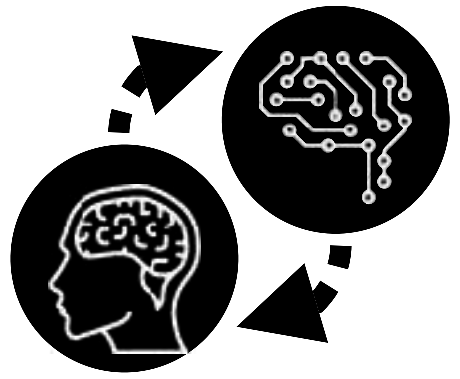
# Designing Human-AI Interaction

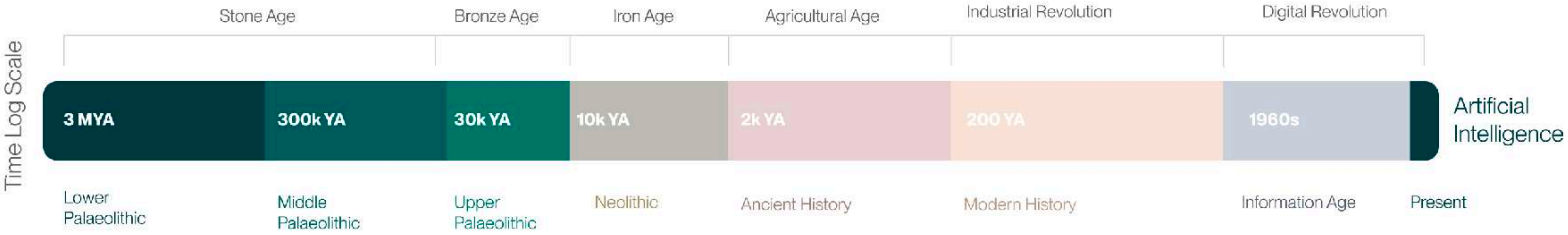
Misha Sra (sra@ucsb.edu)

Human-AI Experience (HAX) Lab

July 2025

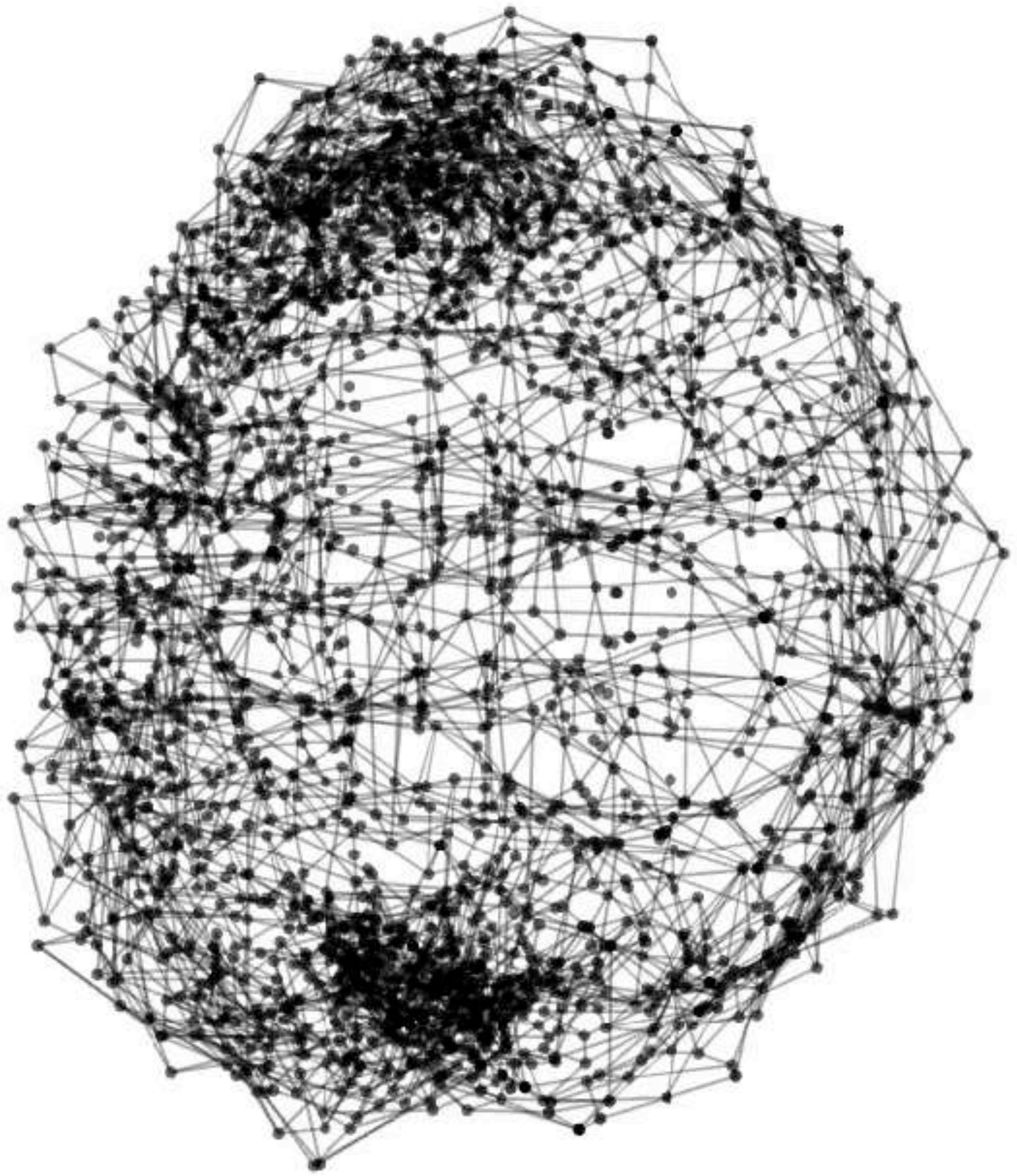
# EVOLUTION OF TOOL USE



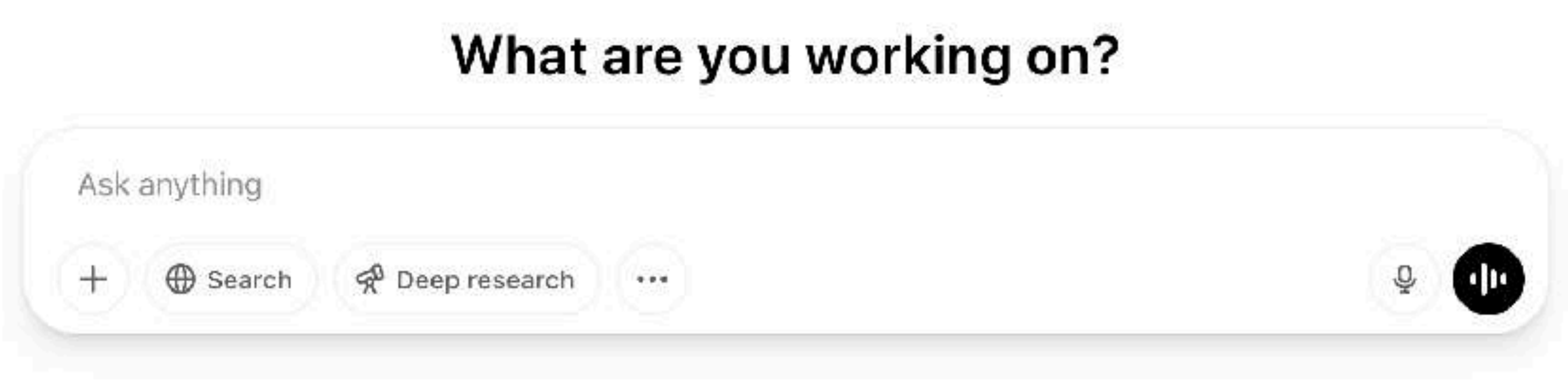


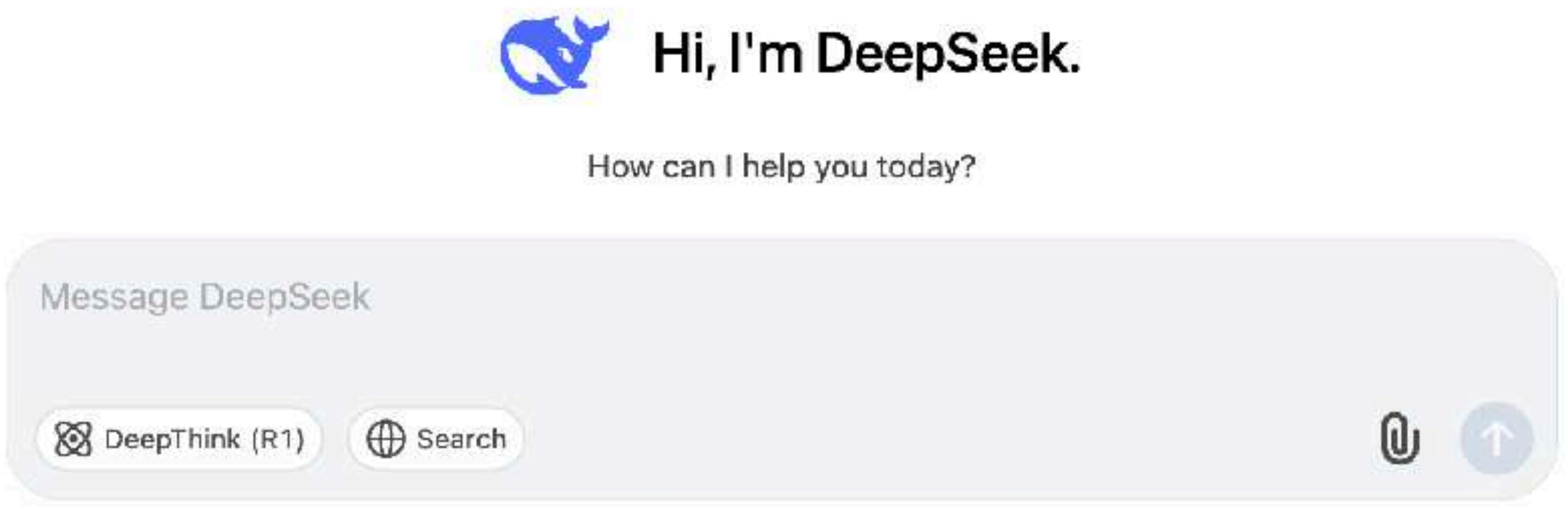
# TRADITIONAL TOOLS ARE FAILING EXECUTORS

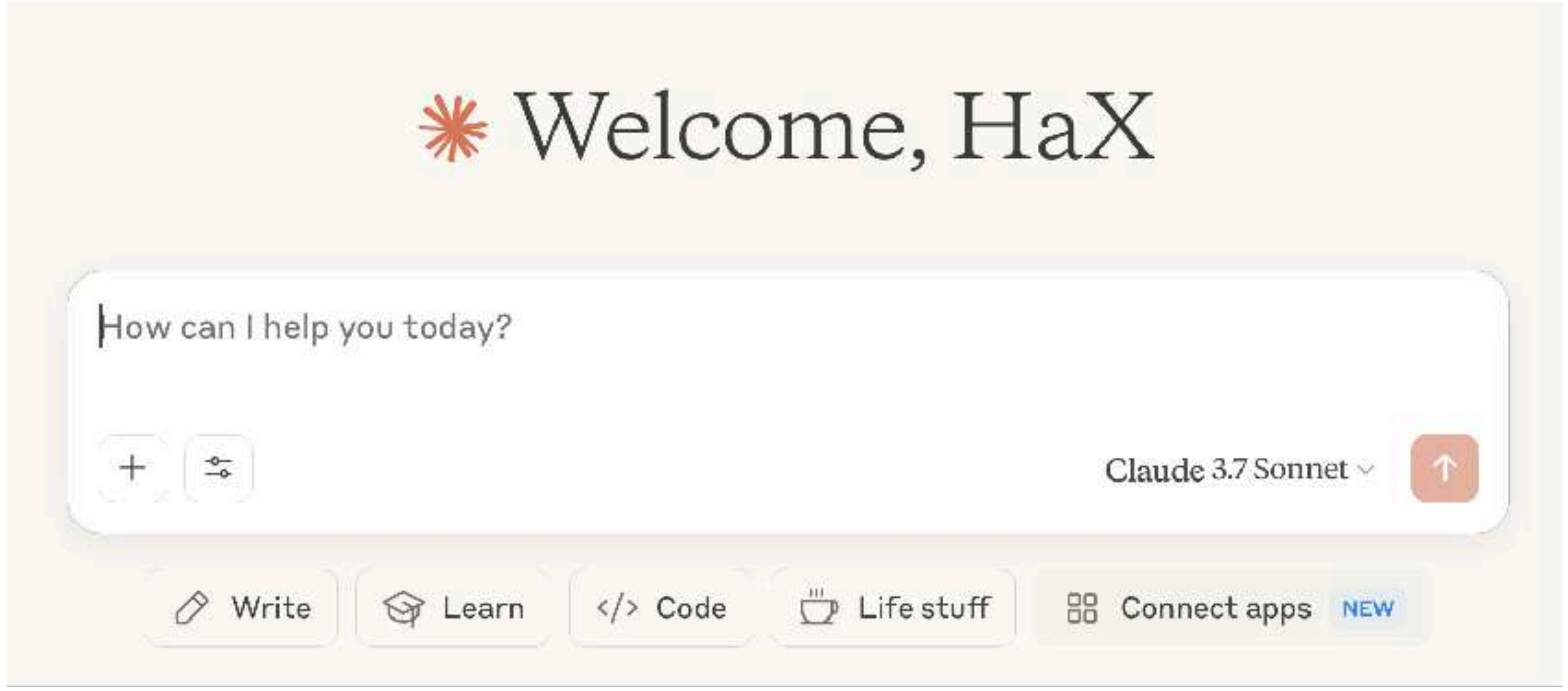
# AI IS DYNAMIC, SELF-IMPROVING SYSTEM

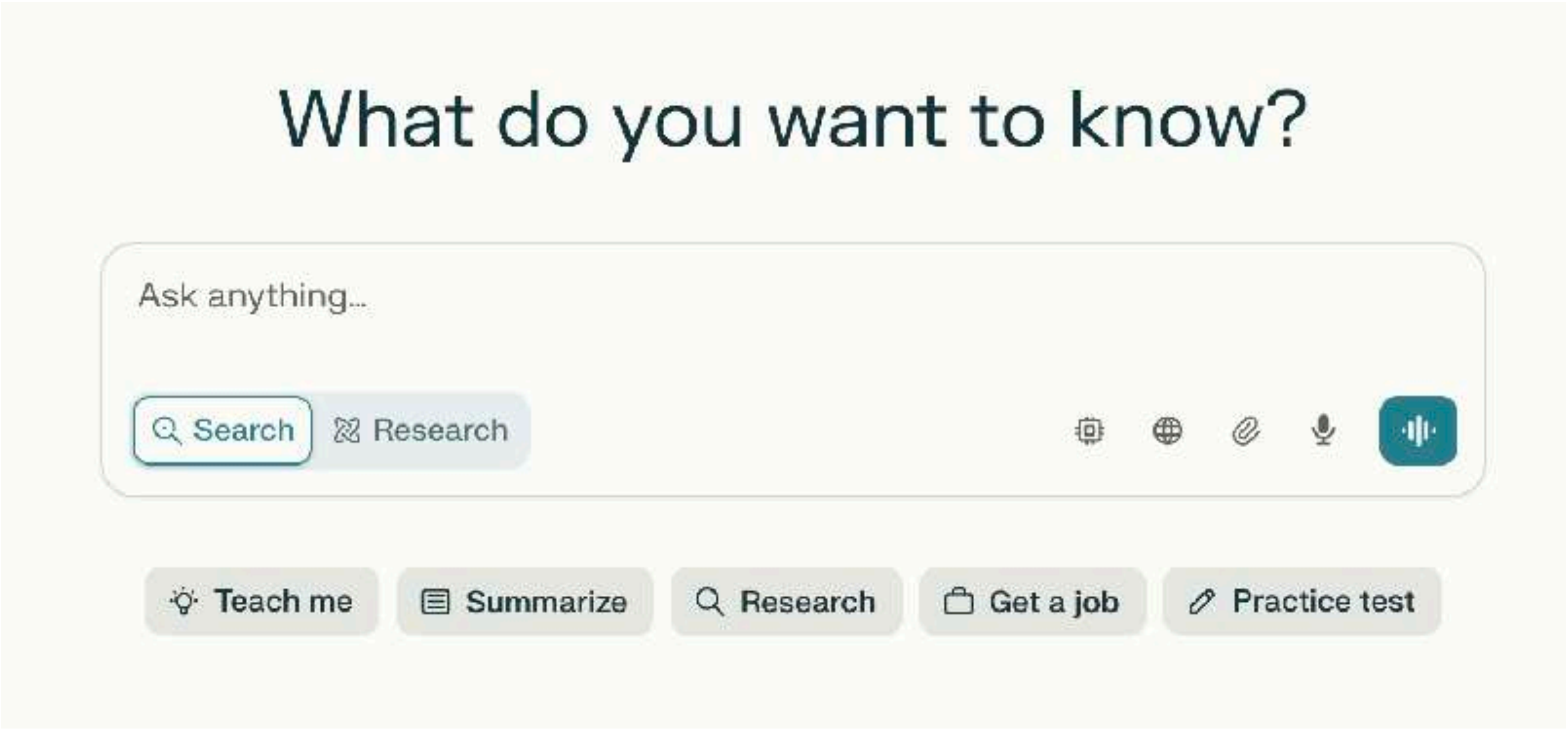


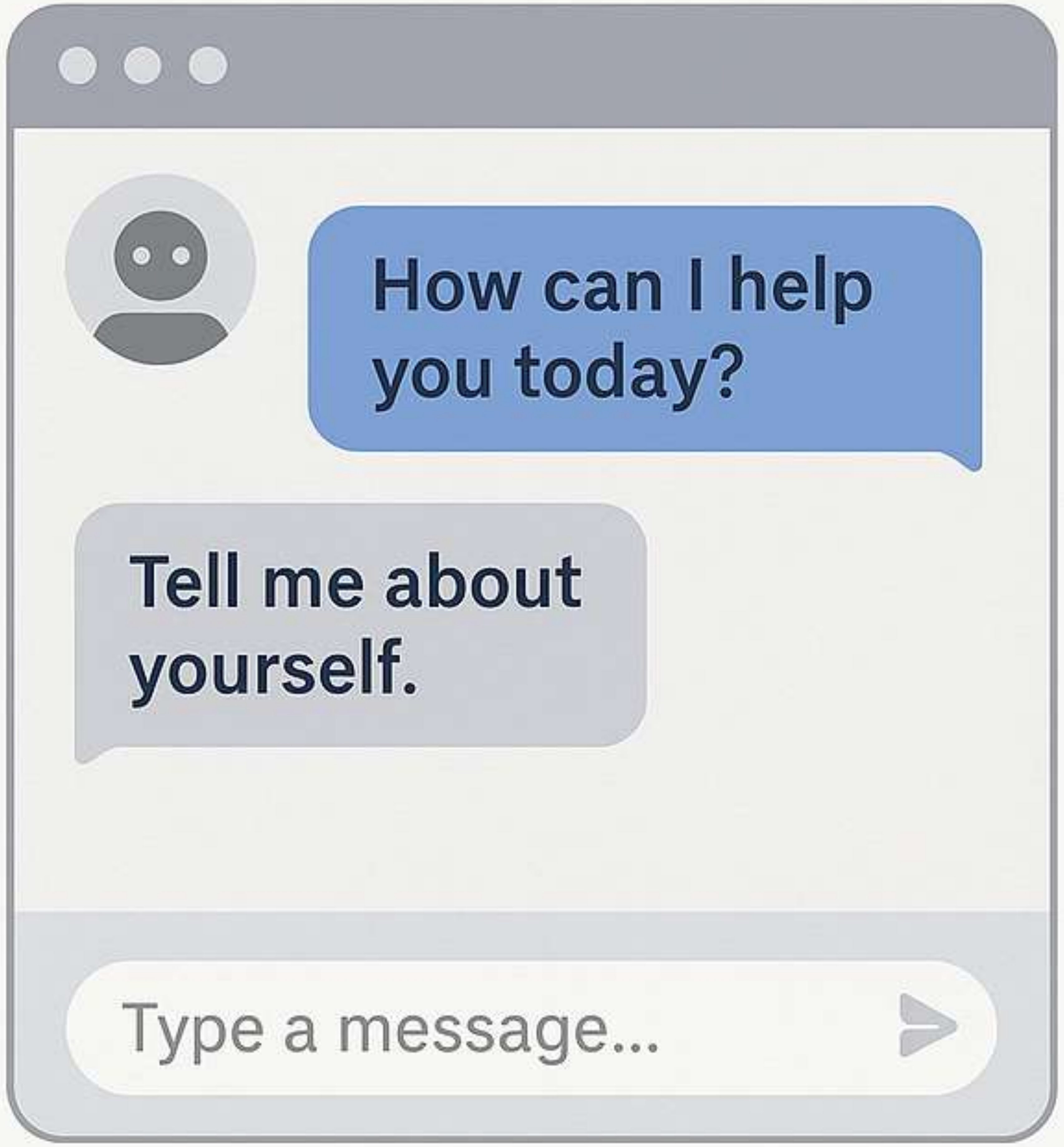
# AI interactions are command-centric






What if instead of this…

Image generated with ChatGPT

# Examples of Spatial Human-AI Interaction (cognitive and motor tasks)

CONFLICT MANAGEMENT

LEARNING

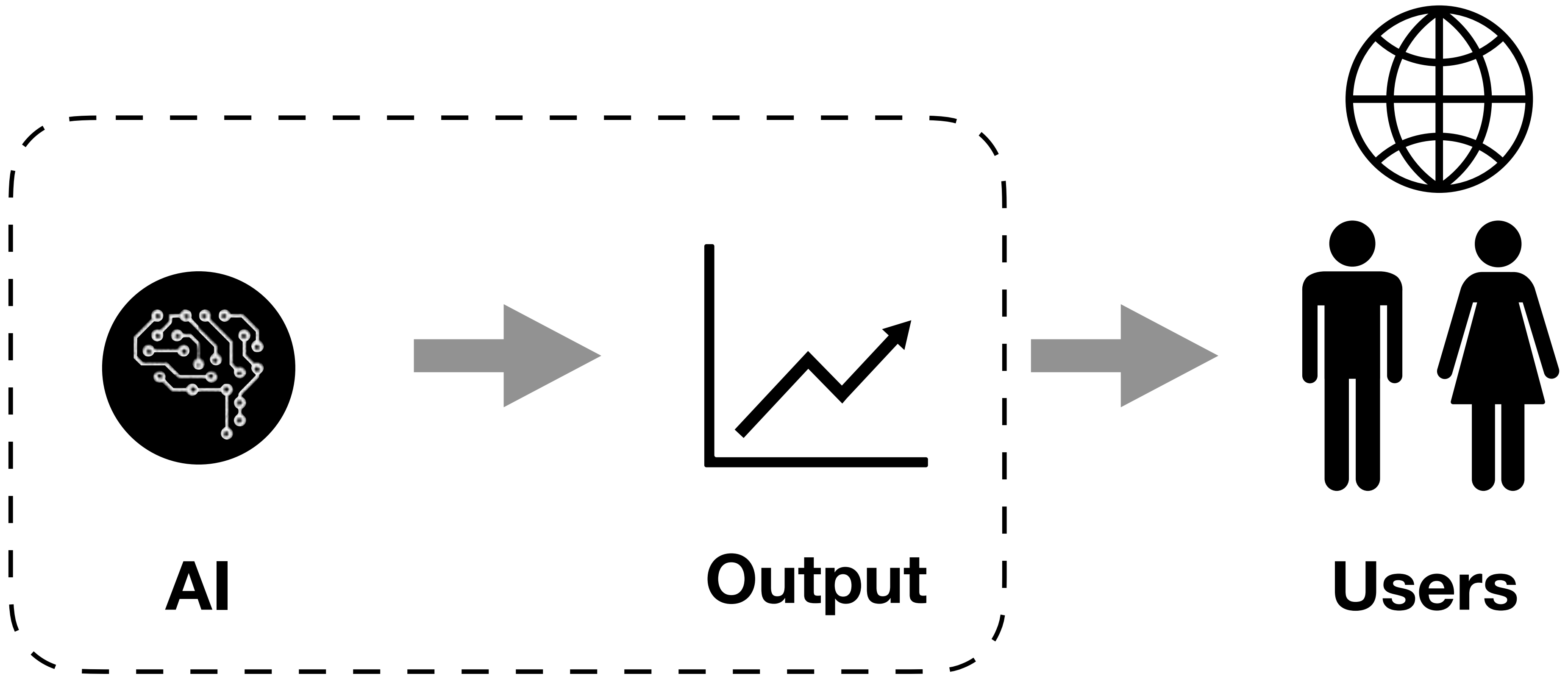
DANCE/CHOREOGRAPHY

MENTAL HEALTH

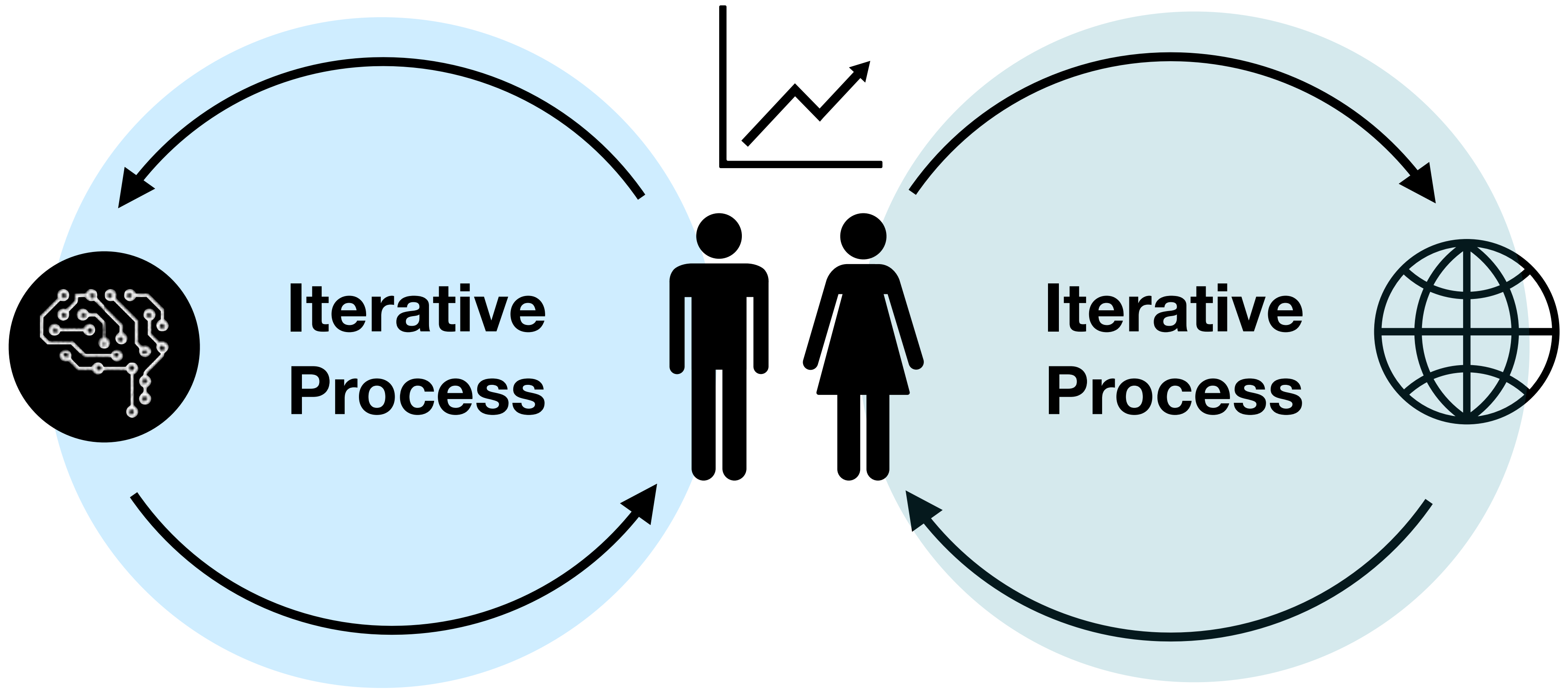
PHYSICAL THERAPY

TRAINING

## Current Approach




## Our Approach

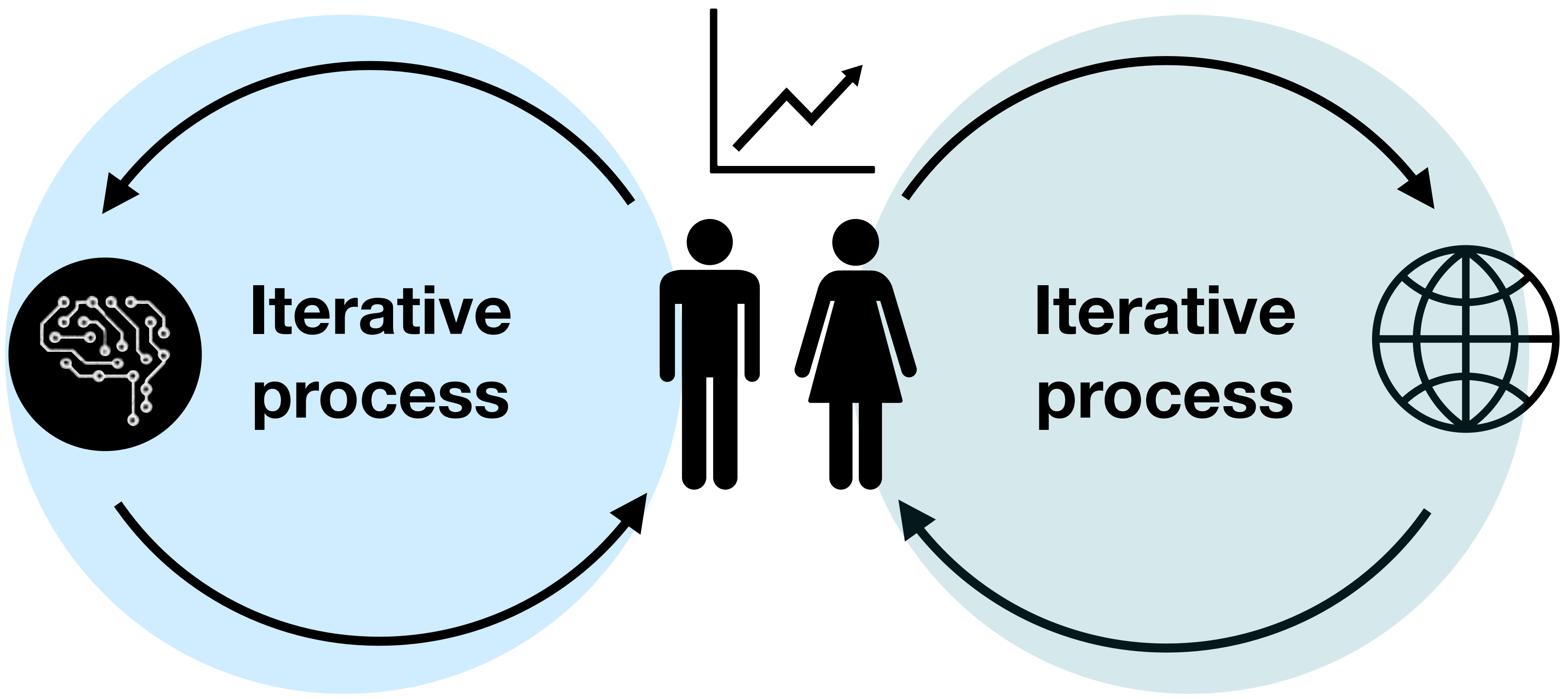



- AI trained to meet mathematical objectives with minimal input from end users
- No understanding of people's needs and little consideration of the negative impact of AI on user behavior and by extension on society

- AI considers both the user and their context to solve problems meaningful to users
- Focuses on understanding user interaction and needs across domain-specific tasks with positive impact on user behavior and society

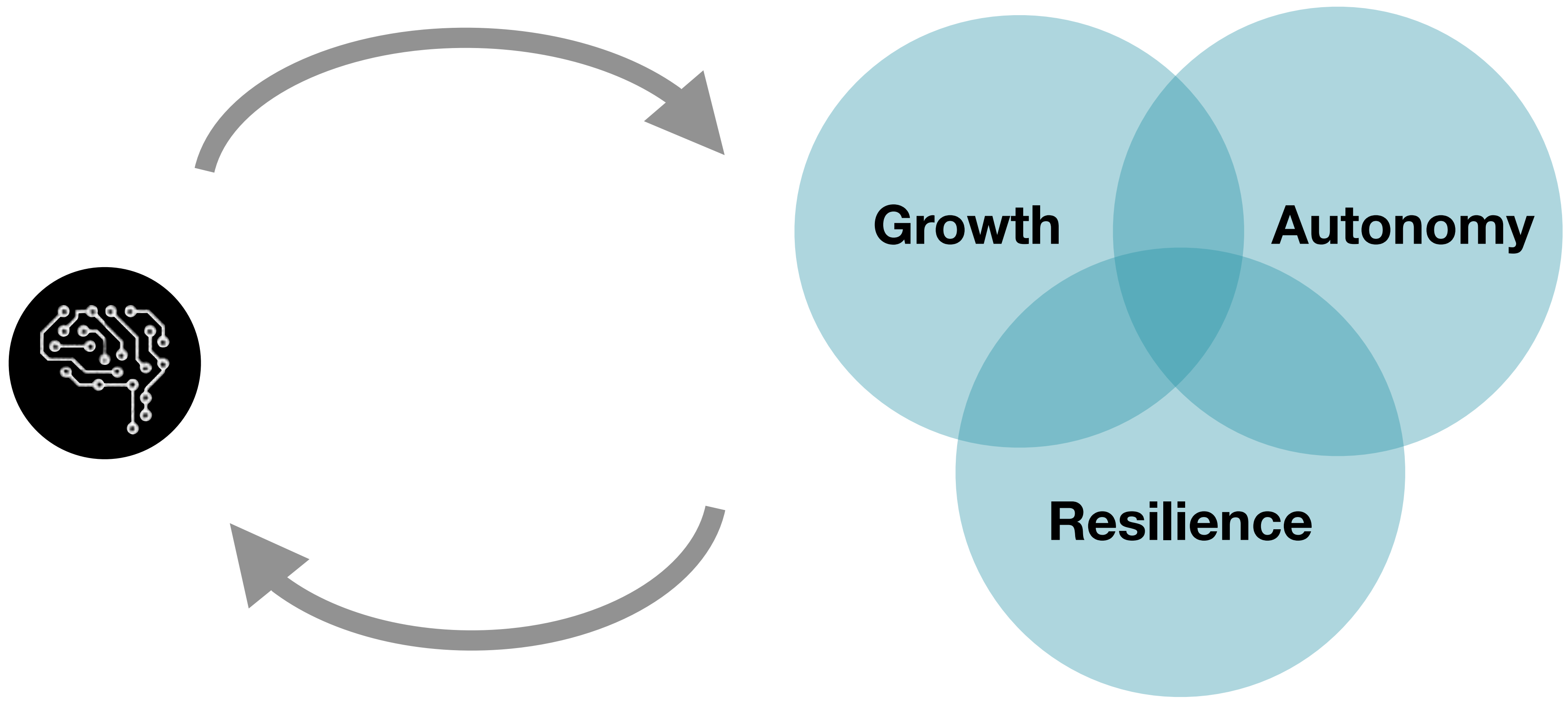
# Human-AI Systems

## What we should do




**Build Human-AI systems with insights from users and their context**

## Where that should take us




**Building and studying Human-AI systems that augment human potential**


# Growth

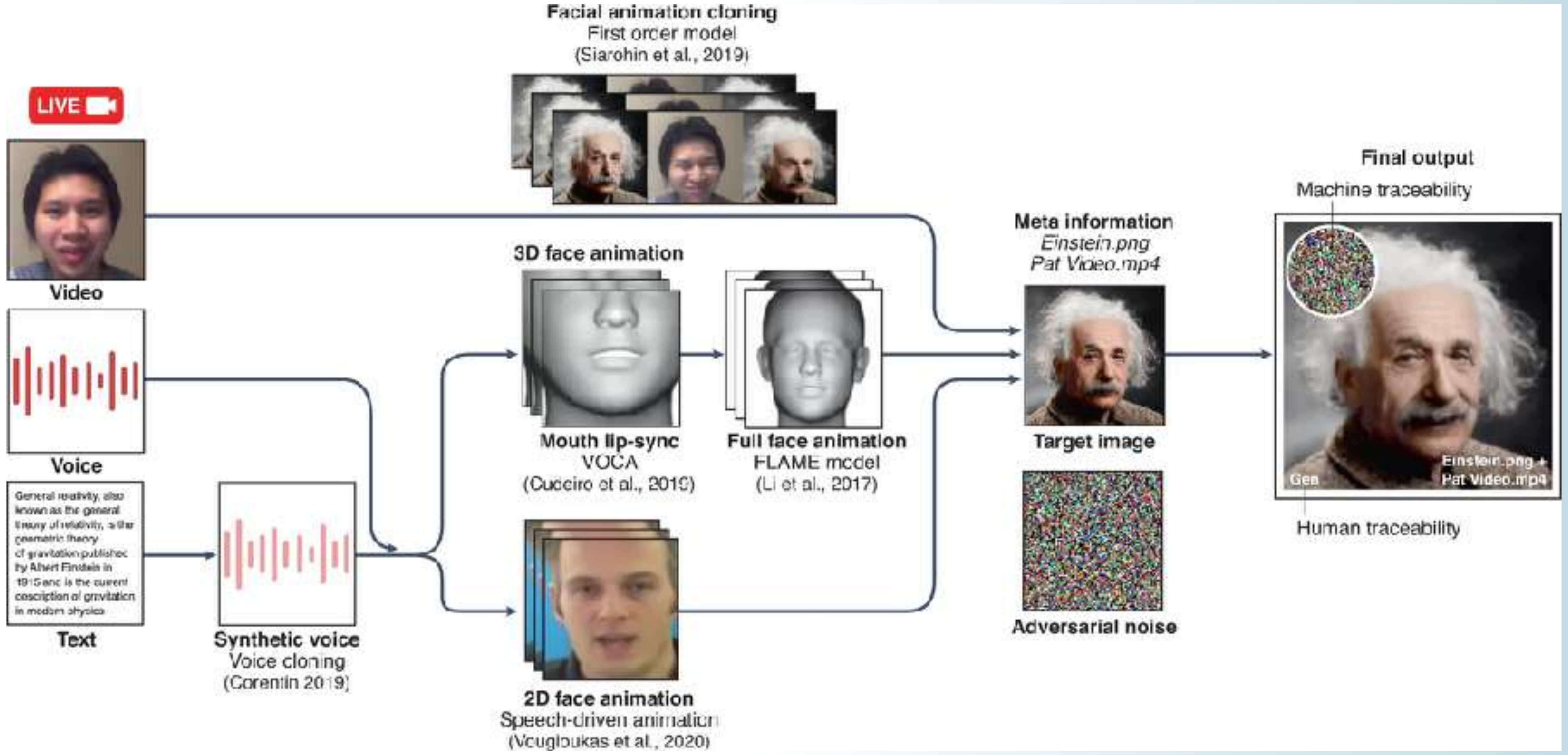
Supporting learning and continuous development

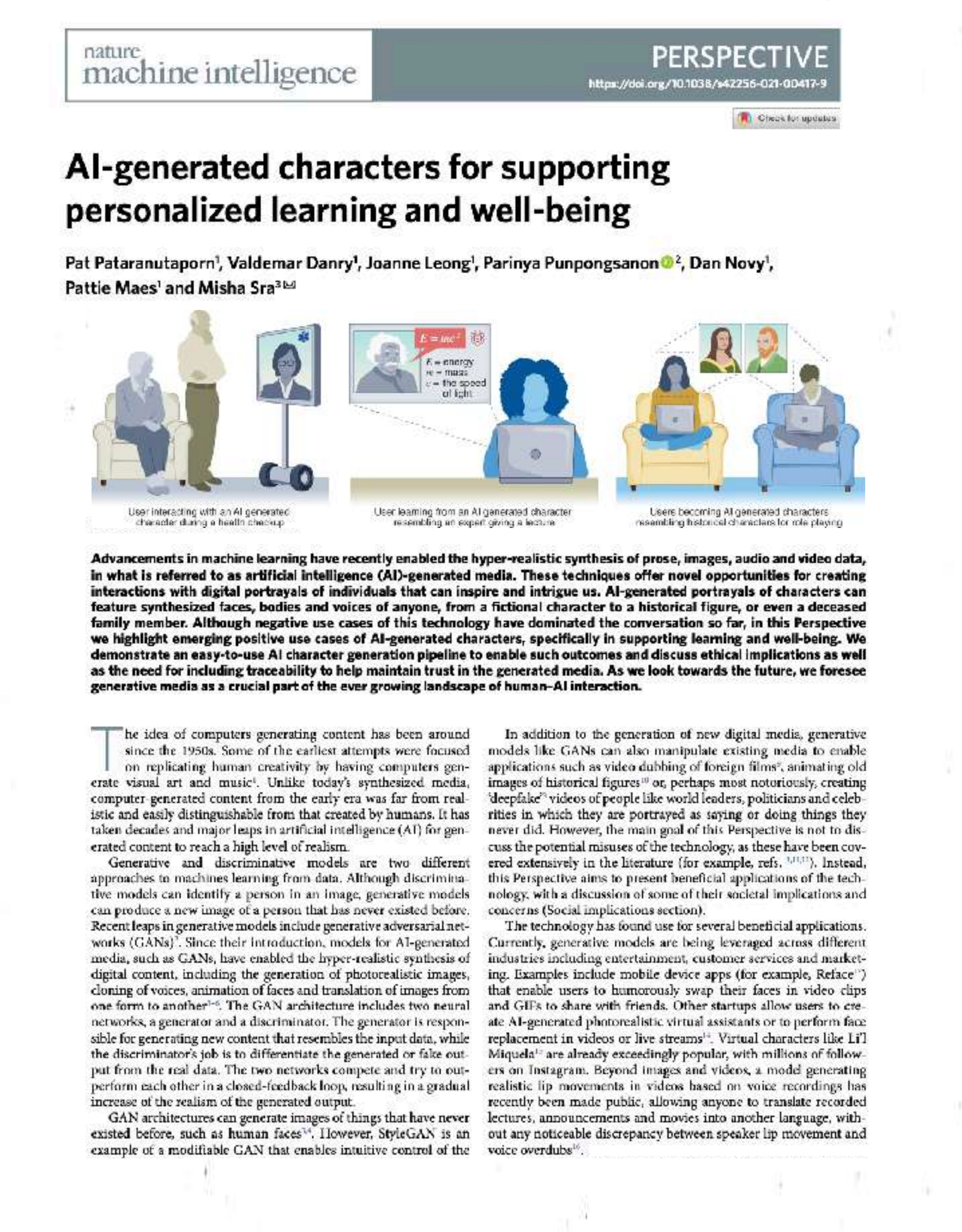
- GenAI for Learning & Wellbeing
- AI Generated Instructors
- Living Memories

UCSB mit media lab

# AI-Generated Characters for Supporting Personalized Learning and Wellbeing

Pat Pataranutaporn, Valdemar Danry, Joanne Leong, Parinya Punpongsanon, Dan Novy, Pattie Maes & Misha Sra





nature machine intelligence
PERSPECTIVE
https://doi.org/10.1038/s42256-021-00417-9
Check for updates

## AI-generated characters for supporting personalized learning and well-being

Pat Pataranutaporn[1], Valdemar Danry[1], Joanne Leong[1], Parinya Punpongsanon[2], Dan Novy[1], Pattie Maes[1] and Misha Sra[3]

User interacting with an AI generated character during a health checkup

User learning from an AI generated character resembling an expert giving a lecture

Users becoming AI generated characters resembling historical characters for role playing

**Advancements in machine learning have recently enabled the hyper-realistic synthesis of prose, images, audio and video data, in what is referred to as artificial intelligence (AI)-generated media. These techniques offer novel opportunities for creating interactions with digital portrayals of individuals that can inspire and intrigue us. AI-generated portrayals of characters can feature synthesized faces, bodies and voices of anyone, from a fictional character to a historical figure, or even a deceased family member. Although negative use cases of this technology have dominated the conversation so far, in this Perspective we highlight emerging positive use cases of AI-generated characters, specifically in supporting learning and well-being. We demonstrate an easy-to-use AI character generation pipeline to enable such outcomes and discuss ethical implications as well as the need for including traceability to help maintain trust in the generated media. As we look towards the future, we foresee generative media as a crucial part of the ever growing landscape of human–AI interaction.**

The idea of computers generating content has been around since the 1950s. Some of the earliest attempts were focused on replicating human creativity by having computers generate visual art and music[1]. Unlike today's synthesized media, computer-generated content from the early era was far from realistic and easily distinguishable from that created by humans. It has taken decades and major leaps in artificial intelligence (AI) for generated content to reach a high level of realism.

Generative and discriminative models are two different approaches to machines learning from data. Although discriminative models can identify a person in an image, generative models can produce a new image of a person that has never existed before. Recent leaps in generative models include generative adversarial networks (GANs)[7]. Since their introduction, models for AI-generated media, such as GANs, have enabled the hyper-realistic synthesis of digital content, including the generation of photorealistic images, cloning of voices, animation of faces and translation of images from one form to another[1–6]. The GAN architecture includes two neural networks, a generator and a discriminator. The generator is responsible for generating new content that resembles the input data, while the discriminator's job is to differentiate the generated or fake output from the real data. The two networks compete and try to outperform each other in a closed-feedback loop, resulting in a gradual increase of the realism of the generated output.

GAN architectures can generate images of things that have never existed before, such as human faces[3,4]. However, StyleGAN is an example of a modifiable GAN that enables intuitive control of the

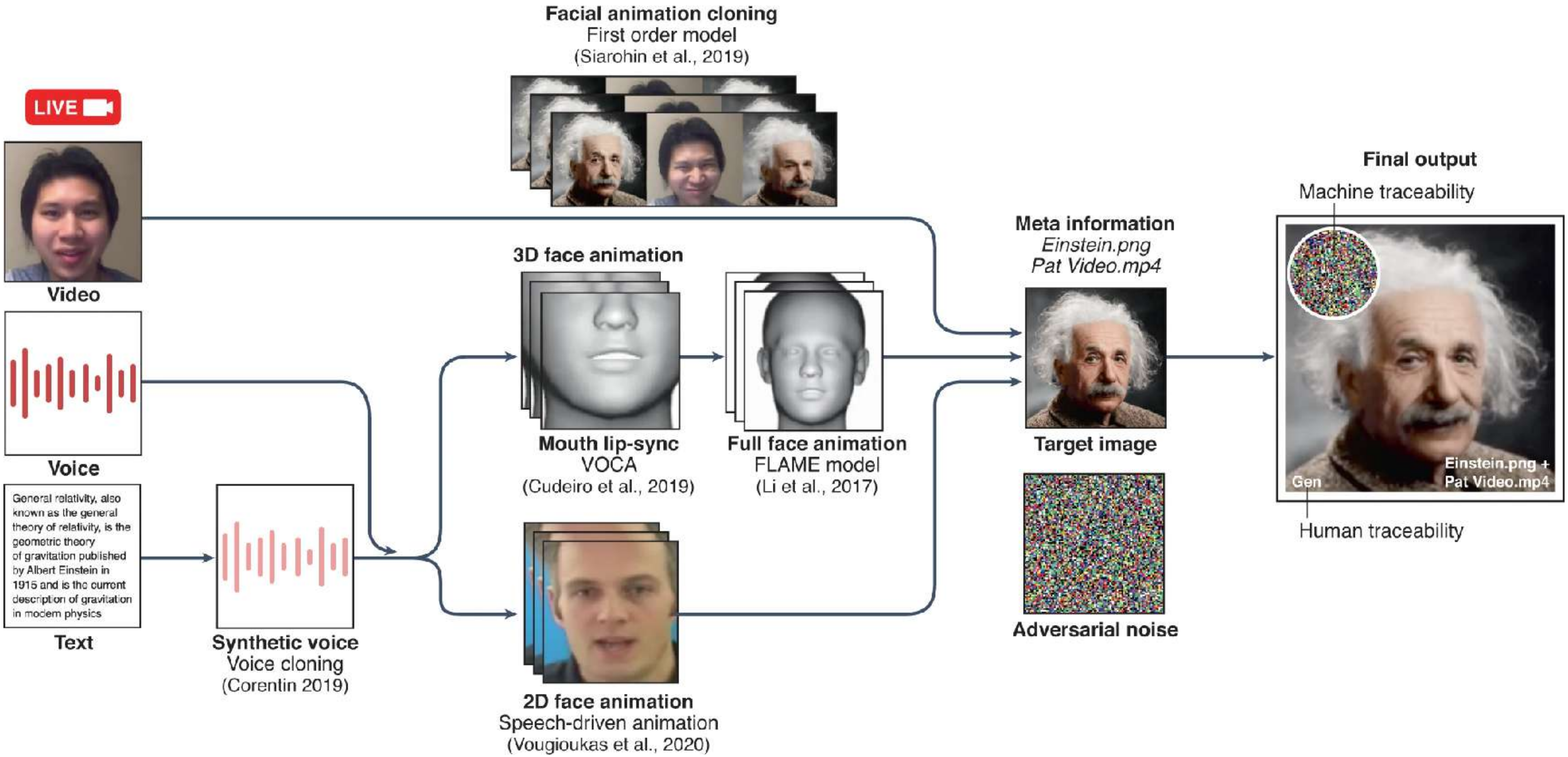
In addition to the generation of new digital media, generative models like GANs can also manipulate existing media to enable applications such as video dubbing of foreign films[8], animating old images of historical figures[10] or, perhaps most notoriously, creating 'deepfake'[11] videos of people like world leaders, politicians and celebrities in which they are portrayed as saying or doing things they never did. However, the main goal of this Perspective is not to discuss the potential misuses of the technology, as these have been covered extensively in the literature (for example, refs. [3,11,12]). Instead, this Perspective aims to present beneficial applications of the technology, with a discussion of some of their societal implications and concerns (Social implications section).

The technology has found use for several beneficial applications. Currently, generative models are being leveraged across different industries including entertainment, customer services and marketing. Examples include mobile device apps (for example, Reface[13]) that enable users to humorously swap their faces in video clips and GIFs to share with friends. Other startups allow users to create AI-generated photorealistic virtual assistants or to perform face replacement in videos or live streams[14]. Virtual characters like Li'l Miquela[15] are already exceedingly popular, with millions of followers on Instagram. Beyond images and videos, a model generating realistic lip movements in videos based on voice recordings has recently been made public, allowing anyone to translate recorded lectures, announcements and movies into another language, without any noticeable discrepancy between speaker lip movement and voice overdubs[16].

**Published in Nature Machine Intelligence (2021)**

Pataranutaporn, P., Danry, V., Leong, J., Punpongsanon, P., Novy, D., Maes, P., & Sra, M. (2021). AI-generated characters for supporting personalized learning and well-being. Nature Machine Intelligence, 3(12), 1013-1022

# AI-Generated Characters for Supporting Personalized Learning and Wellbeing

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# AI-Generated Characters for Supporting Personalized Learning and Wellbeing

## Diverse Genders, Races, Ethnic Backgrounds, and Fictional & Historical Figures

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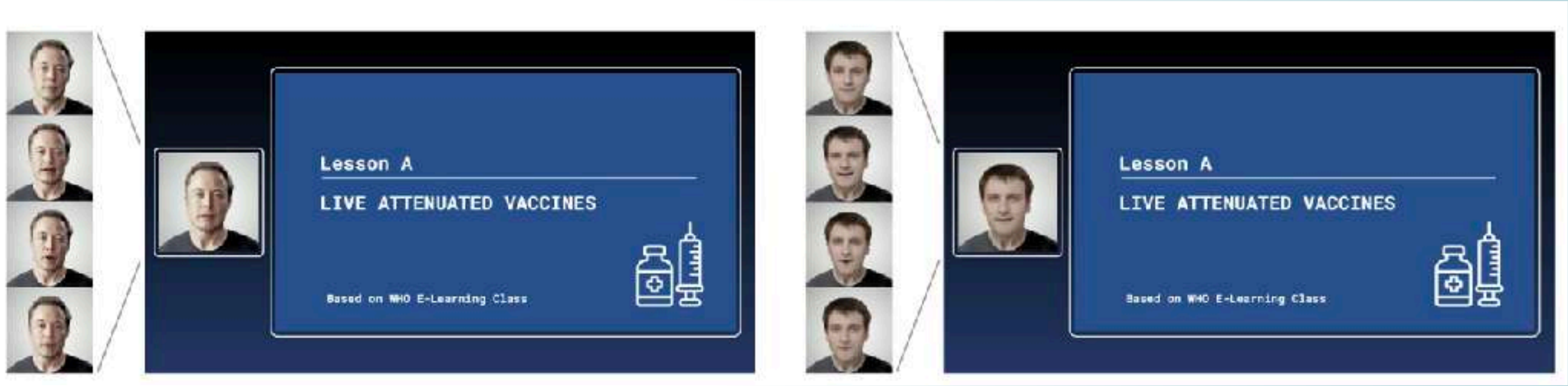
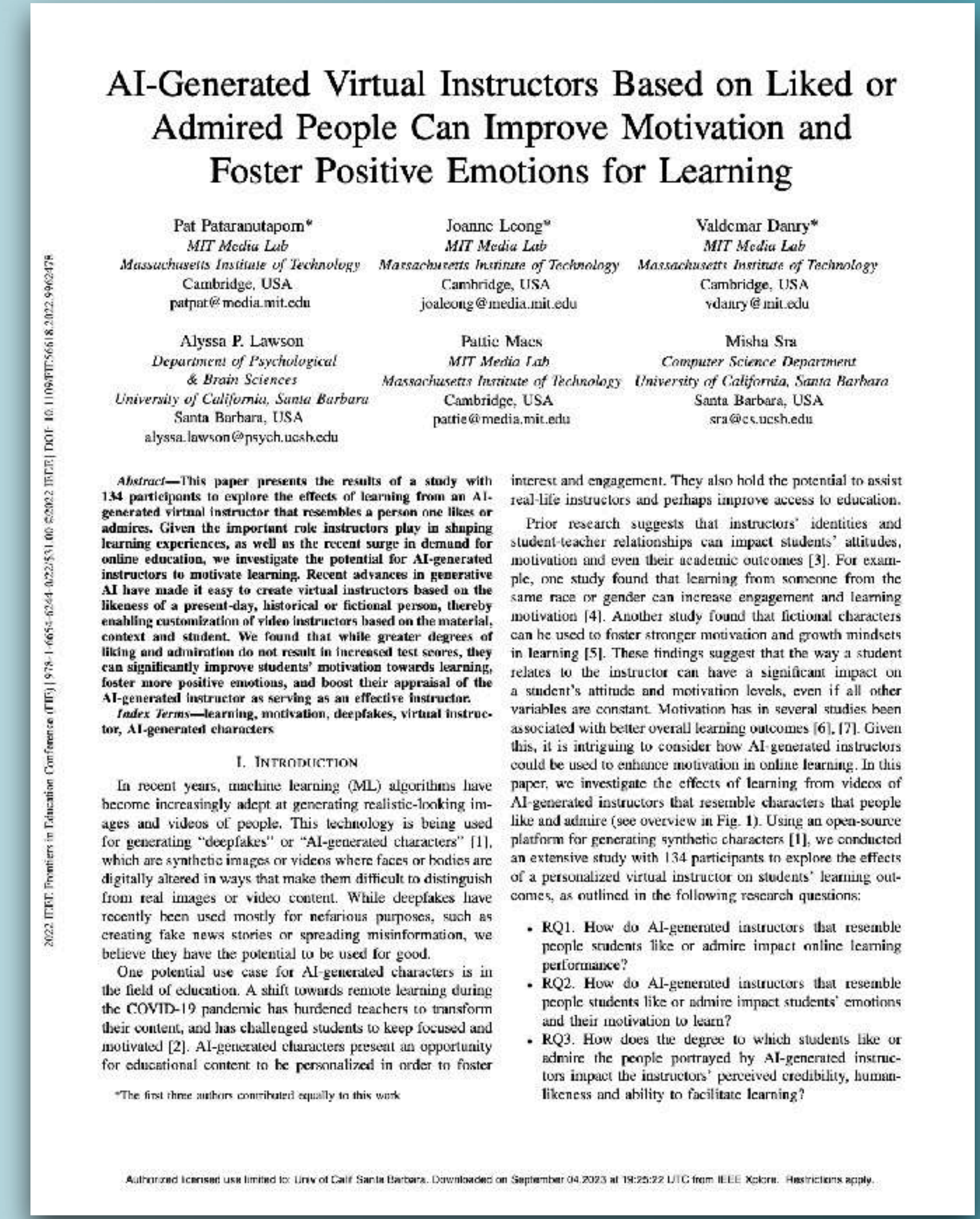
# AI-Generated Virtual Instructors Based on Liked or Admired People Can Improve Motivation and Foster Positive Emotions for Learning

Pat Pataranutaporn, Joanne Leong, Valdemar Danry, Alyssa P. Lawson, Pattie Maes, Misha Sra



# AI-Generated Virtual Instructors Based on Liked or Admired People Can Improve Motivation and Foster Positive Emotions for Learning

Pat Pataranutaporn*
MIT Media Lab
Massachusetts Institute of Technology
Cambridge, USA
patpat@media.mit.edu

Joanne Leong*
MIT Media Lab
Massachusetts Institute of Technology
Cambridge, USA
joaleong@media.mit.edu

Valdemar Danry*
MIT Media Lab
Massachusetts Institute of Technology
Cambridge, USA
vdanry@mit.edu

Alyssa P. Lawson
Department of Psychological & Brain Sciences
University of California, Santa Barbara
Santa Barbara, USA
alyssa.lawson@psych.ucsb.edu

Pattie Maes
MIT Media Lab
Massachusetts Institute of Technology
Cambridge, USA
pattie@media.mit.edu

Misha Sra
Computer Science Department
University of California, Santa Barbara
Santa Barbara, USA
sra@cs.ucsb.edu

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*Abstract*—**This paper presents the results of a study with 134 participants to explore the effects of learning from an AI-generated virtual instructor that resembles a person one likes or admires. Given the important role instructors play in shaping learning experiences, as well as the recent surge in demand for online education, we investigate the potential for AI-generated instructors to motivate learning. Recent advances in generative AI have made it easy to create virtual instructors based on the likeness of a present-day, historical or fictional person, thereby enabling customization of video instructors based on the material, context and student. We found that while greater degrees of liking and admiration do not result in increased test scores, they can significantly improve students' motivation towards learning, foster more positive emotions, and boost their appraisal of the AI-generated instructor as serving as an effective instructor.**

*Index Terms*—**learning, motivation, deepfakes, virtual instructor, AI-generated characters**

## I. Introduction

In recent years, machine learning (ML) algorithms have become increasingly adept at generating realistic-looking images and videos of people. This technology is being used for generating "deepfakes" or "AI-generated characters" [1], which are synthetic images or videos where faces or bodies are digitally altered in ways that make them difficult to distinguish from real images or video content. While deepfakes have recently been used mostly for nefarious purposes, such as creating fake news stories or spreading misinformation, we believe they have the potential to be used for good.

One potential use case for AI-generated characters is in the field of education. A shift towards remote learning during the COVID-19 pandemic has burdened teachers to transform their content, and has challenged students to keep focused and motivated [2]. AI-generated characters present an opportunity for educational content to be personalized in order to foster interest and engagement. They also hold the potential to assist real-life instructors and perhaps improve access to education.

Prior research suggests that instructors' identities and student-teacher relationships can impact students' attitudes, motivation and even their academic outcomes [3]. For example, one study found that learning from someone from the same race or gender can increase engagement and learning motivation [4]. Another study found that fictional characters can be used to foster stronger motivation and growth mindsets in learning [5]. These findings suggest that the way a student relates to the instructor can have a significant impact on a student's attitude and motivation levels, even if all other variables are constant. Motivation has in several studies been associated with better overall learning outcomes [6], [7]. Given this, it is intriguing to consider how AI-generated instructors could be used to enhance motivation in online learning. In this paper, we investigate the effects of learning from videos of AI-generated instructors that resemble characters that people like and admire (see overview in Fig. 1). Using an open-source platform for generating synthetic characters [1], we conducted an extensive study with 134 participants to explore the effects of a personalized virtual instructor on students' learning outcomes, as outlined in the following research questions:

- RQ1. How do AI-generated instructors that resemble people students like or admire impact online learning performance?
- RQ2. How do AI-generated instructors that resemble people students like or admire impact students' emotions and their motivation to learn?
- RQ3. How does the degree to which students like or admire the people portrayed by AI-generated instructors impact the instructors' perceived credibility, human-likeness and ability to facilitate learning?

*The first three authors contributed equally to this work



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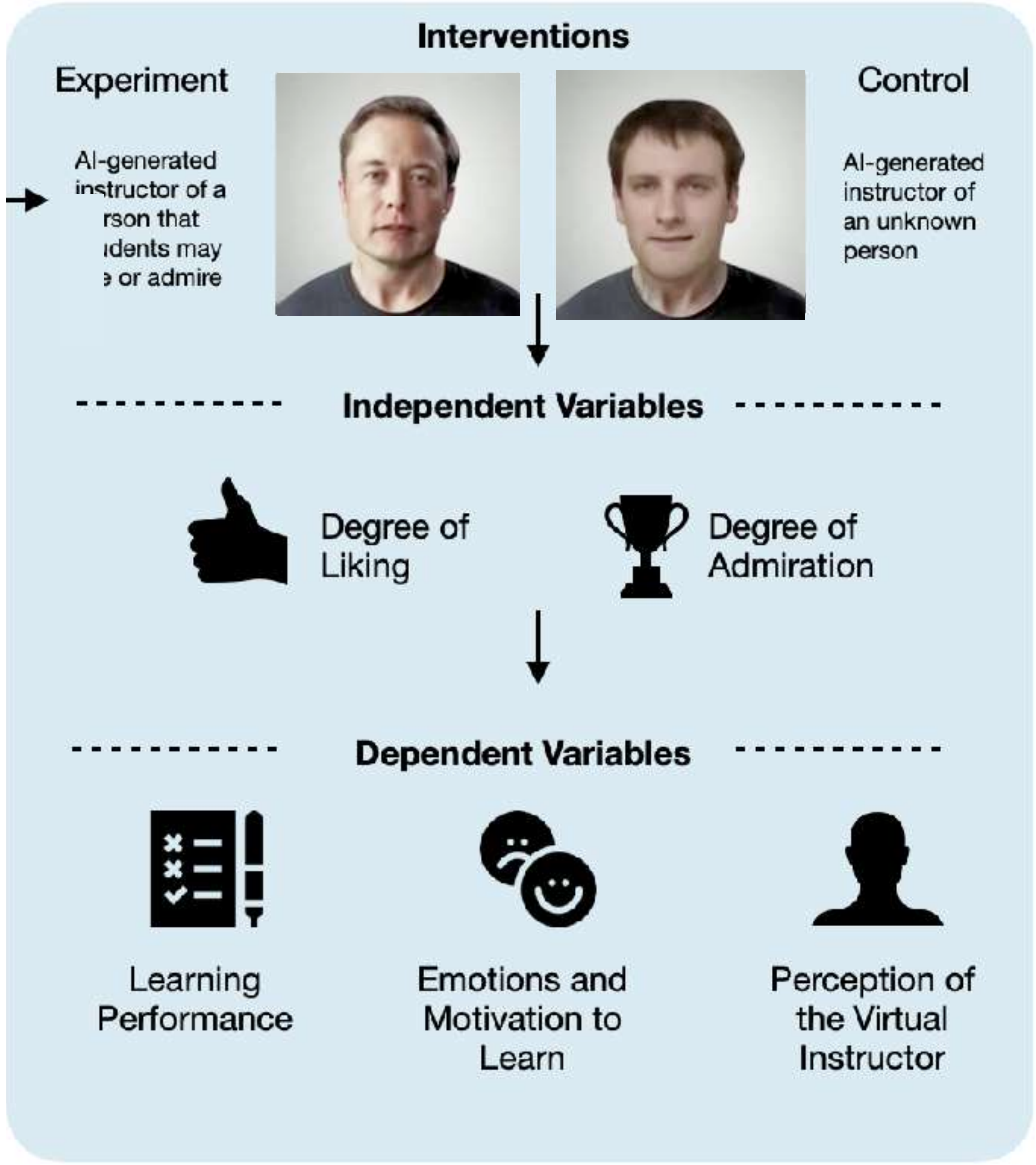
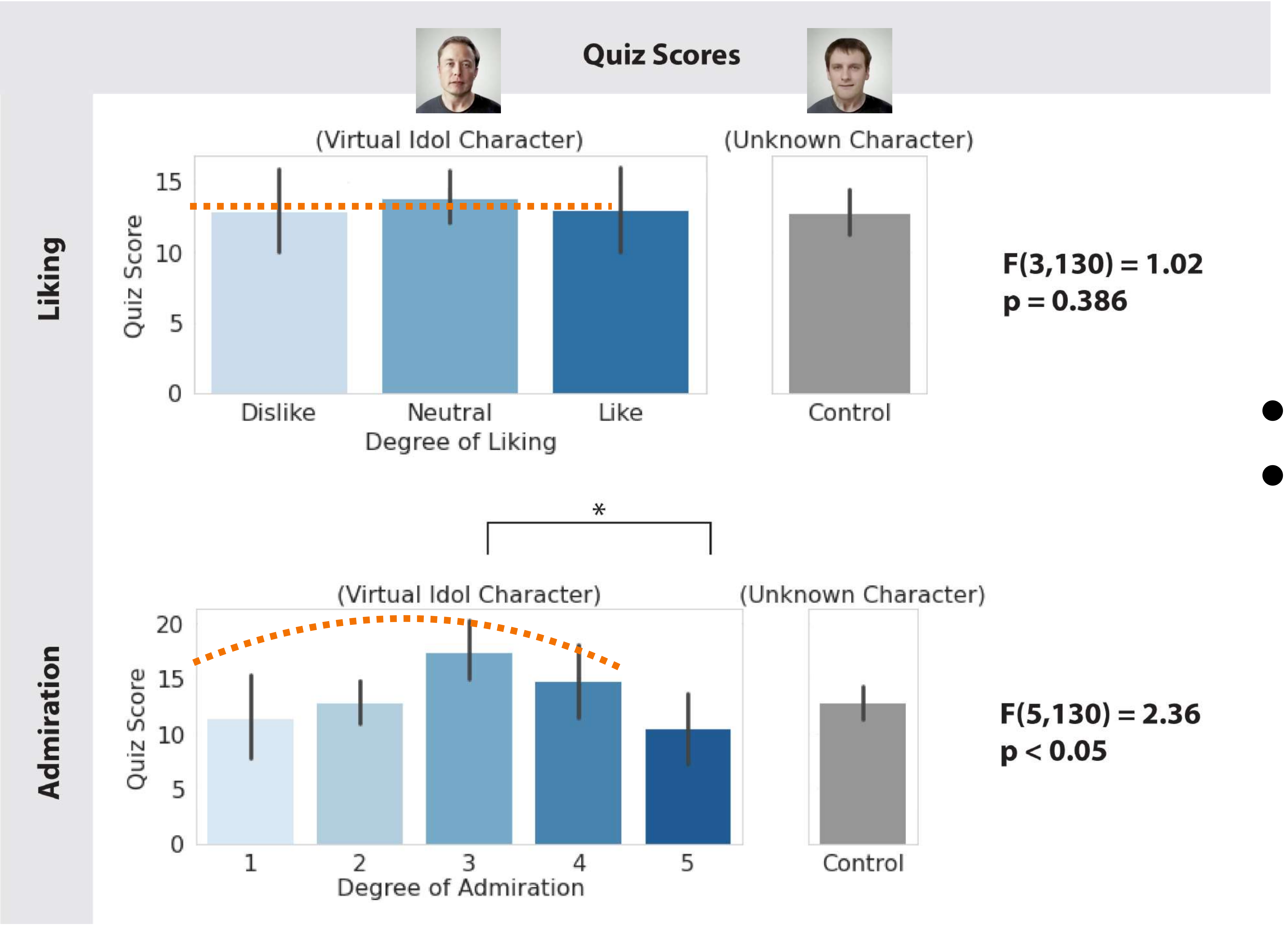



## Experiment Setup

- 134 participants
- Between subjects online study
- 2 part study (Lesson & Survey, Quiz)
- **2 Independent Variables (Like / Admire)**
- Likert Scale Questions
- Statistical Analysis

Pataranutaporn, P., Leong, J., Danry, V., Lawson, A. P., Maes, P., & Sra, M. (2022, October). AI-generated virtual instructors based on liked or admired people can improve motivation and foster positive emotions for learning. In 2022 IEEE Frontiers in Education Conference (FIE) (pp. 1-9). IEEE..

# Learning Performance

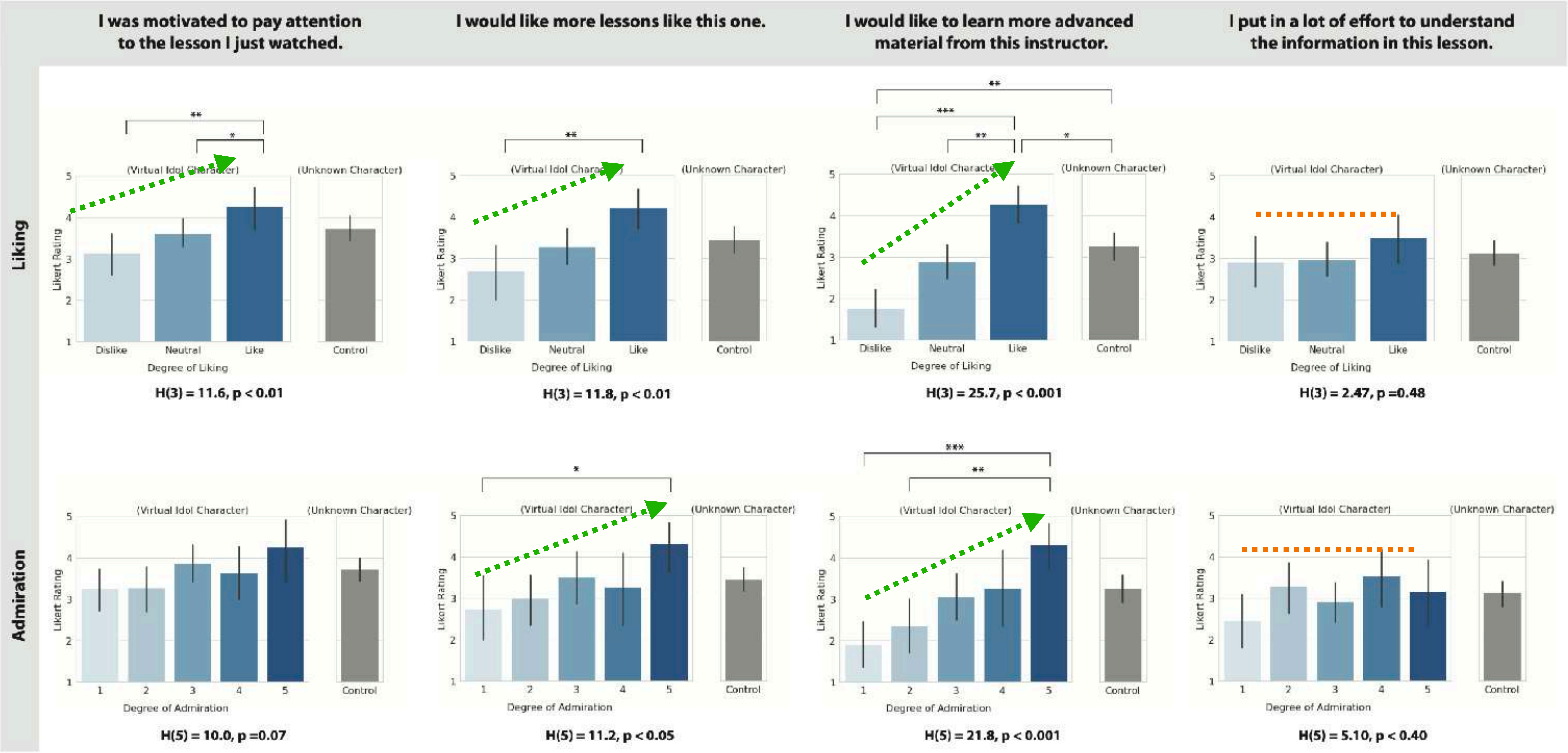



- No significant difference in quiz scores (liking)
- Moderate admiration appears beneficial

Pataranutaporn, P., Leong, J., Danry, V., Lawson, A. P., Maes, P., & Sra, M. (2022, October). AI-generated virtual instructors based on liked or admired people can improve motivation and foster positive emotions for learning. In 2022 IEEE Frontiers in Education Conference (FIE) (pp. 1-9). IEEE..

# Motivation

Enhances desire to advance learning

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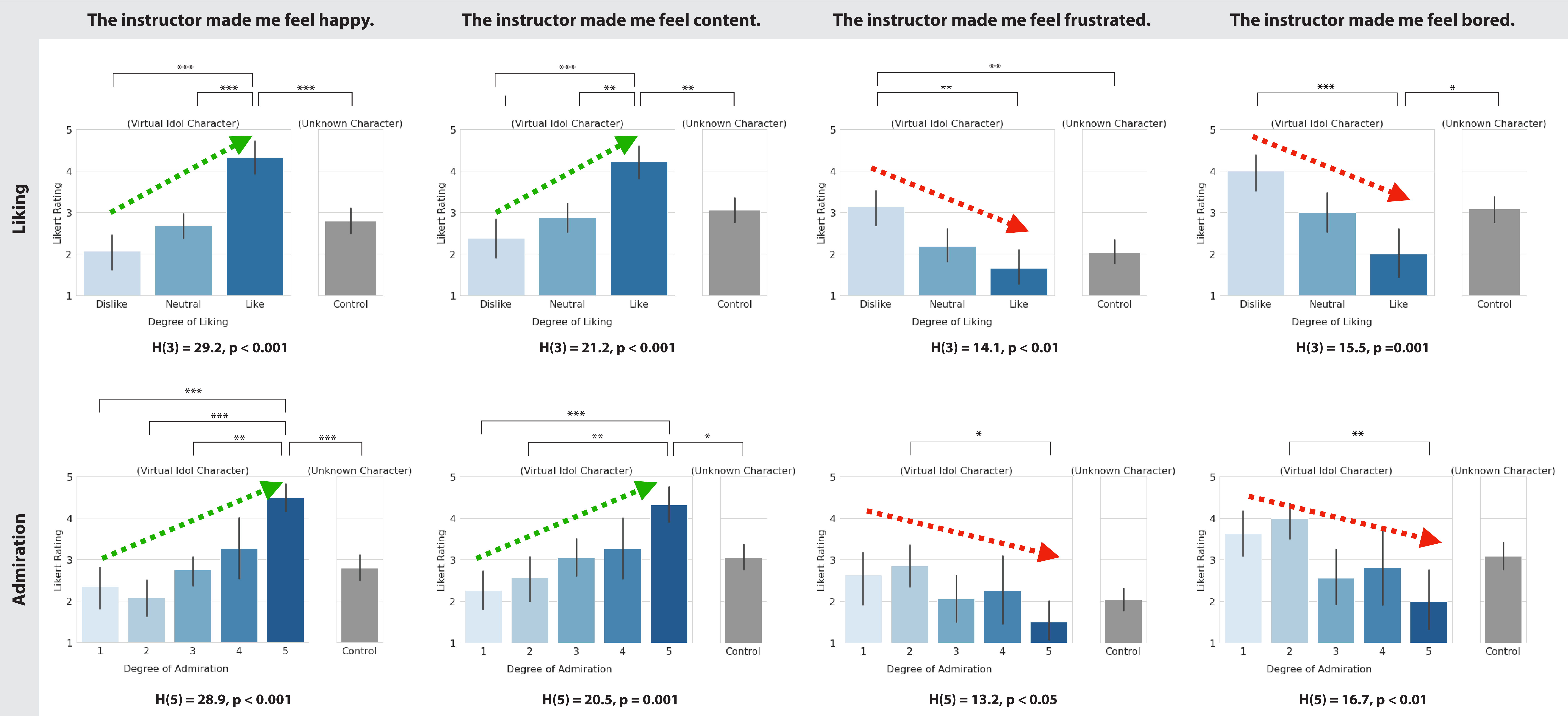
# Emotions

Enhances satisfaction

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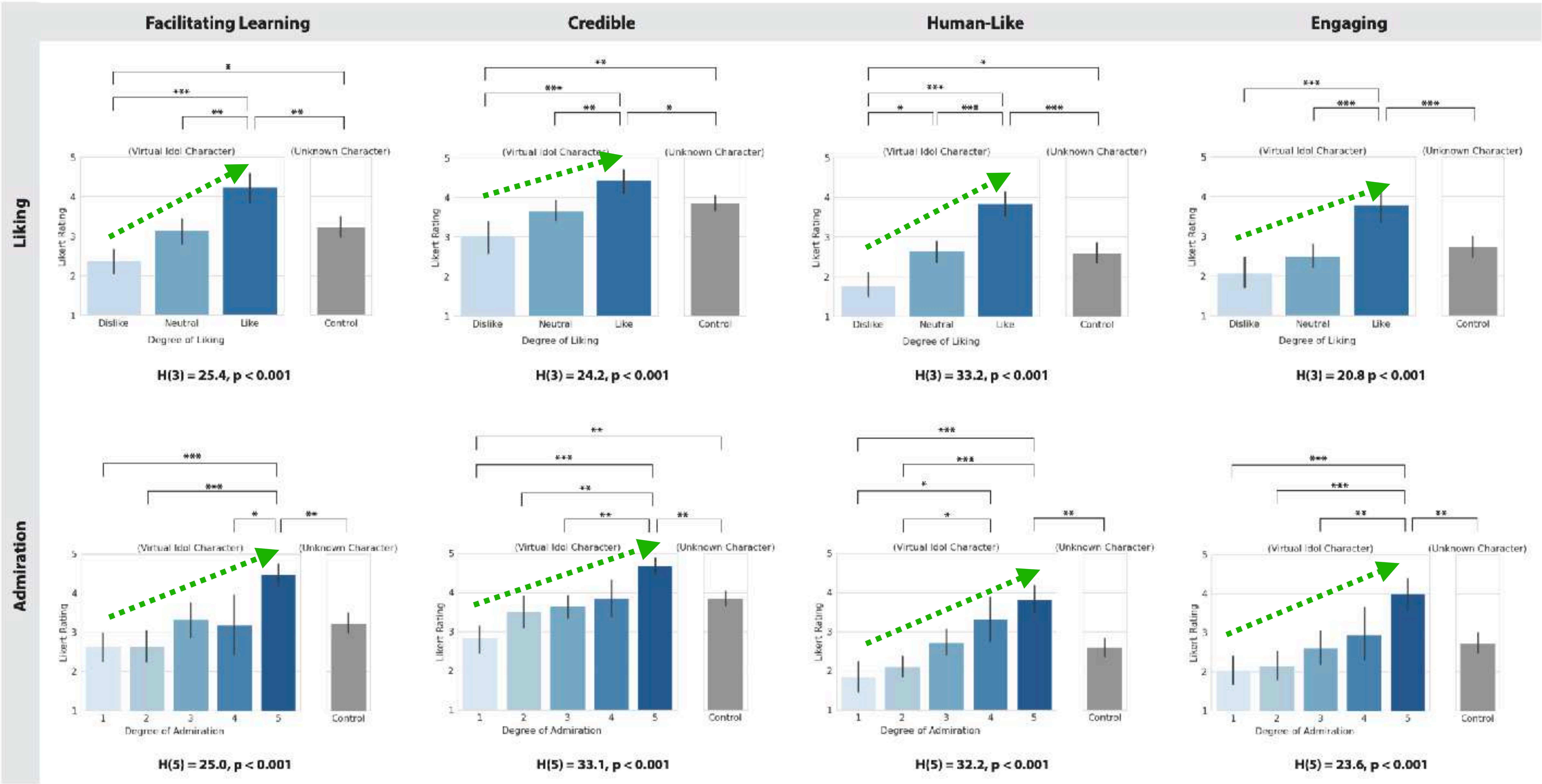
# Perception of Virtual Instructor




Students have a more positive perception of the pedagogical agent

# Ethics

## Misportrayal and Disinformation

- Risk of easily spreading inaccurate information

## Privacy and Consent

- Prevent distress
- How to seek consent for deceased persons?

## Replacement

- Supplement rather than replace educators

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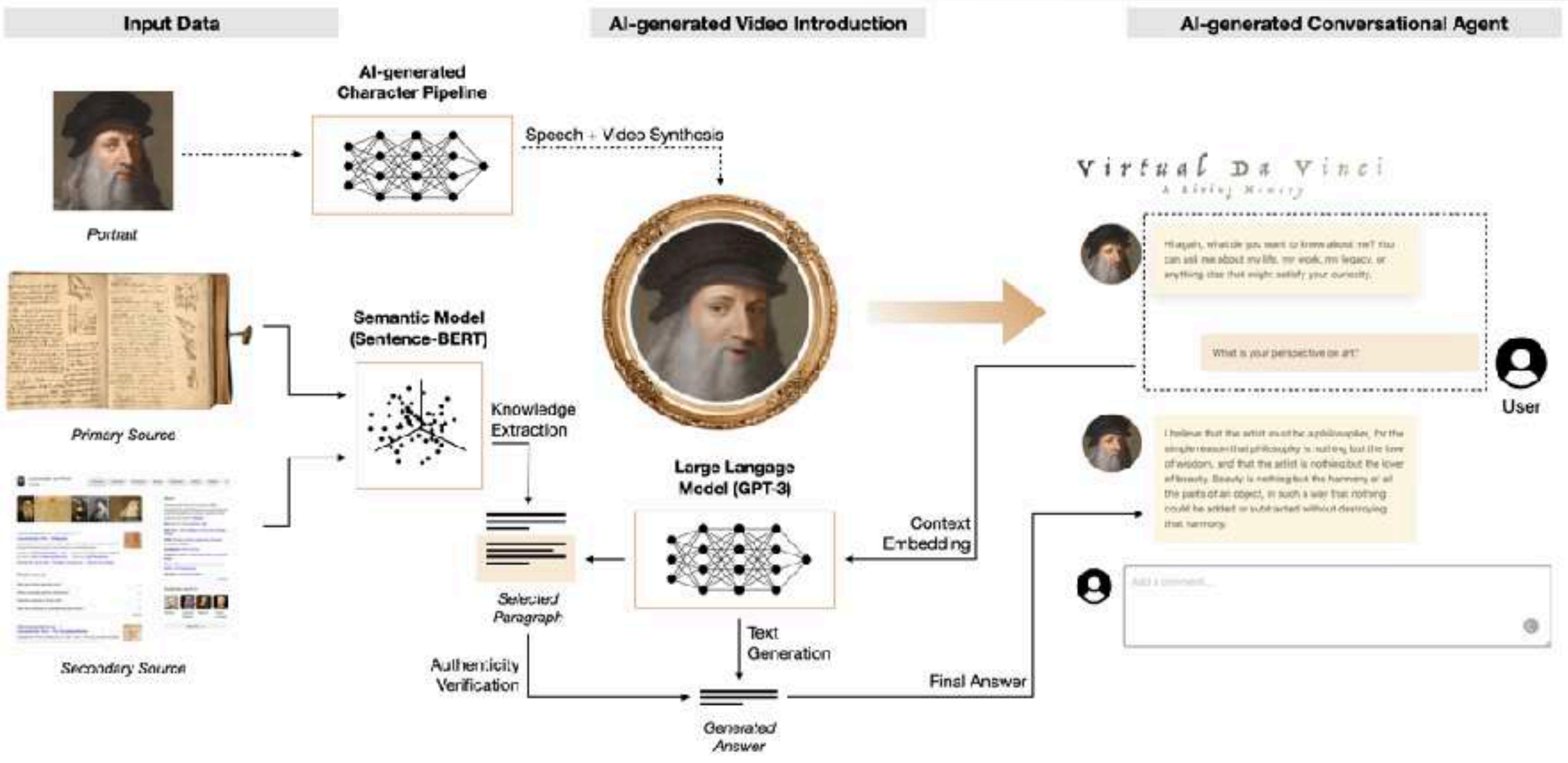
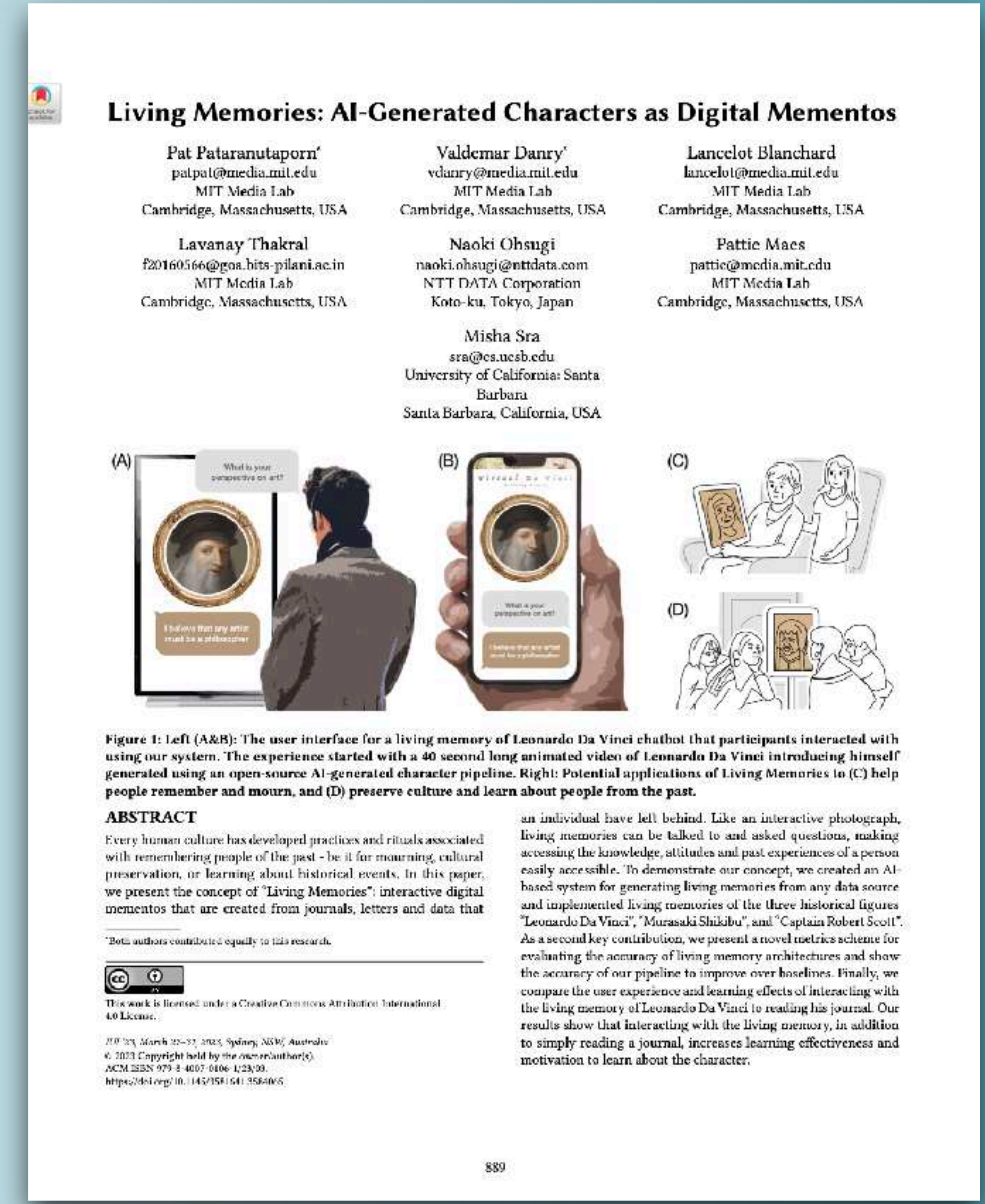
# Living Memories: AI-Generated Characters as Digital Mementos


Pat Pataranutaporn, Valdemar Danry, Lancelot Blanchard, Lavanay Thakral, Naoki Ohsugi, Pattie Maes, Misha Sra

## Living Memories: AI-Generated Characters as Digital Mementos


Pat Pataranutaporn*
patpat@media.mit.edu
MIT Media Lab
Cambridge, Massachusetts, USA

Valdemar Danry*
vdanry@media.mit.edu
MIT Media Lab
Cambridge, Massachusetts, USA

Lancelot Blanchard
lancelot@media.mit.edu
MIT Media Lab
Cambridge, Massachusetts, USA

Lavanay Thakral
f20160566@goa.bits-pilani.ac.in
MIT Media Lab
Cambridge, Massachusetts, USA

Naoki Ohsugi
naoki.ohsugi@nttdata.com
NTT DATA Corporation
Koto-ku, Tokyo, Japan

Pattie Maes
pattie@media.mit.edu
MIT Media Lab
Cambridge, Massachusetts, USA

Misha Sra
sra@cs.ucsb.edu
University of California: Santa Barbara
Santa Barbara, California, USA


**Figure 1: Left (A&B): The user interface for a living memory of Leonardo Da Vinci chatbot that participants interacted with using our system. The experience started with a 40 second long animated video of Leonardo Da Vinci introducing himself generated using an open-source AI-generated character pipeline. Right: Potential applications of Living Memories to (C) help people remember and mourn, and (D) preserve culture and learn about people from the past.**


### ABSTRACT

Every human culture has developed practices and rituals associated with remembering people of the past - be it for mourning, cultural preservation, or learning about historical events. In this paper, we present the concept of "Living Memories": interactive digital mementos that are created from journals, letters and data that an individual have left behind. Like an interactive photograph, living memories can be talked to and asked questions, making accessing the knowledge, attitudes and past experiences of a person easily accessible. To demonstrate our concept, we created an AI-based system for generating living memories from any data source and implemented living memories of the three historical figures "Leonardo Da Vinci", "Murasaki Shikibu", and "Captain Robert Scott". As a second key contribution, we present a novel metrics scheme for evaluating the accuracy of living memory architectures and show the accuracy of our pipeline to improve over baselines. Finally, we compare the user experience and learning effects of interacting with the living memory of Leonardo Da Vinci to reading his journal. Our results show that interacting with the living memory, in addition to simply reading a journal, increases learning effectiveness and motivation to learn about the character.


*Both authors contributed equally to this research.

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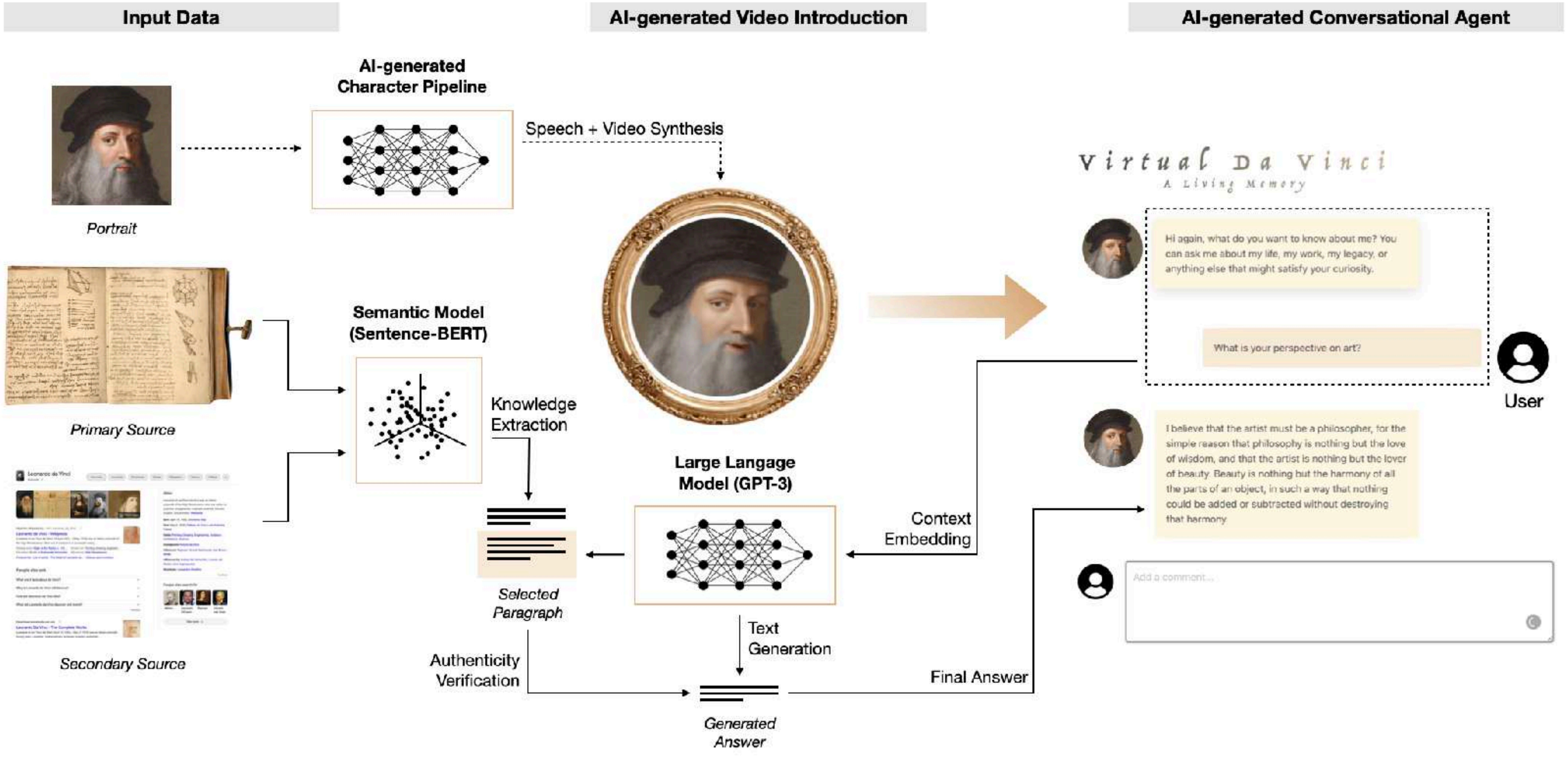


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# Living Memories: AI-Generated Characters As Digital Mementos

| Character | Question | Ground truth | Finetuned GPT-3 | LLM+Semantic (Ours) |
|---|---|---|---|---|
| Leonardo Da Vinci | How should figures be depicted in a painting? | The limbs should be adapted to the body with grace. | In my opinion a figure in a painting should be represented as it is seen by the eye… | I think that the figures in a painting should be depicted in a way that is graceful. |
| Leonardo Da Vinci | What is the United Nations? | I am not sure. | It is a union of all the peoples of the earth. | I am not sure. |

Pataranutaporn, P., Leong, J., Danry, V., Lawson, A. P., Maes, P., & Sra, M. (2022, October). AI-generated virtual instructors based on liked or admired people can improve motivation and foster positive emotions for learning. In 2022 IEEE Frontiers in Education Conference (FIE) (pp. 1-9). IEEE.

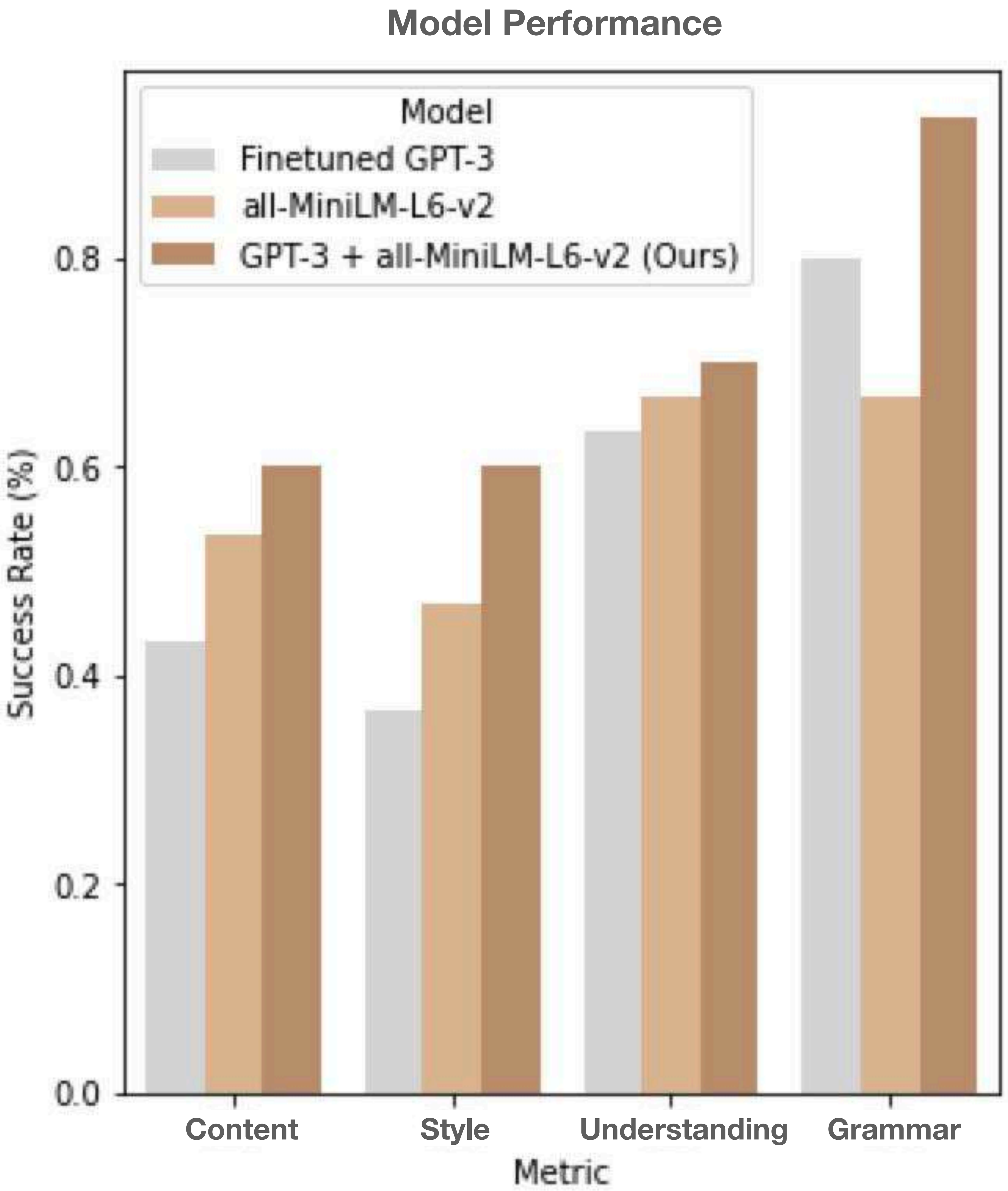
# Living Memories: AI-Generated Characters As Digital Mementos

Content Preservation

Style Preservation

Understandability

Grammar




Our model outperforms both the fine-tuned GPT-3 Curie and MiniLM-L6-v2 BERT models in preserving source content and style, understandability, and grammatical fluency when answering questions.

N = 86

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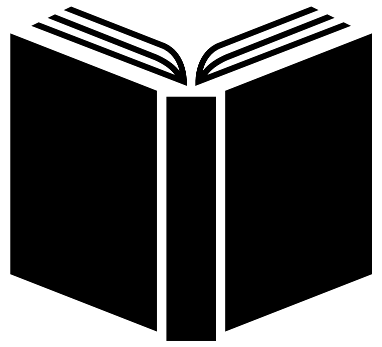
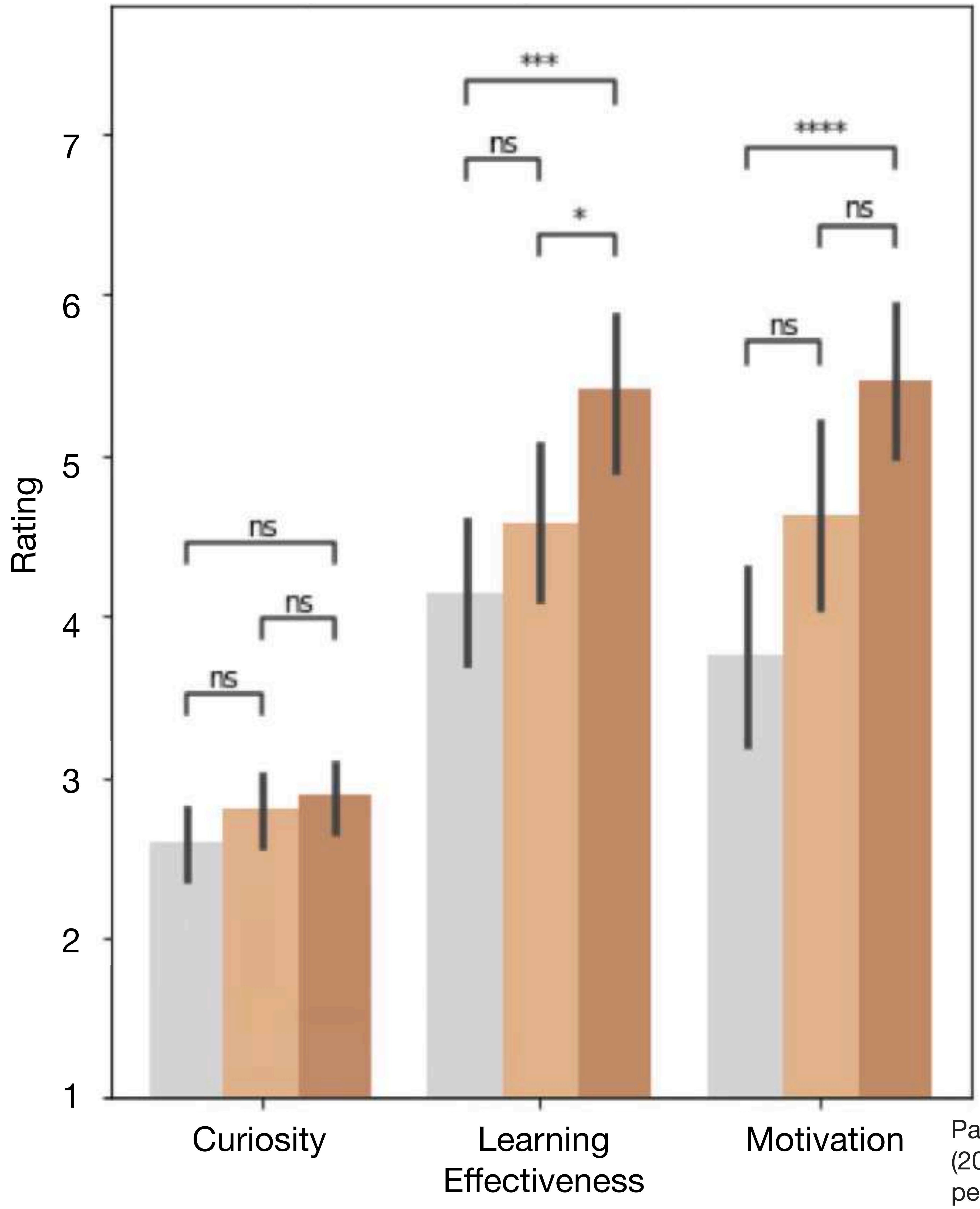


Reading About Da Vinci

Interacting with Living Memory of Da Vinci

Reading About Da Vinci

Interacting with Living Memory of Da Vinci




N = 90

In this study, we demonstrate that using Living Memory to augment the reading about Da Vinci creates the most impactful learning experience.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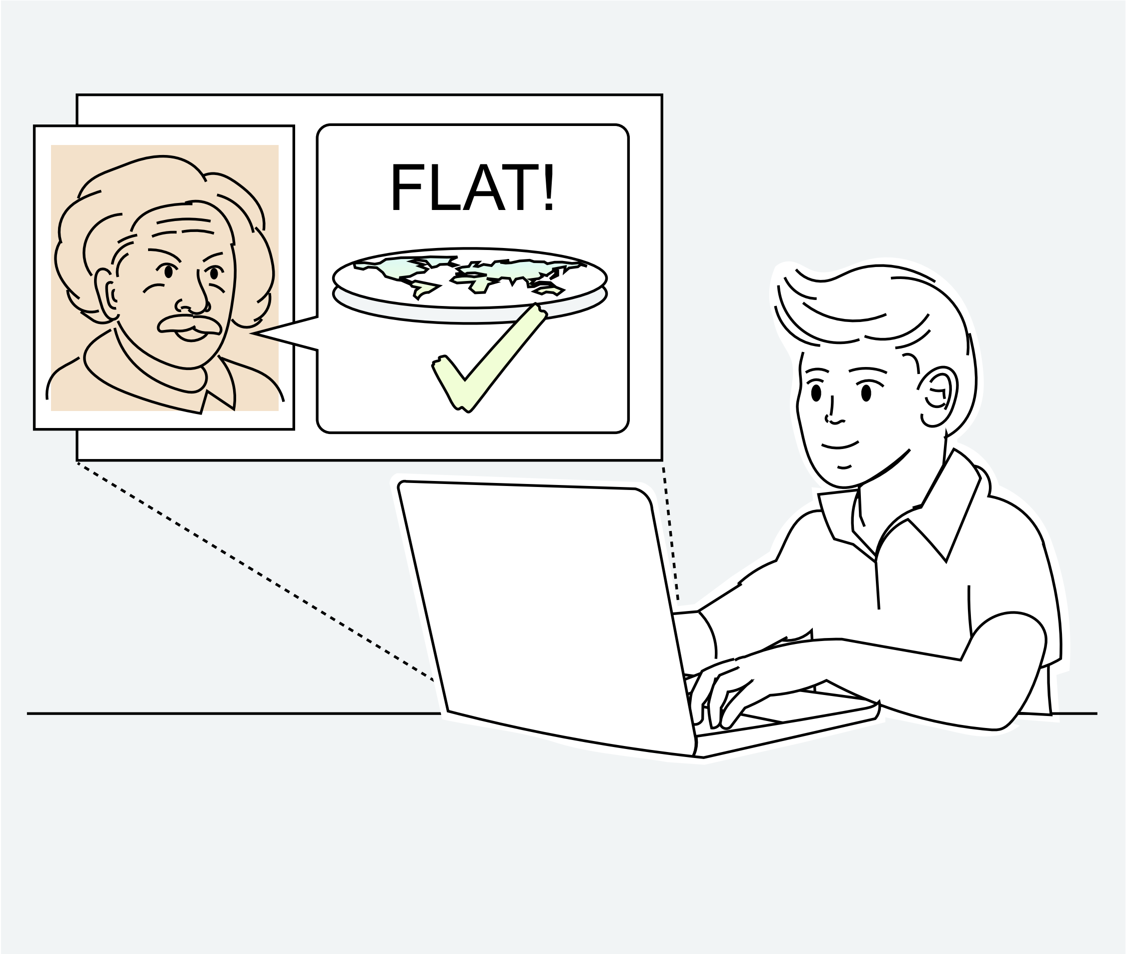
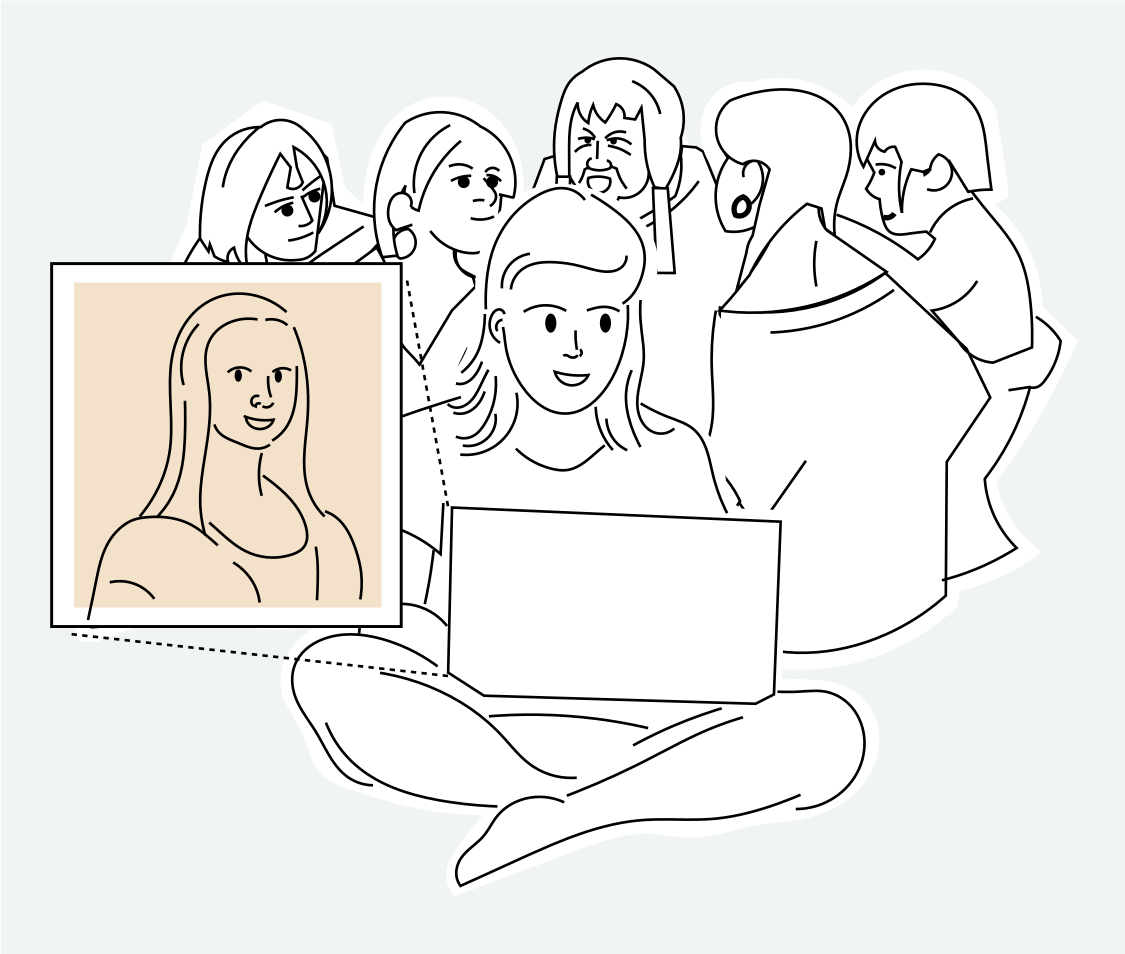
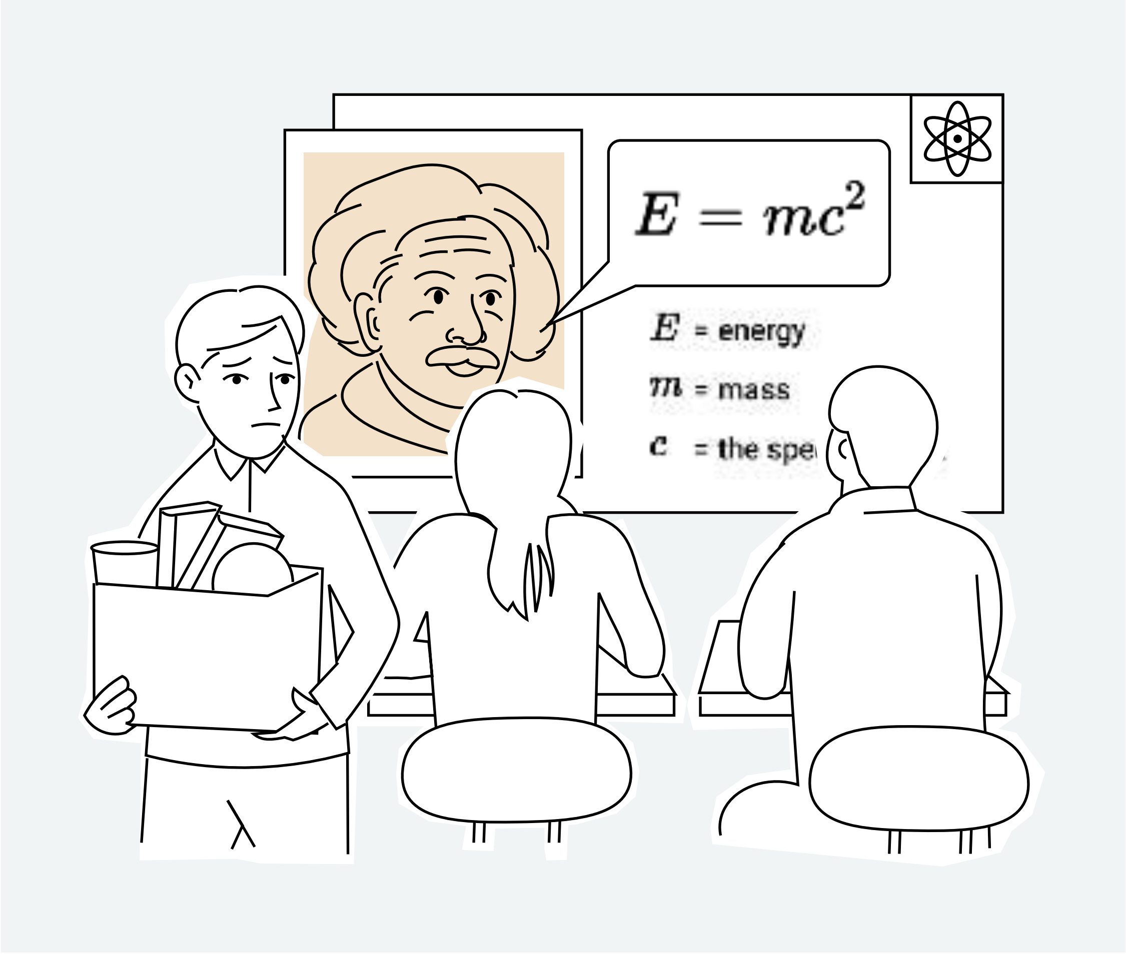
Consent and Privacy



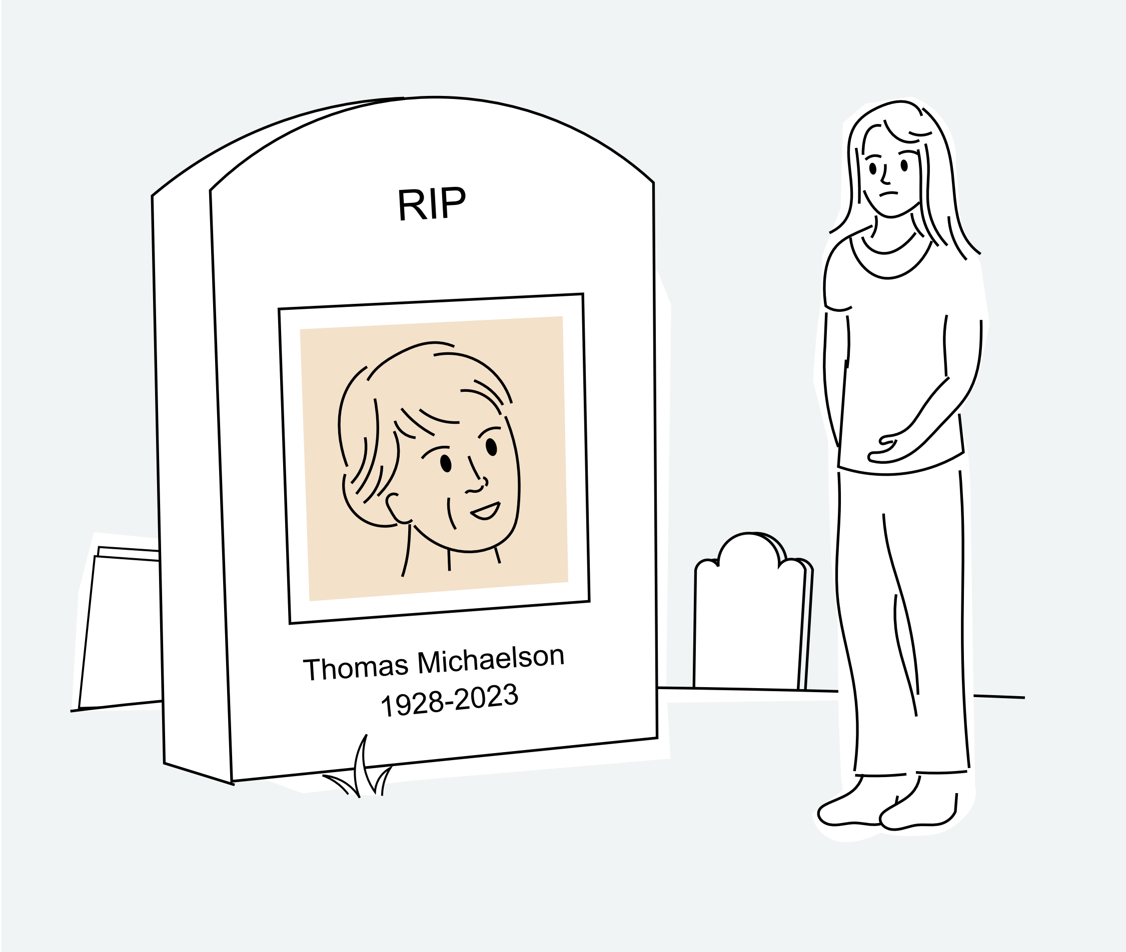

Authenticity



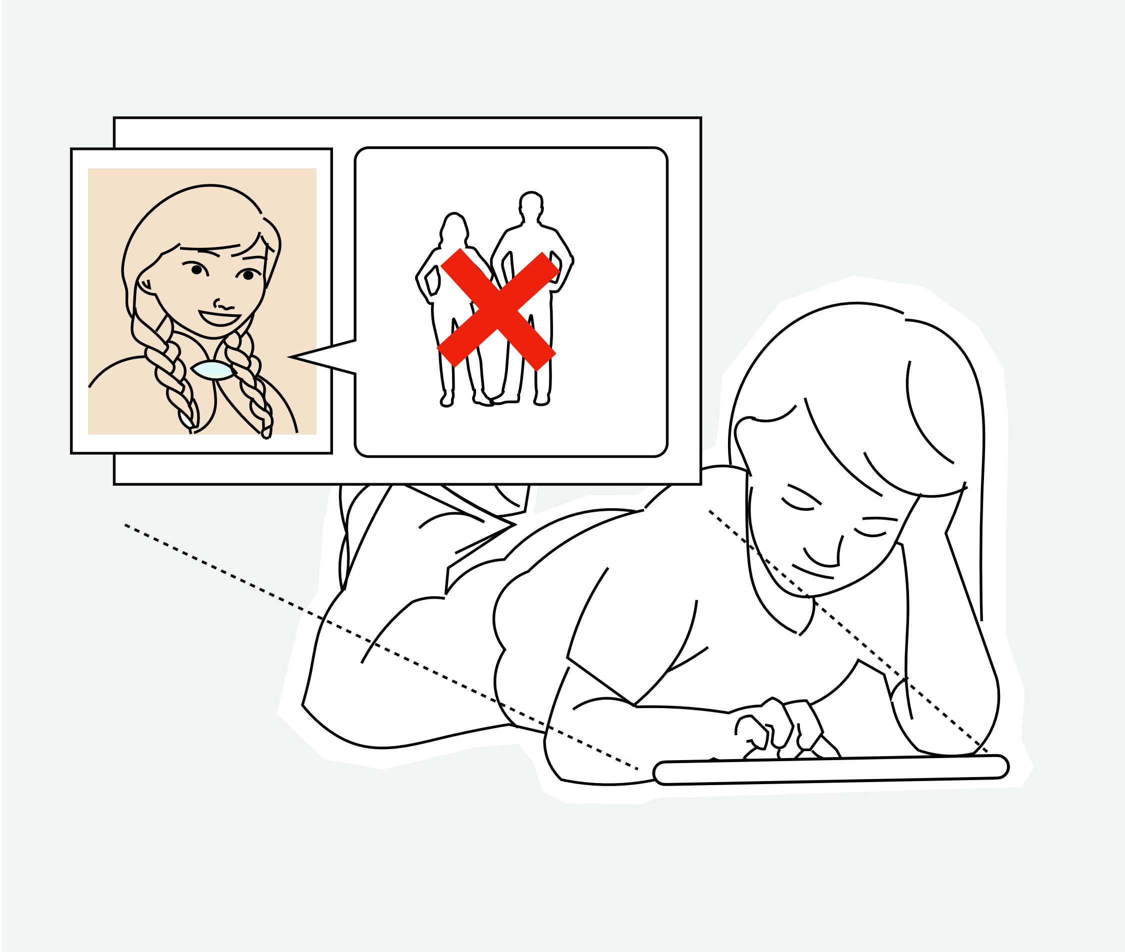
Over-use




Supplanting Teachers




Postmortem Existence



Promote Harm

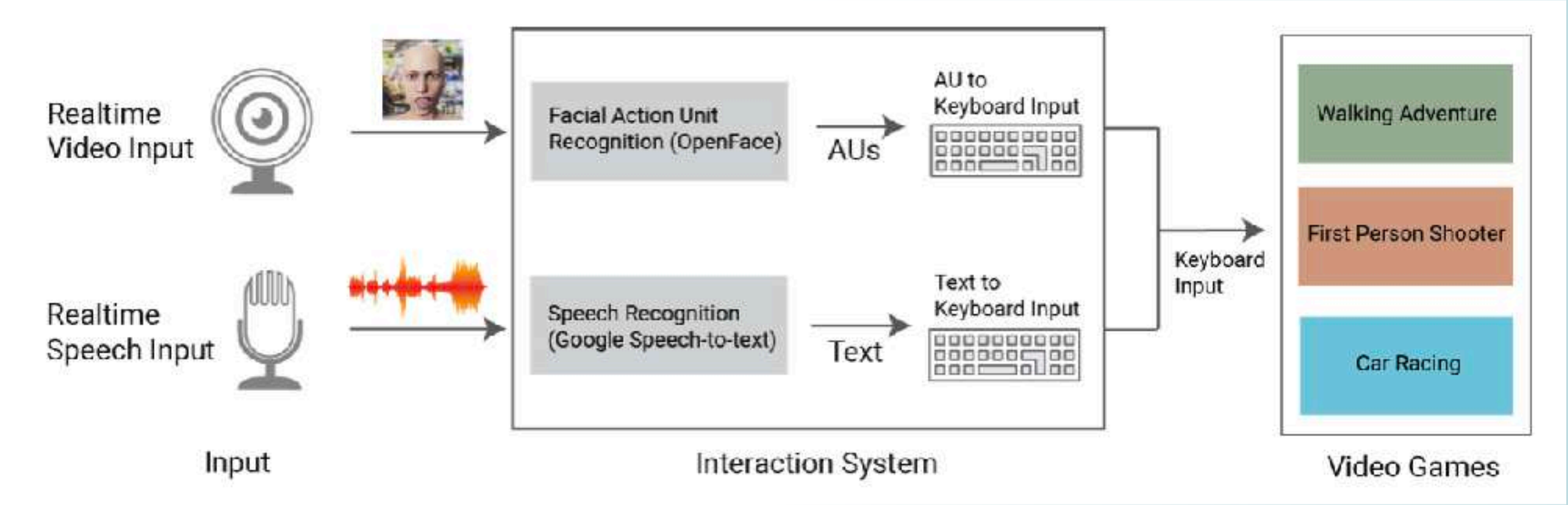

# Autonomy

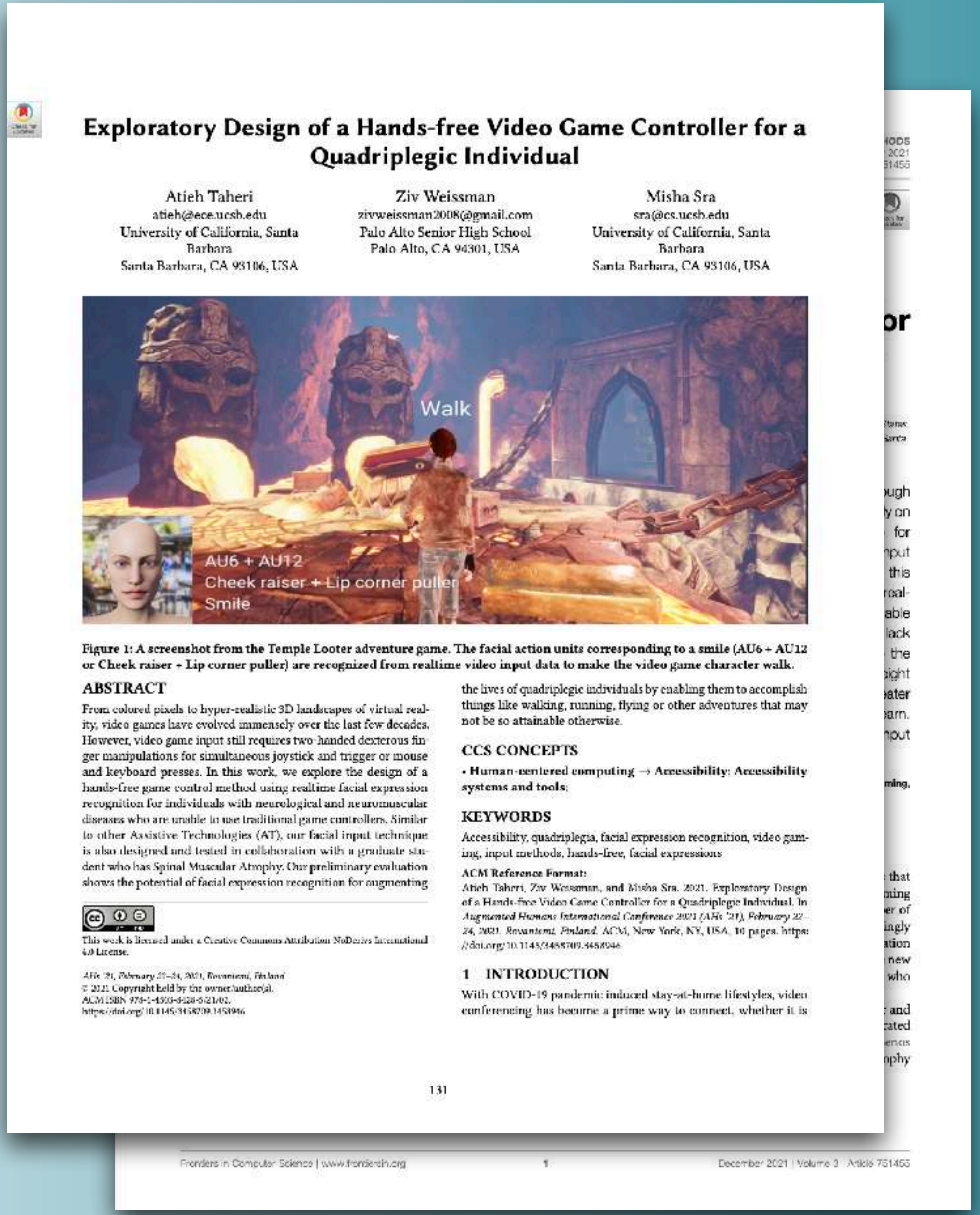
Fostering personal agency and independence

- Hands-free Input for Quadriplegia

# Facial Expression Recognition as Input for People With Quadriplegia 🏆

Atieh Taheri, Ziv Weissman & Misha Sra



## Exploratory Design of a Hands-free Video Game Controller for a Quadriplegic Individual

Atieh Taheri, atieh@ece.ucsb.edu, University of California, Santa Barbara, Santa Barbara, CA 93106, USA
Ziv Weissman, zivweissman2008@gmail.com, Palo Alto Senior High School, Palo Alto, CA 94301, USA
Misha Sra, sra@cs.ucsb.edu, University of California, Santa Barbara, Santa Barbara, CA 93106, USA



**Figure 1: A screenshot from the Temple Looter adventure game. The facial action units corresponding to a smile (AU6 + AU12 or Cheek raiser + Lip corner puller) are recognized from realtime video input data to make the video game character walk.**

### ABSTRACT

From colored pixels to hyper-realistic 3D landscapes of virtual reality, video games have evolved immensely over the last few decades. However, video game input still requires two-handed dexterous finger manipulations for simultaneous joystick and trigger or mouse and keyboard presses. In this work, we explore the design of a hands-free game control method using realtime facial expression recognition for individuals with neurological and neuromuscular diseases who are unable to use traditional game controllers. Similar to other Assistive Technologies (AT), our facial input technique is also designed and tested in collaboration with a graduate student who has Spinal Muscular Atrophy. Our preliminary evaluation shows the potential of facial expression recognition for augmenting the lives of quadriplegic individuals by enabling them to accomplish things like walking, running, flying or other adventures that may not be so attainable otherwise.

### CCS CONCEPTS

• **Human-centered computing → Accessibility; Accessibility systems and tools;**

### KEYWORDS

Accessibility, quadriplegia, facial expression recognition, video gaming, input methods, hands-free, facial expressions

**ACM Reference Format:**
Atieh Taheri, Ziv Weissman, and Misha Sra. 2021. Exploratory Design of a Hands-free Video Game Controller for a Quadriplegic Individual. In *Augmented Humans International Conference 2021 (AHs '21), February 22–24, 2021, Rovaniemi, Finland.* ACM, New York, NY, USA, 10 pages. https://doi.org/10.1145/3458709.3458946

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*AHs '21, February 22–24, 2021, Rovaniemi, Finland*
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ACM ISBN 978-1-4503-8428-5/21/02.
https://doi.org/10.1145/3458709.3458946

### 1 INTRODUCTION

With COVID-19 pandemic induced stay-at-home lifestyles, video conferencing has become a prime way to connect, whether it is

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Frontiers in Computer Science | www.frontiersin.org 1 December 2021 | Volume 3 | Article 751455

**Published in ACM Augmented Humans (2021) and Frontiers in CS (2021)**

Taheri, A., Weissman, Z., & Sra, M. (2021, February). Exploratory design of a hands-free video game controller for a quadriplegic individual. In Proceedings of the Augmented Humans International Conference 2021 (pp. 131-140).

Taheri, A., Weissman, Z., & Sra, M. (2021). Design and evaluation of a hands-free video game controller for individuals with motor impairments. Frontiers in Computer Science, 3, 751455.

# Motivation

- PhD student with SMA (now post-doc at CMU)
- No voluntary control of any muscles except right thumb and face
- Video games offer a way to build community
- Accessibility in games/gaming systems does not consider severe motor impairments

# Facial Expression Recognition as Input for People With Quadriplegia

**Video gaming has evolved tremendously**

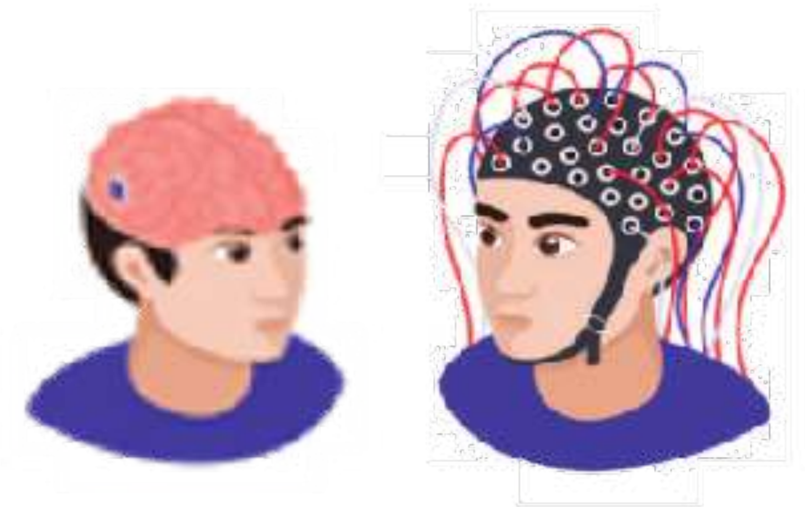
**Video games are demanding in terms of hand motor skills**

**Video games are not very accessible for those with hand motor impairments**

Taheri, A., Weissman, Z., & Sra, M. (2021, February). Exploratory design of a hands-free video game controller for a quadriplegic individual.
In Proceedings of the Augmented Humans International Conference 2021 (pp. 131-140).

# Facial Expression Recognition as Input for People With Quadriplegia

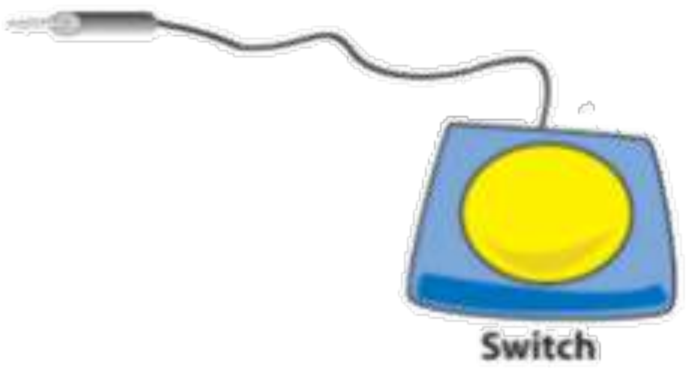
Brain-computer Interface (BCI)



Voice Recognition

Gaze Tracking


Switch

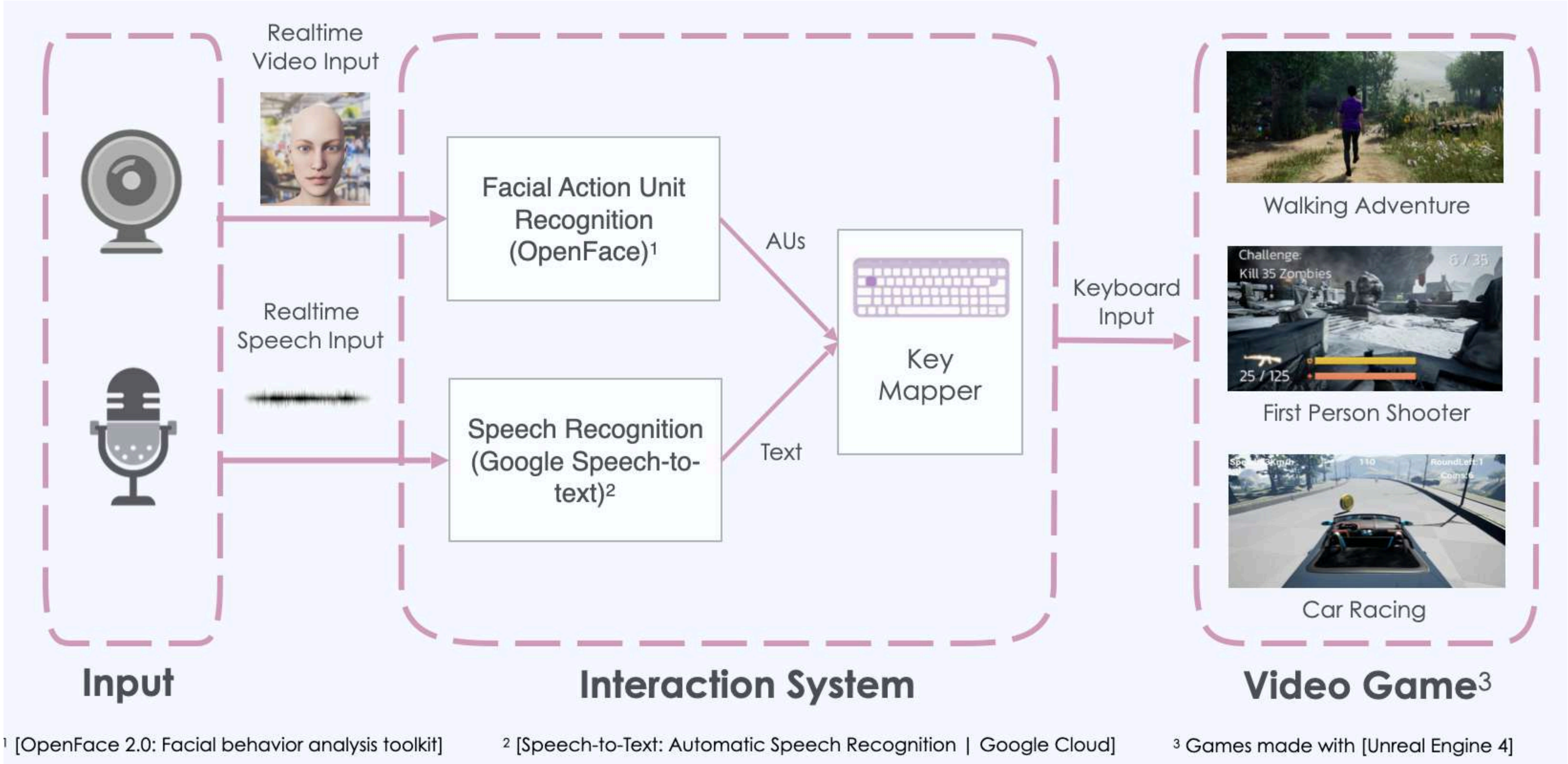



Tongue-computer Interface (TCI)

Microsoft’s Xbox Adaptive Game Controller

Quadstick Game Controller

# Facial Expression Recognition as Input for People With Quadriplegia





Taheri, A., Weissman, Z., & Sra, M. (2021, February). Exploratory design of a hands-free video game controller for a quadriplegic individual.
In Proceedings of the Augmented Humans International Conference 2021 (pp. 131-140).

# Facial Expression Recognition as Input for People With Quadriplegia

Cheek Raiser (*Orbicularis oculi, pars orbitalis*)

AU6

Lip Corner Puller (Zygomatic Major)

AU12

Smile or Happiness



https://imotions.com/blog/facial-action-coding-system/

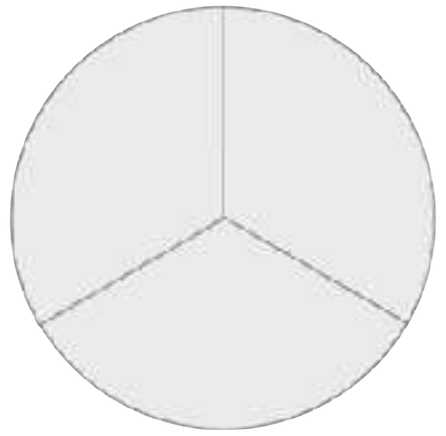
# Facial Expression Recognition as Input for People With Quadriplegia

- 12 volunteers with MD and SMA (5F, 18-45)
- Two zoom sessions to minimize researcher and user fatigue

- First 1.5-hour session:
  - Pre-study questionnaire
  - Installation process
  - Tutorial game
- Second 1.5-hour session:
  - Post-study questionnaire (usability, ux, game x)
  - Study game: FPS

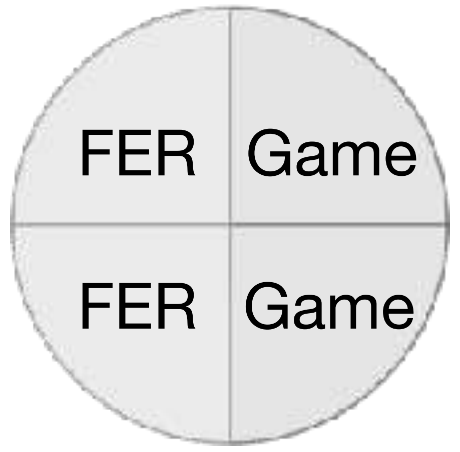
Taheri, A., Weissman, Z., & Sra, M. (2021, February). Exploratory design of a hands-free video game controller for a quadriplegic individual.
In Proceedings of the Augmented Humans International Conference 2021 (pp. 131-140).

# Facial Expression Recognition as Input for People With Quadriplegia



- Usability
- UX
- Functionality

Interaction Framework
[McNamara and Kirakowski (2006)]

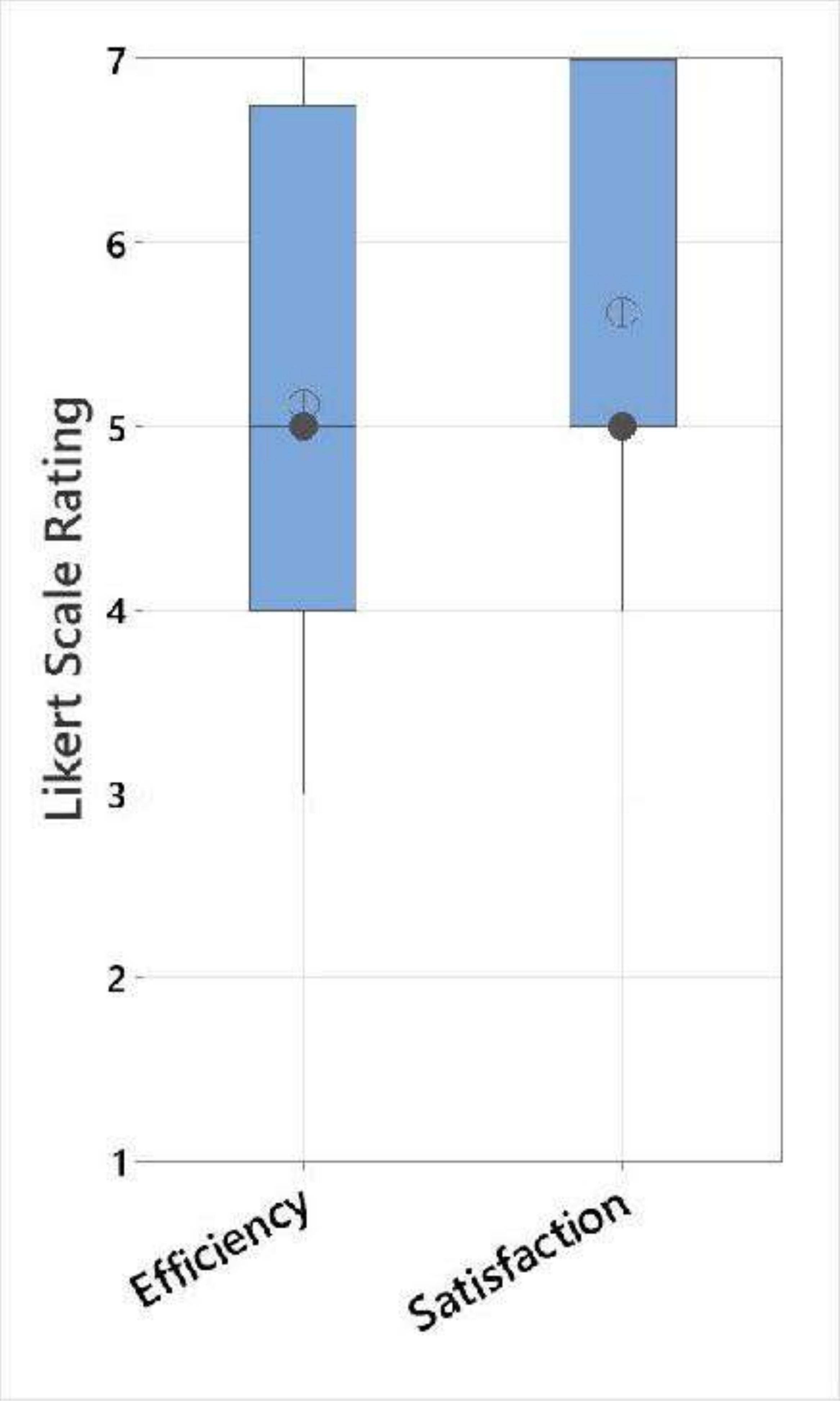


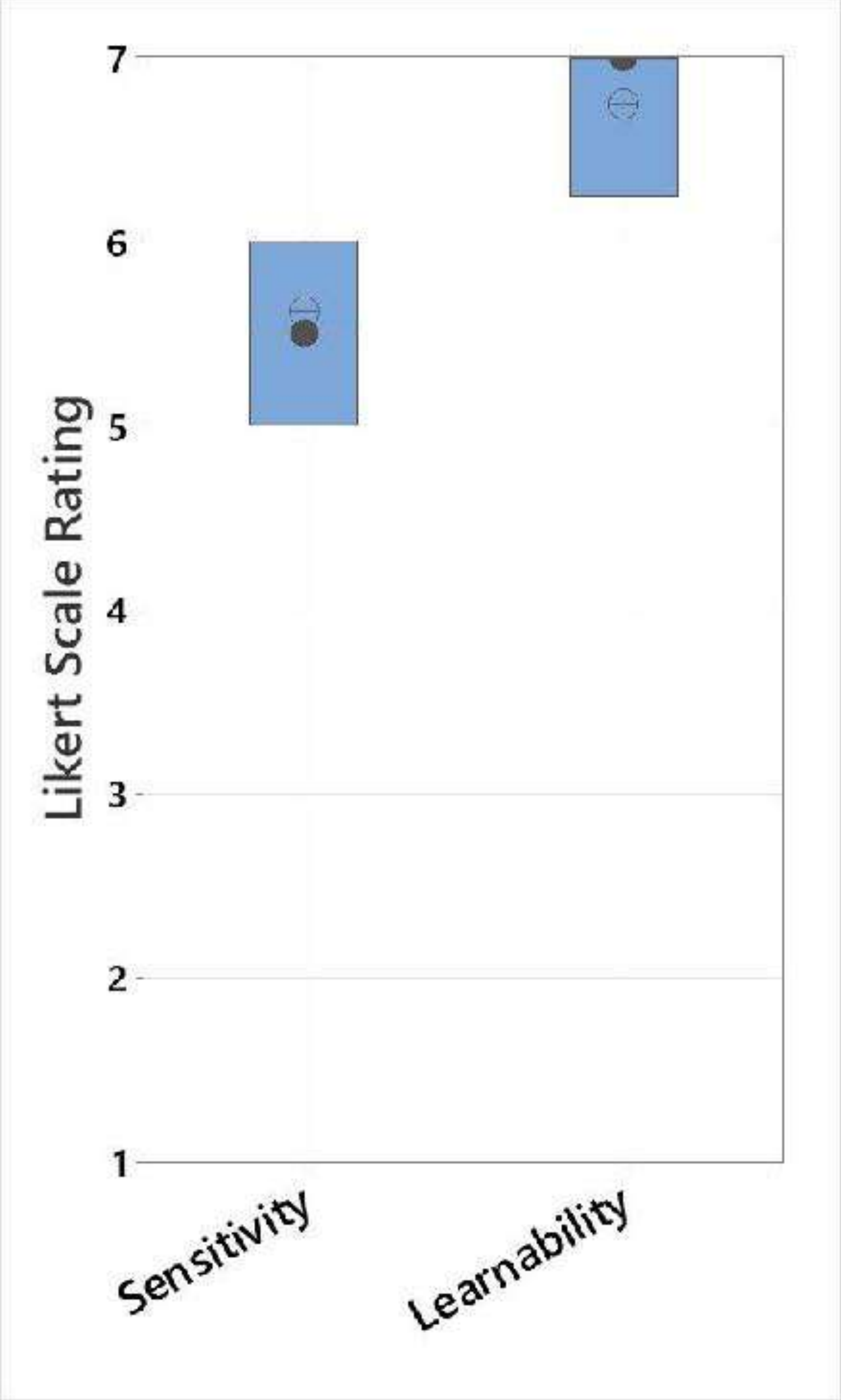

- Sensitivity
- Learnability

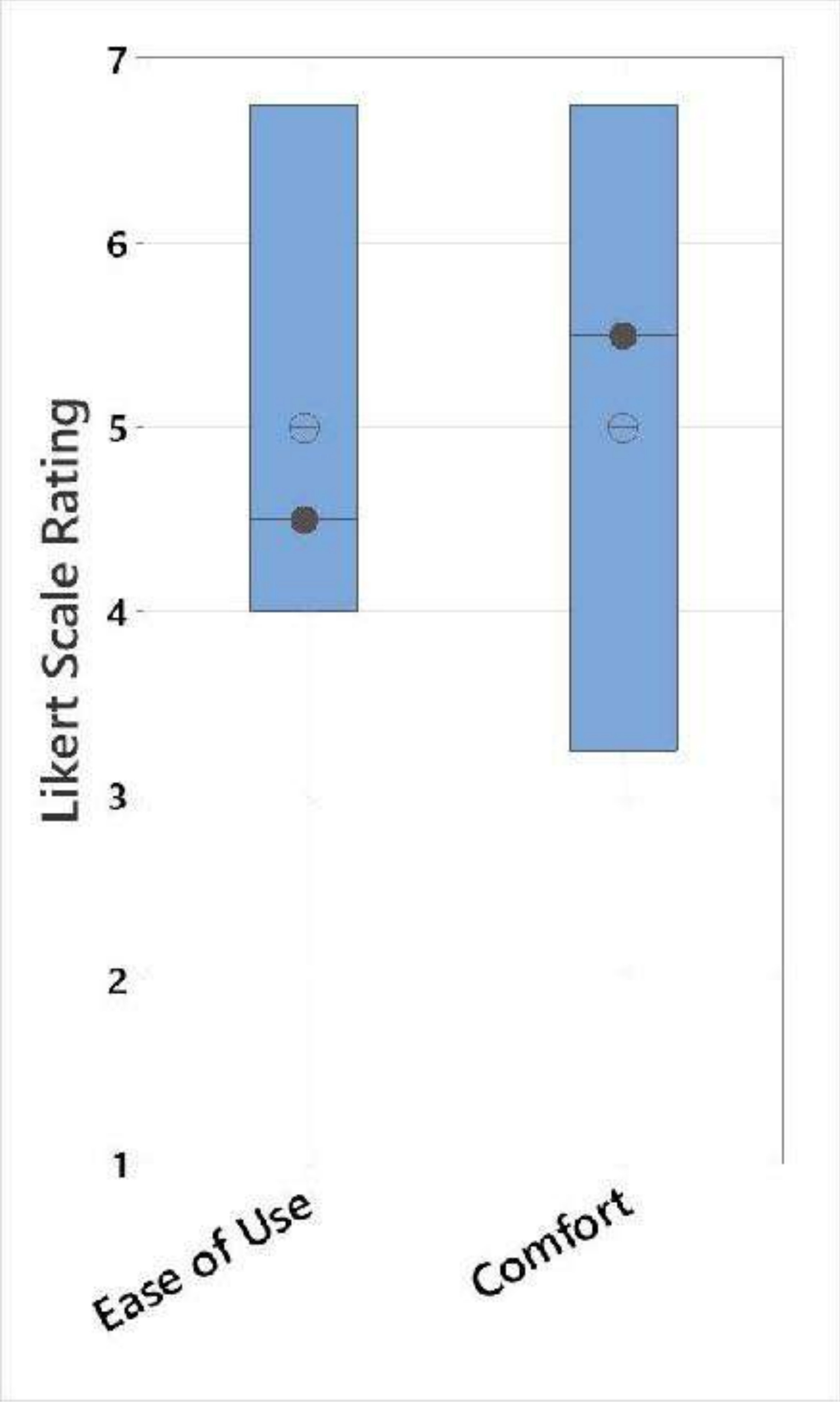
- Ease of use
- Comfort

Critical Incident Technique
[Flanagan (1954)]

N = 8

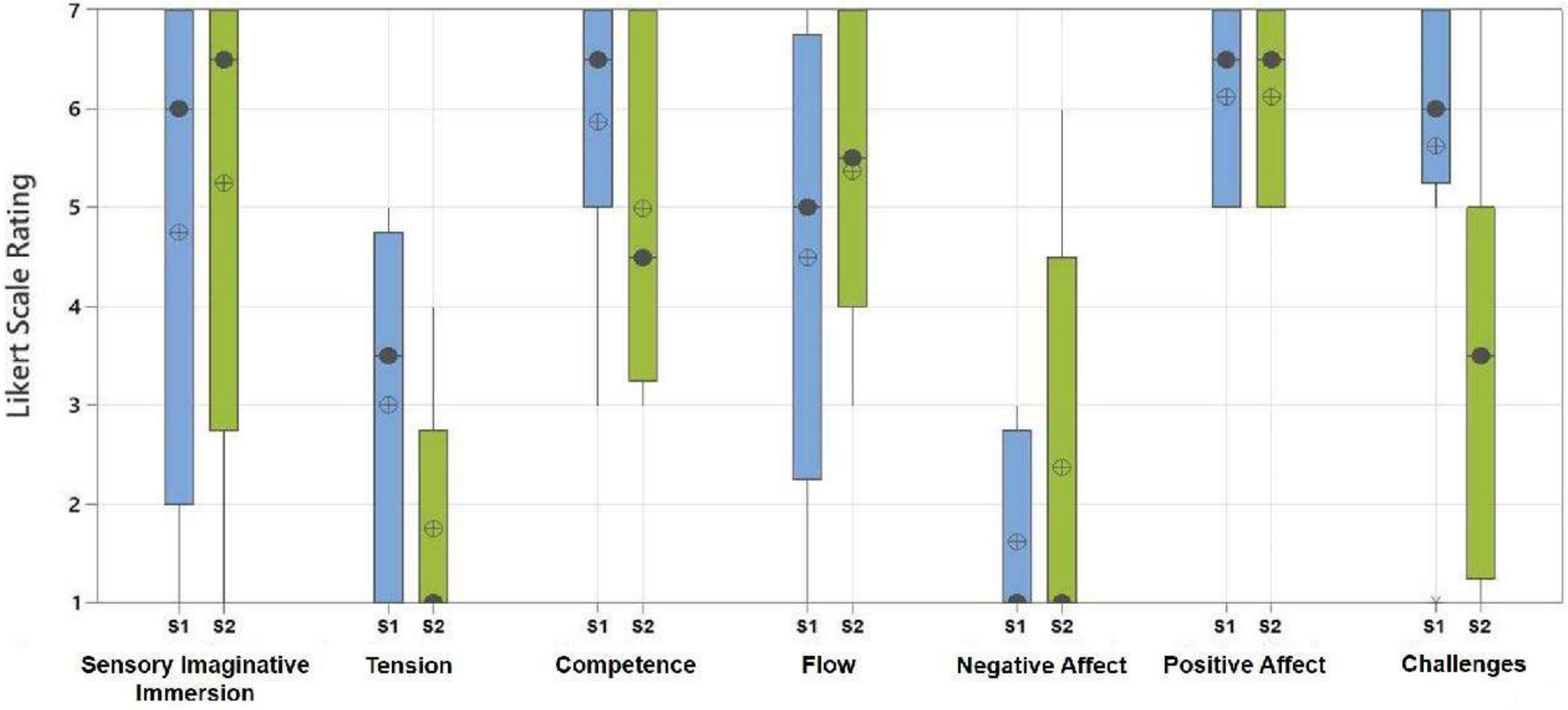



Taheri, A., Weissman, Z., & Sra, M. (2021). Design and evaluation of a hands-free video game controller for individuals with motor impairments. Frontiers in Computer Science, 3, 751455.

# Facial Expression Recognition as Input for People With Quadriplegia




| | | |
|---|---|---|
| Sensory & Imaginative Immersion | S1: I was interested in the game's story. | .95 |
| | S2: It felt like a reach experience. | |
| Tension | S1: I felt frustrated playing the FPS game. | .77 |
| | S2: I felt irritable. | |
| Competence | S1: I felt successful. | .9 |
| | S2: I felt skillful. | |
| Flow | S1: I forgot everything around me. | .52 |
| | S2: I was fully occupied with the game. | |
| Negative Affect | S1: I felt bored. | .77 |
| | S2: I found it tiresome. | |
| Positive Affect | S1: I enjoyed it. | 1 |
| | S2: I felt good. | |
| Challenges | A1: I felt challenged. | .48 |
| | S2: I had to put a lot of effort into it. | |

IJsselsteijn et al. (2013)]

Taheri, A., Weissman, Z., & Sra, M. (2021). Design and evaluation of a hands-free video game controller for individuals with motor impairments. Frontiers in Computer Science, 3, 751455.

# Facial Expression Recognition as Input for People With Quadriplegia

- P2: "*It was very intuitive and* ***easy to learn*** *how to use. Just the fact that I can have potentially one extra mode of input would be huge.*"

- P7 said there is "***nothing*** **that I do not like!** Once I learned which facial expression is connected to a specific action, it became very exciting."

- P4/6 said what they liked most was being able to play **without using their hands**

- Several participants "loved it," or said "it was fantastic" or "it was way too fun." One participant said they are "eagerly awaiting its availability."

Taheri, A., Weissman, Z., & Sra, M. (2021). Design and evaluation of a hands-free video game controller for individuals with motor impairments. Frontiers in Computer Science, 3, 751455.

# Facial Expression Recognition as Input for People With Quadriplegia

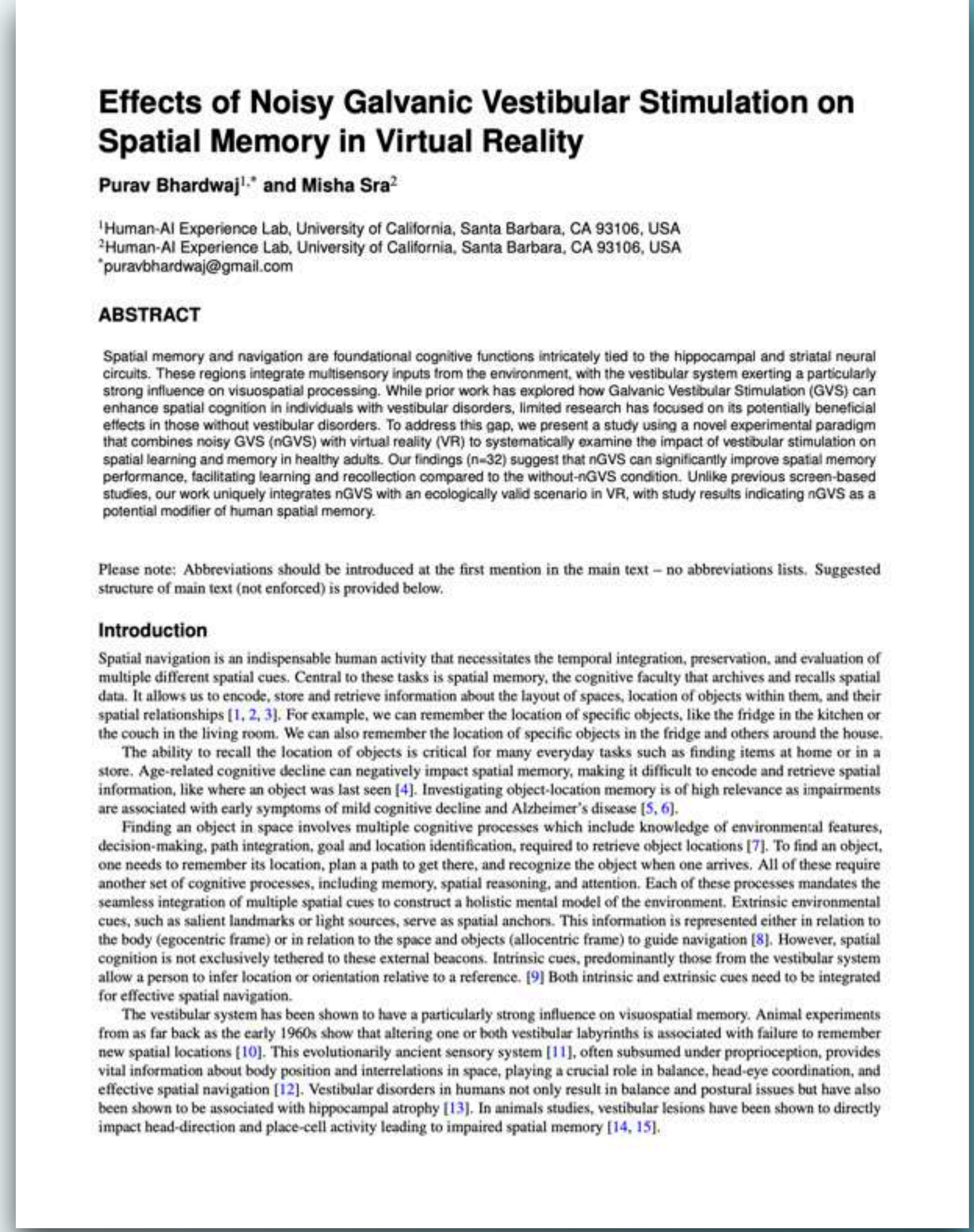

# Resilience

Empowering individuals to adapt and flourish

- Spatial Memory with nGVS
- Facial Paralysis Rehab Therapy

# Effects of Noisy Galvanic Vestibular Stimulation on Spatial Memory in Virtual Reality

Purav Bhardwaj and Misha Sra



## Effects of Noisy Galvanic Vestibular Stimulation on Spatial Memory in Virtual Reality

Purav Bhardwaj[1,*] and Misha Sra[2]

[1]Human-AI Experience Lab, University of California, Santa Barbara, CA 93106, USA
[2]Human-AI Experience Lab, University of California, Santa Barbara, CA 93106, USA
[*]puravbhardwaj@gmail.com

### ABSTRACT

Spatial memory and navigation are foundational cognitive functions intricately tied to the hippocampal and striatal neural circuits. These regions integrate multisensory inputs from the environment, with the vestibular system exerting a particularly strong influence on visuospatial processing. While prior work has explored how Galvanic Vestibular Stimulation (GVS) can enhance spatial cognition in individuals with vestibular disorders, limited research has focused on its potentially beneficial effects in those without vestibular disorders. To address this gap, we present a study using a novel experimental paradigm that combines noisy GVS (nGVS) with virtual reality (VR) to systematically examine the impact of vestibular stimulation on spatial learning and memory in healthy adults. Our findings (n=32) suggest that nGVS can significantly improve spatial memory performance, facilitating learning and recollection compared to the without-nGVS condition. Unlike previous screen-based studies, our work uniquely integrates nGVS with an ecologically valid scenario in VR, with study results indicating nGVS as a potential modifier of human spatial memory.

Please note: Abbreviations should be introduced at the first mention in the main text – no abbreviations lists. Suggested structure of main text (not enforced) is provided below.

### Introduction

Spatial navigation is an indispensable human activity that necessitates the temporal integration, preservation, and evaluation of multiple different spatial cues. Central to these tasks is spatial memory, the cognitive faculty that archives and recalls spatial data. It allows us to encode, store and retrieve information about the layout of spaces, location of objects within them, and their spatial relationships [1, 2, 3]. For example, we can remember the location of specific objects, like the fridge in the kitchen or the couch in the living room. We can also remember the location of specific objects in the fridge and others around the house.

The ability to recall the location of objects is critical for many everyday tasks such as finding items at home or in a store. Age-related cognitive decline can negatively impact spatial memory, making it difficult to encode and retrieve spatial information, like where an object was last seen [4]. Investigating object-location memory is of high relevance as impairments are associated with early symptoms of mild cognitive decline and Alzheimer's disease [5, 6].

Finding an object in space involves multiple cognitive processes which include knowledge of environmental features, decision-making, path integration, goal and location identification, required to retrieve object locations [7]. To find an object, one needs to remember its location, plan a path to get there, and recognize the object when one arrives. All of these require another set of cognitive processes, including memory, spatial reasoning, and attention. Each of these processes mandates the seamless integration of multiple spatial cues to construct a holistic mental model of the environment. Extrinsic environmental cues, such as salient landmarks or light sources, serve as spatial anchors. This information is represented either in relation to the body (egocentric frame) or in relation to the space and objects (allocentric frame) to guide navigation [8]. However, spatial cognition is not exclusively tethered to these external beacons. Intrinsic cues, predominantly those from the vestibular system allow a person to infer location or orientation relative to a reference. [9] Both intrinsic and extrinsic cues need to be integrated for effective spatial navigation.

The vestibular system has been shown to have a particularly strong influence on visuospatial memory. Animal experiments from as far back as the early 1960s show that altering one or both vestibular labyrinths is associated with failure to remember new spatial locations [10]. This evolutionarily ancient sensory system [11], often subsumed under proprioception, provides vital information about body position and interrelations in space, playing a crucial role in balance, head-eye coordination, and effective spatial navigation [12]. Vestibular disorders in humans not only result in balance and postural issues but have also been shown to be associated with hippocampal atrophy [13]. In animals studies, vestibular lesions have been shown to directly impact head-direction and place-cell activity leading to impaired spatial memory [14, 15].

**Published in Nature Scientific Reports (2025)**

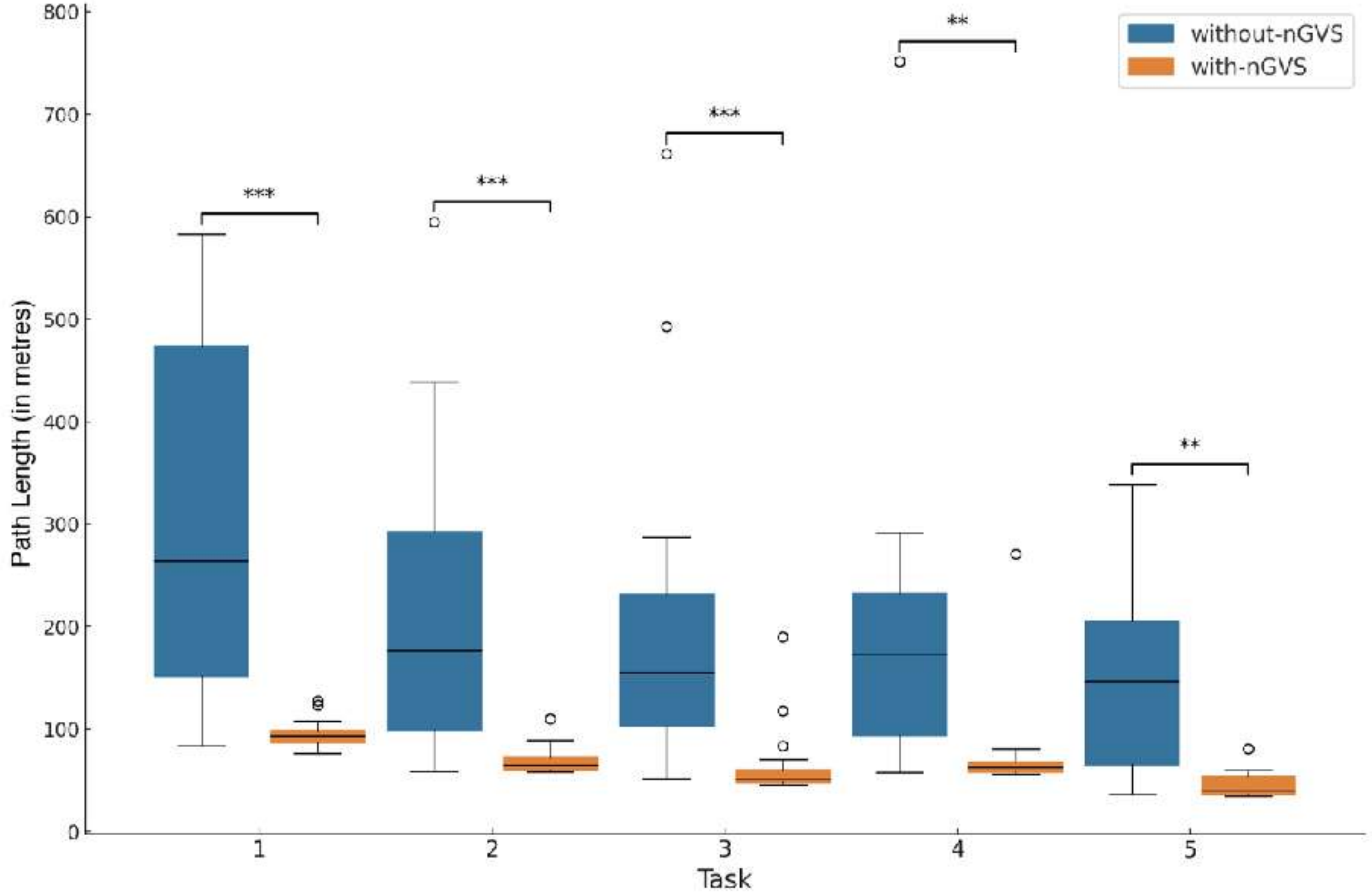
Bhardwaj, P., & Sra, M. Effects of Noisy Galvanic Vestibular Stimulation on Spatial Memory in Virtual Reality. In Nature Scientific Reports (2025).


## Experiment Setup

- 32 participants (16F, 19-48yo)
- Between subjects VR study
- 2 part process (encoding, decoding)
- Path lengths, ttc
- Questionnaires
- Data analysis

Bhardwaj, P., & Sra, M. Effects of Noisy Galvanic Vestibular Stimulation on Spatial Memory in Virtual Reality. In Nature Scientific Reports (2025).

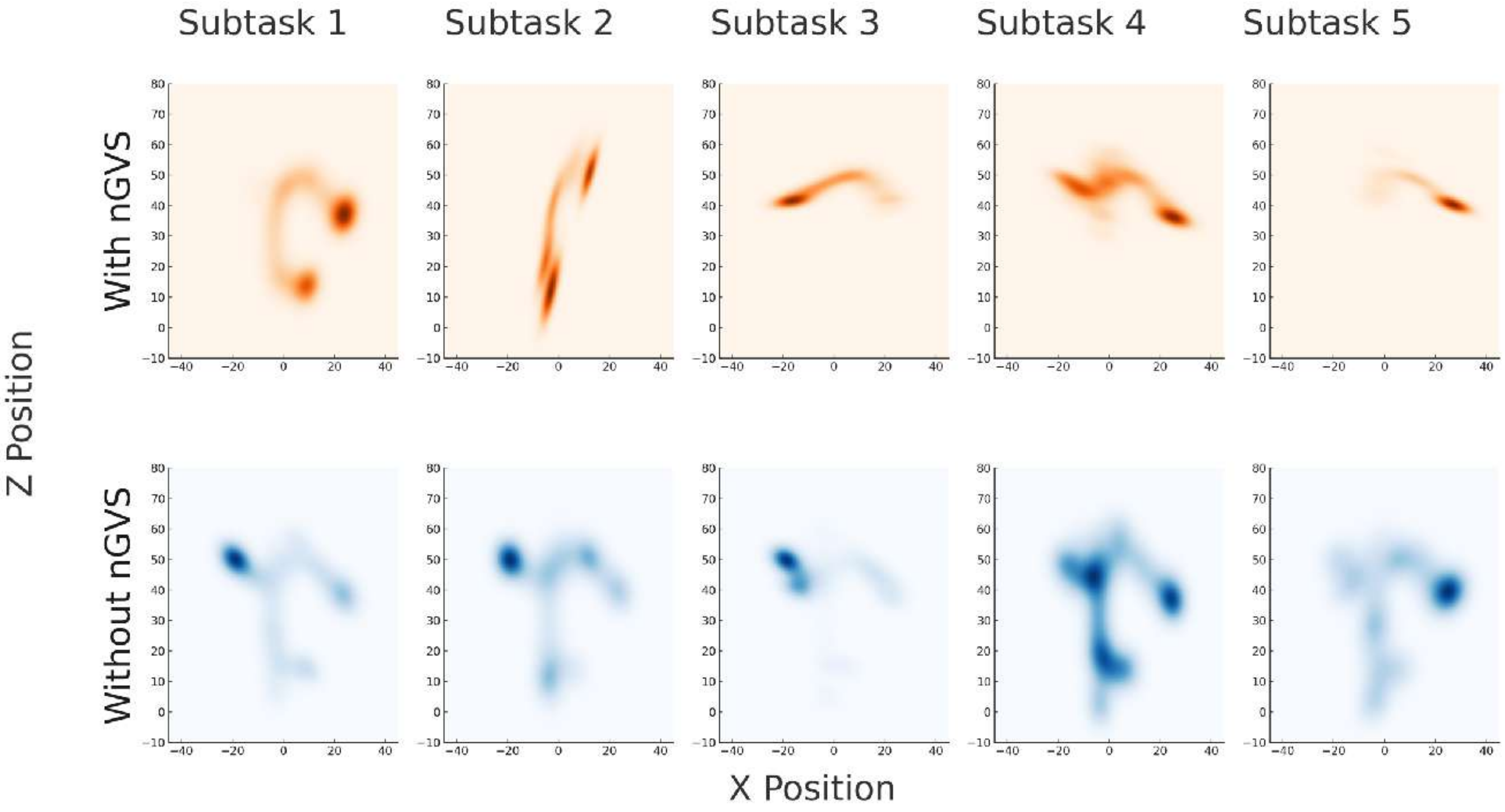
# Path length




- Significant difference in path lengths between the with-nGVS and without-nGVS conditions
- nGVS may contribute to enhanced spatial navigation efficiency

Bhardwaj, P., & Sra, M. Effects of Noisy Galvanic Vestibular Stimulation on Spatial Memory in Virtual Reality. In Nature Scientific Reports (2025).

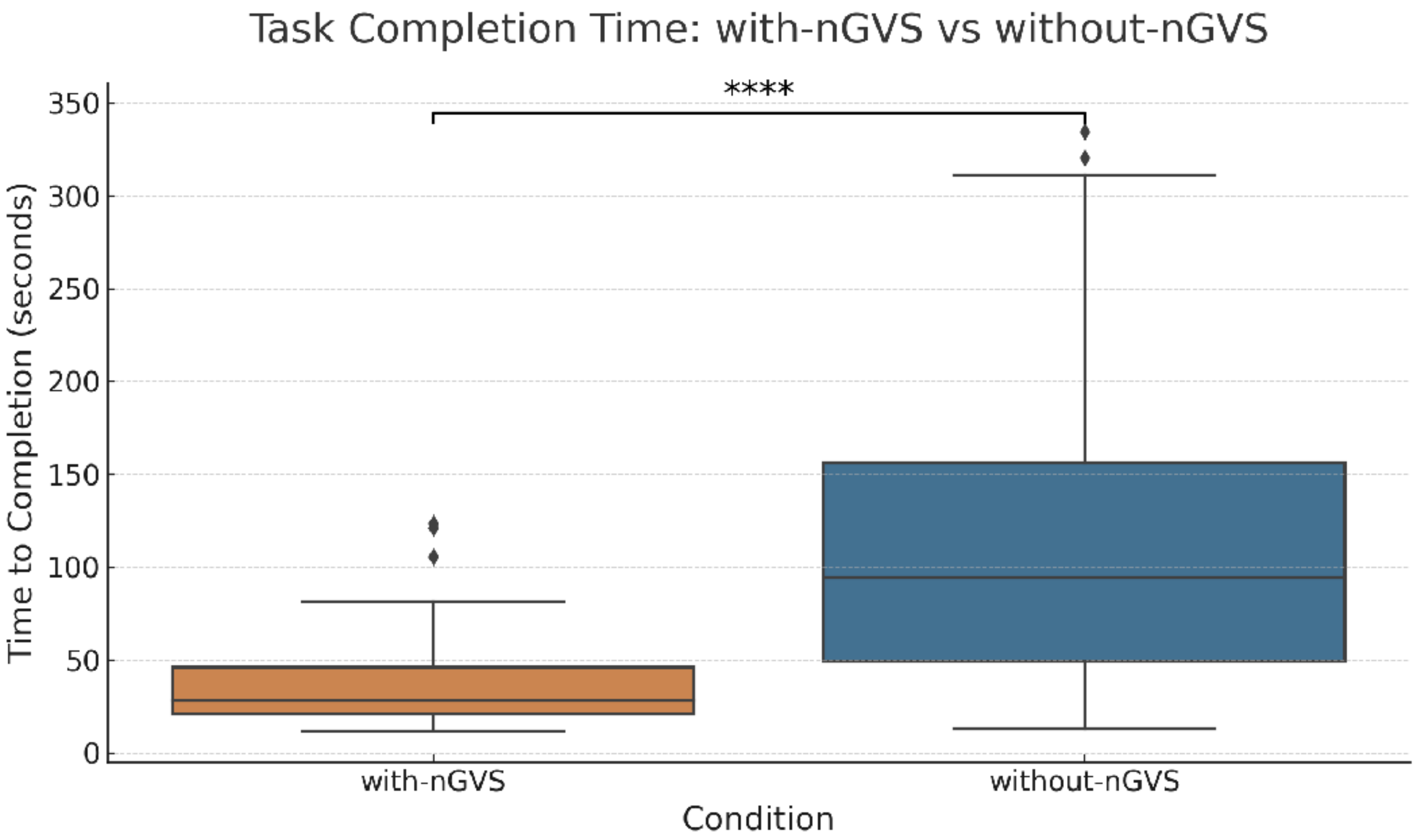
# Path length heatmaps




- Differences observed in paths which were more direct and purposeful vs meandering and exploratory.

Bhardwaj, P., & Sra, M. Effects of Noisy Galvanic Vestibular Stimulation on Spatial Memory in Virtual Reality. In Nature Scientific Reports (2025).

# Time to completion



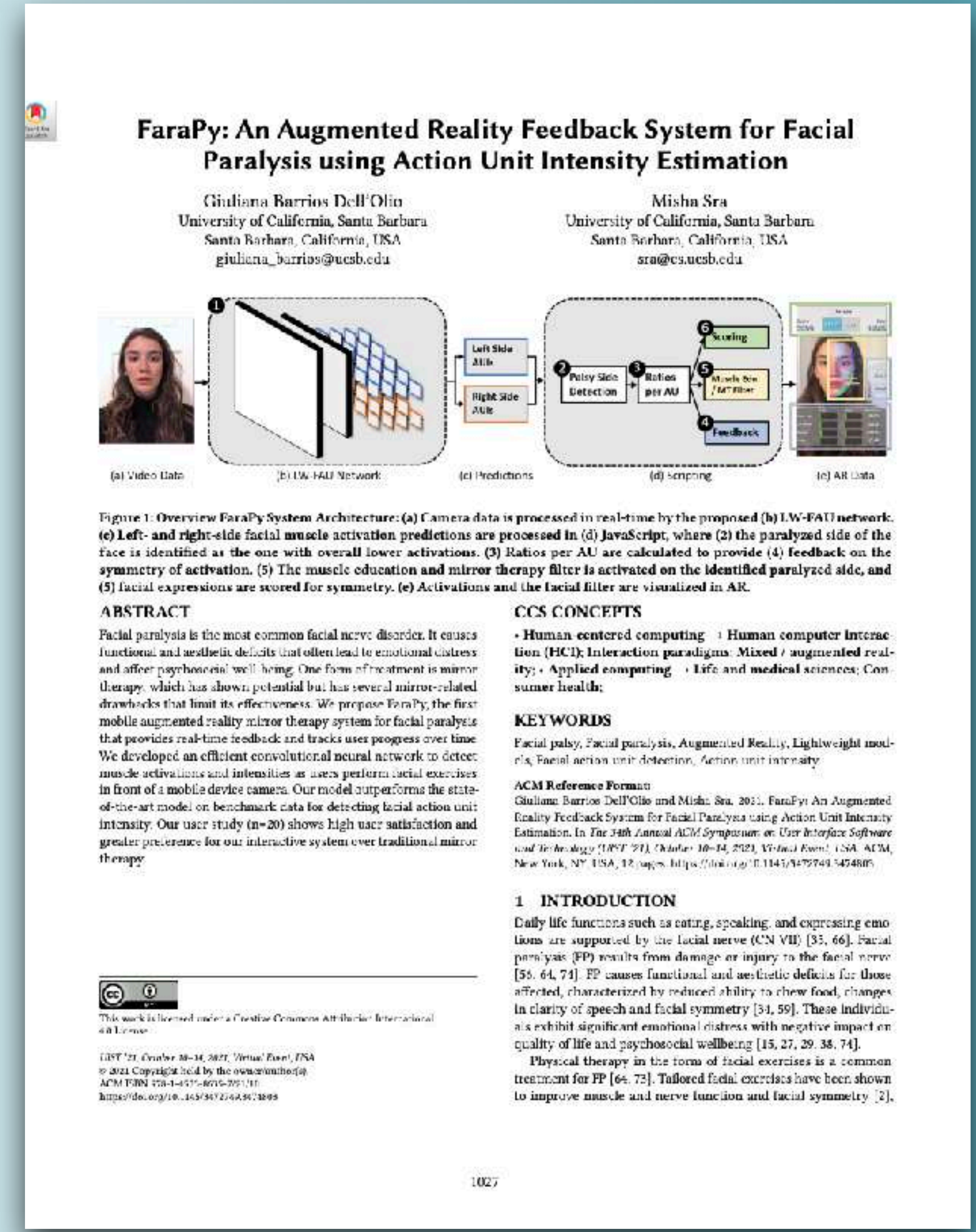

- Significant difference between time taken to complete the multi-stage navigation task.

Bhardwaj, P., & Sra, M. Effects of Noisy Galvanic Vestibular Stimulation on Spatial Memory in Virtual Reality. In Nature Scientific Reports (2025).

UCSB

# FaraPy: an Augmented Reality Feedback System for Facial Paralysis Using Action Unity Intensity Estimation

Giuliana Barrios Dell'Olio, Misha Sra

## FaraPy: An Augmented Reality Feedback System for Facial Paralysis using Action Unit Intensity Estimation

Giuliana Barrios Dell'Olio
University of California, Santa Barbara
Santa Barbara, California, USA
giuliana_barrios@ucsb.edu

Misha Sra
University of California, Santa Barbara
Santa Barbara, California, USA
sra@cs.ucsb.edu

(a) Video Data (b) LW-FAU Network (c) Predictions (d) Scripting (e) AR Data

Figure 1: **Overview FaraPy System Architecture: (a) Camera data is processed in real-time by the proposed (b) LW-FAU network. (c) Left- and right-side facial muscle activation predictions are processed in (d) JavaScript, where (2) the paralyzed side of the face is identified as the one with overall lower activations. (3) Ratios per AU are calculated to provide (4) feedback on the symmetry of activation. (5) The muscle education and mirror therapy filter is activated on the identified paralyzed side, and (5) facial expressions are scored for symmetry. (e) Activations and the facial filter are visualized in AR.**

### ABSTRACT

Facial paralysis is the most common facial nerve disorder. It causes functional and aesthetic deficits that often lead to emotional distress and affect psychosocial well-being. One form of treatment is mirror therapy, which has shown potential but has several mirror-related drawbacks that limit its effectiveness. We propose FaraPy, the first mobile augmented reality mirror therapy system for facial paralysis that provides real-time feedback and tracks user progress over time. We developed an efficient convolutional neural network to detect muscle activations and intensities as users perform facial exercises in front of a mobile device camera. Our model outperforms the state-of-the-art model on benchmark data for detecting facial action unit intensity. Our user study (n=20) shows high user satisfaction and greater preference for our interactive system over traditional mirror therapy.



UIST '21, October 10–14, 2021, Virtual Event, USA

ACM ISBN 978-1-4503-8635-7/21/10
https://doi.org/10.1145/3472749.3474803

### CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI)**; **Interaction paradigms**; **Mixed / augmented reality**; • **Applied computing** → **Life and medical sciences**; Consumer health;

### KEYWORDS

Facial palsy, Facial paralysis, Augmented Reality, Lightweight models, Facial action unit detection, Action unit intensity

**ACM Reference Format:**
Giuliana Barrios Dell'Olio and Misha Sra. 2021. FaraPy: An Augmented Reality Feedback System for Facial Paralysis using Action Unit Intensity Estimation. In *The 34th Annual ACM Symposium on User Interface Software and Technology (UIST '21), October 10–14, 2021, Virtual Event, USA*. ACM, New York, NY, USA, 12 pages. https://doi.org/10.1145/3472749.3474803

### 1 INTRODUCTION

Daily life functions such as eating, speaking, and expressing emotions are supported by the facial nerve (CN VII) [35, 66]. Facial paralysis (FP) results from damage or injury to the facial nerve [56, 64, 71]. FP causes functional and aesthetic deficits for those affected, characterized by reduced ability to chew food, changes in clarity of speech and facial symmetry [34, 59]. These individuals exhibit significant emotional distress with negative impact on quality of life and psychosocial wellbeing [15, 27, 29, 38, 74].

Physical therapy in the form of facial exercises is a common treatment for FP [64, 73]. Tailored facial exercises have been shown to improve muscle and nerve function and facial symmetry [2],

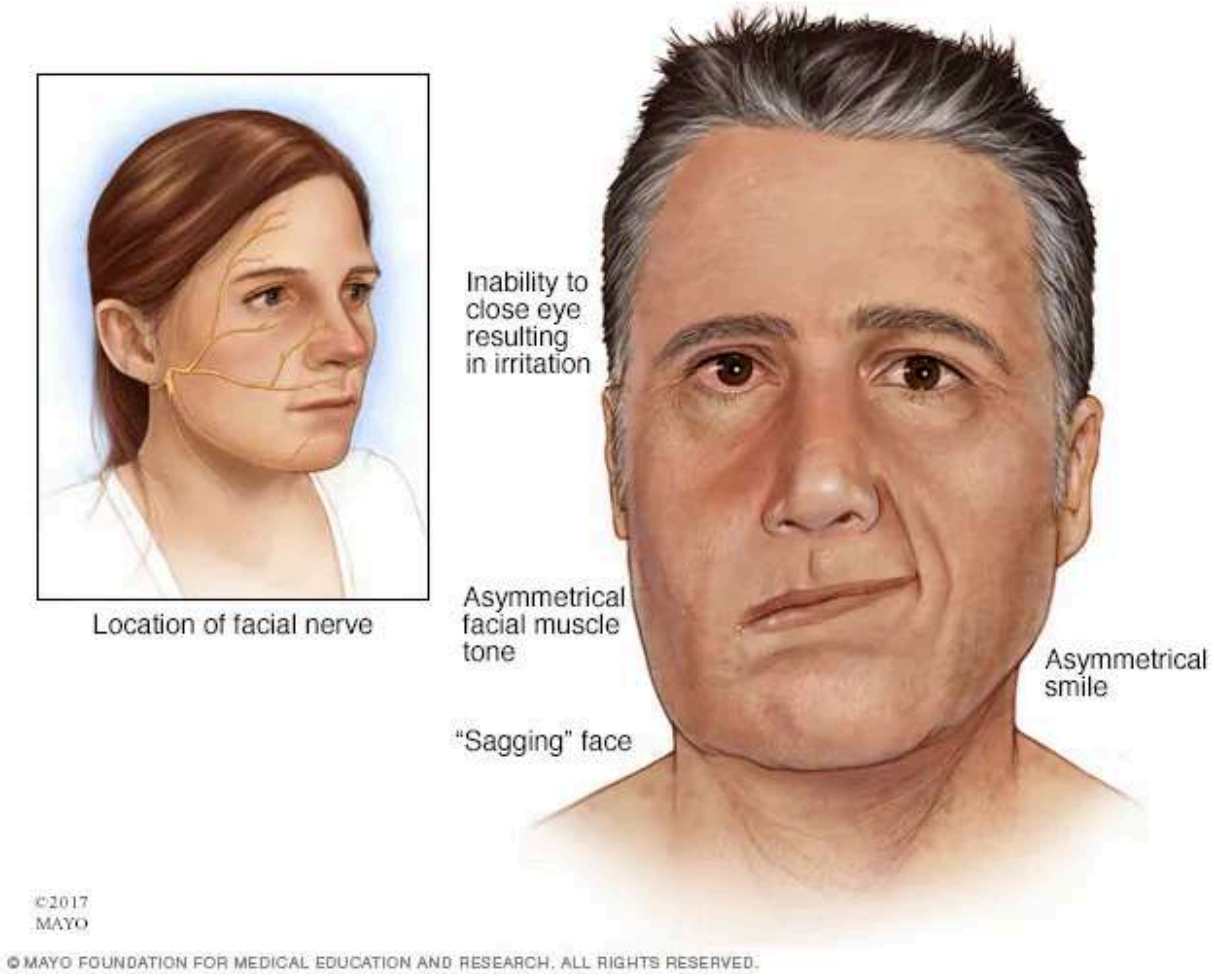
1027

**Published in ACM UIST (2021)**

Barrios Dell'Olio, G., & Sra, M. (2021, October). Farapy: An augmented reality feedback system for facial paralysis using action unit intensity estimation. In The 34th Annual ACM Symposium on User Interface Software and Technology (pp. 1027-1038).

# Motivation

- Facial paralysis (CN VII) is a debilitating consequence of many diseases such as stroke, brain tumors, viral infections etc.
- Results in drooping of facial features, difficulty in eating/speaking/blinking and communicating through facial expressions
- Causes significant emotional distress, lowers quality of life and impacts psychosocial wellbeing
- Mirror therapy is the state-of-the-art therapy
- Lacks actionable feedback, ability to track progress, and causes anxiety

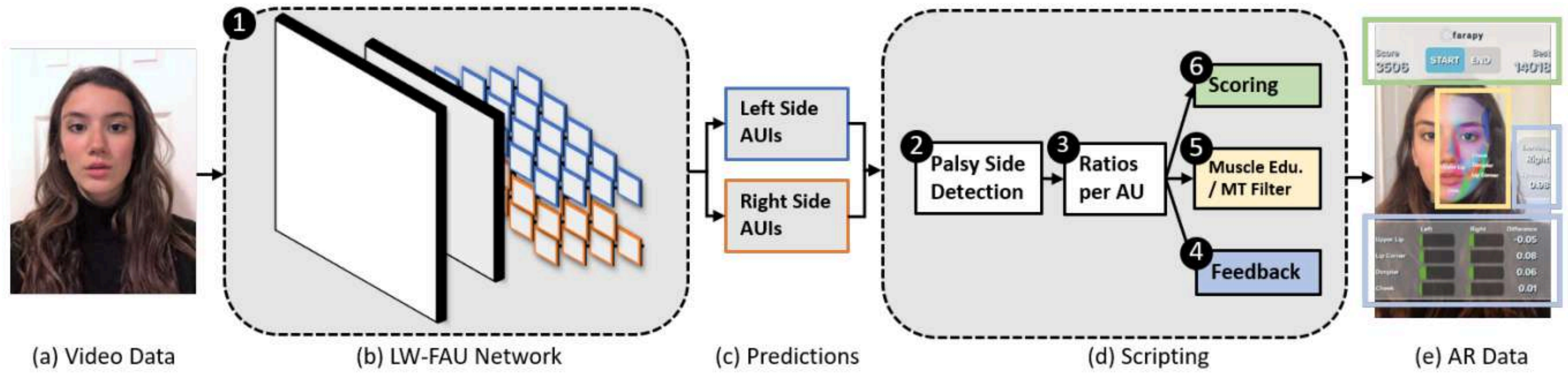


# Challenges

- No existing FP benchmark datasets or trained models
- Need for detecting muscles independently on each side of the face
- Need for realtime feedback
- Need to run on a mobile device
- Easy to use

Barrios Dell'Olio, G., & Sra, M. (2021, October). Farapy: An augmented reality feedback system for facial paralysis using action unit intensity estimation. In The 34th Annual ACM Symposium on User Interface Software and Technology (pp. 1027-1038).

# Pipeline




Yingruo Fan, Jacqueline C. K. Lam, and Victor O. K. Li. 2020. Facial Action Unit Intensity Estimation via Semantic Correspondence Learning with Dynamic Graph Convolution. (2020). https://arxiv.org/pdf/2004.09681

Barrios Dell'Olio, G., & Sra, M. (2021, October). Farapy: An augmented reality feedback system for facial paralysis using action unit intensity estimation. In The 34th Annual ACM Symposium on User Interface Software and Technology (pp. 1027-1038).

# AR Feedback


https://docs.snap.com/lens-studio/references/guides/lens-features/tracking/face/face-effects/face-mesh/#download-the-face-mesh-3d-model

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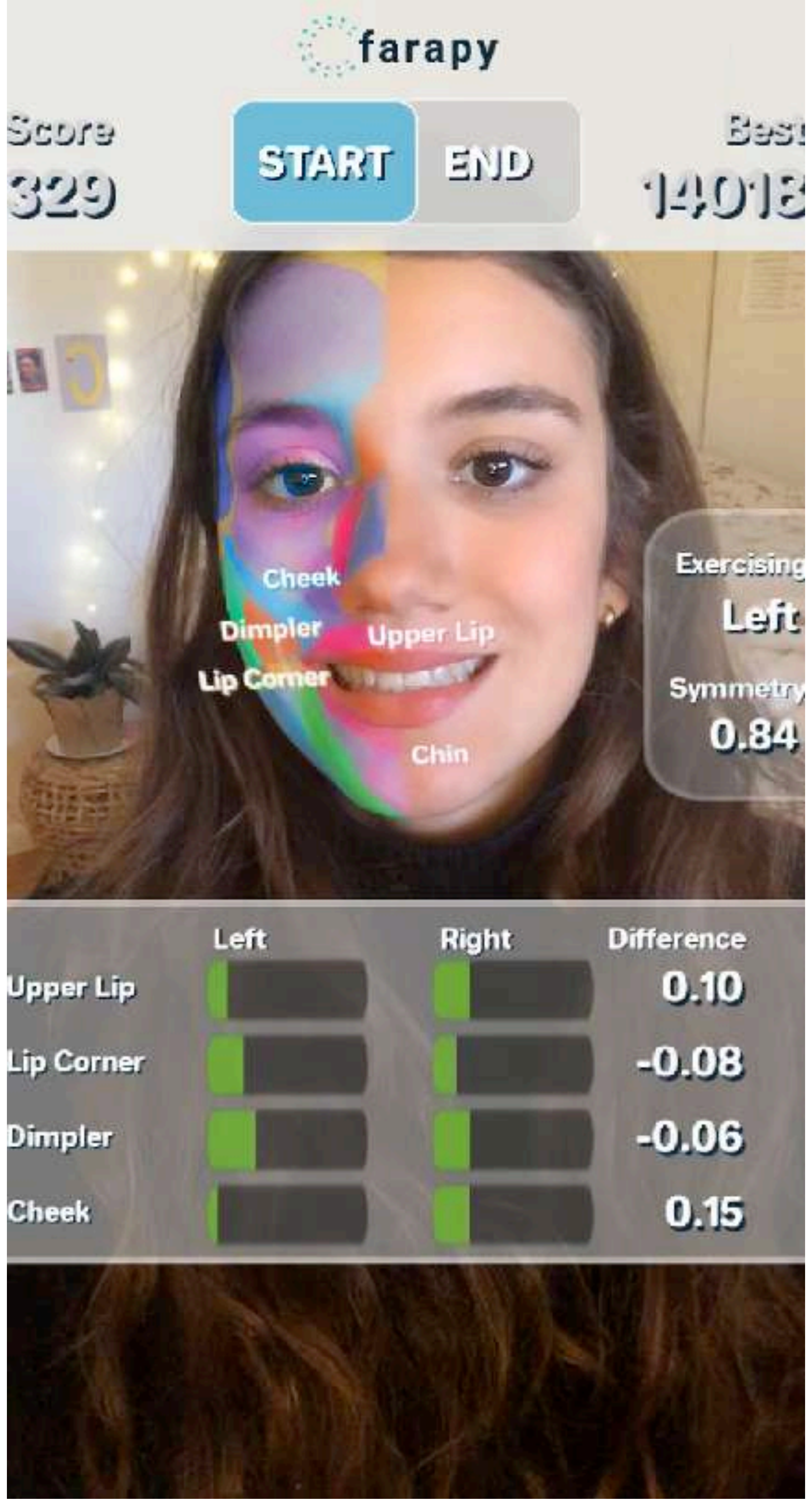
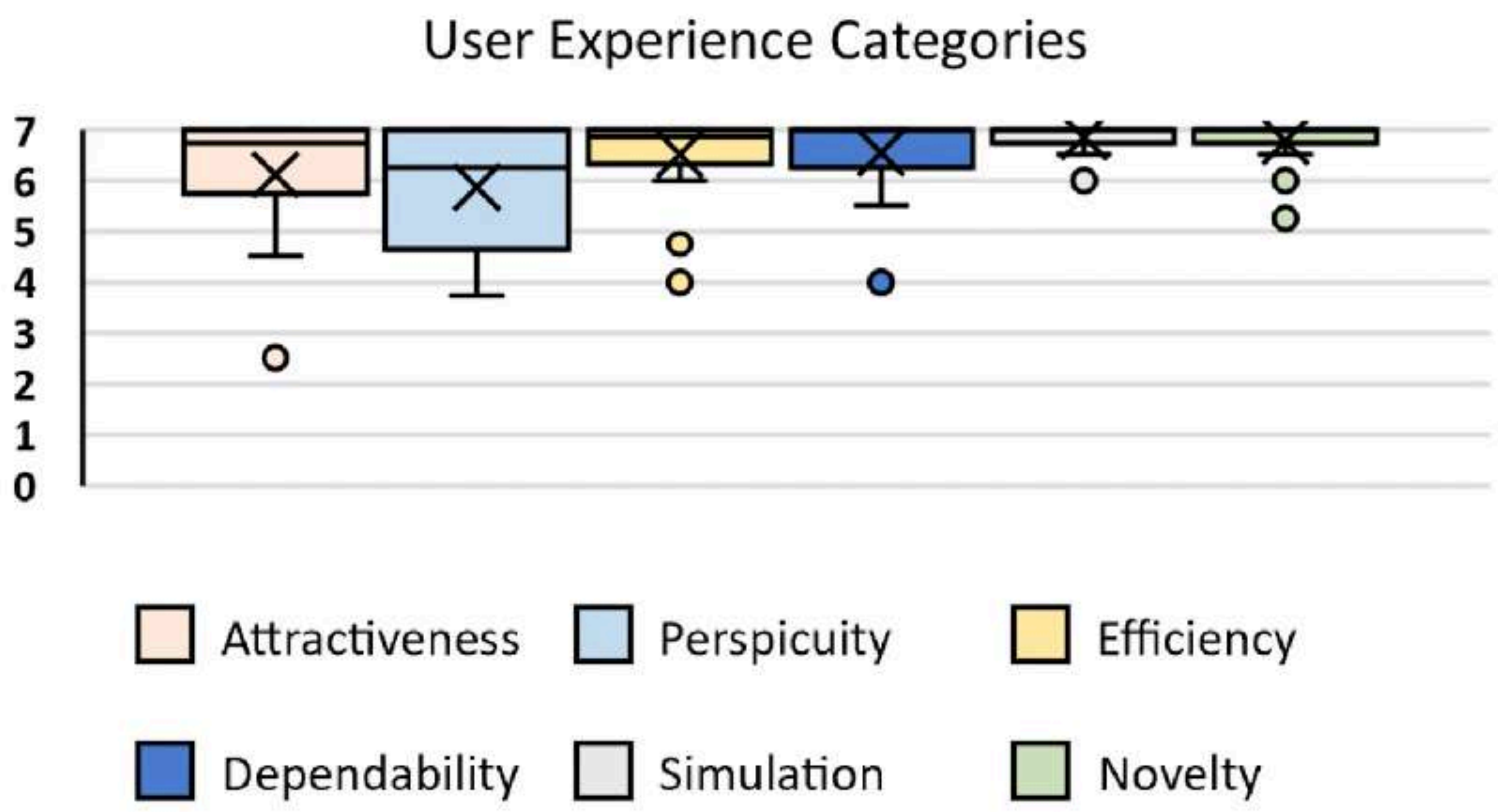
# FaraPy: an Augmented Reality Feedback System for Facial Paralysis Using Action Unity Intensity Estimation




- Evaluation with 20 adults with FP (16F, avg age: 45)
- 5 facial exercises x 5
- 50-50 Android-iOS




*"I would love using this app **daily**. I could see I was controlling the outcome. Definitely **better than a mirror**"* (FPS003).

*"**Motivating** I felt like I was in a video game"* (FPS020).

*"Because I can use the phone and be with it **everywhere**, it's a good innovation"* (FPS011).

*"I think it's **all we have wished for** but had no idea how to get or do"* (FPS017).


Barrios Dell'Olio, G., & Sra, M. (2021, October). Farapy: An augmented reality feedback system for facial paralysis using action unit intensity estimation. In The 34th Annual ACM Symposium on User Interface Software and Technology (pp. 1027-1038).

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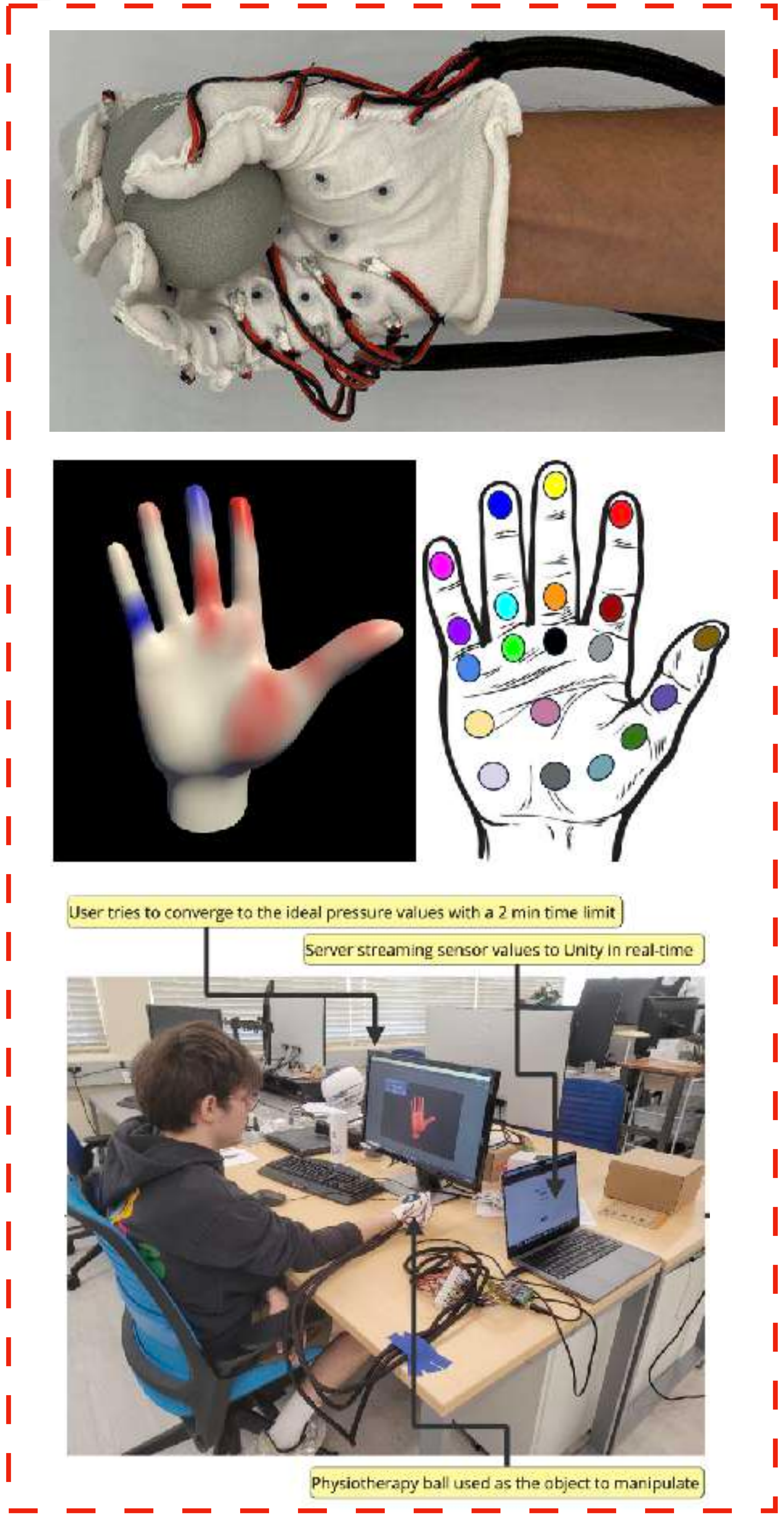
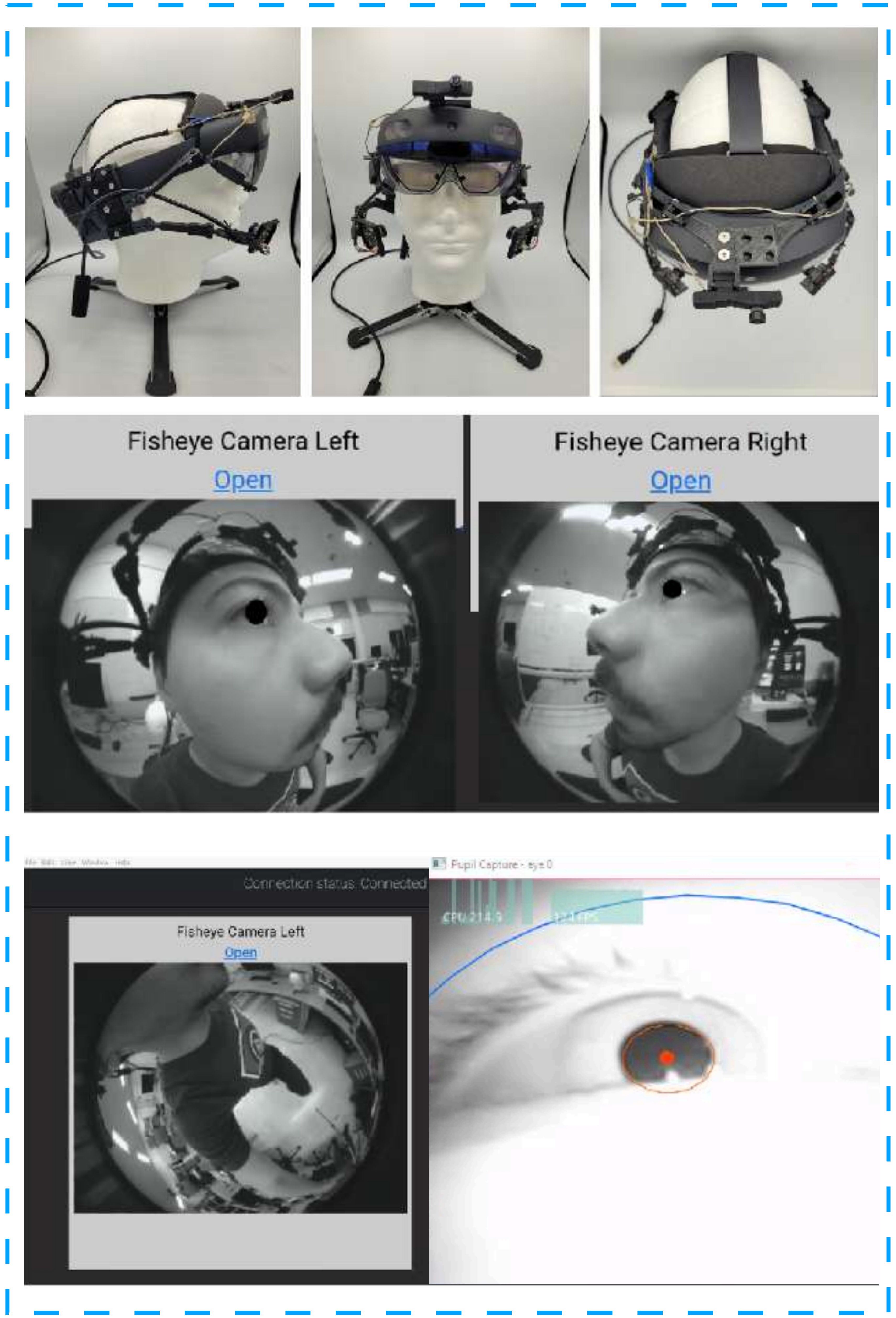
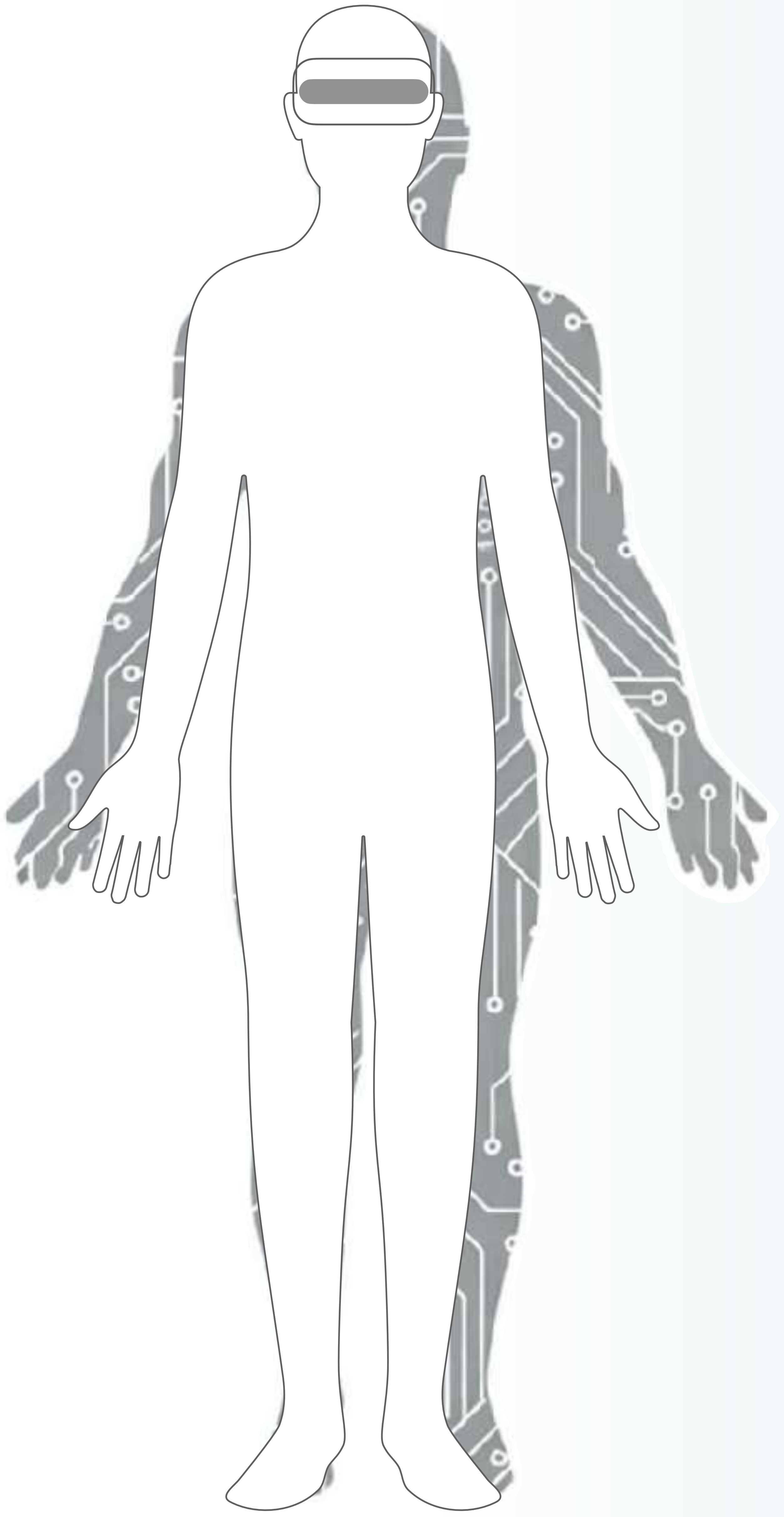

User tries to converge to the ideal pressure values with a 2 min time limit
Server streaming sensor values to Unity in real-time
Physiotherapy ball used as the object to manipulate


Fisheye Camera Left
Open
Fisheye Camera Right
Open
Connection status: Connected
Fisheye Camera Left
Open
Pupil Capture - eye 0

# Vision

Conceptualizing a Science of Human-AI Interaction



# A Science of Human-AI Interaction

**A study of how humans and AI work together as components of a cognitive and sensorimotor system**

By integrating insights from psychology, cognitive science, neuroscience, and social science, we bridge AI's technical capabilities with human cognition, emotion, and behavior to design human-AI systems that truly respond to our needs.

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# Underlying Theories

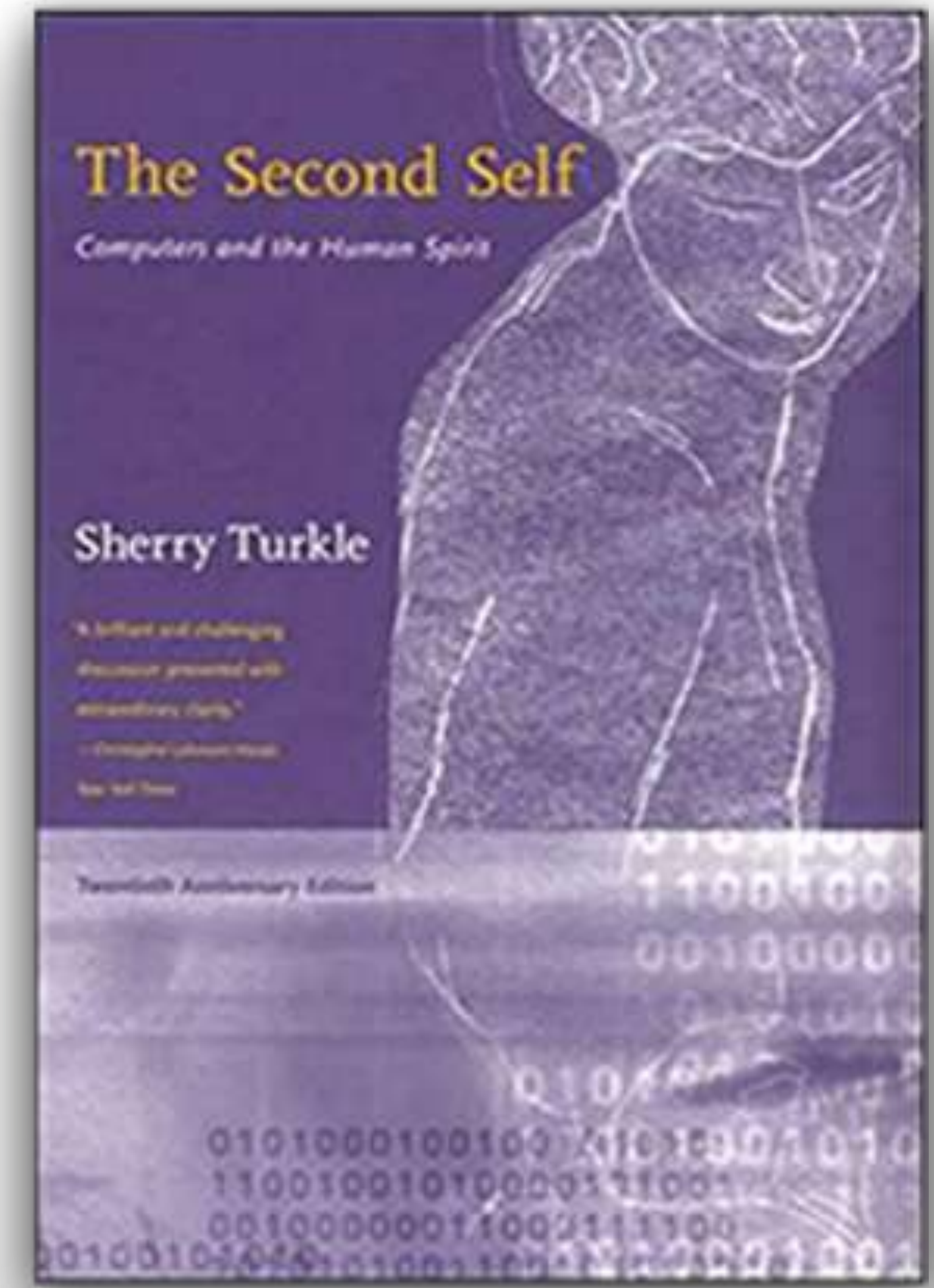
The Second Self (Sherry Turkle, 80’s)

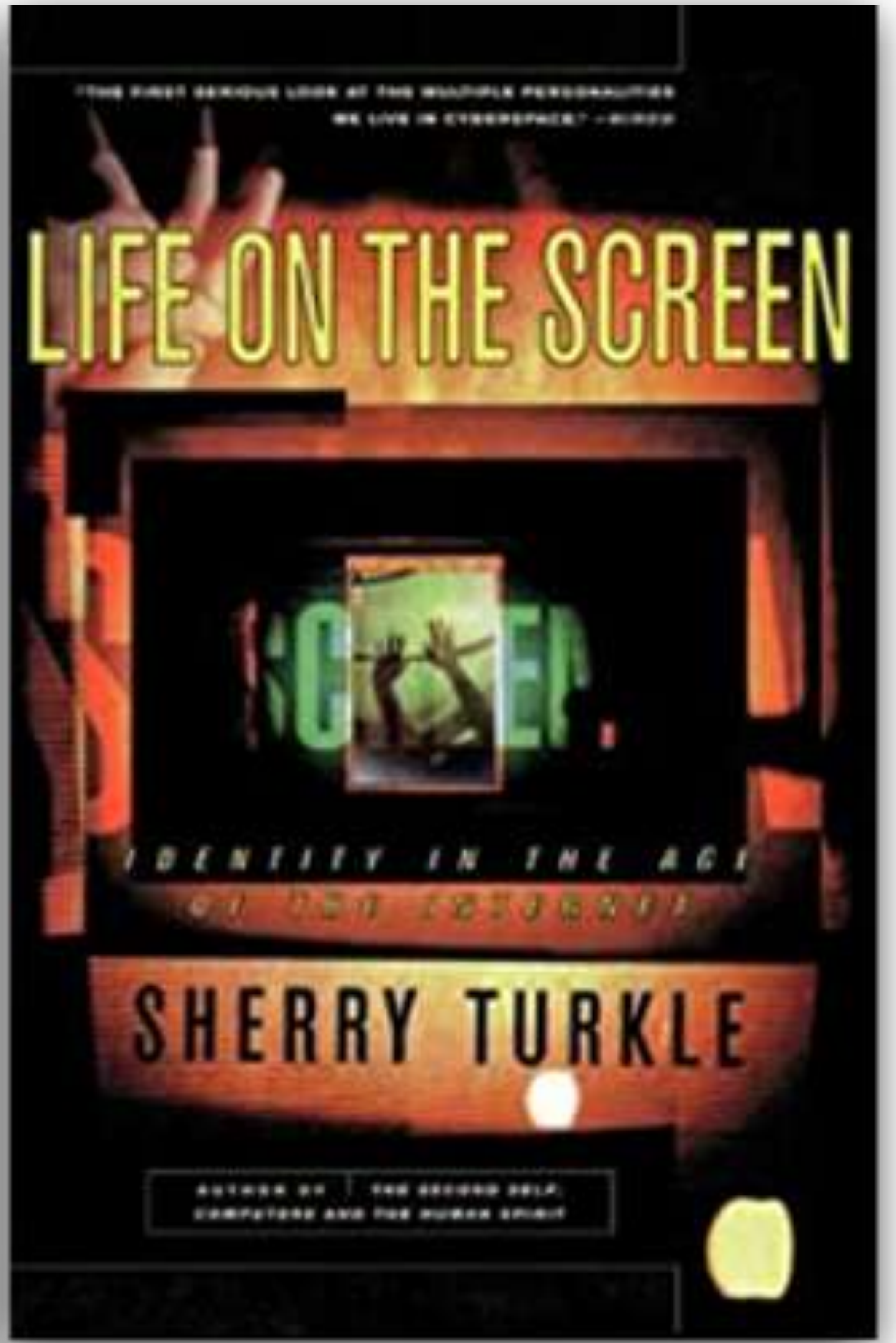
The Media Equation (Nass and Reeves, 90’s)

Distributed Cognition Theory (Ed Hutchins, 00)

# Mind-Machine Symbiosis (‘80s)

**Sherry Turkle**

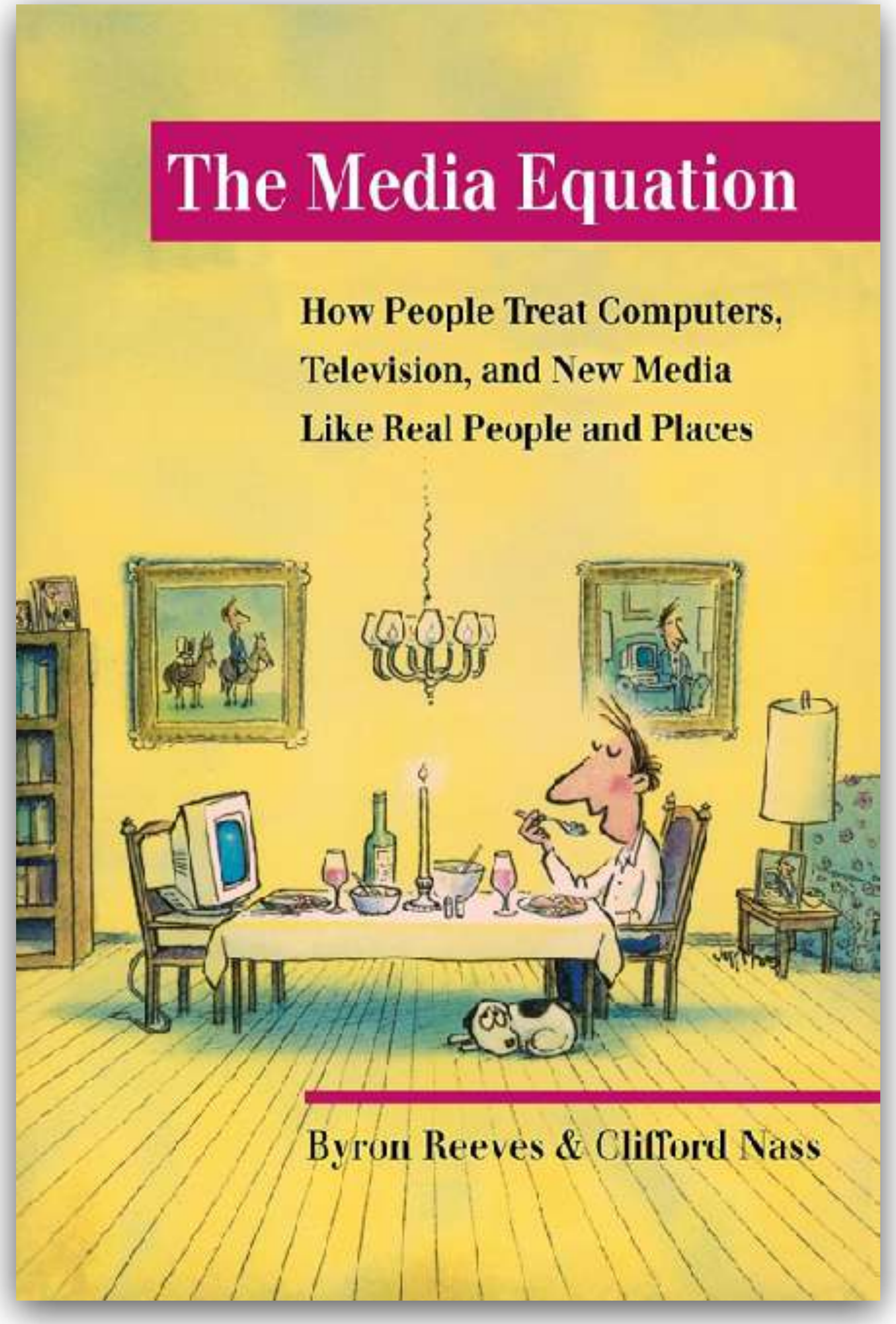



- *The Second Self* highlights how digital tools become **extensions of our cognitive processes**, shaping our perception and problem-solving approach.
- In *Life on the Screen*, Turkle explains that our interactions with digital **tools influence how we think** and conceptualize problems, **altering our cognitive frameworks and even our sense of self.**
- Our thinking is intertwined with the affordances of the technologies we engage with and this has **implications for human-AI interaction** design.

# The Media Equation ('90s)

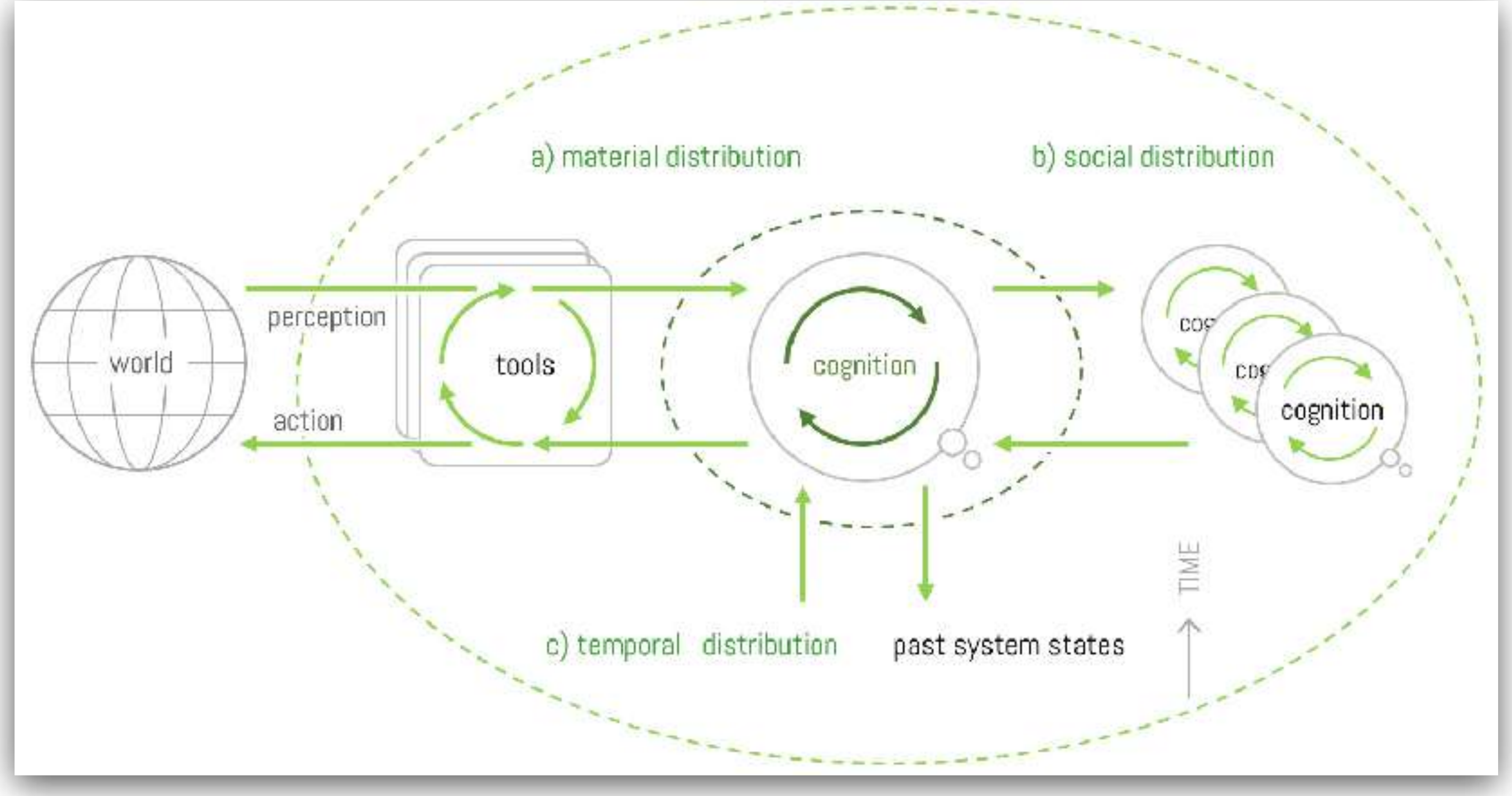
**Clifford Nass & Byron Reeves**




- People treat computers, media, (and now AI systems) as if they were real social actors, applying social rules and norms to their interactions, and responding with behaviors like politeness, empathy, and social expectations.

Edwin Hutchins

# Distributed Cognition Theory ('00)




- Cognition is a distributed activity that occurs across three key areas: a) humans and their physical environment, including tools; b) interactions between multiple people; and c) over time, as it builds on and uses cultural artifacts shaped by previous cognitive processes.

Hutchins, E. (2000). Distributed cognition. International Encyclopedia of the Social and Behavioral Sciences. Elsevier Science, 138, 1-10.

Windhager, F., & Mayr, E. (2024). Digital Humanities and Distributed Cognition: From a Lack of Theory to its Visual Augmentation. Journal of Cultural Analytics, 7(4).

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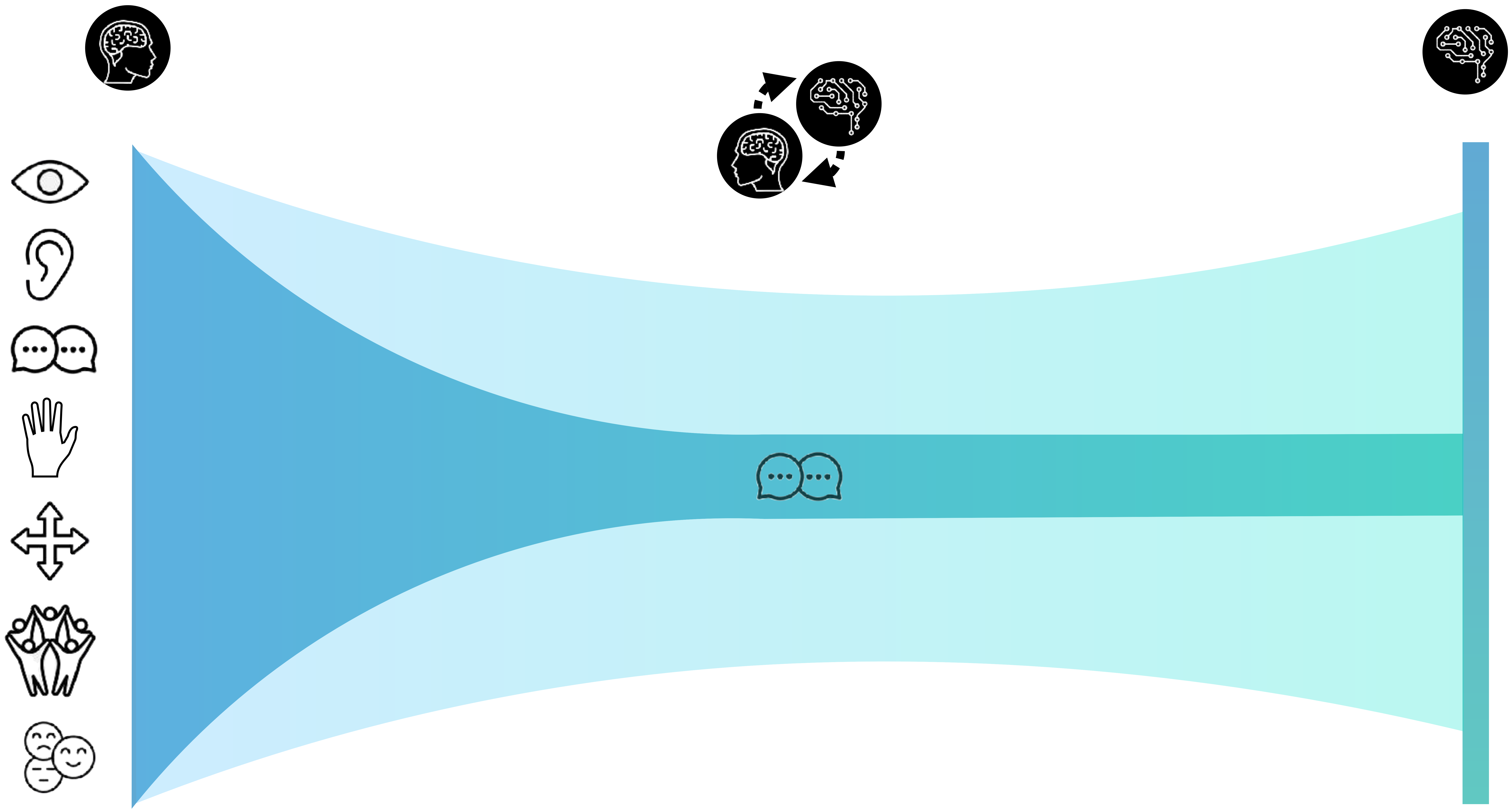
# HUMAN-WORLD INTERACTION

# HUMAN-AI INTERACTION

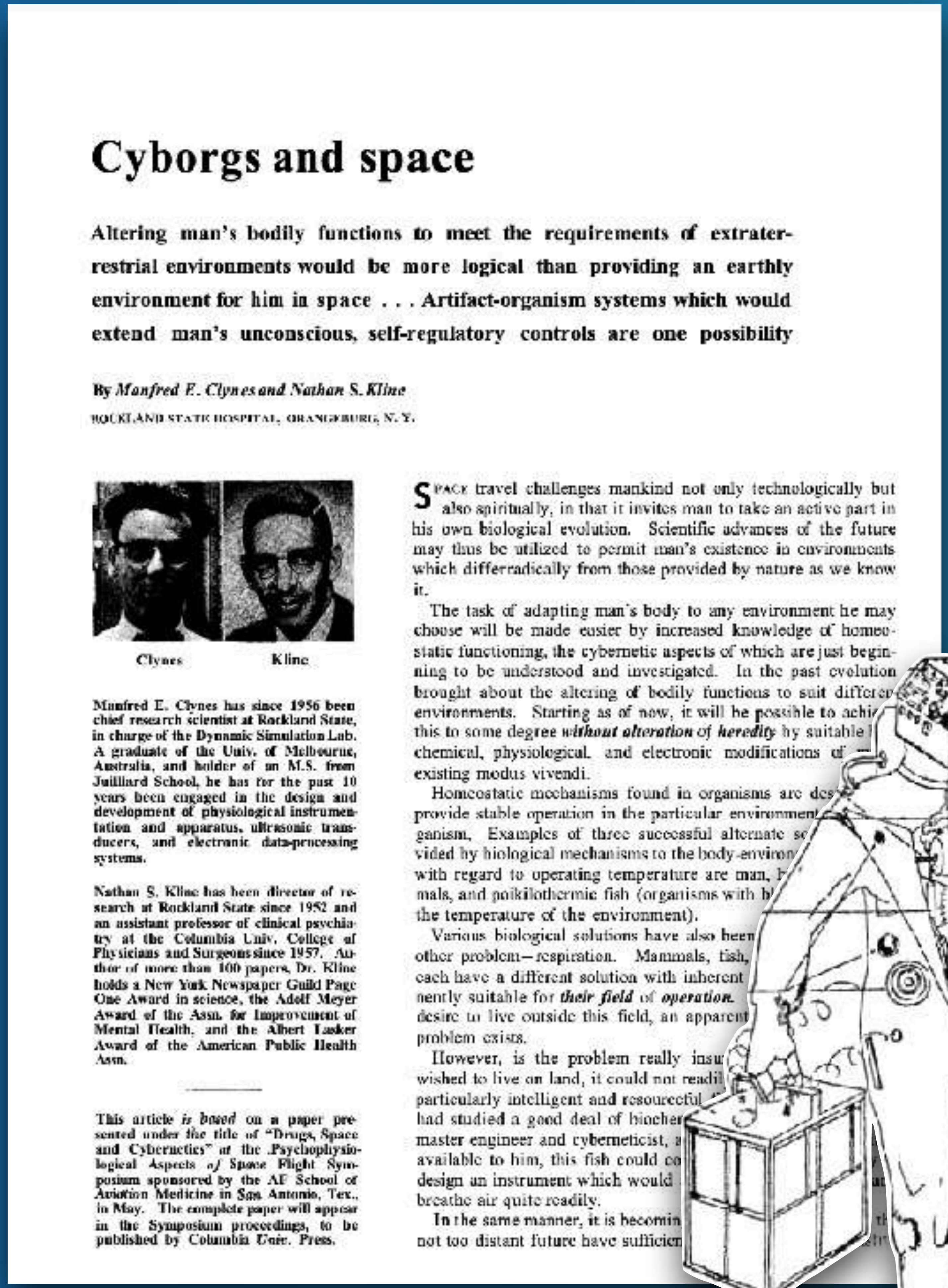


# Ongoing Research Directions


Image generated with ChatGPT

- AI Beyond the Chatbot
- Understanding Human-Agent Interaction
- AI as a Trainer and Coach
- *Lifelong Human-AI Interaction
- Human-AI Systems for Rehab

*more a thought experiment at the moment than a prototype



# Cyborgs and space

**Altering man's bodily functions to meet the requirements of extraterrestrial environments would be more logical than providing an earthly environment for him in space . . . Artifact-organism systems which would extend man's unconscious, self-regulatory controls are one possibility**


*By Manfred E. Clynes and Nathan S. Kline*

ROCKLAND STATE HOSPITAL, ORANGEBURG, N. Y.


Clynes Kline

Manfred E. Clynes has since 1956 been chief research scientist at Rockland State, in charge of the Dynamic Simulation Lab. A graduate of the Univ. of Melbourne, Australia, and holder of an M.S. from Juilliard School, he has for the past 10 years been engaged in the design and development of physiological instrumentation and apparatus, ultrasonic transducers, and electronic data-processing systems.

Nathan S. Kline has been director of research at Rockland State since 1952 and an assistant professor of clinical psychiatry at the Columbia Univ. College of Physicians and Surgeons since 1957. Author of more than 100 papers, Dr. Kline holds a New York Newspaper Guild Page One Award in science, the Adolf Meyer Award of the Assn. for Improvement of Mental Health, and the Albert Lasker Award of the American Public Health Assn.

This article *is based* on a paper presented under *the* title of "Drugs, Space and Cybernetics" at the Psychophysiological Aspects *of* Space Flight Symposium sponsored by the AF School of Aviation Medicine in San Antonio, Tex., in May. The complete paper will appear in the Symposium proceedings, to be published by Columbia Univ. Press.

SPACE travel challenges mankind not only technologically but also spiritually, in that it invites man to take an active part in his own biological evolution. Scientific advances of the future may thus be utilized to permit man's existence in environments which differradically from those provided by nature as we know it.

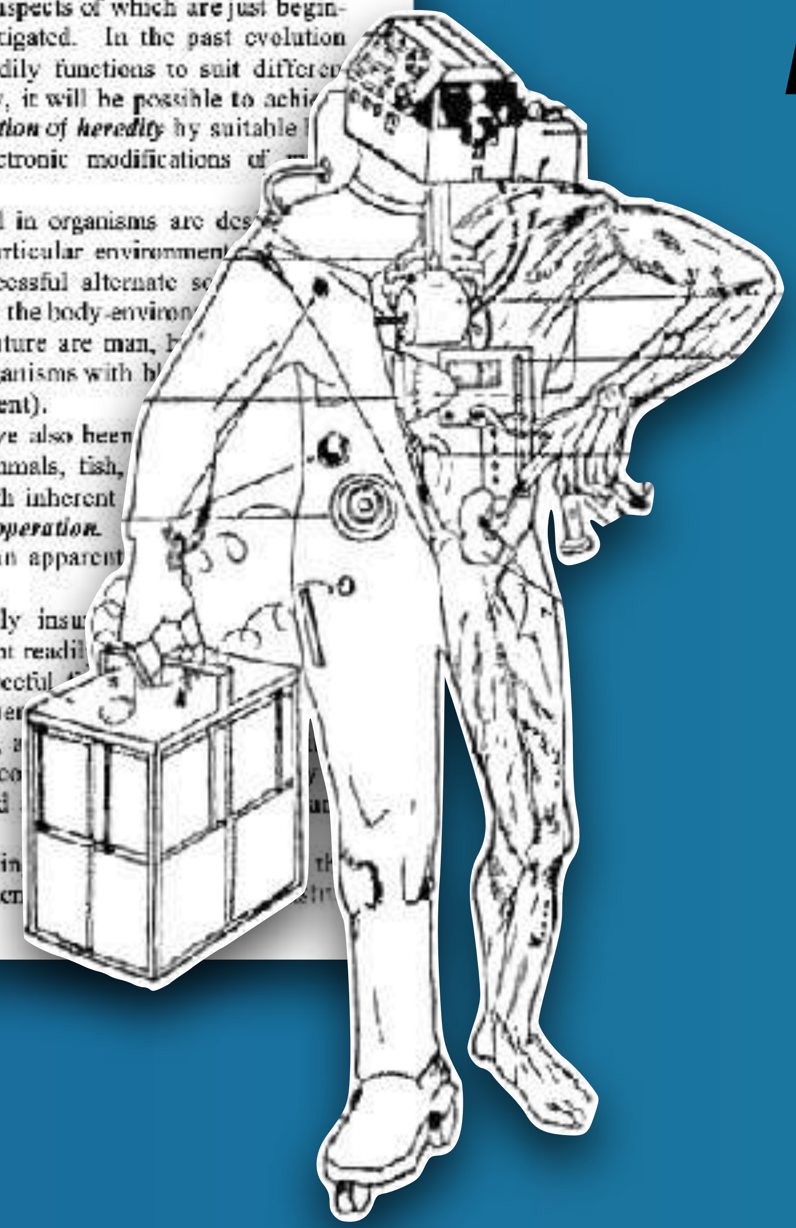
The task of adapting man's body to any environment he may choose will be made easier by increased knowledge of homeostatic functioning, the cybernetic aspects of which are just beginning to be understood and investigated. In the past evolution brought about the altering of bodily functions to suit differen
environments. Starting as of now, it will be possible to achi
this to some degree ***without alteration*** of ***heredity*** by suitable
chemical, physiological and electronic modifications of
existing modus vivendi.

Homeostatic mechanisms found in organisms are des
provide stable operation in the particular environment
ganism. Examples of three successful alternate so
vided by biological mechanisms to the body-environ
with regard to operating temperature are man, h
mals, and poikilothermic fish (organisms with bl
the temperature of the environment).

Various biological solutions have also been
other problem—respiration. Mammals, fish,
each have a different solution with inherent
nently suitable for ***their field*** of ***operation.***
desire to live outside this field, an apparent
problem exists.

However, is the problem really insu
wished to live on land, it could not readil
particularly intelligent and resourceful
had studied a good deal of biocher
master engineer and cyberneticist,
available to him, this fish could co
design an instrument which would
breathe air quite readily.

In the same manner, it is becomin
not too distant future have sufficien



*"The purpose of* ***AI*** *is to leave the human free to explore, to create, to think, and to feel."*

*-Clynes & Kline (1960)*