AUGMENTED REFLECTION TECHNOLOGY

Feasibility Evaluation for Stroke Rehabilitation

Simon Hoermann

with
Leigh Hale, Stanley J. Winser and Holger T. Regenbrecht
Outline

Augmented Reflection Technology (ART)

TheraMem Rehabilitation Game

Clinical Feasibility Study
Augmented Reflection Technology (ART)
Augmented Reflection Technology
3D Scene Construction

3D Scene View

Client’s View
Augmented Reflection Technology - Settings

- Colour etc.
- Mirroring
- Size and Position
- 3D models
- 2D Backgrounds
Movement Amplification

- e.g. 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)
TheraMem – Rehabilitation Game
TheraMem Game

The patient moves their hands inside the box
ART::TheraMem Software Architecture (simplified)

- Render Left
- Render Right
- 3D Scene
- Amplification Ctrl
- Fingertracking
- Bgr Subtraction
- Video Left
- Video Right
- 3D environment
- 3D objects (plants)
- Interaction/Logic
Hypotheses

a) The system can be used for physical rehabilitation, in particular for after-stroke therapy in a clinical setting

b) Using a casual computer game approach engages the 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 help patients to exercise with the game
ART System Configuration

- Client’s screen
- ART computer
  Visual Manipulations (mirroring, scaling, moving, augmenting, …)
- Box left
- Box right
- Operator’s Screen
- Operator’s Keyboard & Mouse
- Therapist’s Mouse
Utility Evaluation

Student Evaluations

- Post-stroke rehabilitation lab week for about 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

• “Best neuro lab ever!”
• “It is so cool”
• “Great fun.”
• “It’s fun! Not boring like most exercises we give patients.”
Clinical Feasibility
Clinical Environment
Clinical Setting

(a) Operator screen
(b) ART boxes
(b) User screen
(d) Physiotherapist
Preliminary Study with subject-matter experts for protocol refinement

Evaluation of protocol and refinement with two healthy participants:

- One participant with a expertise in HCI and technology
- One participant with proficiency in physiotherapy
Clinical Protocol Outline

4 sessions of 1h

First session:
- Assessment of patient’s motor capabilities
- Orientation of patient to the ART

Second & Third Session:
- 3-5 patient tailored exercises based on the outcomes of assessment

Fourth Session
- Exercises
- Reassessment of patient’s motor capabilities
Patients

5 chronic stroke patients:
• stable motor deficits (> 5 years since stroke)
• different impairment severity (2 dependent, 3 independent)
• different range of impairments
• all having motor-deficits in their upper limb
## Initial Assessment

<table>
<thead>
<tr>
<th>Assessment item</th>
<th>PT0</th>
<th>PT1</th>
<th>PT2</th>
<th>PT3</th>
<th>PT4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fugl-Meyer measure (Wrist)/10</strong></td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td><strong>Fugl-Meyer measure (Hand)/14</strong></td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td><strong>Motor Assessment Scale (Upper arm)/6</strong></td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td><strong>Motor Assessment Scale (Hand)/6</strong></td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td><strong>Motor Assessment Scale (Advanced hand)/6</strong></td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td><strong>Nine Hole Peg Test (remove pegs)</strong></td>
<td>NA*</td>
<td>NA*</td>
<td>NA*</td>
<td>NA*</td>
<td>22 sec</td>
</tr>
<tr>
<td><strong>Nine Hole Peg Test (remove pegs using ART)</strong></td>
<td>NA*</td>
<td>NA*</td>
<td>NA*</td>
<td>NA*</td>
<td>49 sec</td>
</tr>
<tr>
<td><strong>Modified Ashworth Scale</strong></td>
<td>1+</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>1+</td>
</tr>
<tr>
<td><strong>Sensory assessment of hand</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light touch / 2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Pain / 2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Proprioception / 2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

*NA: Not assessed or stopped on patients request*
TheraMem questionnaire
lightly modified

Tries & Time

**Difficulty** to play the game
Unusable - Very easy to use

Difficulty to **reach** tiles (squares)
Very difficult - Very easy to reach

Difficulty of tile (square) **selection**
Very difficult - Very easy to select

How **fast** did you perceive your (impaired) hand to **move**
Much slower than normal – Much faster than normal

Did you have any **discomfort** in your (impaired) hand
No discomfort – A lot of discomfort (pain)

**Enjoyment** / fun to perform the exercise
Not enjoying it - Very enjoyable
Patients’ engagement

Patient’s:
1. Understanding of instructions.
2. Performance in exercises
3. Active participation in the exercise
4. Maximum effort to complete exercises.
5. Expressed positive attitude towards exercise
6. Acknowledged need and potential benefit of exercise

Rating of therapeutic value of exercise for patient

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Never</td>
<td>Seldom</td>
<td>Some of the time</td>
<td>Most of the time</td>
<td>Nearly Always</td>
<td>Always</td>
</tr>
</tbody>
</table>

Comments / Suggestions / Additional Observations
Final Semi-structure Interview

How would you describe your experience with this therapeutic system?

What were your difficulties/expectations/motivations?

Do you have improvement suggestions for the device? Any problems you experienced?

What did you think of the location / room / setting and seating positions?

Did you feel Security/Safety during the therapy?

Did you have the perception that you improved your condition, was there any change in your arm?

Would you suggest (to other stroke patients) to use this system?

When do you think would be a good time to start using the system?

Could you imagine using the system without the (permanent) presence of a physiotherapist?

Would you use the system at home?
44 games of TheraMem were played by patients of which 42 were successfully completed.
Support Device: Elbow-splint
Support Device: Pointing-Stick
Use of Support Devices

![Bar chart showing the use of support devices for different patients.](chart.png)

- **No Support Device**
- **Elbow Splint & Pointing Device & Amplification**
- **Elbow Splint & Amplification**
- **Amplification (alone)**
- **Pointing Device (alone)**
- **Use of Elbow Splint (alone)**

Number of exercises performed by patients PT0 to PT4.
Average Time for Completion
Average Tries for Completion
Patients’ Engagement

<table>
<thead>
<tr>
<th></th>
<th>PT0</th>
<th>PT1</th>
<th>PT2</th>
<th>PT3</th>
<th>PT4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Understanding of instructions</td>
<td>6.0</td>
<td>6.0</td>
<td>4.0</td>
<td>6.0</td>
<td>6.0</td>
</tr>
<tr>
<td>2. Performance in exercises</td>
<td>6.0</td>
<td>4.7</td>
<td>4.0</td>
<td>4.7</td>
<td>6.0</td>
</tr>
<tr>
<td>3. Active participation in the exercise</td>
<td>4.7</td>
<td>5.0</td>
<td>3.0</td>
<td>6.0</td>
<td>6.0</td>
</tr>
<tr>
<td>4. Maximum effort to complete exercises</td>
<td>6.0</td>
<td>6.0</td>
<td>4.0</td>
<td>6.0</td>
<td>6.0</td>
</tr>
<tr>
<td>5. Expressed positive attitude towards exercise</td>
<td>4.7</td>
<td>5.0</td>
<td>3.0</td>
<td>6.0</td>
<td>6.0</td>
</tr>
<tr>
<td>6. Acknowledged need and potential benefit of exercise</td>
<td>4.7</td>
<td>4.7</td>
<td>3.0</td>
<td>6.0</td>
<td>6.0</td>
</tr>
</tbody>
</table>
Patients’ rating for TheraMem

- Time (Minutes)
- Tries (times 10)
- Game Play Difficulty: easy - hard
- Reaching Difficulty: easy - hard
- Selection Difficulty: easy - hard
- Movement Speed: slower - normal - ...
- Discomfort: no - extreme
- Enjoyment: not at all - very much

[Bar chart showing patient ratings for TheraMem, comparing 'Pointing Device' and 'No Pointing Device' across various factors.]
Equipment (ART)  
Physiotherapist’s rating

Equipment feasibility for clinical usage: 7  
Therapeutic value: 8  
Diagnostic value: 0  
How interesting are the tasks: 10  
Degree of motivation for the patient 10  
Ease of administering tasks (by PT) 7  

(0- not at all useful to 10- very useful)
TheraMem only  
(Physiotherapist’s rating)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment feasibility for clinical usage:</td>
<td>10</td>
</tr>
<tr>
<td>Therapeutic value:</td>
<td>8</td>
</tr>
<tr>
<td>Diagnostic value:</td>
<td>0</td>
</tr>
<tr>
<td>How interesting is the task:</td>
<td>8*</td>
</tr>
<tr>
<td>Degree of motivation for the patient</td>
<td>10*</td>
</tr>
<tr>
<td>Ease of administering tasks (by PT)</td>
<td>10</td>
</tr>
</tbody>
</table>

(0- not at all useful to 10- very useful)

* Fades away with repetition of task
### Changes from Initial to Final Assessment

<table>
<thead>
<tr>
<th>Assessment item</th>
<th>PT0</th>
<th>PT1</th>
<th>PT2</th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Fugl-Meyer measure (Wrist)/10</strong></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+1</td>
</tr>
<tr>
<td><strong>Fugl-Meyer measure (Hand)/14</strong></td>
<td>+4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Motor Assessment Scale (Upper arm)/6</strong></td>
<td>+1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Motor Assessment Scale (Hand)/6</strong></td>
<td>+1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Motor Assessment Scale (Advanced hand)/6</strong></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Nine Hole Peg Test (remove pegs)</strong></td>
<td>~120 sec</td>
<td>NA*</td>
<td>NA*</td>
<td>NA*</td>
<td>33 sec (+11)</td>
</tr>
<tr>
<td><strong>Nine Hole Peg Test (remove pegs using ART)</strong></td>
<td>NA*</td>
<td>NA*</td>
<td>NA*</td>
<td>NA*</td>
<td>26 sec (-23)</td>
</tr>
<tr>
<td><strong>Modified Ashworth Scale</strong></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>Pain / 2</td>
<td>0</td>
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</table>

*NA*: Not assessed or stopped on patients request.
Conclusion

• The ART system is feasible for the use in clinical physiotherapeutic settings

• Patients are able to successful complete TheraMem

• Assistive devices might be required for patients with severe motor-impairments

• Patients were highly engaged in the exercises

• Patients liked the system and suggested it for further use
Thank you for your attention!
Contact & Acknowledgements

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Where to from here?

- More Clinical Case Studies
- Further developments
- Sub-Acute Stroke Rehabilitation Feasibility Study
- Randomized Controlled Trial
- Deployment
References

Paper about the original concept of ART - AMB:

ISMAR – TheraMem Paper:

Technological Paper on ART & TheraMem (accepted manuscript):