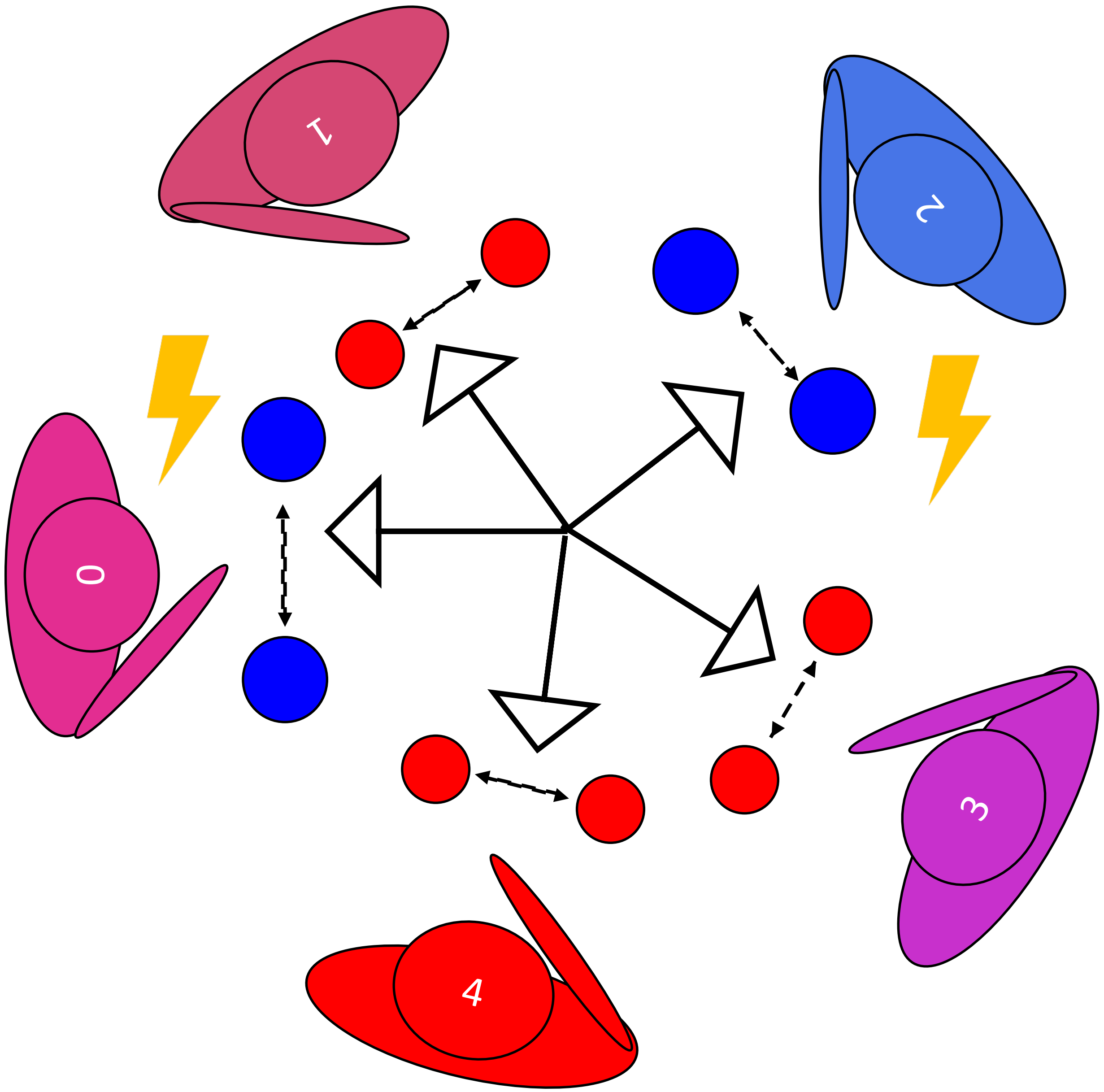
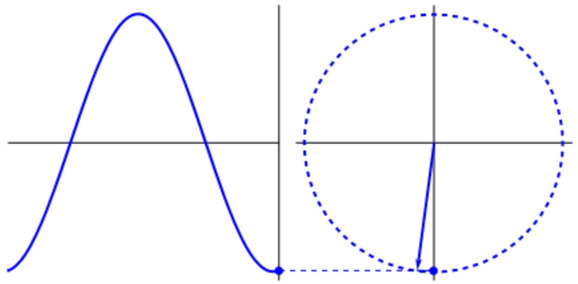
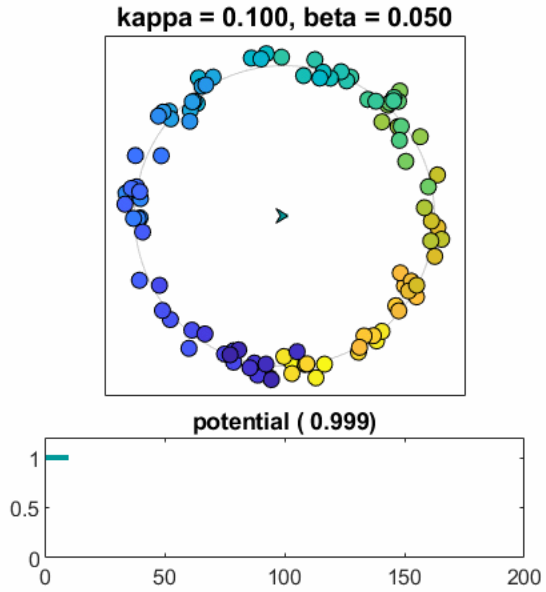
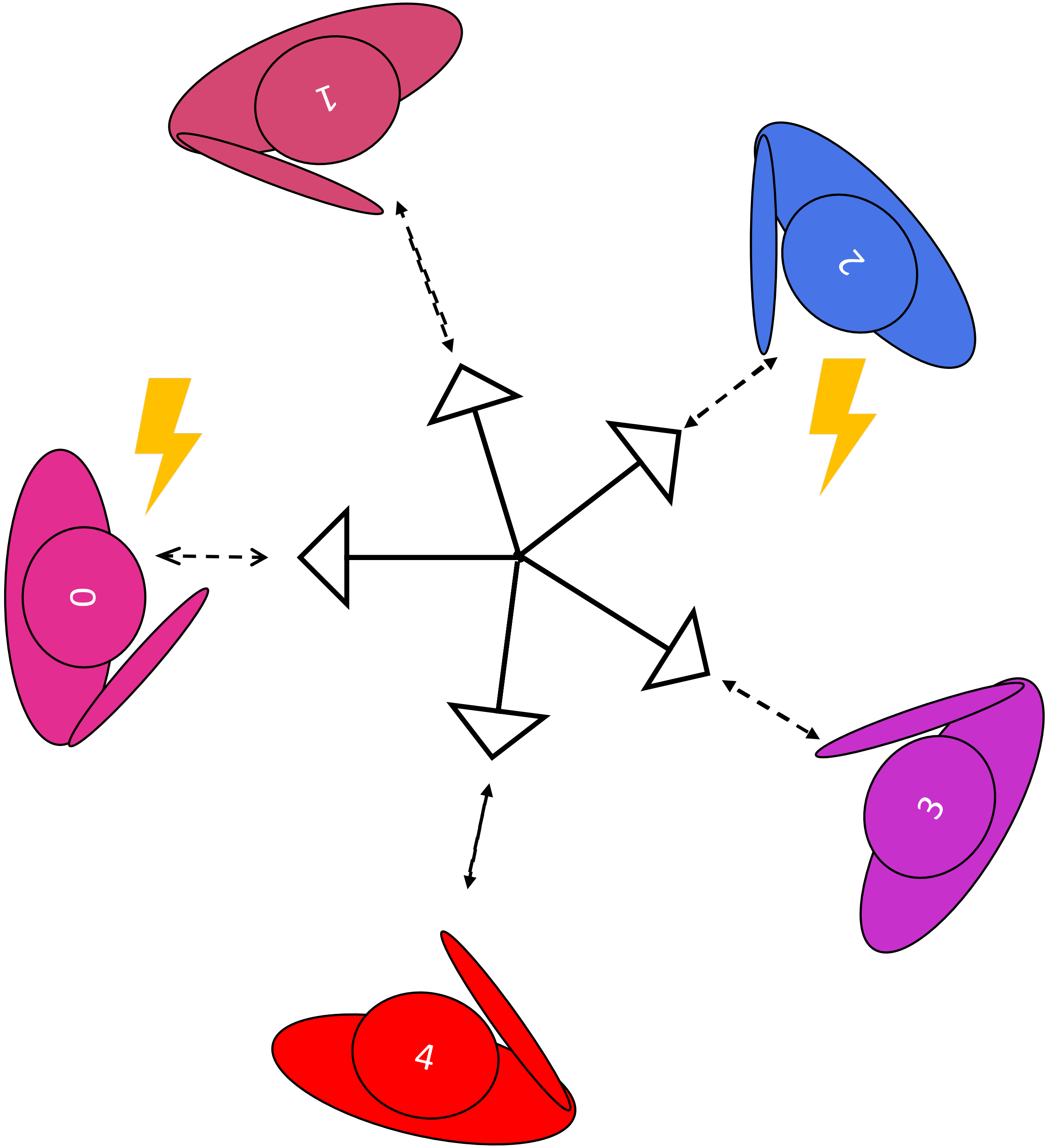

Information Transmission
0
1
2
3
4

SOCIAL CONNECTEDNESS - PROPAGATION


1
2
0
3
4




kappa = 0.100, beta = 0.050
potential (0.999)
1
0.5
0
0
50
100
150
200



PHASE I

SYNC UP

ESTABLISH SYNC – CONNECT

ONE ORGANISM

INDUCE FEAR in n=2 (0 and 2)

MOTOR CONTAGION

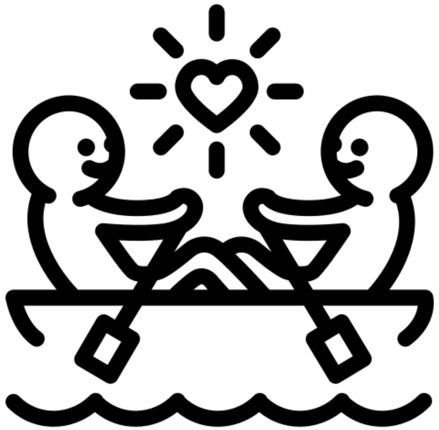
OBSERVE MOTOR CONTAGION in 1 and 3 and 4

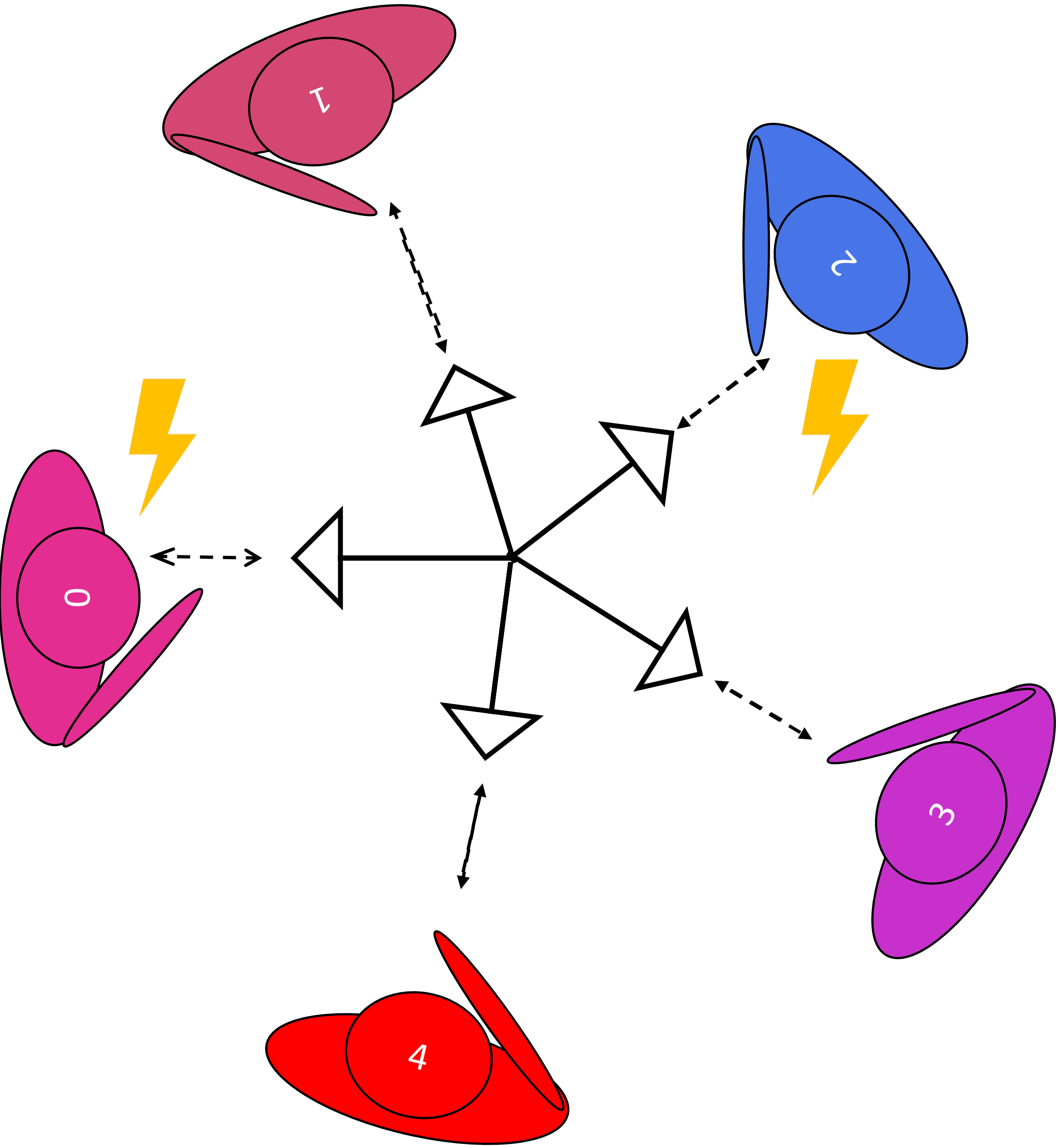
Requirements

- Oscillatory motion
- 1D/2D
- Degrees of freedom /proximal
- Naturalistic

- HELLO TOGETHER/ LOOPS

Pain x Sync x Endorphines





PHASE II

SYNC UP

ESTABLISH SYNC – CONNECT

ONE ORGANISM

INDUCE FEAR in n=2 (0 and 2)

MOTOR CONTAGION

OBSERVE MOTOR CONTAGION in 1 and 3 and 4

AMPLIFY

- FEAR = slow down, exaggerate slow down of L2 of P0 and P2 so group syncs up to L2s of P0 and P2 (for L0-L2 mapping 1:1 motion physical to SHS) ”I am ok, they wait for me, sync – less pain”

ATTENUATE

- FEAR = slow down, dampen the lack of speed of L0 for L2 of P0 and P2, by speeding up of L2 “I am slow, they do not know, I seem ok - sync maintained”

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SHARESPACE FOR HEALTH, SPORT AND ART

Sharespace for Health - Social low-back pain exergame

Simplified visualisation of the Low Back Pain Scenario showing (top) group exercises in VR with L0 patients and their L1 avatars, and (bottom) the AR-version with (L0) patients at two different locations, L1 avatars of other patients, and the L3 autonomous avatar of the therapist.

Target: 2024 and 2025 World Pain Conference

ShareSpace for sport - Family peloton cycling

Target: Paris 2024 & Tour de France 2025

Two phases of the Sport scenario showing (top) L0 amateur cyclists learning how to ride in a virtual peloton composed of their own (L1) avatars guided by an autonomous L3 avatar, and (bottom) "on-road" (Melinda) and "at-home" (Peter) cyclists sharing the hybrid space composed, for at-home cyclists, of their own (L1) avatars guided by Melinda and L2-L3 avatars.

Feb 2023

Breaking down the peloton cycling scenario

Family context

Performance context

Predictability
Maximize — Minimize

Interaction type
Cooperative — Competitive

Sensorimotor primitives encoded
Gross/Global — Fine/Subtle

Transformation
Amplified — Amplified/Attenuated

ShareSpace for Art – Shared Creativity

Artistic production in the Deep Space 8k at Ars Electronica Festival and scenario illustration with L0 humans (white) human-driven L1 (yellow), semi-autonomous L2 (pink) and fully autonomous L3 (green avatars)

Target: Ars Electronica Festival 2024 & 2025

Thank you !