Primary Joint Effects in Arm-Based Seated VR Locomotion

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Gesture-Based Locomotion

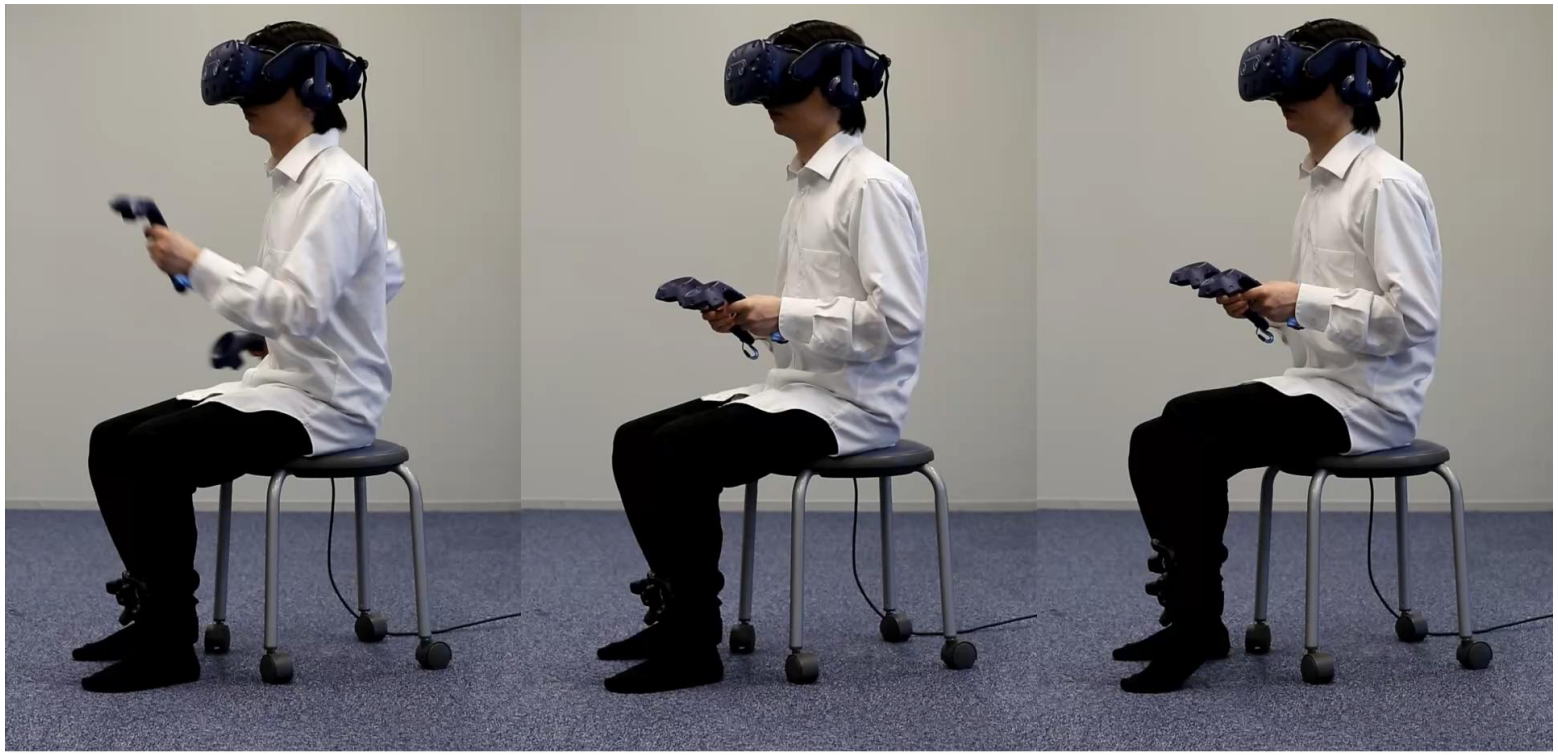
Sendai, Japan
November 16 -18
VRST 2026

- **Enhances** the **sense of walking** compared to controllers.
- **Can be performed seated** for safety and comfort.



Our Previous Work (VRST 2025) *

- Expected walking speed **depends on the gesture**: SIP > GIP > TIP



Swing-in-Place (SIP) Grip-in-Place (GIP) Tap-in-Place (TIP)

* Kitaura *et al*., “Not All WIP Are Perceived Equally: Different Speed Expectations in Seated Walk-in-Place Locomotion”, The ACM Symposium on Virtual Reality Software and Technology, November 2025, pp.1-11, No. 10

Arm-Based Gestures

- **Are** one of the most **common locomotion metaphors**.



*1



*2



*3

*1 Pai and Kunze, “Armswing: using arm swings for accessible and immersive navigation in AR/VR spaces”, The International Conference on Mobile and Ubiquitous Multimedia, November 2017, pp.189-198

*2 Kitaura *et al*., “Not All WIP Are Perceived Equally: Different Speed Expectations in Seated Walk-in-Place Locomotion”, The ACM Symposium on Virtual Reality Software and Technology, November 2025, pp.1-11, No. 10

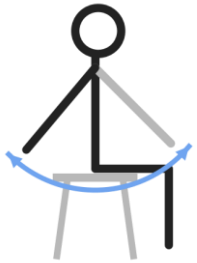
*3 Calandra *et al*., “Arm Swinging vs Treadmill: A Comparison Between Two Techniques for Locomotion in Virtual Reality”, Eurographics Association - Short Papers, April 2018, pp.53-56

What Is an “Arm-Based Gesture”?

- Swinging pattern



Bent arm



Extended arm

- Range of motion



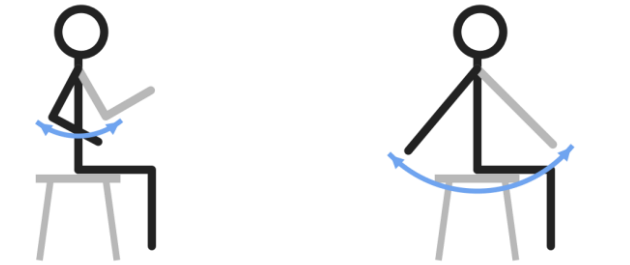
Small



Large

What Is an “Arm-Based Gesture”?

- Swinging pattern



Bent arm　　Extended arm

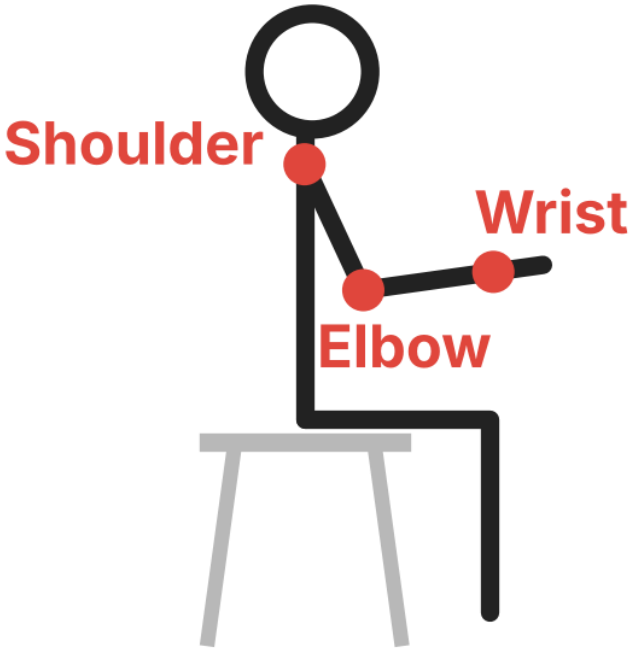
- Range of motion



Small　　Large

Our focus: **Primary Joint**

= the center of rotation



Research Questions

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RQ1: Does the primary joint change user experience?

→ **Study 1**
User Experience

RQ2: Does the primary joint change expected walking speed?

→ **Study 2**
Speed Expectations

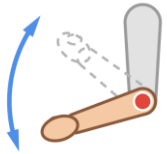
RQ3: What explains the difference in expected walking speed?

→ **Study 3**
Motor Characteristics
& Further Analysis

Investigated Arm-Based Gestures



Shoulder



Elbow



Wrist



Apparatus & Participants

- Apparatus
  - HMD: Vive Pro Eye
  - Input: Vive controllers
  - Seat: backless stool
  - Software: Unity
- Participants
  - N = 18 (14 male, 4 female)
  - Aged 20–25 (M = 21.1)
  - Same participants in all three studies

Overview of the Three-Part Study

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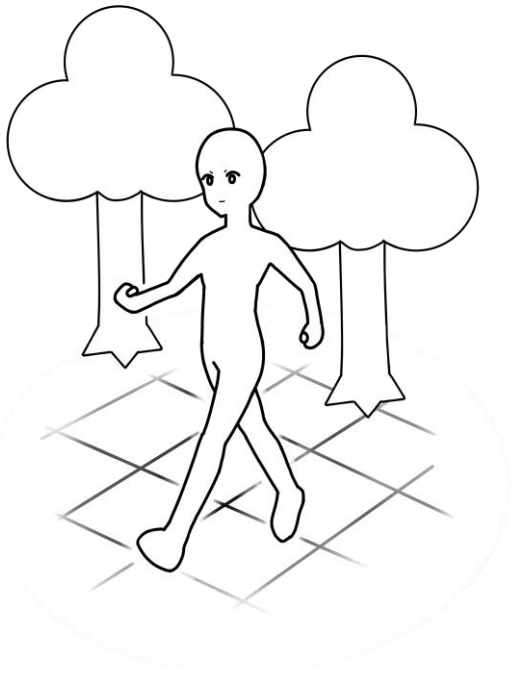
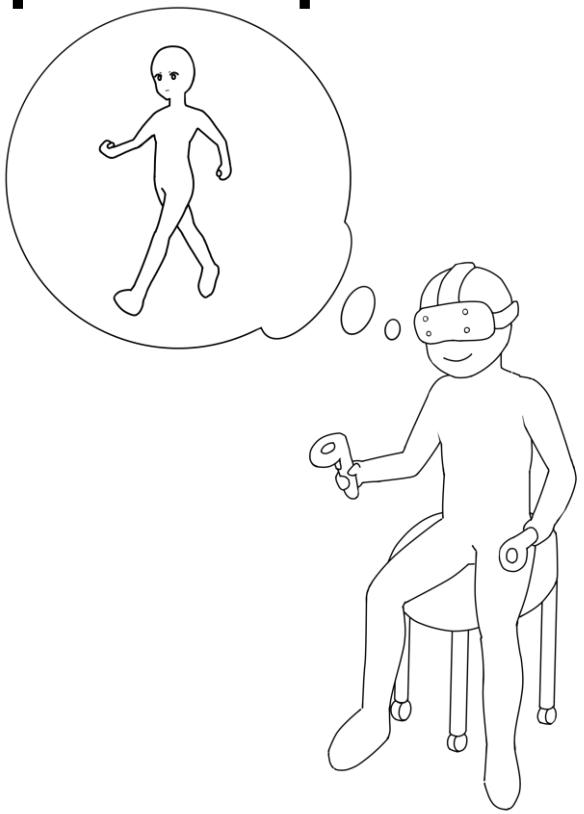
Study 1
User Experience



Study 2
Speed Expectations



Study 3
Motor Characteristics



Study 1 Method :
How We Measured User Experience

Walking Phase



Questionnaires

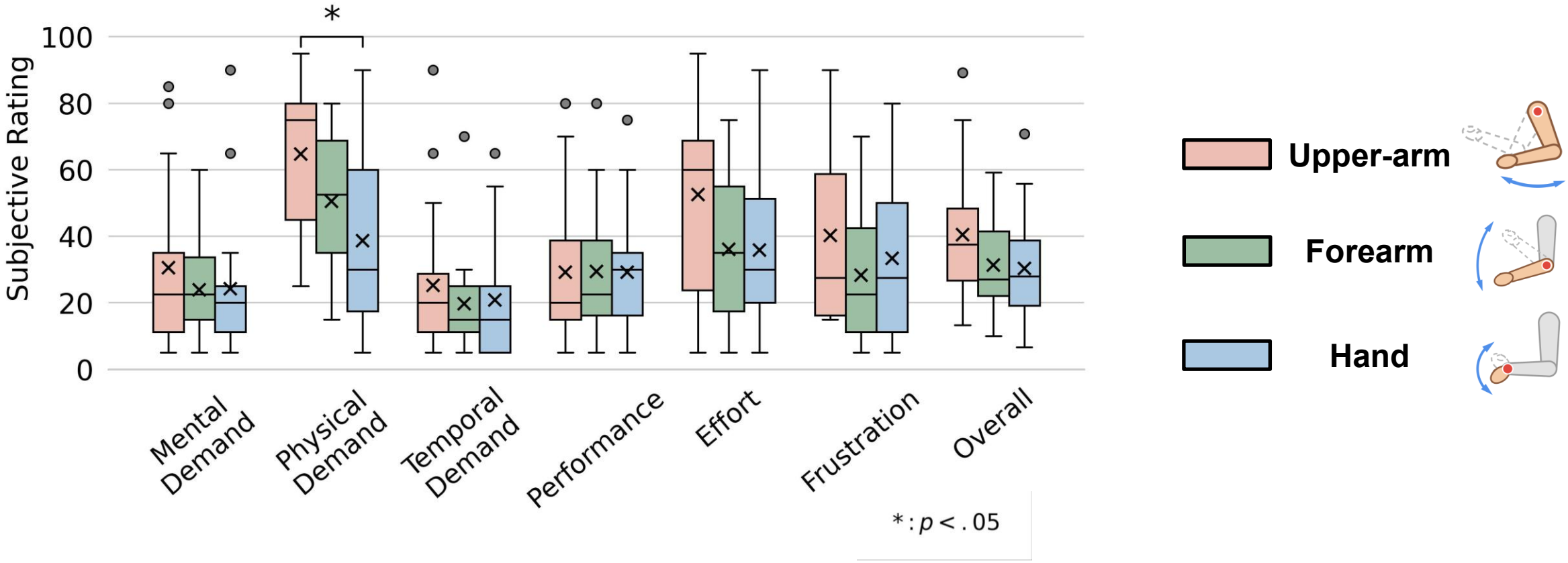
Presence Questionnaire

NASA-RTLX

× 3 gestures

Study 1 Results : User Experience

- **Presence**: no significant difference
- **Physical Demand**: **Upper-arm Swinging > Hand Swinging**



Answer to RQ1

RQ1: Does the primary joint change user experience?

Yes.

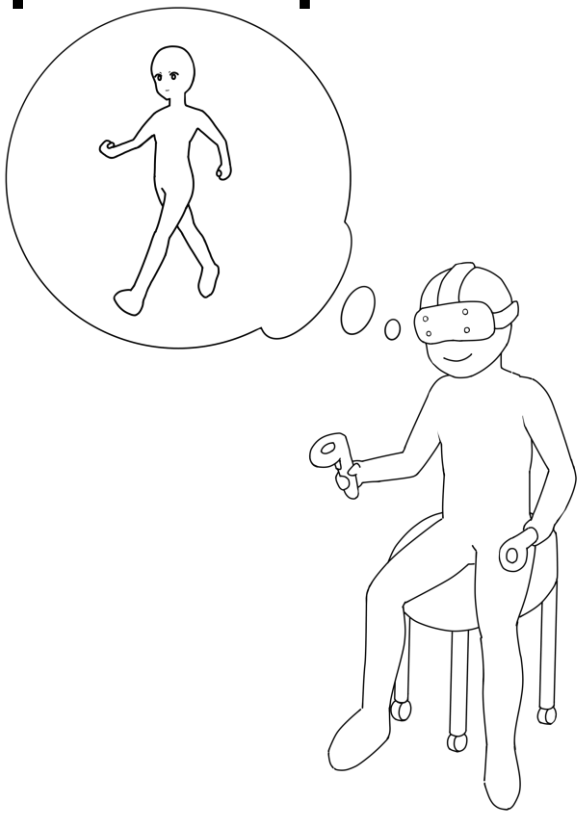
Swinging from the **shoulder** showed higher **Physical Demand** than swinging from the wrist.

Overview of the Three-Part Study

Study 1
User Experience



Study 2
Speed Expectations



Study 3
Motor Characteristics



Study 2 Method :
How We Measured "Natural" Speed

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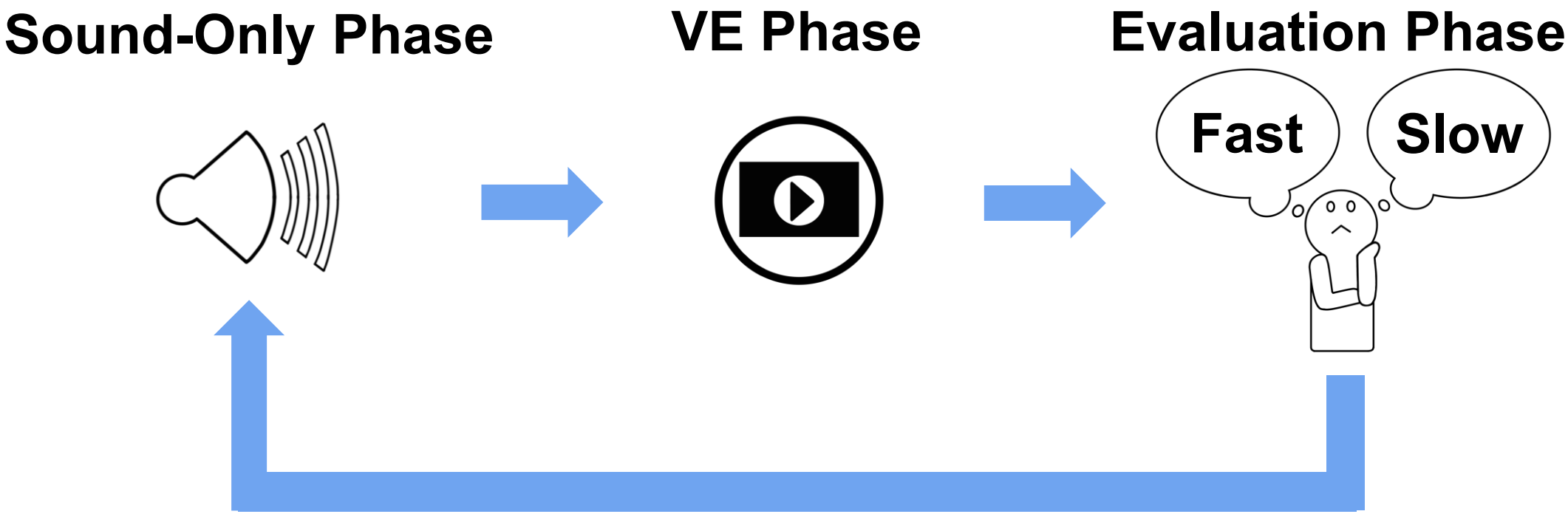
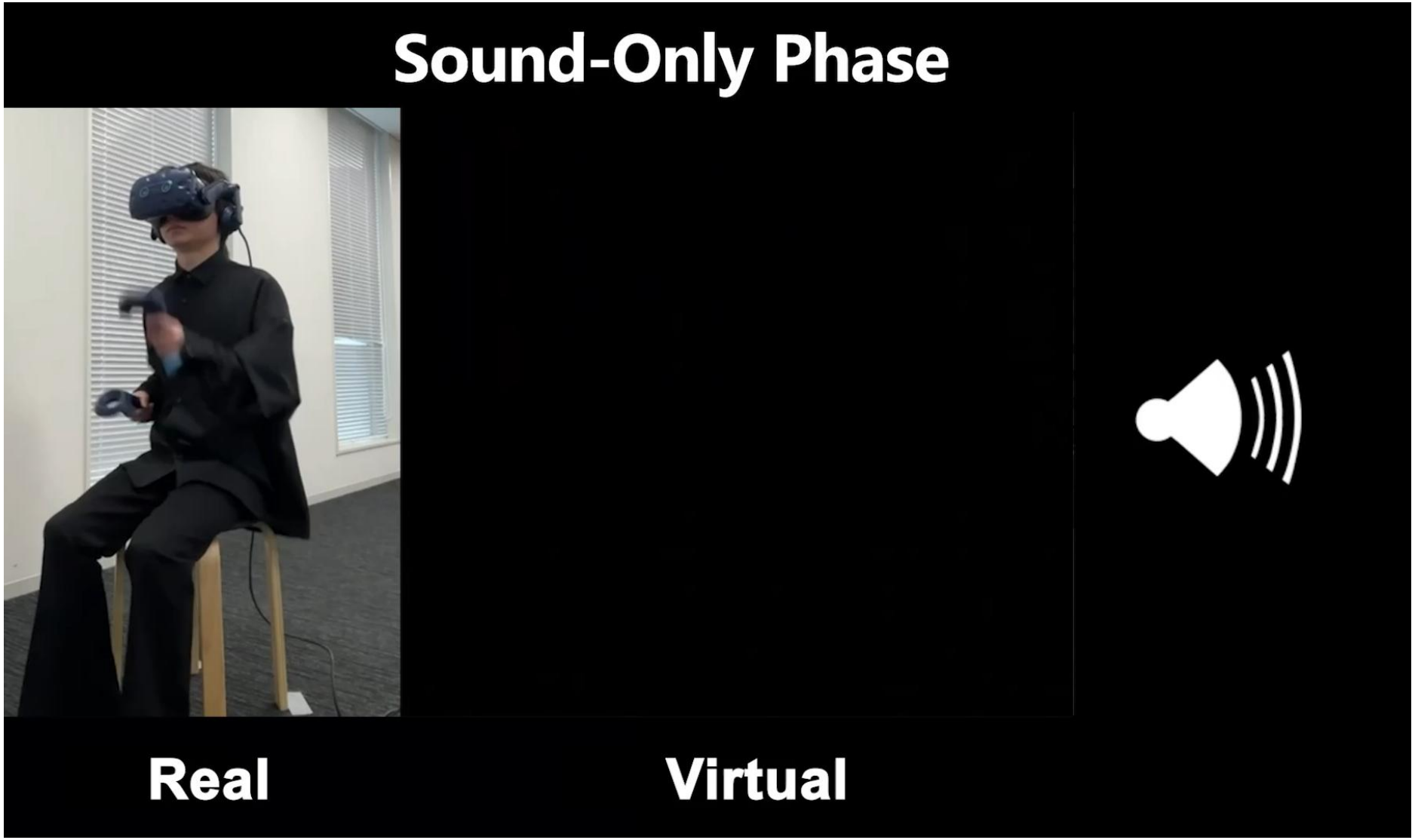
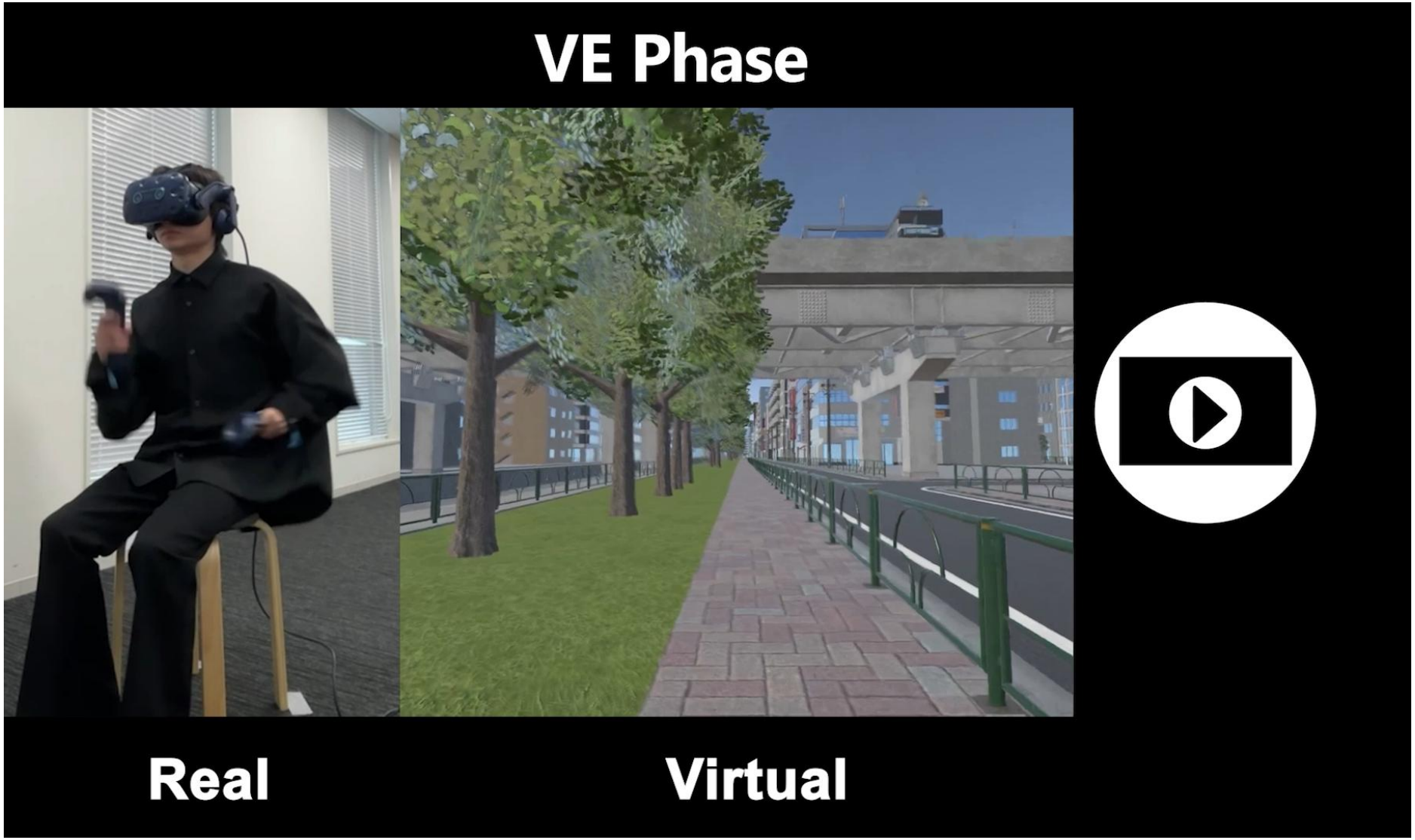


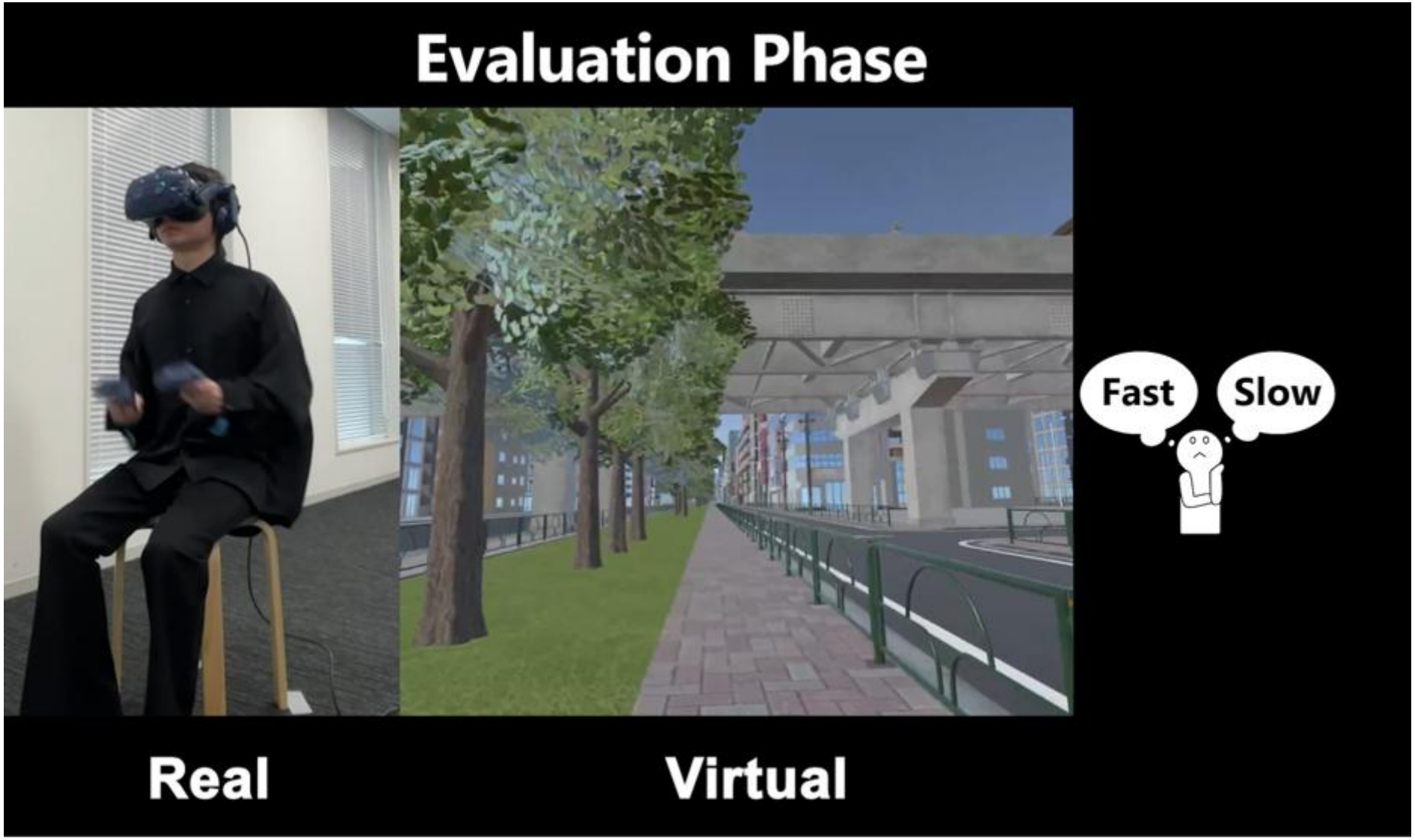
Study 2 Method :
How We Measured "Natural" Speed



Study 2 Method :
How We Measured "Natural" Speed

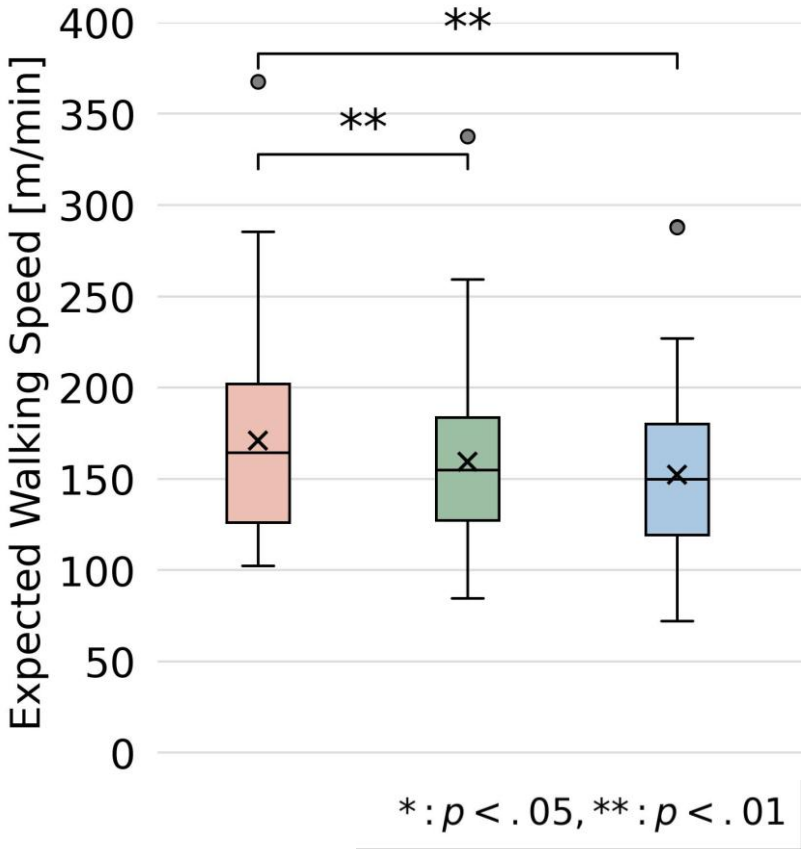


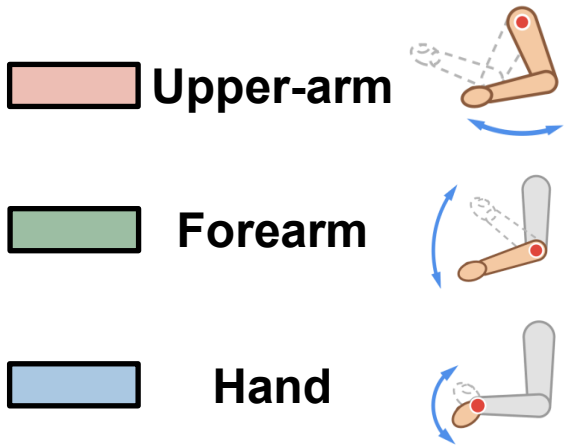
Study 2 Method :
How We Measured "Natural" Speed



Study 2 Results : Speed Expectations

- **Upper-arm Swinging** was expected to be **faster** than other swingings.





Answer to RQ2

RQ2: Does the primary joint change expected walking speed?

Yes.

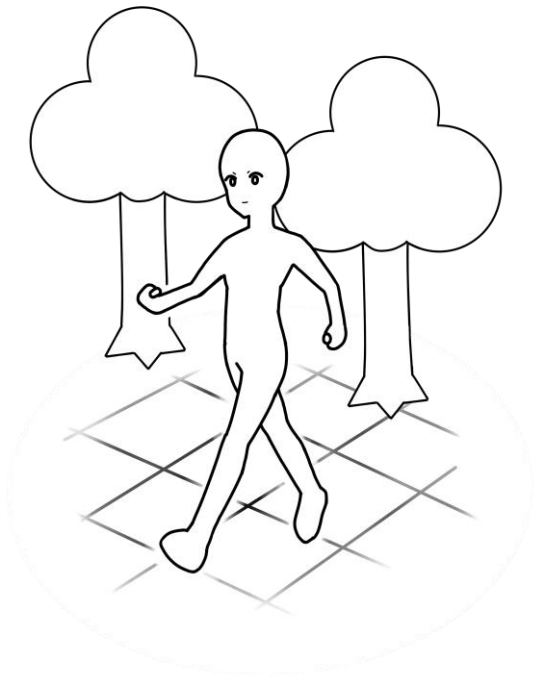
Swinging from the **shoulder** made users expect a **faster** walking speed than swinging from the elbow or wrist.

Answer to RQ2

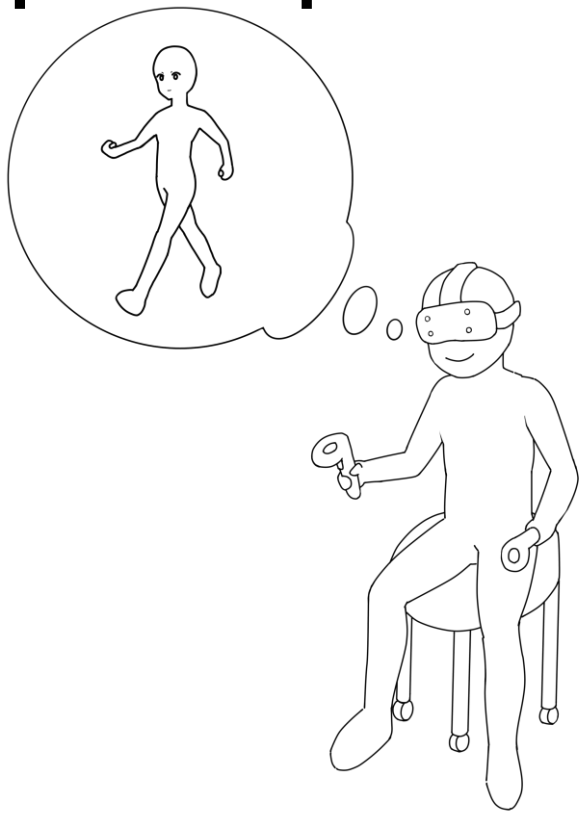
Why does Upper-arm Swinging feel faster?
Does each gesture's achievable tempo influence it?

Overview of the Three-Part Study

Study 1
User Experience



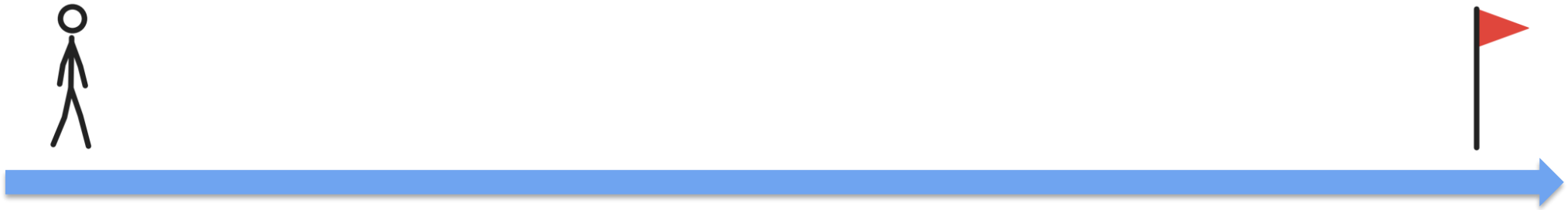
Study 2
Speed Expectations



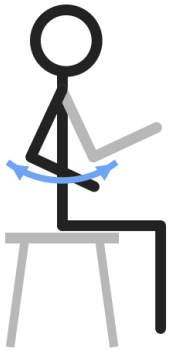
Study 3
Motor Characteristics



Study 3 Method:
How We Measured Input Tempo

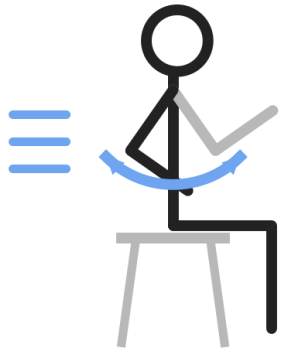


Virtual Walking: 50 m



Normal Walking

gesture at a natural tempo

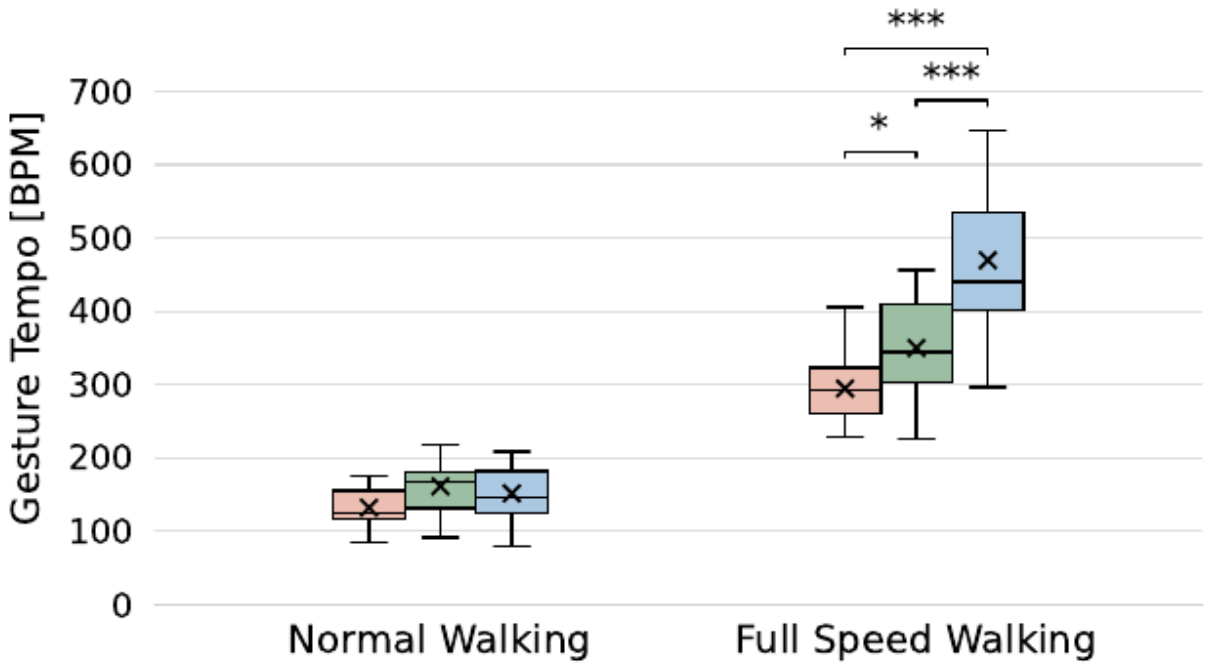


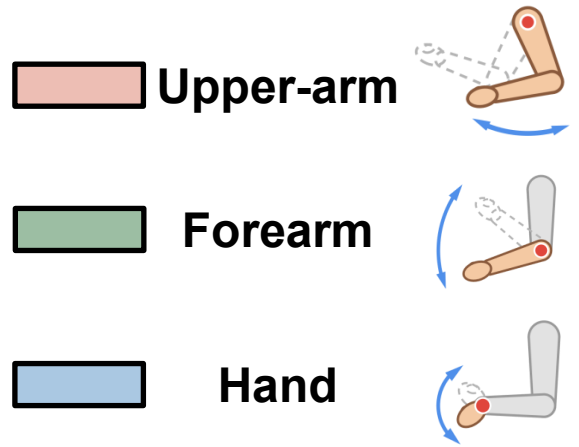
Full Speed Walking

gesture as fast as possible

Study 3 Results: Motor Characteristics

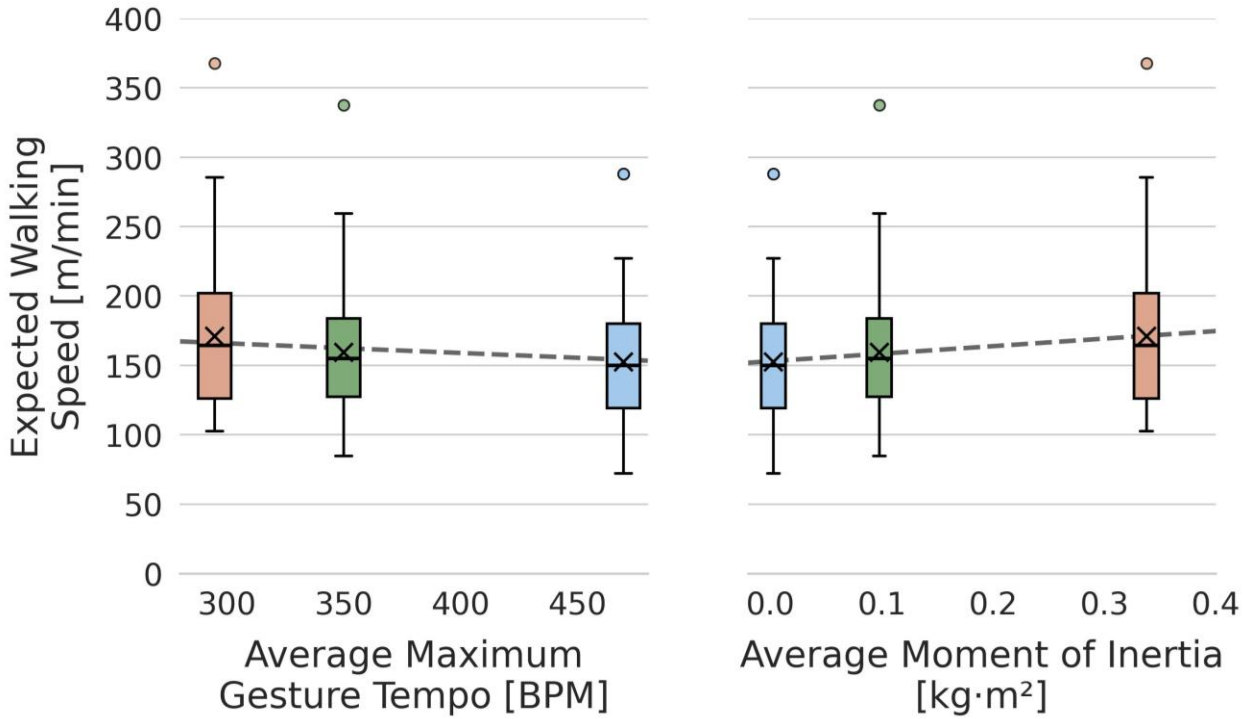
- **Full speed:** Hand > Forearm > Upper-arm
  - Heavier segment → slower max tempo

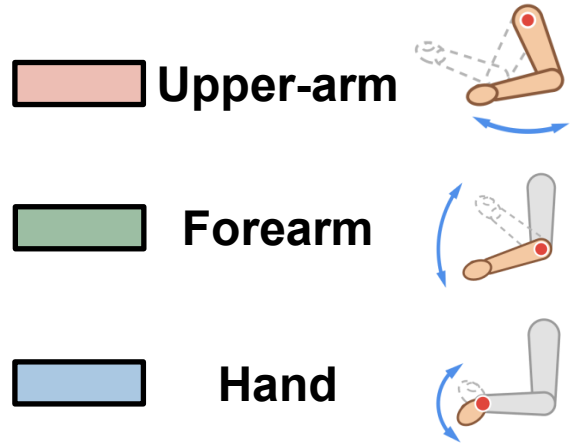




Further Analysis: Heavier Feels Faster

- **Higher max tempo** → **lower** expected speed
- **Larger moment of inertia** → **higher** expected speed





Answer to RQ3

RQ3: What explains the difference in expected walking speed?

Gestures with a **lower maximum tempo** and a **larger moment of inertia** were associated with a **faster** expected walking speed.

Discussion

Heavier gestures cannot be swung as fast.

Users may use this **physical constraint as a cue** to scale up their expected speed.

The **primary joint** should be considered and reported.

Conclusion

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RQ1

Does it affect user experience?

Yes. Upper-arm Swinging  showed higher **Physical Demand** than Hand Swinging .

RQ2

Does it affect expected walking speed?

Yes. Upper-arm Swinging  led to a **faster** expected walking speed than Forearm  and Hand Swinging .

RQ3

What explains the difference

A **lower maximum tempo** and a **larger moment of inertia** were associated with a faster expected walking speed.