sEMG-Based Assessment of Engagement in VR-Integrated BALANSens Ankle Rehabilitation

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Introduction

- Robotic rehabilitation suffers from low patient adherence due to repetitive exercises.
- VR environments enhance engagement and motivation by providing immersive, interactive therapy.
- This study explores VR's impact on motivation and adherence using sEMG-based assessment.

BALANSens Robotic Platform

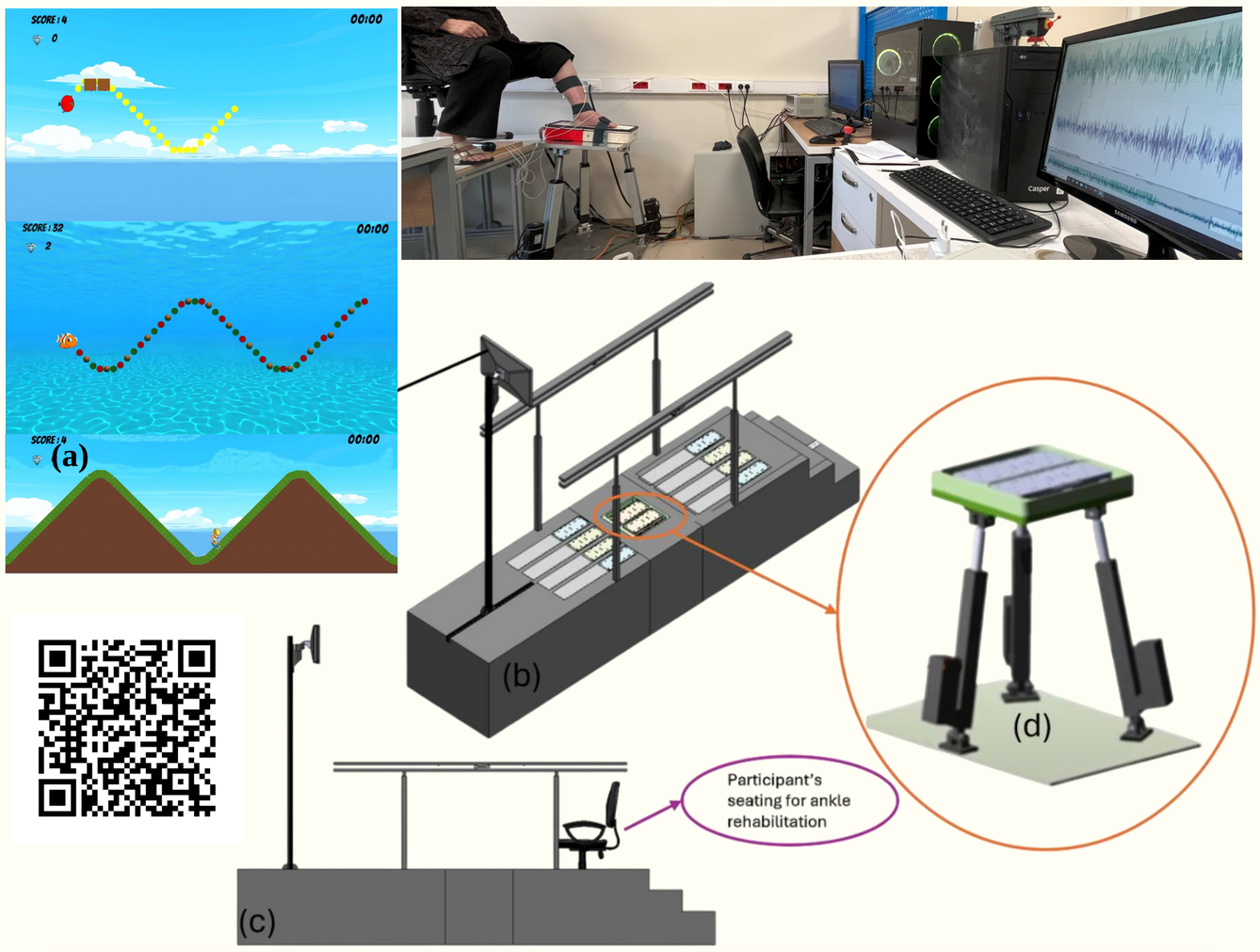
- 3-DOF parallel manipulator using a revolute-prismatic-spherical (RPS) configuration
- Provides balance rehabilitation with multiple feedback modalities
- Adjusts range of motion (RoM) individually for safe interaction

Design of Virtual Reality Environment

- Based on key motivational frameworks
- Features challenge and variability to sustain engagement
- Participants control a VR proxy (e.g., a bird collecting coins) using dorsiflexion (DF) and plantarflexion (PF) movements.

Real-time sEMG Recording & Conditioning

- sEMG signals collected using Biosignal Plux© sensors
- Electrodes placed on tibialis anterior and gastrocnemius muscles
- sEMG features extracted by using energy-based analysis



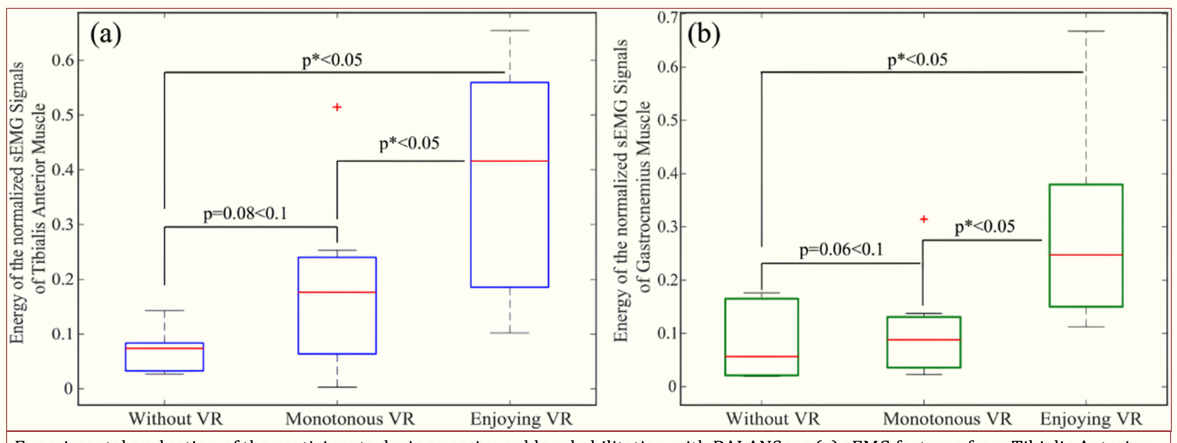
BALANSens Platform with VR feedback (a) Designed games for passive ankle rehabilitation (b) Isometric view of BALANSens platform (c) Rear view of BALANSens platform, prepared for ankle rehabilitation (d) 3RPS parallel manipulator

Experimental Procedure

- Session 1: Passive ankle rehabilitation with three conditions:
  - Without VR
  - Monotonous VR
  - Enjoyable VR
- Session 2: Active ankle rehabilitation with different difficulty levels
  - Easy task
  - Challenging task
- Seven healthy volunteers (aged 20-42) participated.
- Engagement measured using sEMG signals and Intrinsic Motivation Inventory (IMI) questionnaire

Results

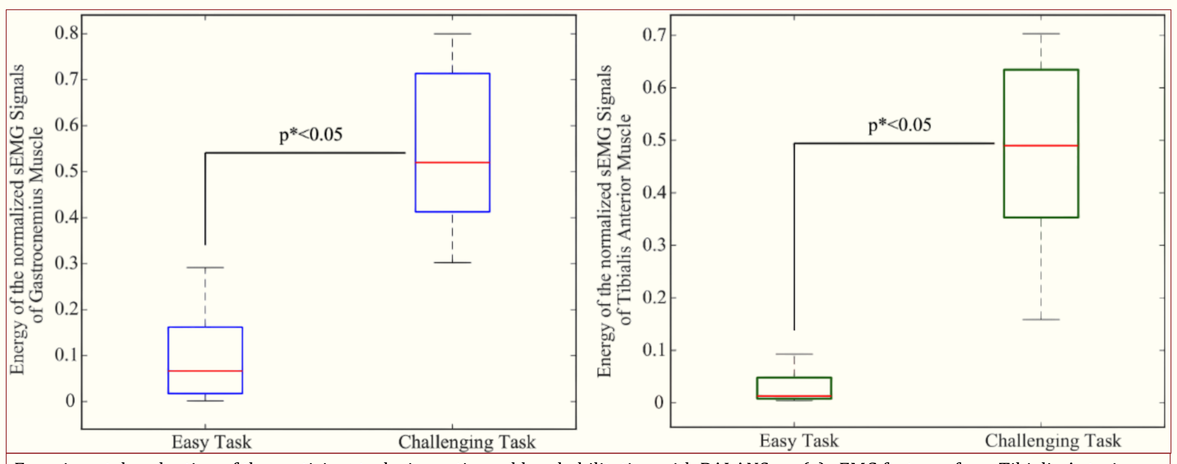
- sEMG signals showed significantly higher engagement in the enjoyable VR condition.
- Significant increase in sEMG energy feature during challenging tasks compared to easy tasks in VR.
- IMI questionnaire results correlated higher interest and effort scores with engaging VR scenarios.



Experimental evaluation of the participants during passive ankle rehabilitation with BALANSens (a) sEMG features from Tibialis Anterior muscle (b) sEMG features from Gastrocnemius muscle

Conclusion

- VR integration in robotic rehabilitation significantly enhances engagement, which is proven by sEMG analysis.
- Combining motivation questionnaires with sEMG data provides a strong evaluation framework.
- Experimental results confirm the feasibility and effectiveness of the approach.
- Future studies will explore long-term effects and clinical applications for stroke patients.



Experimental evaluation of the participants during active ankle rehabilitation with BALANSens (a) sEMG features from Tibialis Anterior muscle (b) sEMG features from Gastrocnemius muscle

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