Cognitive and Physical
Games for the Elderly:
how effective are they?

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We live longer –
but our society gets older...

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Eurostat
In aging, negative cortical plasticity has four mutually reinforcing components that create a downward spiral of degrading brain function:

**Reduced schedules of brain activity**
- Reduced engagement in cognitively demanding activities (retirement, not learning new things)
- Lack of continuous refinement of receptive fields/cortical organization
- Less stimulation for attention/reward
  ➔ Brain disuse

**Noisy processing**
- Deterioration of sensory organs
- Poor signal quality received in cortex
- Brain must adjust by lengthening space and time integration constants
- Costs: temporally and spatially noisy processing of stimuli and slowing of information processing speed

**Weakened neuromodulatory control**
- Changes in metabolism of neurotransmitters (acetylcholine, dopamine, serotonin, norepinephrine)
- Changes in connectivity of relevant brain areas
- Weakened control of the brain over its own plasticity

**Negative learning**
- Adaptation to degraded processing
- Changes in behavior accelerate cognitive decline
- E.g.: difficulties in understanding the rapid speech of a child on the phone
  ➔ turn up volume or
  ➔ avoid such conversations

Mahncke, Bronstone, & Merzenich (2006), *Progress in Brain Research*
As we grow we lose functional capacity...

Li et al. (2004), Psychol Sci; Li et al. (2009), Psychol Res
...and also physical capacity...

CRF – Cardiorespiratory fitness (treadmill test until volitional exhaustion)

Peak CRF – Maximal aerobic power (peak VO2)

METs – Metabolic equivalents
(1 MET = oxygen uptake of 3.5 mL/kg per minute = energy expenditure at resting state)

Jackson et al. (2009), Arch Intern Med
The good news...

- Our brain is built in a way that can counteract the decline...

- Brain synapses change / can be regenerated in the time frame of days!
Dementia: 21st century epidemic

Dementia has obtained epidemic dimensions lately, with even worse forecasts for the near future.


There is no treatment!

Research evidence: preventing dementia is the only way of tackling it.

(Brookmeyer, Johnson, Ziegler-Graham & Arrighi, 2007; Roberson & Mucke, 2006; Valenzuela & Sachdev, 2005)
Prevention methods

- **Physical exercise**
  - Train body...
    (Colcombe, et al., 2006; Colcombe & Kramer 2013)

- **Cognitive exercise**
  - Train mind
    (Ball, et al. 2002; Mahncke, Connor, Appelman, et al., 2006; May, Hajak, Steffens, et al., 2007; Willis, Tennstedt, Marsiske, et al. 2006; Valenzuela, 2008)

**Proper training**

→ induces neural plasticity changes
→ slows down or inverts cognitive decline

(Smith et al., 2009)
Technology and Active Ageing

- Can technology intervene non-pharmacologically?
- Can we make internet developments fight against cognitive decline and promote active ageing?
- Can elderly people improve their health by playing games over the internet?
- Are there any such “silvergames” for “grown up kids”?

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What’s the difference between different games

- Different attitudes towards elderly and kids...???
- Difference in design between silvergames and kids’ games ???
- What is the optimal design strategy ???
- Is there any evidence out there ???
- ...Neuroscience ...


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Resting state MEG

- short term-changes of variability
- older brains are less dynamic
- dynamic brains are better
- neuronal variability relates to cognitive function

(Garret et al, 2013)
Game effectiveness: ...towards the evidence (Cont’d)

- Can we improve by behavioural exercises?
  - behavioural variability improves cognitive function in mice...
  - enriched environment and spatial memory
  - long-term training of old mice reduces spatial memory errors...

(Bennet et al, 2005)
Game effectiveness: ...towards the evidence (Cont’d)

- Behavioural activity:
  - Kids at school age:
    - v.large (change lesson every 45')
  - Older age: less (e.g. Greek kafenio)
  - Wang et al, (2012) study elderly people:
    - how active they are
    - activity index
    - Doing more types of activities relates to cognitive functions...
    - follow up in 2.5 y: low activity group goes down (cognitively) more quickly
W. Schlee refers to "Learned Rigidity"

- kinds of activities we do and learn during life time...
- Games specific heuristics (e.g. chess)
- Cognitive and attentional demand vs efficiency of the game strategy:
  - Experts: have got low demands and more strategies
  - Novices: big demands & few strategies.
Game design: aiming for effectiveness

- Aim for silver games: aim at novice level!
- To enhance cognitive function:
  - 1) use cognitive demanding games
  - 2) promote behavioural and neuronal variability by preventing game specific strategies
     - switch games or change rules...
Long Lasting Memories (LLM)

- 1st time worldwide combination of computer based physical and cognitive training
- Exercises properly designed for silver minds
- Auto-adapting levels of difficulty along elder’s performance so as to achieve optimal training effects
- Game based activities, for elderly (>60), that are also fun to use and play with (exergaming)

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What is LLM?

- Long Lasting Memories (LLM) is an integrated ICT platform which combines:
  - state-of-the-art cognitive exercises
  - with physical activity (in the form of games)
  - in the framework of an advanced ambient assisted living environment (sensor based e-home)
LLM Platform

**LLM Components**

- Independent Living Component (ILC)
- Cognitive Training Component (CTC)
- Physical Training Component (PTC)
- Central Management System (CMS)

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Component 1: Effects of Physical Exercise in the Elderly

- Regular physical exercise, significantly improves physical functioning of individuals at any age.
- Engagement of elderly individuals in regular physical exercise programs has demonstrated improvement in:
  - Aerobic capacity, muscular strength, muscular endurance, flexibility, balance,
  - Motor control and performance,
  - Skill acquisition,
  - Coordination,
  - Cognition and psychological well being.

(www.who.int/hpr/ageing/heidelberg_eng.pdf)
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Requirements for behavioral training to drive large-scale plasticity

**Intense schedules of activity**
- Thousands of trials
- Frequent engagement
- Adaptively increase task demands

**Refine stimulus processing**
- Increase fidelity
- Use complex, dynamic inputs
- Decrease spatial/temporal integration constants
- Support generalization and in-context function

**Enhance neuromodulation**
- Activation, arousal, reward, novelty
- Increase demands on attentional control

**Strengthen critical life skills**
- Force engagement in difficult tasks
- Shape new behaviors
- Positively reinforce enhanced function

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LLM home example
Integrate two existing ICT solutions with physical training equipment, thus delivering innovative ageing-well / independent-living support services for elders.

Demonstrate the significant impact potential of LLM service in different EU countries.

Verify the technical, organisational and legal feasibility of LLM service along the complete value chain of stakeholders.

Verify the sustainability, scalability and applicability of LLM services across Europe.

Technical Integration
Trial Deployment
Service Marketability

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The YouTube Video

- Project Video:
  http://www.youtube.com/watch?feature=player_embedded&v=tXnUc4ICi1Y

Or (with English subtitles):
http://www.youtube.com/watch?feature=player_embedded&v=ilABZtm8eGM

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Focus on (physical) exergaming
Effects of physical training

- **Reduction of chronic disease symptoms.** Improvement of fitness, muscle strength and quality of life.
  
  (Pedersen & Saltin, 2006)

- **Quality of life improvement for seniors**
  
  (Hassmen, Koivula & Uutela, 2000)

- **Mediating suffering from chronic diseases like**
  
  - cancer (Courneya & Friedenreich, 1999) &
Theoretical model for body train-based prevention of cognitive decline

Thurm (2012), NeuroReha; Erickson et al. (2012), Neuroscientist
Exergaming & technology
Exergaming

- Attractive and motivating
- Virtual and mixed reality games
- Interactive treatment\(^1,2\) and training in fully- or semi-controlled 2D or 3D environments
  - Haptic interfaces, tabletop interfaces, sensor-enabled game input controllers (Nintendo Wii), motion tracking cameras (Sony EyeToy, Microsoft X-Box) etc.


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Virtual reality

- VR use computers to create virtual worlds, simulating real worlds and conditions (or even unreal, wishful...), through which the user feels is included, capable of moving and interacting with surrounding objects (like in real world).

- Applications:
  - Education
  - entertainment (edutainment)
  - Interventions in special target groups with specific behavioural features (e.g. autistics)

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Semi-virtual environments

- Augmented reality
- Still VR (computer based)
- Objects of the environment take part in the process
- User participation with bodily movements
- Collaborative group games
Our Goal

- Improve physical and cognitive health of seniors and ultimately quality of life

Exercise types/categories

- Aerobic
- Muscle flexibility
- Muscle strength
- Balance

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FFA user-centered design cycle

- Iterative procedure
- Steps
  1. Recording of user needs and preferences
  2. Design of game scenarios based on previous information
  3. Testing in real world settings / record end-users reactions and beliefs
Solutions to accessibility issues

- Adoption of user-centered design principles
  - Multiple game content format
  - Simple game scenarios, comprehensible instructions
  - Repetition on exercise execution, easy-learning

- “Senior-friendly” HCI system
  - Strengthens mood
  - Motivation
  - Attractive environment and interest maintenance
Using Wii Remote control

- Accelerometer based function:
  - Static acceleration (position/status due to gravity)
  - Mechanical acceleration (motion)
  - 3 – axes
  - Bluetooth technology for PC connection
Wii Balance Board

- Pressure sensors
- 4 sensors for centre of gravity estimation
- Bluetooth for PC connection
XNA 3d Graphics

- 3d graphic and game development platform
- Quick and easy development (rapid)
- Numerous applications and games based on XNA available
- Easy integration of existing games in FitForAll
Managing interface examples
FFA platform description

- Mixed Virtual Reality
- Virtual Reality
- Wii Remote Controller
- Wii Balance Board
- 3D Game Technology
- Sensors

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Physical Games
Instructions based on text, images and sound/speech

Light walking on the spot. Move both arms and legs. Raise each knee to a point midway between the kneecap and top hip bone.
Try to keep a constant speed of 0-3km/h
In case you move faster the time sign at the top left corner will become red.
Press the Start Button so to start with the task.

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Repetitive approach for process/exercise execution
Easy interface – simple/familiar content
Feedback based

Δείκτες άσκησης, όπως χρόνος, απόσταση, ταχύτητα, κ.ά.

Steps: 61
Distance: 42.7 m
Speed: 2.81 km/h
Time: 00:42

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Platform evaluation by questionnaires

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Questionnaire items (I)

- **Usability**¹,²
  - Was FitForAll difficult to learn how to use?
  - Were the instructions given by the computer clear and understandable and easy to follow?
  - Were the letters on the screen easy to read?
  - Was the physical training installation well adapting to your exercising abilities?

- **User satisfaction**¹,²
  - How beneficial do you believe is FitForAll for you?
  - How often would you use FitForAll if you had it at home?
  - FitForAll was amusing and I enjoyed my sessions with it.
  - Using Fit-For-All was boring and did not interest me.


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Questionnaire items (II)

- Affective evaluations of an object → implicitly influence and even shape one’s perception and attitudes regarding that object, as well as to predict engagement with that object.

- Existing usability measurement tools lack this feature.

- Affective
  - It is fun / unpleasant
  - I dislike it
  - I am feeling cheerful / strong / tired / refreshed / stressed / calm / bored


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## Results (I)

<table>
<thead>
<tr>
<th>Section</th>
<th>Range (min-max score)</th>
<th>Mean (SD)</th>
<th>Neutral Mean</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Affective</td>
<td>10 – 70</td>
<td>57.43 (5.64)</td>
<td>30.00</td>
<td>$p &lt; .00001^d$</td>
</tr>
<tr>
<td>Usability</td>
<td>5 – 34</td>
<td>28.21 (3.29)</td>
<td>17.00</td>
<td>$p &lt; .00001^e$</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>7 – 35</td>
<td>28.43 (3.72)</td>
<td>14.00</td>
<td>$p &lt; .00001^f$</td>
</tr>
</tbody>
</table>

^aRange = the possible minimum and maximum score for each section
^bSD= standard deviation
^cNeutral Mean= the value that would be anticipated if all the answers indicated a rating that was equally positive or negative.
^d,e,f significant at the 0.05 level


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## User experiences

<table>
<thead>
<tr>
<th></th>
<th>Perceived improvements in motor functions and related activities (e.g., mobility, balance, walking).</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.</td>
<td>Benefits of learning new things, including how to use the computer.</td>
</tr>
<tr>
<td>3.</td>
<td>Affective improvements, more cheerful (&quot;feel more alive!&quot;).</td>
</tr>
<tr>
<td>4.</td>
<td>Lost weight.</td>
</tr>
<tr>
<td>5.</td>
<td>Not everyone may have the aptitude to do the program (e.g. severe arthritis or advanced dementia patients)</td>
</tr>
<tr>
<td>6.</td>
<td>The background should be more colorful; add music during exercises; Have a virtual coach to give instructions and commands for exercises.</td>
</tr>
</tbody>
</table>


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Drop out compared to number of seniors per group

Long Lasting Memories Trials Drop Out (%)

Number of seniors per intervention group

Konstantinidis, E.I., Billis, A., Grigoriadou, E., Sidiropoulos, S., Fasnaki, S., Bamidis, P.D.  
Affective computing on elderly physical and cognitive training within live social networks (2012) 
Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 7297 LNCS, pp. 339-344.

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Some preliminary conclusions

- Positive emotions (joy, calm)
- Easy-to-learn
- Well understandable instruction set
- Perceived satisfaction
- Positive emotions increase usability and training engagement
- Emotions play a significant role in accepting an HCI platform such as FFA

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Suggestions

- ...currently “passive” affective elements
- ...have to be transformed into a more affectively “active” interaction system
  - Recognize affective state of user
  - Readjust and reshape game characteristics e.g. scenario, content, difficulty level
- Further pilots are in progress and are already planned for few next months to highlight and support present findings
Overall preliminary results

- From all trial sites
- 4 countries
Cognitive improvements

* p < .05  
** p < .01  
*** p < .001

significant

Group × Session interactions for

** episodic memory**

$F(1,293) = 40.27, \quad p = < .0001$

and

** working memory**

$F(1,295) = 6.22, \quad p = < .013$


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Key Aspects of AUTH Pilot

- Compare cognitive status groups
- Different interventions (integrated solution vs isolated components)
- Measured intervention-related brain changes
- Measured physical condition in addition to cognitive performance
- Follow up measures (6 and 12 months)
- Neurophysiological investigation

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Randomised control intervention

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## Pilot Overview

<table>
<thead>
<tr>
<th>Timeline for the pilot</th>
<th>Start Date</th>
<th>End Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st iteration</td>
<td>01/11/2010</td>
<td>15/01/2011</td>
</tr>
<tr>
<td>2nd iteration</td>
<td>14/02/2011</td>
<td>15/04/2011</td>
</tr>
<tr>
<td>3rd iteration</td>
<td>11/05/2011</td>
<td>06/07/2011</td>
</tr>
<tr>
<td>4th iteration</td>
<td>18/10/2011</td>
<td>20/12/2011</td>
</tr>
<tr>
<td>5th Iteration</td>
<td>26/01/2012</td>
<td>21/03/2012</td>
</tr>
</tbody>
</table>

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Timeline of iterations

N = 581
2 months
Training

N = 403
Post-test (2 weeks)

N = 268
6 months
Pre-test (2 weeks)

N = 30
6 months
Follow up 1 (on going)

N = 11
Follow up 2 (on going)

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Analysis as a function of type of intervention

LLM intervention

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Intervention Group

- LLM (N= 98)
- CTC (cognitive, N= 26)
- PTC (physical, N= 16)
- Active controls (N= 70)
- Passive controls (N= 34)

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Physical training
Clinical symptoms

PTC vs CTC

* p = .037

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LLM intervention

Follow up Analyses

How long does it last?

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Follow up analyses
Memory

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Follow up Analyses
Clinical symptoms

GDS scores

pre  post  6months  12months

P = .031

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Follow up Attention

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Neuphysiological investigation of the LLM intervention

Brain changes (EEG analyses)
Synchronization analysis

Does synchronization increase after LLM intervention?

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EEG Analysis

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Synchronization analysis

- Pathological aging (AD) is associated with loss of synchronization (may index loss of connectivity between distant brain regions –anterior/posterior-)

- Greater synchronization is expressed in lower mean values

- Comparison LLM vs Active controls on mean synchronization difference between pre and post for pair of channels

- 109 participants (56 LLM, 53 Active controls)
Frantzidis, C., et al., Cognitive and physical training for the elderly: evaluating outcome efficacy by means of neurophysiological synchronization,

International Journal of Psychophysiology (2013), Under review
Neurophysiological analysis on FFA

Effects of exergaming on brain synchronisation?

Comparison of mean differences between regions and the overall scores before and after intervention (pre-post)

• (1) Tests:
  - MMSE, MoCA, TMTb, GDS,
  - Paired t-tests (Bonferroni correction)

• (2) Pearson’s $r$ correlation, correlations for synchronisations of regions (pre-post) & test scores (pre-post) (Bonferroni correction)

• 13 participants with Physical exercise ($\Sigma A$)

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ΣΑ vs NA: on geriatric depression (GDS)

Physical training (ΣΑ) significantly better than cognitive (NA)

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ΣΑ vs ΕΟΕ: general cognitive functioning (MoCA)

Significant improvement of physical training group compared to active control

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Body capacity improvement:

Fullerton scale (Rose, Lucchese & Wiersma, 2006)

- Loss of weight
- Muscle strengthening
- Improvement of flexibility
- Improvement of aerobic capacity
- Improvement of balance

...and also: decrease of pain symptoms (!!!)
What else? Functional brain connectivity

What else? Functional brain connectivity in bands

General Conclusions

- LLM intervention effective in improving cognitive performance
- LLM benefits not only for healthy old adults, but for the impaired participants too
- Stronger and longer lasting effects for memory
- Positive effects in other domains for at least 6 months
General Conclusions

- Also, greater synchronization in LLM group relative to active control in several brain areas
- Cognitive processes important for independent living
- LLM important service to promote healthy aging
Commercialisation

- Business plans in 5 EU countries (local business plans)

- Greek business plan through the Research Committee of AUTH

- Admin issues completed July 2013

- Market ready, low-priced product ...
Current developments

- Motion support in space through Kinect
- Creation of FitForAll protocol for SmartTV
- Personalised training
  - along the physical condition and performance of the user
Smart TV User Interface

- **Health**
- **Fitness**
- **Events**

- **Distance**
- **Gait**

- **Calories**
- **Steps**

- **Logout**
- **Select**
- **Return**

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DISCOVER – Skills for Carers

- Pan-European project, offering **information, advice, guidance** and **training** to support the **wellbeing of carers** in their caring role.

- Fostering a **shared learning environment** for communities of carers; to share experiences, knowledge, challenges and questions.

- Using **everyday technologies** like the internet, mobile phones and other digital devices to reach carers in the comfort of their own home as well as through the use of community locations.

- **Raising awareness** of the **benefits** of acquiring digital based skills for carers as well as sharing this with those they care for, all of which will be done in a mutually supportive way.
Sample eLearning content

Diane Brown (Home Visit and Fast Stroke Assessment Adult)

Start

Quizzes
Sample eLearning content
Projects Info:

- **LLM:**
  - www.longlastingmemories.eu
  - YouTube llmdissemination channel

- **USEFIL:**
  - www.usefil.eu
  - Follow @USEFIL in twitter
  - http://www.linkedin.com/groups/USEFIL-FP7-Project-4327695?gid=4327695&trk=hb_side_g

- **DISCOVER:**
  - http://www.discover4carers.eu/
  - Follow @DISCOVER4carers in twitter

- pdbamidis@gmail.com, @bamidis

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Thank you!

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