User Testing Procedure for Hololimb VR Application Single-Session Feedback Collection

1. Introduction

Purpose

This document outlines the procedure for conducting a single-session user test of the **HoloLimb VR application** with one participant. The aim is to gather detailed feedback on the application's **usability**, **comfort**, and **effectiveness** in facilitating the therapeutic task of mirroring for phantom limb pain (PLP). The application supports both **Augmented Reality (AR)** and **Virtual Reality (VR)** modes, and participants will experience both conditions during the session. Feedback will be collected through questionnaires and interviews to evaluate the user experience, cognitive load, and pain perception.

Task

- **Mirroring**: In the Mirroring task, users will perform movements with their intact arm, which will be replicated in real-time on a completely virtual arm.
- The application has been developed in two different technologies: **Augmented Reality (AR)** and **Virtual Reality (VR)**. At any time, users can experience both conditions thanks to a built-in feature that allows switching between AR and VR.
- At the end of each experience, users will complete questionnaires to evaluate the **cognitive load** of the task and their overall experience.

Research Questions (RQ)

1. **RQ1**: Does the application make the therapeutic task a positive experience?
2. **RQ2**: Is the therapeutic task facilitated through the use of the application?

Research Variables

- **V1. Experience Satisfaction** (related to RQ1):
  - V1.1 Evaluation of the overall experience.
  - V1.2 Evaluation of the AR/VR switching feature.
- **V2. Cognitive Effort** (related to RQ2):
  - V2.1 Evaluation of cognitive load.
- **V3. Pain Perception** (related to RQ3):
  - V3.1 Evaluation of pain pre/post-session (single session).
  - V3.2 Evaluation of long-term effects.

Measurement Tools

Variable	Object	Tool	When	Who
V1.1	Evaluation of the experience	UEQ (User Experience Questionnaire)	After the experience	Experimenter
V1.2	Evaluation of AR/VR switching	Open-ended questions about interaction	After the experience	Experimenter
V2.1	Evaluation of cognitive load	NASA-TLX (Task Load Index)	After the experience	Experimenter
V3.1	Evaluation of pain pre/post	VAS (Visual Analogue Scale) / NRS	Before and after the experience	Experimenter
V3.2	Evaluation of long-term effects	Brief Pain Inventory (BPI)	After each session	Experimenter

2. Preparation

2.1 Equipment Needed
- **HoloLimb VR application** installed on a **Meta Quest 3** headset.
- Computer for streaming the experience (headset and computer must be on the same network).
- Internet connection (WiFi or 4G).
- Timer or stopwatch to track session duration.
- Comfortable seating and a quiet, well-lit environment.

2.2 Participant Requirements
- **Inclusion Criteria**:
  - Age ≥ 18 years.
  - Unilateral upper-limb amputation.
  - Chronic phantom limb pain (persistent for at least 3 months).
  - Proficiency in Italian.
- **Exclusion Criteria**:
  - Severe psychiatric disorders.
  - Epilepsy or sensitivity to virtual reality.

2.3 Pre-Testing Setup

1. **Informed Consent**:
   - ○ Explain the purpose of the test, what the participant will do, and how their data will be used.
   - ○ Obtain written consent.
2. **Baseline Information**:
   - ○ Collect demographic information (age, gender, time since amputation).
   - ○ Briefly explain the HoloLimb application and its purpose.

---

3. Testing Procedure

3.1 Session Structure

- **Duration**: 15 minutes.
- **Objective**: Evaluate the application's usability, cognitive load, and effectiveness in reducing phantom limb pain.

3.2 Steps for the Session

1. **Pre-Session**:
   - ○ Start the HoloLimb application on the Meta Quest 3 headset.
   - ○ Enable streaming from the headset to the experimenter's computer.
   - ○ The participant completes pre-session questionnaires:
     - ■ **VAS (Visual Analogue Scale)** and **NRS (Numerical Rating Scale)** for pain assessment.
2. **During the Session**:
   - ○ Start the **Mirroring Task**:
     - ■ The participant performs movements with their intact arm, which are replicated in real-time on a virtual arm.
     - ■ The participant switches between **AR** and **VR** modes using the application's built-in feature.
   - ○ Monitor the participant for any signs of discomfort or motion sickness.
3. **Post-Session**:
   - ○ The participant completes post-session questionnaires:
     - ■ **UEQ (User Experience Questionnaire)** for overall experience.
     - ■ **NASA-TLX (Task Load Index)** for cognitive load.
     - ■ Open-ended questions about the AR/VR switching feature.
   - ○ Conduct a brief interview to gather qualitative feedback (see **Section 5**).

---

4. Feedback Form (Close-Ended Questions)

4.1 Scoring Parameters
- Use a **5-point Likert scale** for close-ended questions:
    - 1 = Strongly Disagree
    - 2 = Disagree
    - 3 = Neutral
    - 4 = Agree
    - 5 = Strongly Agree

4.2 Questions
1. The VR headset was comfortable to wear.
2. The application was easy to use.
3. The virtual limb looked realistic.
4. The movements felt natural and intuitive.
5. The application helped me feel more connected to my missing limb.
6. I experienced any discomfort or motion sickness during the session.
7. I would use this application regularly to manage my phantom limb pain.
8. The instructions provided were clear and easy to follow.
9. The session duration (15 minutes) was appropriate.
10. Overall, I am satisfied with the HoloLimb application.

---

5. Open-Ended Questions for Interview

5.1 Usability
1. What did you like most about the application?
2. Were there any aspects of the application that you found difficult or confusing?
3. How would you describe the overall ease of use of the application?

5.2 Comfort and Immersion
4. How comfortable was the VR headset during the session?
5. Did you experience any discomfort or motion sickness? If yes, please describe.
6. How immersive did you find the virtual limb experience?

5.3 Effectiveness
7. Do you feel the application helped you connect with your missing limb? If yes, how?
8. Did you notice any changes in your phantom limb pain during or after the session?

5.4 Suggestions for Improvement

9. What improvements would you suggest for the application?
10. Are there any additional features or exercises you would like to see in the application?

---

6. Data Collection and Reporting

6.1 Data Collection

- **Quantitative**: Record scores from the close-ended questions (**UEQ, NASA-TLX, VAS, NRS**).
- **Qualitative**: Summarize responses from the open-ended questions.

6.2 Reporting

1. **Introduction**: Purpose and objectives of the test.
2. **Methodology**: Testing procedure and data collection methods.
3. **Results**:
   - Quantitative: Average scores for each close-ended question.
   - Qualitative: Key themes and suggestions from open-ended questions.
4. **Discussion**: Interpretation of results and implications for future improvements.
5. **Conclusion**: Summary of findings and recommendations.

Bibliography

References

1. Finn, S. B., Perry, B. N., Clasing, J. E., Walters, L. S., Jarzombek, S. L., Curran, S., Rouhanian, M., Keszler, M. S., Hussey-Andersen, L. K., Weeks, S. R., Pasquina, P. F., & Tsao, J. W. (2017). A randomized, controlled trial of mirror therapy for upper extremity phantom limb pain in male amputees. *Frontiers in Neurology, 8*, 267. https://doi.org/10.3389/fneur.2017.00267
2. Purushothaman, S., Kundra, P., Senthilnathan, M., Sistla, S. C., & Kumar, S. (2023). Assessment of efficiency of mirror therapy in preventing phantom limb pain in patients undergoing below-knee amputation surgery—a randomized clinical trial. *Journal of Anesthesia, 37*(3), 387–393. https://doi.org/10.1007/s00540-023-03173-9