Out of reach?
A novel AR interface approach for motor rehabilitation

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Outline

1. Background: ART and Motor Rehabilitation
2. *TheraMem* Game and System
3. Usability Study
4. Utility Evaluation
5. Conclusion
Augmented Reflection Technology*

*going to be published in *Presence
Augmented Reflection Technology
Augmented Reflection Technology

Client’s View

3D Scene View
Augmented Reflection Technology

Desired manipulation options:
- Mirroring: none, left, right, both
- Size: environment or limb
- Position: x, y, z
- Movement: amplitude, pace (also shake/jitter)
- Timing: slow down, speed up, delayed
- Appearance: colour, visibility
- Touch: virtual or tactile (being touched or touch)
- Temperature (real, perceived)
- Grasp: virtual or real (being grasped or grasp)
- Immersion: resolution, fps, latency
- Foreign limb vs. own limb
- ...
Augmented Reflection Technology

- Colour etc.
- Mirroring
- Size and Position
- 3D models
- 2D Backgrounds
TheraMem
TheraMem::Background

Motor Rehabilitation with VR/AR

Cameirão, Bermúdez i Badia, Oller & Verschure (2008)
TheraMem::Background

(A) VR exercise setup, (B) birdball exercise game, (C) conveyor exercise game, and (D) soccer exercise game

TheraMem::Background

Exercise

Neuroplasticity
TheraMem

Goals and Assumptions

a) The system will be used for physical (functional and motor) rehabilitation, in particular for after-stroke therapy.

b) Using a casual computer game approach increases the motivation and engagement of the clients (patients) and might distract them from pain or discomfort while moving their impaired upper limb (arm/hand)

c) A controlled amplification of the movement of the impaired limb will lead to a systematic and gradual improvement of motor movement (in particular range of reaching and selection movements)
TheraMem System
TheraMem Game

Game started
Time: 116 Tries: 38
Amplification Factor 2.0 \[ s_{\text{new}} = s_{\text{ori}} \times (f+1) \]

Camera Video Stream (original movement)

User’s View (left hand with amplified movement)
3D Scene Construction
ART::TheraMem Software Architecture (simplified)

- Render Left
  - Amplification Ctrl
  - Fingertracking
  - Bgr Subtraction
  - Video Left

- Render Right
  - Amplification Ctrl
  - Fingertracking
  - Bgr Subtraction
  - Video Right

- 3D Scene

- 3D environment
- 3D objects (plants)
- Interaction/Logic
TheraMem

- System Development and Test
- Usability Study
- Utility Evaluations
  - Physio Students Lab week
  - SoP Seminar & Neuro SIG meeting
  - Interviews with experts
Usability
Usability Study

- N=45 (10f, 35m; age: M = 37.8, SD = 13.5)
- independent variables altered during experiment:
  1. amplification factor of one hand within-subject; (0.0, 1.0, 1.5, 2.0, 2.5)
  2. knowledge about amplification factor between subject; part A and B of study
- Task: solve Memory game efficiently (#of tries, time to completion)
- Measurements:
  - tries and time
  - usability (effectiveness, efficiency, satisfaction)
  - difficulty in reaching and selection
  - timeliness of system responses (part A)
  - perceived speed of left and right hand (part B)
  - observations (qualitative)
Usability Study

Hypotheses and expectations

Part A (no prior knowledge):
• Participants complete game successfully with or without amplification
• Participants would notice and remark on the amplification
• reaction times of the system, selection and reach performance and overall usability would be rated clearly above midpoint
• increase in amplification -> increase tries
• increase in amplification -> decrease ease of use, reachability, selectability, and enjoyment
Usability Study

Hypotheses and expectations

Part B (prior knowledge):
• Participants would have the ability to rate the amount of perceived amplification
• Game performance could strongly influence participant success, with quality and user ratings affected by a low number of tries and shorter completion time

• System usability would not be affected by age
Usability Study

Results

• General Linear Model (GLM in SPSS 18)*
• check for linear and quadratic effects
• 5 (amplification: within) x 2 (part: A vs. B, between) x age (covariate) design

• time to completion: marginal linear increase with increased amplification
• time also marginally increased with age
• number of tries increased significantly and linearly with amplification

*statistics by Thomas Schubert, Lisbon
Usability Study

Results

- *Ease* of reaching, selecting, and general use was averaged for each condition (internal consistencies were high, all Cronbach’s α > .80)
- experienced ‘ease’ was highest in condition 2 (quadratic trend) for part A
- ‘ease’ decreased significantly with amplification
- scores well above midpoint (mathematically and psychologically)
Usability Study

Results

- Age was a significant covariate, with subjective ‘ease’ increasing with age
- More enjoyment was reported for medium amplifications than for very low or high amplification (quadratic trend)
- All scores well above the midpoint
Usability Study

Results

• satisfaction: averages were significantly above the midpoint of the scale (4)
• age was a marginally significant covariate: older participants tended to be more satisfied
• Part B: the perceived speed of the left hand increased, while the perceived speed of right hand decreased slightly (at amplification 1, left and right hand were perceived to be equally fast)
Usability Study

Usability: Summary & Discussion

- System was usable with subjective ease and satisfaction in all conditions; all participants completed the task successfully, even with high amplifications of the left hand.
- Perceived reaction times, reported ease of reaching, selecting and general, satisfaction -> clearly above midpoints
- Slight amplification was better rated than both higher amplification and no amplification, but only when participants had not been informed in advance.
- Part B: left hand appears to accelerate with increased amplification, but the right hand also appeared to slow down
Utility
Utility Evaluation

Student Evaluations

- Post-stroke rehabilitation lab week for 100 third year physiotherapy students: 8 different hands-on stations: TheraMem one of those
- groups of 3-5
- act as client, operator, observers
- Fill-in questionnaires on:
  - Explain system to peers
  - Use for motor rehab
  - Therapy outcome
Utility Evaluation

Student Evaluations

- 79 questionnaires returned
- 76: potentially successful adjunct therapy for motor and post-stroke rehabilitation
- Other anticipated uses for TheraMem included treatment of
  - cognitive deficits
  - spatial awareness deficits
  - traumatic brain injuries
  - post upper limb surgery
  - agnosia (difficulty recognizing familiar objects or people)
  - physical neglect (e.g. ignoring one side of the body)
Utility Evaluation

Student Evaluations

- “Best neuro lab ever!”
- “It is so cool”
- “Great fun.”
- “It’s fun! Not boring like most exercises we give patients.”
Utility Evaluation

Group Workshops

- Two one hour workshops
- Slide presentation on TheraMem concept and system
- Live demonstration
- Opportunity for the attendees to try TheraMem for themselves
- 1st workshop for ca. 20 academic staff, postgraduate students, and clinical staff of the School of Physiotherapy
- 2nd workshop for six members of a professional ‘Neuromuscular Special Interest Group’
- We asked for general feedback, their views on the utility of the system for post-stroke rehabilitation and the potential of TheraMem for wider use
Utility Evaluation

Group Workshops

- system usable for early stages of post-stroke rehabilitation (motivation and movement)
- system was judged to be mature enough for use in clinical interventions
- sort of (mechanical) support for the (lower) arm may be needed for our system
- Other potential applications identified by workshop participants included the treatment of
  - cerebral ataxia (gross lack of coordination of muscle movements -> show slowed down movements)
  - patients with cognitive deficiencies or disabilities (perhaps modifications needed)
  - sensory deficiencies (provision of acoustic and (passive) haptic feedback)
  - everyday functional tasks (gripping a ball, holding a cup, manipulating small objects)
Utility Evaluation

Guided Interviews

- Seven experienced practitioners were individually interviewed
- Fields of practice included physiotherapy, neuromuscular rehabilitation, and rehabilitation medicine, with specializations in post-stroke rehabilitation and traumatic brain injuries (TBI), spinal cord injuries (SCI), chronic pain, hand therapy, prehabilitation (rehabilitation before surgery) and post-operative rehabilitation, including amputees.
- Interview Guide (structured interview) covering:
  - Understanding of TheraMem technology
  - Usefulness of TheraMem for post-stroke and other rehabilitation
  - Technological and therapeutic advantages and disadvantages
  - Future uses and features
Utility Evaluation

Guided Interviews

- all interviewees understood technology and use; rated GUI and general operation (client and operator) as appropriate and of manageable complexity
- Application potential for TheraMem was highly rated, especially for post-stroke and general motor rehab. Other named conditions with therapeutic potential, included: atexia (inability to coordinate muscular movement); complex regional pain syndrome; phantom limb pain; cerebral palsy (muscular impairment, speech and learning difficulties); Spinal Cord Injuries (SCI), Traumatic Brain Injuries (TBI) and cognitive disability.
- Mixed nature of motor and cognitive was considered as unlikely to suit all patients and conditions
- future enhancements: incorporation of more sense-related features (acoustic, tactile), cognitive therapy scenarios, alternative games and AR environments
Conclusion
Summary

• Casual Game approach to motivate motor rehabilitation
• Visual Decoupling and Amplification to Fool the Brain (neuroplasticity)
• Proof of Concept for TheraMem as a usable system
• Potential Utility supported by qualitative responses

• TheraMem can be released into “the wild”
Where to from here?

- Clinical Case Studies (ongoing)
- Further developments
- Clinical Feasibility Study
- RCT?
- Deployment?
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