Learning and generalization of an obstacle negotiation task in virtual reality

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Introduction

- Obstacle negotiation is an essential skill for everyday locomotor performance.
  - Physical interventions for people who have a high risk of falls often involve obstacle negotiation training.

- Recent studies have demonstrated that foot clearance during obstacle negotiation can be trained in a goal-oriented manner by providing people with auditory feedback of errors between actual and desired levels of foot clearance[1-2].

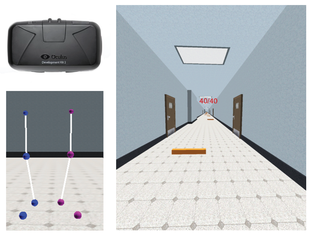
- Although the performance of this skill can be improved within a single day of training, it remains to be seen how this type of locomotor skill is retained and generalized to over-ground walking.

- Here, we developed *a novel virtual obstacle negotiation task* to assess how locomotor skills are learned in fully-immersive virtual environments and how this learning generalizes to obstacle negotiation in the real world.

Methods

Participant characteristics

N	Age	Leg length (LL)
19(10 F)	26±4	0.89±0.06 m



Experimental settings

- Four reflective markers on the toe, heel, knee and hip on each leg, and one marker on Oculus Rift DK2
- Walking in a virtual hallway with a full link-segment lower extremity model

Experimental protocol

Day 1

Object height estimation in the real world	Obstacle negotiation in the real world (PRE)	Object height estimation in VR	BLOCK 1 40 obstacles w/ feedback	BLOCK 2 40 obstacles w/ feedback	Obstacle negotiation in the real world (POST)	BLOCK 3 40 obstacles w/ feedback	24 hours	Retention 40 obstacles w/o feedback	Obstacle negotiation in the real world (RET)

Day 2

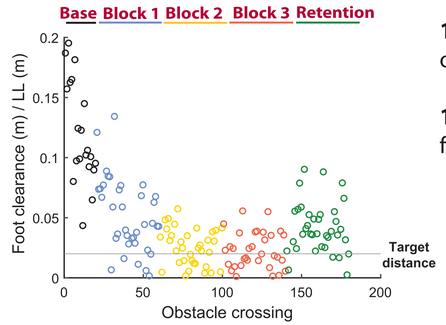
- Four object height estimation
  - Instruction: *"I will place a box 3 steps in front of you. Lift your foot even with the top of the object."*
  - 5 trials per leg per object (5X2X4)
- Obstacle negotiation
  - Instruction: *"Minimize the vertical distance between your foot and the obstacle. You will receive auditory feedback according to your foot clearance distance."*
  - Feedback
    - A pleasant sound: Foot clearance was within a target range of 0-2 cm
    - An error sound which scaled with foot height: foot clearance was greater than 2cm
    - A failure sound: During a collision

Outcome Variables

- Foot clearance (minimum distance while crossing an obstacle) in VR and the real world
- Estimated heights of objects

Results

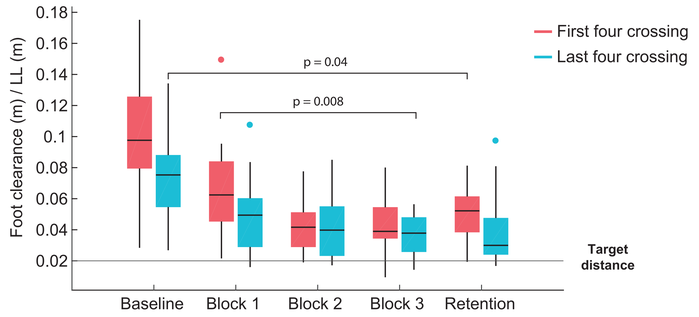
1. Representative foot clearance shows a gradual reduction in foot clearance throughout practice blocks and retention



1.1 Foot clearance gradually decreased on Day 1.

1.2 There was a slight increase in the foot clearance during retention.

2. Goal-oriented obstacle negotiation was improved, and the skill was retained in virtual reality on the next day

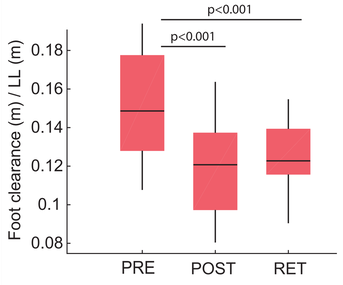


2.1 A significant reduction in foot clearance was observed during the acquisition period.

2.2 Initial and final performance on Day 2 without auditory feedback was not significantly different than the final performance of Day 1 with feedback.

2.3 Performance on Day 2 significantly improved compared to the baseline.

3. The improvements observed in the virtual environment also transferred to the real world

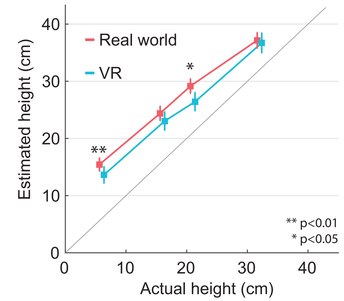


3.1 The over-ground foot clearance after two blocks of skill training was reduced compared to the foot clearance before training.

3.2 The reduction in over-ground foot clearance was maintained during the retention period.

Results

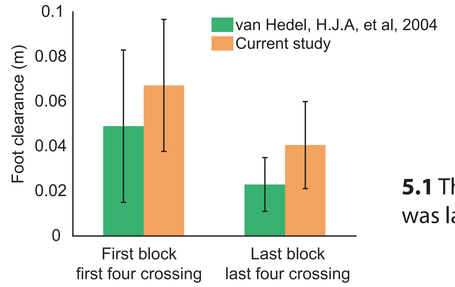
4. Object height was consistently overestimated in VR and the real world



4.1 Object height was generally overestimated to a lesser extent in VR than the real world.

4.2 Lower heights were significantly less overestimated in VR than the real world.

5. Skill acquisition in our virtual environment was similar to a previous study using physical obstacles



5.1 The magnitude of foot clearance was larger in VR than the real world

Conclusions

1. Our findings suggest that a VR obstacle negotiation task can be learned and retained on the next day, and the skill can be transferred from VR to the real world.

2. Although object height was overestimated in both VR and the real world in contrast to previous findings[3], the overestimation was consistently less in VR.
- There may be a safety buffer when people estimate object height, which may be more prominent in the real world due to the real threat of potential tripping.

3. Similar improvements in the previous and current study provide evidence of feasibility of the paradigm in VR, supporting potential therapeutic applications of VR for locomotor skill learning.

References

1. T. Erni & V. Dietz. *Journal of Physiology* (2001). **2.** H. J. A van Hedel & V. Dietz. *Clinial Neurophysiology* (2004). **3.** Renner et al. ACM Computing Surveys (2013)

Acknowledgements

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