Virtual human technologies for cognitively-impaired older adults’ care: the LOUISE and Virtual Promenade experiments

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Population aging

• Caregiver shortage.
• Disability in older adults: impact on caregivers’ health.
• Costs: need for cost-efficient solutions.
Two important causes for loss of autonomy

• Dementia:
  • 25% of people over 80 have dementia;
  • over 100 million by 2050.

• Falls:
  • ~40% of people over 65 fall every year;
  • 10% of fallers injured.
Assistive technologies

Products and services that facilitate seniors’ daily lives and help compensate for disabilities.

Issues:
- usefulness;
- usability;
- acceptance;
- ethics;
- costs.
Goals

• Assess applicability of virtual humans for user-friendly and pleasant assistive technologies.
• Address cognitive impairment and falls.

➢ Two experimental systems developed.
Outline

1. Designing for older adults
2. Virtual humans for older adults
3. Experimental systems:
   1. LOvely User Interface for Servicing Elders (LOUISE)
   2. Virtual Promenade
4. Future work
5. Conclusions and recommendations
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Design challenges

Environmental constraints

Cognitive limitations
- Age-related cognitive declines
- Pathological cognitive declines

Psychomotor disorders

Physical limitations
- Age-related sensory declines
- Motor control
- Motor strength

Cultural constraints
Living lab participatory design

- Action research [Levin, 1946]
- User-centered design [Norman & Draper, 1986]
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The virtual human dichotomy

As non-self

- Embodied conversational agents (ECAs) = virtual interactive characters.
- Issues: appearance, expressiveness, interaction.

As self (avatars)

- Extensions of one’s self in the virtual world.
- Issues: identification, body ownership, controls.

Virtual Human Toolkit (USC ICT)

Snowboarder avatar in Amped Freestyle Snowboarding (Microsoft, 2001)
As non-self: ECAs for older adults

Advantages:
• no learning;
• attention and engagement;
• easy understanding;
• personalization.

[Ortiz et al., 2007; Carrasco et al., 2008; Morandell et al., 2008]

Applications:
• virtual assistants;
• virtual butlers;
• coaches;
• companions.

Yaghoubzadeh et al., 2013, 2015.

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As self: games for fall prevention and rehabilitation

- Strong motivational power.
- Emphasis on pre-fall prevention.
- Focus on balance, muscle strength and limb coordination.

Ogonowski et al., 2016. iStoppFalls project.

Profitt and Lange, 2013. Fitness exercise game.
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Experimental systems

LOUISE

- Accessible ECA-based user interface;
- cognitive;
- non-self.

Virtual Promenade

- A virtual reality-based Post-Fall Syndrome (PFS) treatment tool;
- cognitive + physical;
- self.
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LOUISE participatory design overview

• Starting point: attentional disorders.
• Wizard of Oz (WoZ) study (14 AT pros, 8 older adults):
  • put together a first prototype;
  • create and validate attention estimation method;
  • perform anthropological analysis of videos.
• Feedback analysis:
  • questionnaires (37 respondents);
  • focus group (9 older adults);
  • staff meetings (~12 physicians + psychologists).
• Fully automatic prototype.
• Evaluation through 4 realistic use cases (14 older adults).
Phase 1 – Wizard of Oz study
Phase 1 – insights gained

• Attention estimator:
  • over 80% of correct decisions;
  • age independent.

• Experiments:
  • positive feedbacks from older adults;
  • character not expressive enough;
  • 6/8 older participants successfully interacted;
  • attention prompting effective;
  • need for context reminders.

• Anthropological analysis:
  • elders with cognitive impairment interact in a “social” way;
  • closed/contracted questions to be privileged.
Phase 2 – questionnaires and focus group

- Questionnaires: 37 people (9 older adults).
- Focus group: 9 older adults (from 67 to 89).

<table>
<thead>
<tr>
<th>Topics</th>
<th>Questionnaires</th>
<th>Focus group</th>
</tr>
</thead>
<tbody>
<tr>
<td>embodiment (appearance)</td>
<td>young woman</td>
<td>robot</td>
</tr>
<tr>
<td>personalization</td>
<td>important</td>
<td>not discussed</td>
</tr>
<tr>
<td>personalization features</td>
<td>character’s voice</td>
<td>adapt to cognitive decline</td>
</tr>
<tr>
<td>most useful applications</td>
<td>assistant and butler</td>
<td>UI and entertainment</td>
</tr>
<tr>
<td>where to display the ECA</td>
<td>device already owned</td>
<td>not discussed</td>
</tr>
<tr>
<td>privacy concerns</td>
<td>more for older adults</td>
<td>not if truly useful</td>
</tr>
</tbody>
</table>
Phase 3 – automation and applications

LOUISE automated system
BML = Behavior Markup Language
Assistive Interaction Scenario Markup Language (AISML)

- Scenario: `<scenario> </scenario>`
- Based on utterances:

  `<utterance id="name" type="chosen_type" wait="time" mode="mode"> ...
  content ...
  </utterance>`

- Utterances contain:
  - a BML command (behavior to be played);
  - transitions (possible next utterances, depending on user’s answer);
  - a “recontextualisation” BML command (to be played after attention loss).
<scenario>
  <utterance id="start" type="statement">
    <command>
      <speech id="sp" type="application/ssml"> Hello! </speech>
      <head id="hd" start="sp:end" type="NOD" amount="0.5"/>
    </command>
  </utterance>
  <transition>Ready?</transition>
  <recontextualisation>
    <speech id="sp" type="application/ssml"> I was saying. </speech>
  </recontextualisation>
  <utterance>
    <utterance id="Ready?" type="question" wait="5">
      <command>
        <speech id="sp" type="application/ssml"> Are you ready? </speech>
      </command>
      <transition condition="yes">Cool!</transition>
      <transition condition="no">ComeBackLater</transition>
    </utterance>
  </utterance>
</scenario>
Final feature set of LOUISE

- Attention management.
- User speech turn detection.
- Speech recognition.
- Context reminders.
- Image and example video display.
- Easy character addition.
LOUISE validation study

- Goal: test interaction strategies.
- 4 realistic evaluation scenarios:
  - drinking water;
  - choosing the menu for a meal;
  - taking pills;
  - measuring one’s blood pressure.
- Participants:
  - 11 females, 3 males;
  - $71 < \text{age} < 89$ (mean $= 78.8$);
  - $8 < \text{MMSE} < 30$ (mean $= 23.8$).

Careousel Pill dispenser.

Microlife blood pressure monitor.
Interaction strategy – step-by-step task guidance

1. Explain the action to perform while showing video example.
2. Wait.
3. Ask if completed.
4. Choice:
   • If “yes” -> next action.
   • If “no” -> go to step 5.
5. Instruct to perform the action.
7. Ask if completed.
8. Choice:
   • If “yes” -> next action.
   • If “no” -> back to step 5.
Validation study settings
Validation study results

• Usability:
  • 13/14 participants successfully interacted;
  • “social” interaction of most severely impaired participants;
  • speech recognition not reliable enough;
  • positioning issues with the Kinect sensor.

• Positive participants’ feedbacks.

• Task guidance conversation structure well adapted for MCI; more work needed for dementia.
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Stimulation tool for Post-fall syndrome

**PFS symptoms**

- **Psychological:**
  - anxiety;
  - fear of falling.
- **Psychomotor:**
  - psychomotor disadaptation;
  - backward disequilibrium.

- **Issue:** PFS neglected in care practices.
- **Observation:** PFS comparable to PTSD [Bloch et al. 2013].
- **Proposed solution:** Virtual reality therapy.
Virtual Promenade participatory design overview

• User-centered game design:
  • iterative development – playtesting cycle (8 older adults);
  • choice of game controller;
  • design validation (9 older adults).

• Design refinement with professionals’ inputs.

• Pilot evaluation study:
  • in situ testing (8 hospitalized patients);
  • changes allowed during the study.
Phase 1 – participatory design

- Participants: 8 women over 80.
- Tests with several controllers.
- Final design:
  - tutorial, free strolling in the forest, cube collection task in the park;
  - chosen controller = Nintendo 64 controller;
  - validated with 9 older adults.

<table>
<thead>
<tr>
<th>Issue</th>
<th>Changes made</th>
</tr>
</thead>
<tbody>
<tr>
<td>City environment is unwelcoming</td>
<td>Forest and park environments</td>
</tr>
<tr>
<td>Players did not identify with the avatar</td>
<td>7 extra character models</td>
</tr>
<tr>
<td>Flight simulator joystick is too stiff</td>
<td>Support for other game controllers</td>
</tr>
<tr>
<td>Older adults need time to familiarize with the controls</td>
<td>Tutorials that give time to adapt</td>
</tr>
</tbody>
</table>
Top to bottom, left to right: city, forest, tutorial, avatars.
## Phase 2 – focus groups and shadowing

### Focus groups
- **Participants:**
  - physiotherapy team;
  - psychomotricity team.
- **Results:**
  - positive feedbacks on the game;
  - minor changes requested;
  - cube-picking task not meaningful;
  - doubts about usability for patients.

### Shadowing
- **Ethnographic-like method.**
- **Observations:**
  - 2 or 3 patients at a time;
  - very limited space;
  - use of gamified rehabilitation tool;
  - gamified activity enjoyed by patients.
Phase 3 – pilot evaluation study

• Method:
  • pre-post-intervention Fall Efficacy Scale and PTSD Checklist Scale assessment;
  • 2 to 3 sessions, ~30 minutes each;
  • questionnaire after each session.

• Participants:
  • 7 females, 1 male;
  • 75 < age < 99;
  • 12 < MMSE < 27 (mean = 20.9).
Pilot study – results

• 8 participants completed at least 1 session; 7 did 2 or more;

• Changes made:
  • use of Thrustmaster joystick;
  • “easy mode” created.

• Observations:
  • high satisfaction with the visuals;
  • easy controls;
  • mitigated impression of immersion.
  • little or no in-session anxiety;
  • FES not adapted for dementia.
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Future work

• Leveraging both self and non-self.
• Exploring other interaction modalities.
• Personalization to cognitive level and personal tastes.
• Investigating deployment aspects.

LOUISE:
• more flexible interaction management (extend AISML);
• more comprehensive user behavior analysis.

Virtual Promenade:
• adding VR head-mounted display;
• using body ownership measures;
• finding adapted success indicators.
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Conclusions

Experimentations:

- Ecological testing → debunk and fix usability issues.
- Participatory design → high satisfaction of target audience.
- Involving several stakeholders → useful information for current and future steps.
- Off-the-shelf elements → fast prototyping and flexibility.

Observations:

- Older adults more sensitive to aesthetics than realism.
- Importance of personalization in assistive systems.
- Older adults not reluctant to new technology.
- Perceived usefulness is key to acceptance.
Recommendations for participatory design of virtual humans

Participatory design

• Start small.
• Make changes as soon as judged necessary.
• Go see for yourself.
• Go the extra mile.
• Adapt your discourse.

Virtual humans

• Stay aware of novelties.
• Use versatile development tools.
• Carefully design appearance.
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LOUISE: an ECA for cognitive support

Dementia symptoms

• Short-term memory loss
• Executive dysfunction
• Attention disorders
• Aphasia
• Agnosia
• Apraxia
• Psycho-behavioral disorders
Phase 1 – attention estimator

• *A priori* assumptions:
  • attention = looking towards the display;
  • sensor placed on top of the display, in the middle.
• 3 features:
  • $\varphi =$ body orientation;
  • yaw = head’s rotation around vertical axis;
  • pitch = head’s rotation around horizontal axis.
Phase 1 – attention estimator

• Features $f_j$ averaged over 1-second sampling.

• Features normalized as: 

$\bar{f}_j = \frac{\cos(\phi_{Max})}{\cos(\phi_{Max})}$

with $Max_j = 60^\circ$ for $\phi$, $30^\circ$ for yaw and $20^\circ$ for pitch.

• Attention value computed as: 

$A = \sum_{j=1}^{n} \omega_j \bar{f}_j$

with $\omega_\phi = 3; \omega_{yaw} = 4; \omega_{pitch} = 3; n = 3$.

• Decision: empirical hysteresis threshold.