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Exploring LLM-Powered Role and Action-Switching Pedagogical Agents for History Education in Virtual Reality

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Full paper available at: https://lumia-zhu.github.io/Research/index/CHI25_Pedagogical_agent.pdf

Image from https://unimersiv.com/

Virtual reality is reshaping how we experience history in education.

Image from https://unimersiv.com/

Multi-role Pedagogical agent in VR history education

Multi-role pedagogical agents in history education
(Source: Novick et al., 2019)

Pedagogical agents (PAs)
are characters enacted by a computer that interact with the user in a socially engaging manner.

- Supports narrative-driven exploration
- Provides situated and contextual guidance
- Embodies historical perspectives

Mabanza, N., & de Wet, L. (2013). Determining the usability effect of pedagogical interface agents on adult computer literacy training.
Novick, D., Afravi, M., Camacho, A., Rodriguez, A., & Hinojos, L. (2019). Pedagogical-agent learning companions in a virtual reality educational experience.

Current challenges for multi-role pedagogical agents in VR history education

Scripted, Inflexible Responses

Pre-scripted dialogue *limits engagement and adaptability*.

High Interaction Burden

Frequent navigation *between fixed-role agents adding interaction burden, disrupts immersion and learner autonomy.*

Location-bound interactions restrict learner agency

Users must navigate to specific spots or characters to engage, limiting spontaneous exploration.

How might we create more adaptive, context-sensitive agents for rich historical storytelling?

Chardonnet, J.R., Mirzaei, M.A. and Merienne, F., 2021. Influence of navigation parameters on cybersickness in virtual reality.
Petersen, G.B., Mottelson, A. and Makransky, G., 2021, May. Pedagogical agents in educational vr: An in the wild study.
Chheang, V., Sharmin, S., R. L. (2024, January). Towards anatomy education with generative AI-based virtual assistants in immersive virtual reality environments.

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We propose

adaptive role and action-switching pedagogical agents powered by LLMs.

Role-Switching: Enables a PA to dynamically assume different historical roles in response to learner input.

Action-Switching: Dynamically adjusts PA's action based on its responses.

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Research question

- **RQ1**: How do role-switching and action-switching modules **affect user learning outcomes and experience** of VR history education?

- **RQ2**: How can role-switching and action-switching modules **inform future VR history education design** to enhance the learning outcomes and experience?

Prototype design

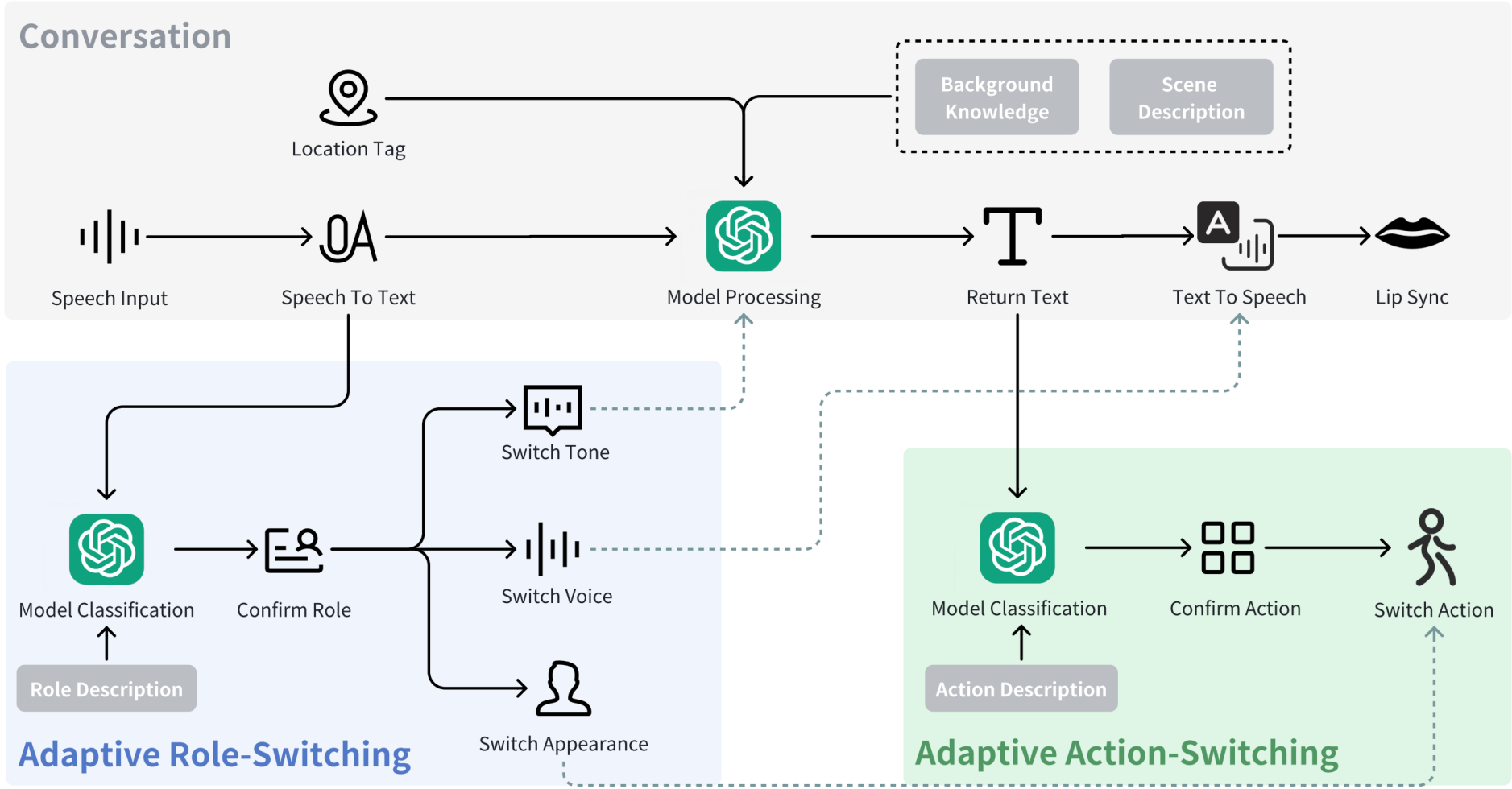
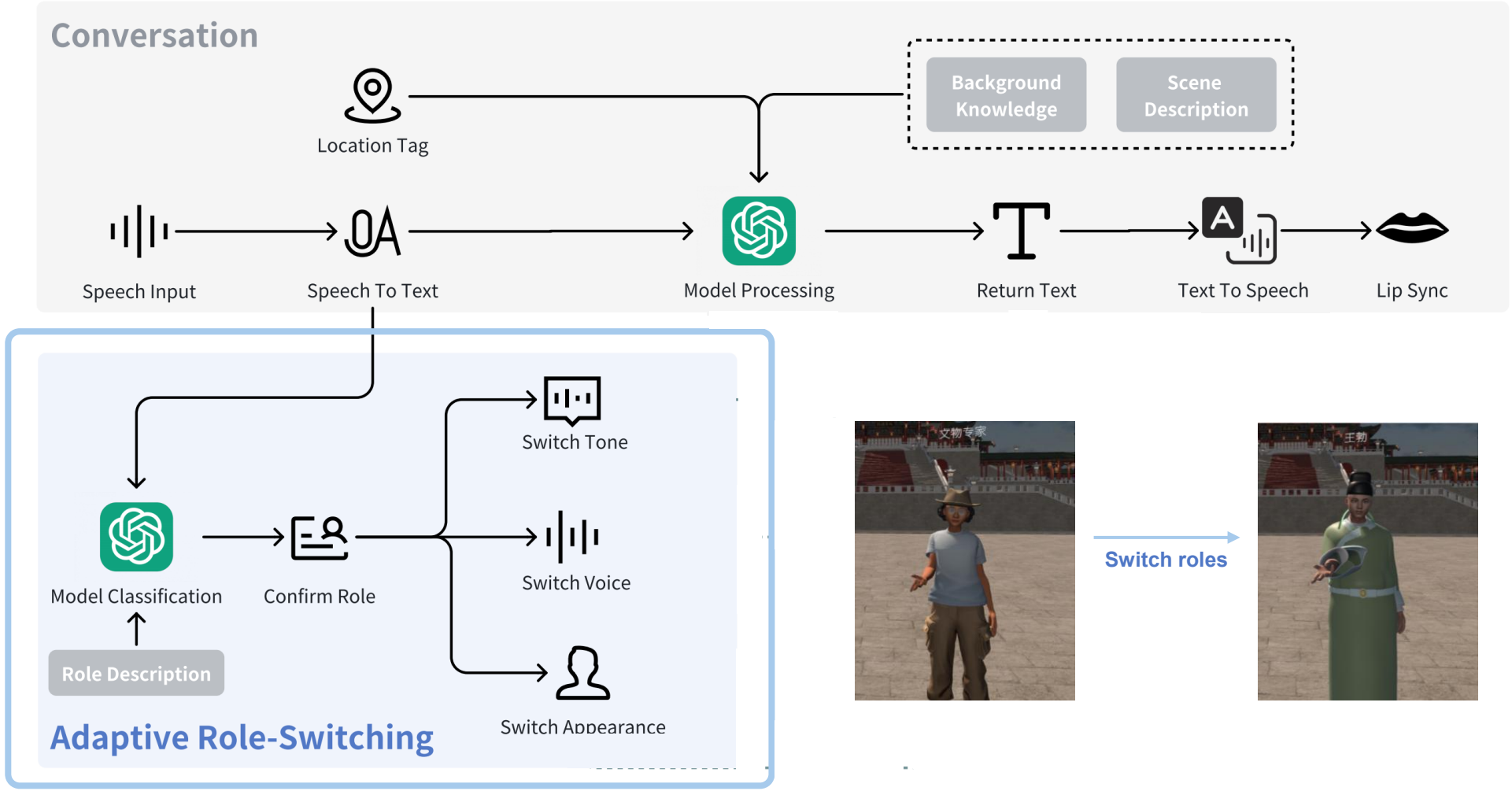


Figure 2. Prototype overview

Adaptive role-switching module



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Adaptive action-switching module

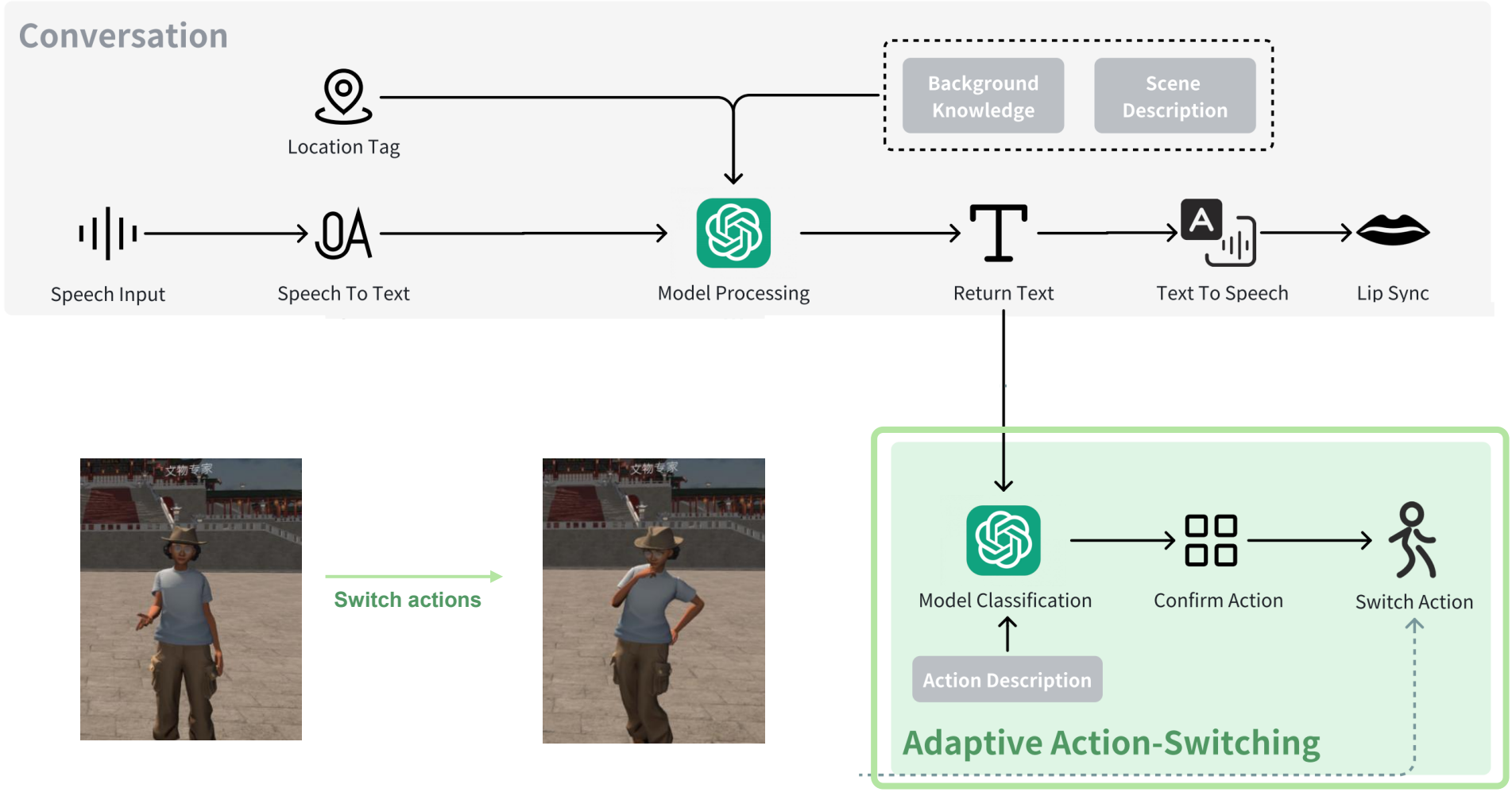

Figure 2. Prototype overview

Roles and actions

Roles

Figure 3. Roles included in the adaptive role-switching

Actions

Category	Actions
Pointing Actions	forward indication, backward indication, leftward indication, rightward indication, upward indication, downward indication
Naturally Expressive Actions	welcome, thinking, extend one hand, extend both hands, nod
Character-specific Actions	raise the wine cup (wang bo), raise a hand to indicate (prince teng), move closer to observe (archaeological expert)
Descriptive Actions	writing, fight, sword dancing, wielding a whip

Table 1. Actions included in the adaptive action-switching

Methodology: roles and actions

Figure 4. Prototype interface

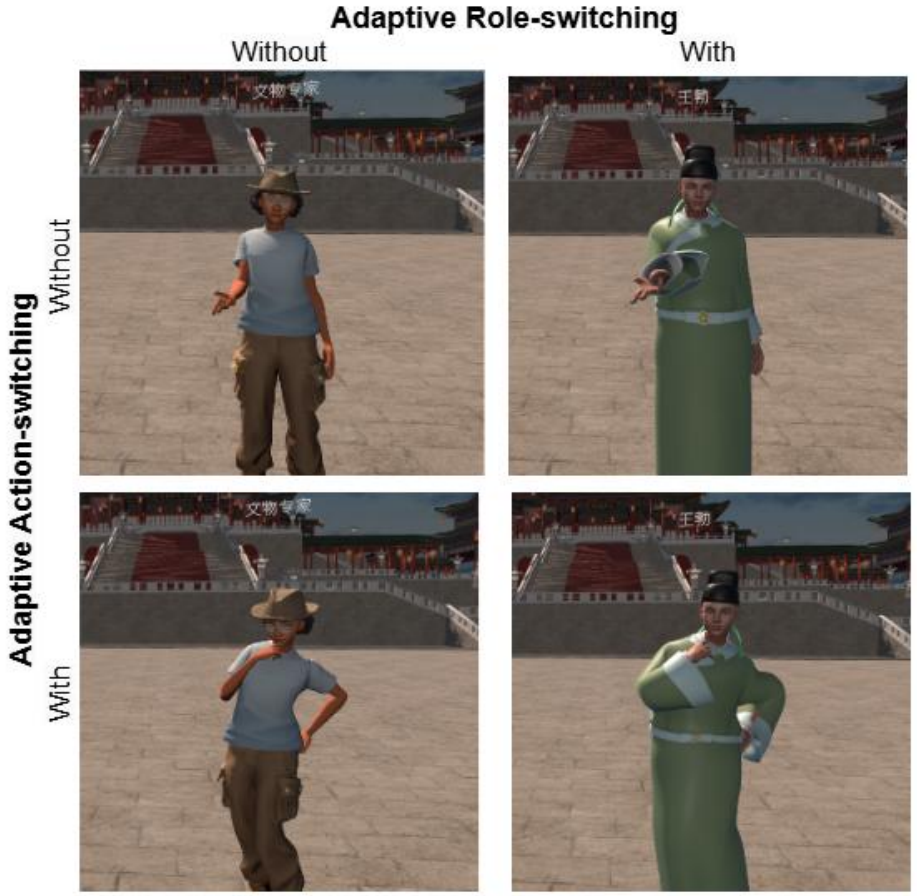

Figure 5. Conditions in user study

Methodology

We conducted a 2 * 2 user study with 84 participants

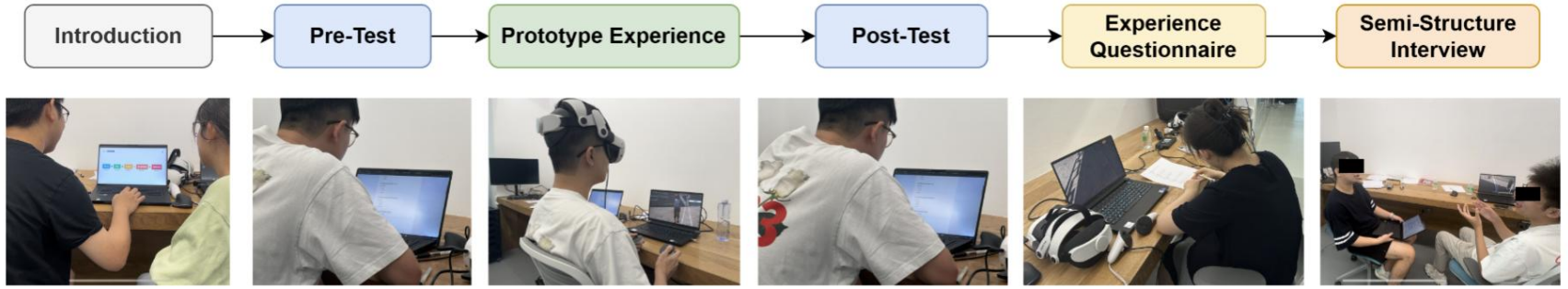

Figure 6. Overview of user study procedure

Variable	Category	Questions	Type	Min/Max
Factual knowledge	Learning outcome	10	Multiple choice	0–10
Conceptual knowledge	Learning outcome	10	Multiple choice	0–10
Usability	Experience	10	5-point Likert	1–5
Social presence	Experience	5	5-point Likert	1–5
Motivation	Experience	12	7-point Likert	1–7
Trustworthiness	Experience	3	Semantic differential	1–5
Expertise	Experience	4	Semantic differential	1–5
Perceived humanness	Experience	4	Semantic differential	1–5
Intrinsic cognitive load	Cognitive load	1	5-point Likert	1–5
Extraneous cognitive load	Cognitive load	1	5-point Likert	1–5
Germane cognitive load	Cognitive load	1	5-point Likert	1–5

Learning outcomes

Learning experience

Table 2. Dependent measures in the study

Methodology

The study proposes five hypotheses:

- **Role-switching** → higher trustworthiness (H2).

  → lower extraneous cognitive load (H5).

- **Action-switching** → higher knowledge acquisition (H1).

  → higher social presence (H3).

  → higher perceived humanness (H4).

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Methodology

The study proposes five hypotheses:

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  → higher social presence (H3).

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Result: learning outcomes

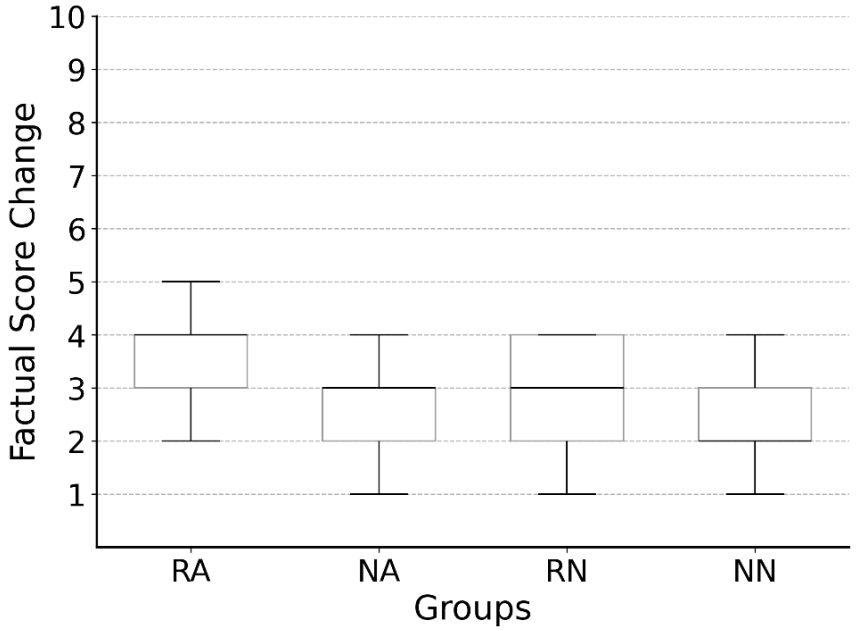

Figure 7. Factual knowledge score change

Role-switching significantly improves participants' **factual knowledge** acquisition.

" I link Wang Bo's appearance and outfit with the knowledge about ' Preface to the Pavilion of Prince Teng '. It's like switching between different characters helps me categorize the information they're teaching me." (P9)

- **Factual Knowledge**: The basic, discrete pieces of information within a discipline, such as facts, terminology, and specific details.
- **Conceptual Knowledge**: Understanding of how ideas, principles, and concepts are interconnected within a broader framework or structure.

Result: learning experience

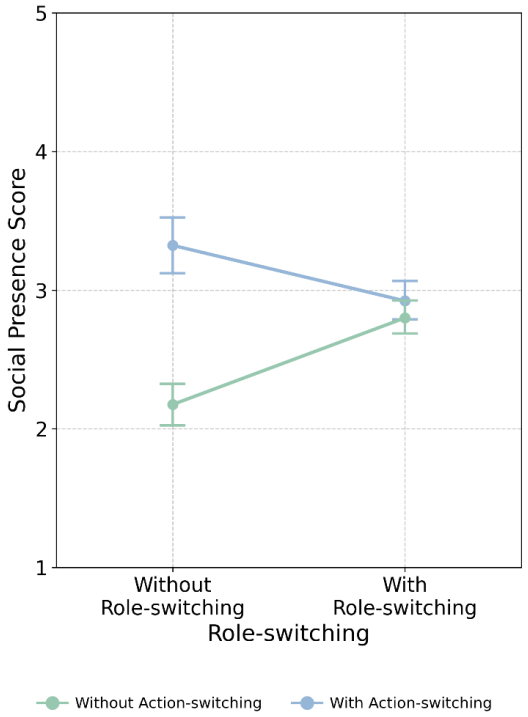

Figure 8. Social presence score across different groups

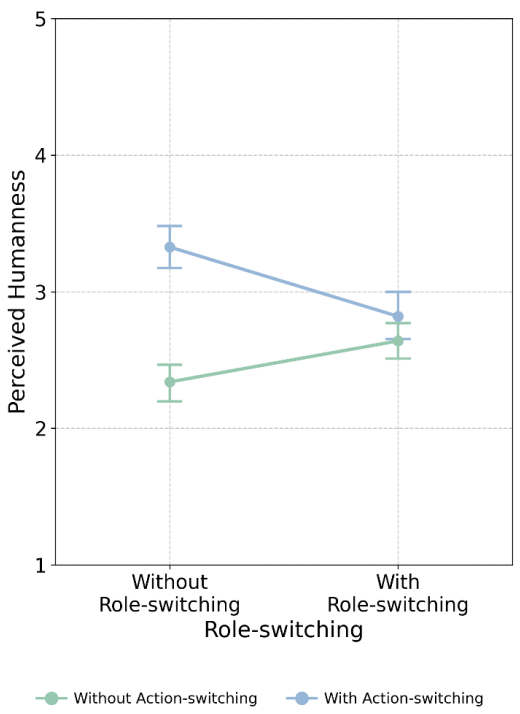

Figure 9. Perceived humanness across different groups

- Role-switching and action-switching demonstrate interaction effects on **social presence**.

  " Because one person suddenly turns into another, it doesn't feel like something that would happen in the real world, constantly reminding me that this isn't real. " (P13)

- Role-switching and action-switching demonstrate interaction effects on **perceived humanness**.

  " When I asked a question, his thoughtful actions made me feel like he was really listening to me. " (P50)

Result: learning experience

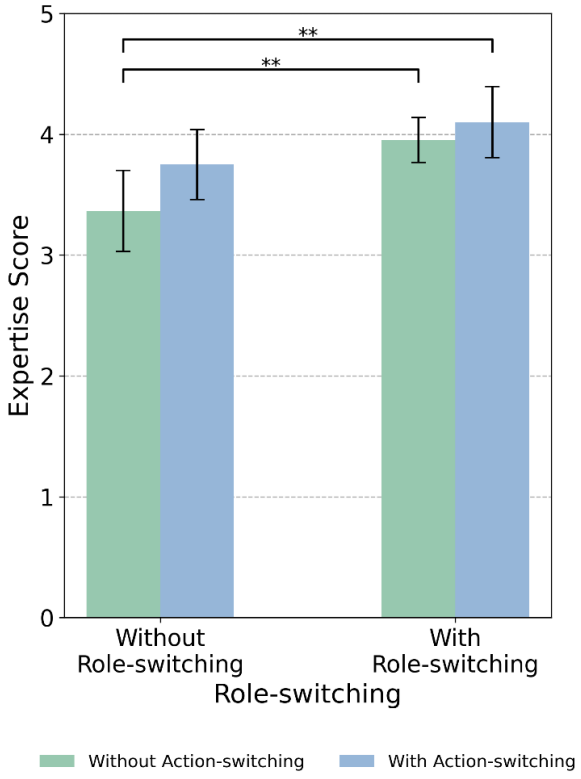

Figure 10. Expertise across different groups

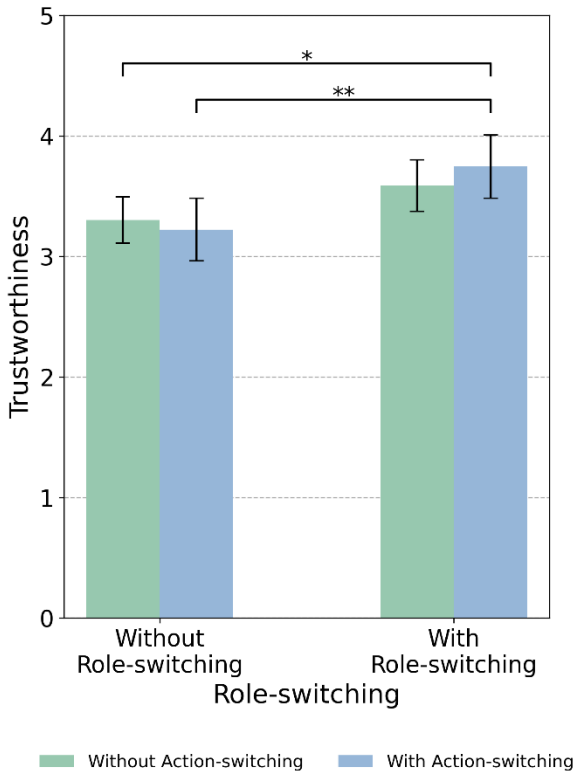

Figure 11. Trustworthiness across different groups

- Both role-switching and action-switching enhance participants' perception of PA's **expertise**.
- Role-switching significantly increases participants' **perceived trustworthiness** of the PA.

  " When I see Wang Bo describing the background of his creation of the ' Preface to the Pavilion of Prince Teng ' in the first person, I tend to believe him more than some one else narrating because he is the author of the poem. " (P42)

- We did not uncover any effects of role-switching and action-switching on **usability**, **learning motivation**, and **cognitive load** from quantitative data.

Qualitative Findings: Benefits & Challenges of Role-Switching

- Role-switching reduces participants' interaction effort in the learning process.

> *" I can just ask him directly, without having to run around to specific places to find agents like in many RPG games. By the time I get to the agent, I might have forgotten what I was thinking about. " (P18)*

- Frequent and instantaneous role-switching disrupt conversational consistency and immersion.

> *" I was asking a question to the archaeological expert, but then the character switched to Wang Bo when responding, which made me feel like I wasn't talking to the same person throughout the conversation. " (P14)*

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Qualitative Findings: Action-Switching in Learning

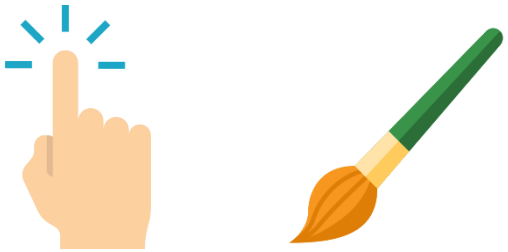
- Participants focus more on the environment and agent's face than on its actions.

  " Honestly, while I was exploring, I didn't really pay much attention to the avatar's actions. Most of my focus was on checking out the Pavilion of Prince Teng's scene, listening to what the avatar was saying, and occasionally looking at its face. I felt like the avatar's actions didn't change much." (P55)

- Different action types influence participants' perception of clarity and realism.

  " When he mentioned that the plaque on the sixth floor of the Pavilion of Prince Teng was written by Su Shi, I wished he would point to it because there are so many plaques, and I wasn't sure which one he meant. " (P45)

  " Normal people don't act like writing a poem while speaking. It seems a bit odd (...) " (P58)



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Design Implications

- Facilitating **multi-perspective historical understanding** through role-switching.
  - Leverage role-switching enabling learners to understand decision-making processes from various historical perspectives.

- Emphasizing effective **navigational actions**.
  - Effective navigation in complex, large scale VR environments (e.g., pointing to specific items or locations).

- Utilizing proactive PAs to **foster historical context awareness**.
  - Provide reminders through action-switching proactively to draw user's attention to key pieces of information they might miss.

Thank You!

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