Intent perception of human and non-human agent during ball throwing task in Virtual Reality

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Introduction

During recent years virtual reality (VR) became increasingly popular as a tool in training scenarios aiming at improved motor function, such as sports training or physiotherapy. While the main focus of such tasks is high intensity and repeatability of the trained movement, the **perception of the movement of the interaction partner was also shown to play an important role in the motor learning process** [1-3]. However, it is yet unclear to what level are humans able to perceive subtle movement cues in VR.

Does the motion of highly realistic virtual avatars provide enough cues about the intent of the action?

Materials & Methods

Virtual Ball Catching

- **Task:** Catch the virtual ball thrown by the avatar using the hand-held controller.

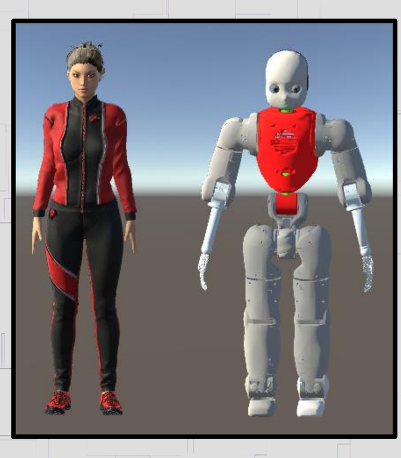
  Attempt to catch the ball every time!
- Report on experiences via questionnaire.

Stimulus Generation

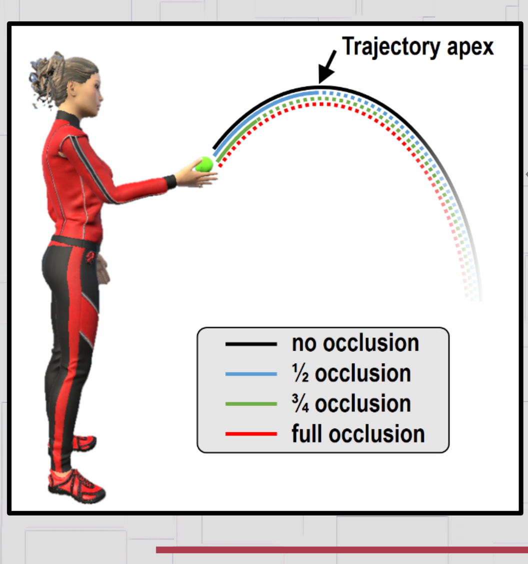
Virtual Throws:

- Based on 28 recorded under-hand throwing movements
- Each throw is retargeted to human-like and robot avatars
  - Avatars are the same height
  - Hand trajectory is the same
  - Ball release point/time is same

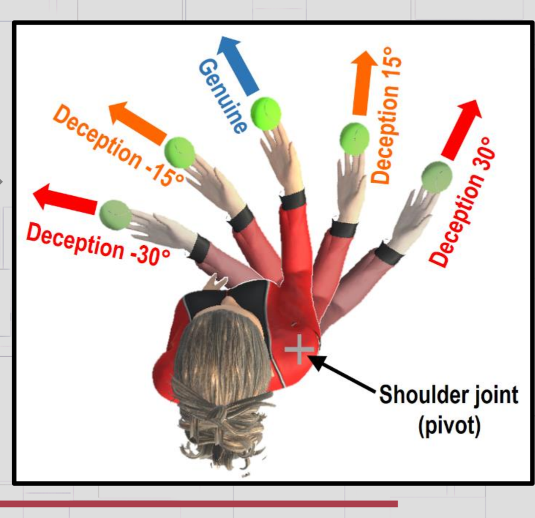
  ⇒ Ball trajectory remains invariant



Conditions:



- Body rotation (direction avatar is facing)
- Ball occlusion
- Deceptive throws
- Trigger press delay (controller trigger press time window for successful catch)



Experimental Paradigm

Experiment 1: Genuine Throws

Familiarisation
- (8 [human] + 8 [robot]) x 1 [*random* body rotation] = **16 throws**
- 110 ms trigger press delay

"Constant" trigger delay group
- (20 [human] + 20 [robot]) x 3 [body rotation] x 4 x 1 [trigger press delay] = **480 throws**
- 77 ms trigger press delay per block

"Adaptive" trigger delay group
- (20 [human] + 20 [robot]) x 3 [body rotation] x 4 [trigger press delay] = **480 throws**
- 110, 88, 66 & 44 ms trigger press delay, decreasing over every experimental block

Experiment 2: Deceptive Throws (Pilot)

Familiarisation
- 8 [human] x 4 [body rotation] = **32 throws**
- Genuine fully visible throws
- 70 ms trigger press delay

"Deception" group
- 8 [human] x 4 [body rotation] x 4 [ball occl.] x (1 [genuine] + 4 [deceptive]) = **640 throws**
- 70 ms trigger press delay

- 20 right-handed subjects (13♀, 27.2 ± 8.7 y.o.) participated in Experiment 1
- 4 right-handed subjects (1♀, 29.8 ± 6.1 y.o.) participated in Experiment 2
- Subjects all with various VR experience were naïve to the purpose of the task
- Dependent variables: **catching (spatial) accuracy** (successful catches & ball-controller distance)

  trigger press (temporal) accuracy (timing of trigger-press w.r.t. ball position)

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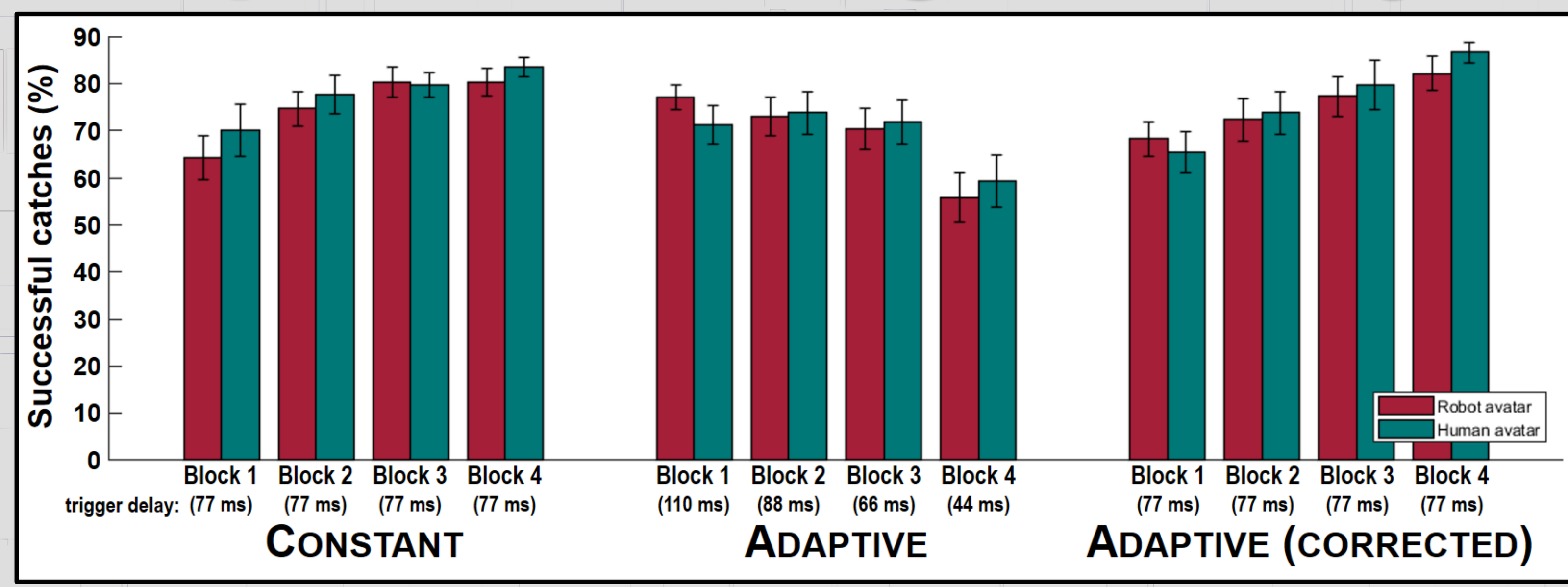
Results

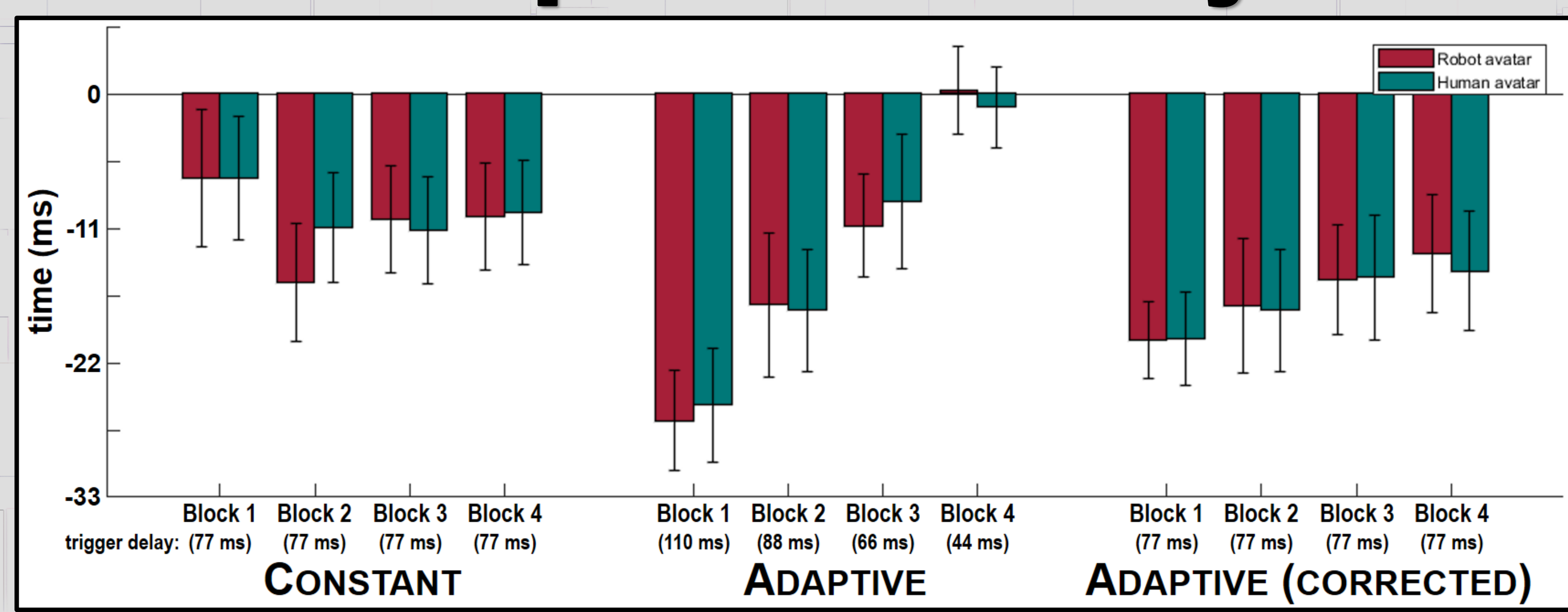
Ex1: Spatial Catching Accuracy



- All subjects **performed well** on the ball catching task (56-91%).
- Adaptive group seemingly performed worse than constant group. However, correcting the trigger press timing to be same as constant group …

  … resulted in **comparable performance** between the two groups.
- Success rate for catching ball thrown by each avatar did not differ significantly.
- Increasing performance over time indicates that **subjects continuously learned** the task ($p < 0.001$)

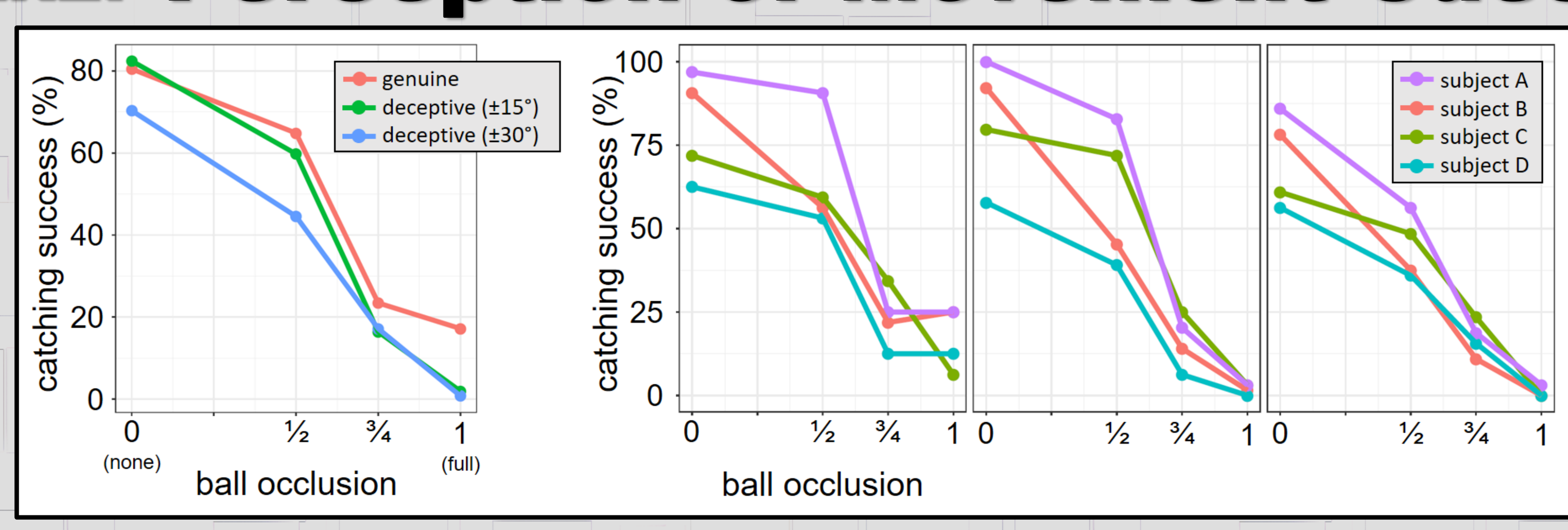
Ex1: Temporal Accuracy



* successful catches only

- Negative average temporal timing of trigger press indicates that subjects mostly **press the trigger early**, potentially leading to ball misses.
- **Temporal accuracy increased slightly** over time (not significant, $p = 0.096$).

Ex2: Perception of Movement Cues



- Ball **occlusion affects** the number of **successful catches** ($p < 10^{-16}$)
- However, main **effect of deception is not significant** ($p = 0.2$)
- NOTE: For genuine throws, at full occlusion the subjects were more successful at intercepting the ball (~20%) than during deceptive throws (< 5%).

  ⇒ Virtual body movement cues possibly reveal throwing direction

Conclusions

- When intercepting virtual ball subjects **rely mostly on** its **trajectory**, but are also able to **estimate the trajectory by observing the body movement cues** of the avatar only.
- The high level of **spatial and temporal accuracy** during the catching task and **high immersion scores** suggest prominent degree of **naturalness** of the virtual reality environment.
- Additional subjects needed for comprehensive analysis of deception effect on performance.
- Hardware improvements (e.g. **haptic glove**) to enhance VR immersion

References

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