Effects of Virtual Environments and Self-representations on Redirected Jumping

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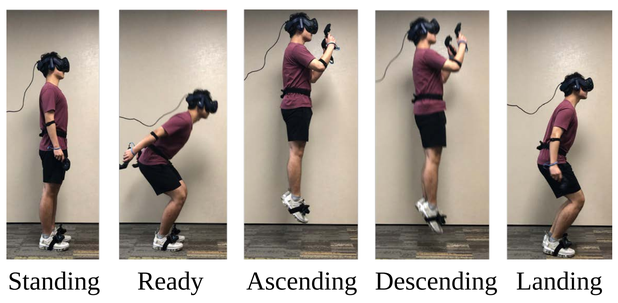
Introduction

- Recently, Redirected Jumping (RDJ) has become hot topics in VR locomotion. RDJ technique was firstly proposed in 2019 [1]. Previous work has measured thresholds of unnoticeable gains for horizontal translation, vertical translation, rotation manipulation and curvature manipulation [1, 2]. The detection thresholds of RDJ have wider ranges than those of redirected walking (RDW).
- Users heavily rely on the visual cues of the virtual environment (VE) and the modeling of feet to perceive the manipulation of translation gains in RDW [3].
- We conducted a comprehensive user study that investigated the effects of virtual environments and self-representations (SRs) on the perception and physical performance of RDJ.

Experiment Design

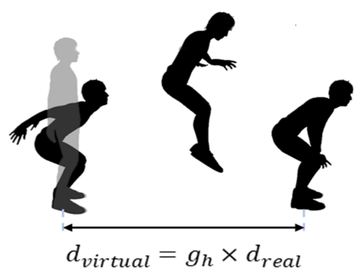
- Jumping state: 5 phases, gain was applied during *ascending* and *descending* phases.



- Horizontal translation gain:

$$g_h = \frac{d_{virtual}}{d_{real}}$$

- One-time two-legged takeoff jumping

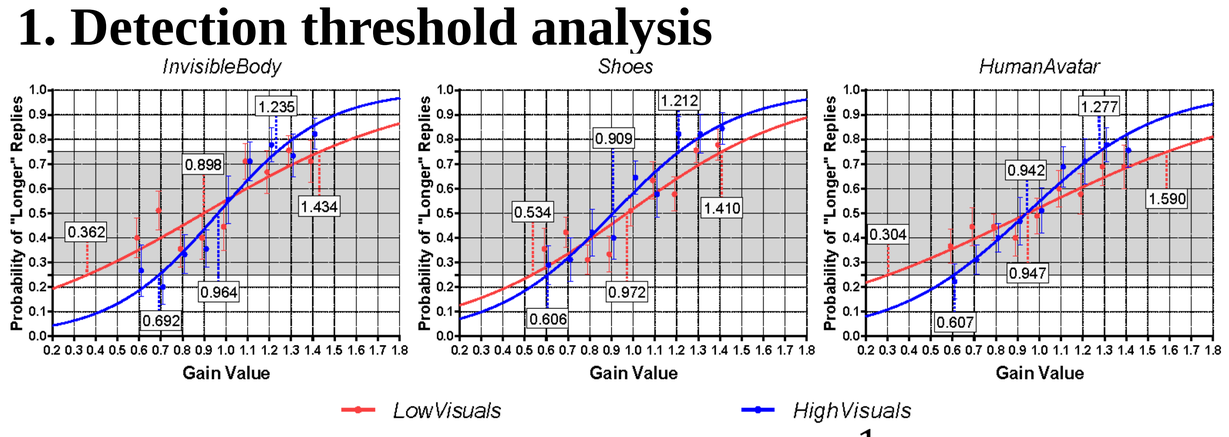


- Pseudo-two-alternative forced-choice experimental design:
  Two VEs were tested:
  - **Low Visual Richness (*LowVisuals*):** a scene composed of a skybox and a plane (5m*5m regular grids were painted).
  - **High Visual Richness (*HighVisuals*):** a scene of a forest with rich visual cues, such as trees, grass, and bridges.
  For each VE condition, three SR conditions were tested:
  - **Invisible Body (*InvisibleBody*):** a fully transparent body.
  - **Shoe Representation (*Shoes*):** a pair of shoes were visible.
  - **Human-like Avatar (*HumanAvatar*):** a human-like avatar was chosen from the pre-created male and female avatars.
- Subjective measurement:
  IPQ, GFP, IMI, SSQ
- Objective measurement:
  1. Preparation time during jumping
  2. Actual jumping distance

Total jumping:
15 participants
×
9 gains (0.6~1.4 in 0.1 intervals)
×
6 conditions (2VEs × 3SRs)
×
3 trials of repetition

Results

1. Detection threshold analysis



- Fitted psychometric function: $y = \frac{1}{1+b\times e^{-ax}}$
- Detection Threshold:
  Lower Detection Threshold (LDT): 25% probability value
  Upper Detection Threshold (UDT): 75% probability value
  Point of Subjective Equality (PSE): 50% probability value

Two-way repeated measures ANOVA
- LDT in *LowVisuals* was significantly smaller than that in *HighVisuals* ($p = .041$)
- UDT in *HighVisuals* was significantly smaller than that in *LowVisuals* ($p = .020$)
- No significant main effect of SRs was found on detection thresholds.

2. Subjective analysis

Measure	Effect	df	F	η^2	p
IPQ	VE	1, 14	28.92***	.674	<.0001
	SR	2, 28	8.79**	.386	.001
	VE×SR	1.32, 18.43	1.31	.085	.28
GFP	VE	1, 14	18.65***	.57	<.001
	SR	1.27, 17.75	26.34***	.653	<.0001
	VE×SR	1.34, 18.81	.31	.022	.649
IMI-T	VE	1, 14	10.90**	.483	.005
	SR	1.44, 20.11	1.37	.089	.269
	VE×SR	2, 28	1.92	.121	.165
IMI-E	VE	1, 14	25.34***	.644	<.0001
	SR	2, 28	12.54***	.472	<.0001
	VE×SR	1.23, 17.23	.87	.058	.388

** $p < 0.01$ *** $p < 0.001$

3. Objective analysis

Two-way repeated measures ANOVA
- In *HighVisuals,* the average preparation time with *HumanAvatar* was higher than that with *InvisibleBody* ($p = .023$) or *Shoes* ($p = .008$).
- The actual jumping distance with *InvisibleBody* was significantly longer than those with *Shoes* ($p = .028$) and *HumanAvatar* ($p = .007$) in both *LowVisuals* and *HighVisuals* VEs.

Conclusion

- The range of unnoticeable translation gains is smaller in the high visual richness VE than that in the low visual richness VE. However, we hardly found significant differences of gain thresholds among different SRs.

Reference

[1] O. Hayashi, K. Fujita, K. Takashima, R. W. Lindeman, and Y. Kitarnura. Redirected jumping: Imperceptibly manipulating jump motions in virtual reality. In *2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*, pp. 386–394. IEEE, 2019.
[2] S. Jung, C. W. Borst, S. Hoermann, and R. W. Lindeman. Redirected jumping: Perceptual detection rates for curvature gains. In *Proceedings of the 32nd Annual ACM Symposium on User Interface Software and Technology*, pp. 1085–1092, 2019.
[3] L. Kruse, E. Langbehn, and F. Steinicke. I can see on my feet while walking: Sensitivity to translation gains with visible feet. In *2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*, pp. 305–312. IEEE, 2018.