Wearable Technology and Mobile Healthcare (WTMH) Lab

Mixed Reality Mirror Therapy System: Integrating Task-Oriented Stroke Rehabilitation with Physical Haptic Feedback and EEG Evaluation

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Abstraction

Stroke is one of the leading causes of disability today, with hemiplegia as its main aftereffect, impairing motor and sensory functions on one side of the body. Mirror therapy uses a mirror to reflect the unaffected healthy hand onto the affected side, utilizing brain illusions to enhance neuroplasticity in rehabilitation. In recent years, VR and AR have been increasingly applied in rehabilitation therapy, each with advantages and limitations in terms of environmental realism and interactivity. This study improves upon the original VRMT system by adding a transparent background for mixed reality, combining mirror therapy, task-oriented rehabilitation, and tactile feedback from physical objects. The enhanced MRMT system was developed and evaluated using EEG, yielding positive results.

Introduction & Objective

In previous research and systems developed by our lab, both VR and AR had areas for improvement in mirror therapy.

- VRMT
  - virtual environment
  - inability to change direction
  - Lack of tactile feedback
- ARMT
  - Unable to interact
  - Lack of tactile feedback

Combine the strengths of both VR and AR, while adding a haptic feedback system to create a more realistic and multisensory stroke rehabilitation experience within a mixed reality environment.

haptic feedback

Interact with virtual Task-oriented objects

+

Hands tracking

+

Passthrough mode With 360° view

Method

System

Controll system

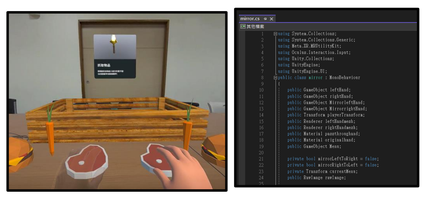
User

Meta Quest 3

Hand tracking

Software system

unity



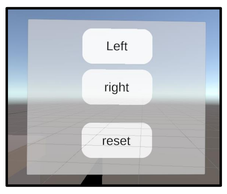
Unity & C# ➞ Rehabilitation scene

Haptic Feedback

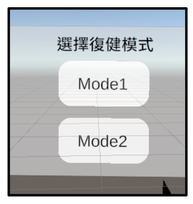
Motion Instruction

User Interface

Starting



Reset



Mode

Software Design

Mirror projection

Meta XR Interaction SDK

Capture hand joint points

Calculate reflected position/rotation Respect to camera center

Detect object that Hand grasping

Generate mirrored hand

Move mirrored object For mirrored hand

Passthrough mode

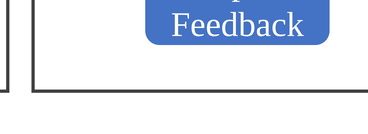
Meta MR Utility kit

Haptic feedback

Simultaneous hands and controllers

Controller as reference point

Generate virtual object & mirrored object



3D model

Unity Asset

Create Render/Collider

Experimental Design

VRMT

60 sec Black scene → Mode 1 X3 → Mode 2 X3

MRMT

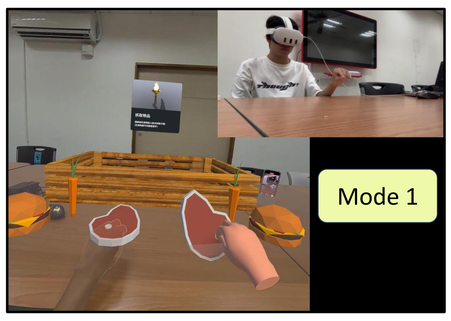
60 sec Black scene → Mode 1 X3 → Mode 2 X3

- Mode1 : Mirror Therapy + task-oriented object
- Mode2 : Mirror therapy + physical shell and projection

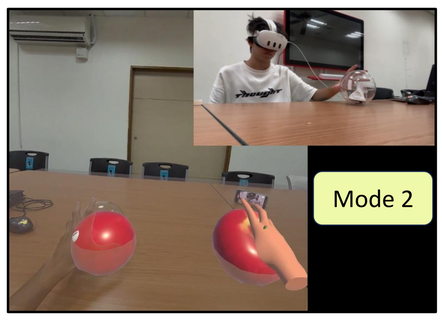
- All modes consisted of 30 seconds of rehabilitation, followed by 30 seconds of black screen rest
- No physical objects in VRMT Mode 2 , virtual object used to mimic the movements of MRMT.

Results

MRMT System



Grasp and place fruits

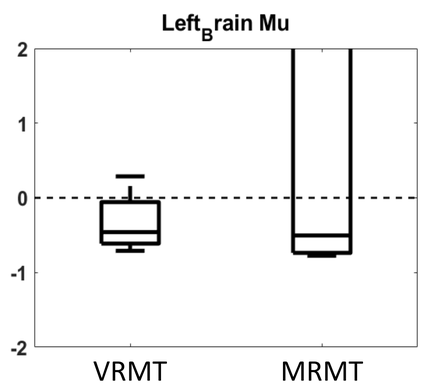


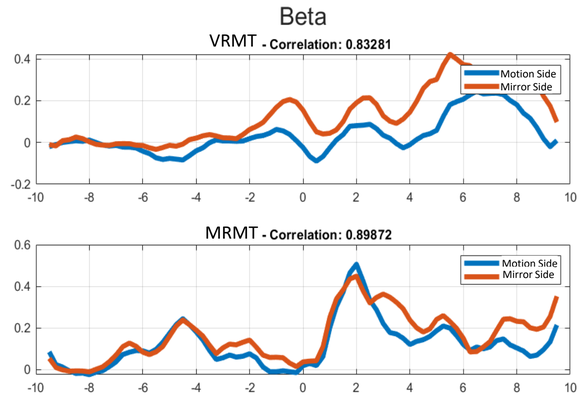
Grasp and transport apples

Demo Video

EEG Result

- In the mu wave, there was no significant difference, but both showed a trend of suppression, indicating activation of the motor cortex.
- In the beta wave, high correlation in both hemispheres, with more pronounced synchronization in MRMT, suggesting potentially better rehabilitation outcomes.





Conclusion & Future Work

Conclusion

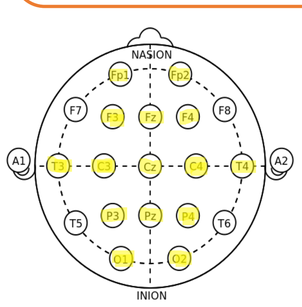
- Combining the advantages of AR and VR, complete a MRMT rehabilitation system.
- Features:
  - ➢Interact with virtual oriented objects
  - ➢Hand tracking
  - ➢360° & Passthrough environment
  - ➢Haptic feedback
- EEG result:
  - ➢Activation in motor-related brain areas
  - ➢MRMT has higher bilateral synchronization response

Future Work

- System:
  - ➢Enhance game design
  - ➢Use object detection replace controller locating
- Evaluation:
  - ➢Increase number of participants
  - ➢Additional EEG evaluations beyond ERD
  - ➢Include stroke patients for comparison

EEG Evaluation

- 15 channels EEG: Fp1, Fp2, F3, Fz, F4, T3, C3, Cz, C4, T4, P3, Pz, P4, O1, O2.
- **Preprocessing**(Independent Component Analysis(ICA), Filtering(2~50Hz))



Mu ERD (8~12Hz)

Mirror Neuron System(MNS) & Motor Cortex activation

Beta ERD (13~30Hz)

Interhemispheric Imbalance & Wider range of brain activation