EXERGAMING
Spielerisches Training für Körper und Geist

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36. Darmstädter Sport-Forum, 2023

Overview

• Technology x Sports: Extended Reality and Sports
• Gaming x Sports: Exergames
• How to: Exergame Design, Research and Implementation
• Conclusion

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TECHNOLOGY x SPORTS
EXTENDED REALITY (XR)
Virtual Reality (VR) // Augmented Reality (AR) // Mixed Reality (MR)

(Modified after: Milgram & Colquhoun, 1999)
Augmented Reality Sports

Augmented Reality Sports

Sports–Agility AR

Augmented Reality Sports

Ghost Pacer
Virtual Reality Sports

Mixed Reality Sports
But…

SWEET SPOT OF IMMERSION…
DESIGN GUIDELINES...

• Focus on the needs of users.
• Make the technology easy to use.
• Allow for personalization.
• Ensure safety and data protection.
• Allow for integration with other technologies.
• Make the technology accessible to all users.
• Collaborate across disciplines.
• Provide feedback and motivation.

MOTIVATION...
8 BILLION PEOPLE
3.7 GAMERS
1.5 PHYSICALLY ACTIVE

HOMO LUDENS?!
Typical Gamer?! 

The Average Gamer
GAMIFICATION

«The use of game-elements and game-design techniques in non-game contexts.»
(K. Werbach & D. Hunter)

SERIOUS GAMES

«Games with a purpose beyond fun.»
(K. Werbach & D. Hunter)
Gameplay Experience: Theories & Models

“Spiel ist eine freiwillige Handlung oder Beschäftigung, die innerhalb gewisser festgesetzter Grenzen von Zeit und Raum nach freiwillig angenommenen, aber unbedingt bindenden Regeln verrichtet wird. Ihr Ziel in sich selber hat und begleitet wird von einem Gefühl der Spannung und Freude und dem Bewusstsein des Andersseins als das gewöhnliche Leben.”

(Johan Huizinga, Homo Ludens – Vom Ursprung der Kultur im Spiel, 1938, S. 37)

(GAMING x SPORTS)
## Exergame History

<table>
<thead>
<tr>
<th>Year</th>
<th>Device/Exergame</th>
<th>Manufacturer/Developer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>Escalade Arcade</td>
<td>Escalade Entertainment</td>
</tr>
<tr>
<td>1983</td>
<td>Suncom Aerobics</td>
<td>Suncom 1980</td>
</tr>
<tr>
<td>1986</td>
<td>Exxon Foot Crz</td>
<td>Exxon Corp.</td>
</tr>
<tr>
<td>1989</td>
<td>Power Pad for Nintendo</td>
<td>Nintendo Entertainment System</td>
</tr>
<tr>
<td>2000</td>
<td>Wii + Wi Remote (Nintendo)</td>
<td>Nintendo 2006</td>
</tr>
<tr>
<td>2004</td>
<td>iWall (Frank Weiss, IMM electronics)</td>
<td>IMM 2004</td>
</tr>
<tr>
<td>2010</td>
<td>Kinect for Xbox (Microsoft)</td>
<td>Microsoft 2010</td>
</tr>
<tr>
<td>2012</td>
<td>Ring Fit Adventure (Nintendo)</td>
<td>Nintendo 2012</td>
</tr>
<tr>
<td>2014</td>
<td>PlayStation Move (Sony)</td>
<td>Sony 2014</td>
</tr>
<tr>
<td>2016</td>
<td>Pokemon GO (Niantic)</td>
<td>Niantic 2016</td>
</tr>
<tr>
<td>2018</td>
<td>Fred Saber (Beat Games)</td>
<td>Beat Saber 2018</td>
</tr>
<tr>
<td>2019</td>
<td>Nike Run Club (Nike)</td>
<td>Nike 2019</td>
</tr>
</tbody>
</table>

## Exergames @home

![Exergames @home](image)
Game-based Rehabilitation

VR Fitness – Immersive Fitness – Gamified Fitness
FROM SPORTIFICATION OF GAMES TO GAMIFICATION OF SPORTS

What’s missing?
Potential **EFFECTIVENESS** of Exergames

- Physical Activity
- Self-Esteem
- Cognitive
- Executive Functions

Potential **ATTRACTIVENESS** of Exergames

- Motivation
- Training Adherence
- Easy Access
- Empowerment
- Engagement
UNEXPLOITED Potential

LOW INTENSITY

NO PHYSICAL-COGNITIVE TRAINING

NO SCIENTIFIC GROUNDING

NO INTERDISCIPLINARY R&D

NO USER INVOLVEMENT

...
INTERDISCIPLINARY, USER-CENTERED, RESEARCH-BASED & ITERATIVE DESIGN PROCESS
Exergame Design Levels

- Focus Groups
- Co-Creation Workshops
- Walkthrough
- Participatory Observation
- Research through Design
- Body Storming
- Technical Exploration
- Field Testing
- Lab Studies
- etc.

User-Centered, Interdisciplinary Design Methods
SENso EXPLORIA

R&D Projects (2018-2021) / supported by Innosuisse

Senso Exploria: User-centered Exergames for MS Patients

(Schättin et al., 2021)
IMIC

INNOVATIVE MOVEMENT THERAPY IN CHILDHOOD

R&D Project (2008-2015) / supported by Mäxi Stiftung

IMIC: Game-Based, Robot-Assisted Movement Therapy

(Martin-Niedecken et al., 2015)
IMIC: Player Experience Journey

PLUNDER PLANET

R&D Project (2015-2018) / supported by Sportfond of Kanton Zurich
THE EXERCUBE

R&D Project and ZHdK-SpinOff (since 2018)

IMPACT OF DIFFERENT DESIGN PARAMETERS
«Plunder Planet» & «The ExerCube»

MOVEMENT CONCEPT
Movement Concept

AUDIO-VISUAL, NARRATIVE DESIGN & MECHANICS
Game Scenarios & Mechanics

CONTROLLER
Controller

FULL-BODY-MOTION CONT

PLAYER MODE
Player Mode

Research-Based, User-Centered Design Iterationen
EVALUATE & ADAPT

Impact of...

CONTROLLER FEATURES

PLAYER MODES

PLAYER-CENTRIC ADAPTATION

MOVEMENT CONCEPTS

MOTOR-COGNITIVE CHALLENGES

EMPOWERMENT

...
ExerCube vs. Personal Trainer

**ExerCube vs. Personal Trainer – Subjective Experience**

**Difference: Mental Focus**

**The ExerCube:**
- Focus on game
  - *You are constantly thinking about what you have to do and how you can outdo the game* (Martin-Niedecken et al. 2019)
  - *Equivalent to the physical exertion of a game* (Martin-Niedecken et al. 2019)

**The Personal Trainer:**
- Focus on body & training
  - *Feel like you're working on the body* (Martin-Niedecken et al. 2019)
  - *Same feedback on the movement patterns* (Martin-Niedecken et al. 2019)

**Difference: Perception of Exertion**

**The ExerCube:**
- Deliberate awareness of physical exertion
  - *Feel like you're working out physically, but more cognitively* (Martin-Niedecken et al. 2019)
  - *You can feel the exertion on the body* (Martin-Niedecken et al. 2019)
  - *Feel like you're working on the body* (Martin-Niedecken et al. 2019)

**The Personal Trainer:**
- Perception awareness of physical exertion
  - *Feel the physical exertion during the movement* (Martin-Niedecken et al. 2019)
  - *You can feel the exertion on the body* (Martin-Niedecken et al. 2019)
  - *Feel like you're working on the body* (Martin-Niedecken et al. 2019)

**Difference: Social Factors**

**The ExerCube:**
- No fear of failure
  - *You feel safe taking risks in a game* (Martin-Niedecken et al. 2019)

**The Personal Trainer:**
- More personal
  - *Feeling of being personally trained* (Martin-Niedecken et al. 2019)

**The ExerCube:**
- More pressure
  - *Feel the pressure is too high* (Martin-Niedecken et al. 2019)

**The Personal Trainer:**
- More pressure
  - *Feel the pressure is too high* (Martin-Niedecken et al. 2019)

**Conclusion:**

- **PT:**
  - Player’s focus more on own body
  - Stronger physical exertion
  - Social pressure

- **ExerCube:**
  - Less physical exertion
  - Stronger cognitive exertion
  - «feel free»

(Martin-Niedecken et al. 2019)
Comparison of Effectiveness

<table>
<thead>
<tr>
<th></th>
<th>ExerCube</th>
<th>Traditional fHiIT</th>
<th>z</th>
<th>p</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average HR [bpm]</strong></td>
<td>155.0 [141.5; 161.3]</td>
<td>159.5 [150.3; 167.0]</td>
<td>-2.878</td>
<td>.003*</td>
<td>0.46</td>
</tr>
<tr>
<td><strong>Average HR</strong> (% of calculated HR\text{max})</td>
<td>78.7 [72.6; 82.2]</td>
<td>81.1 [77.9; 85.8]</td>
<td>-2.837</td>
<td>.005*</td>
<td>0.45</td>
</tr>
<tr>
<td><strong>Maximal HR [bpm]</strong></td>
<td>162.5 [172.0; 191.0]</td>
<td>180.5 [176.0; 190.0]</td>
<td>-0.262</td>
<td>.806</td>
<td>0.04</td>
</tr>
<tr>
<td><strong>Maximal HR</strong> (% of calculated HR\text{max})</td>
<td>93.0 [88.7; 97.4]</td>
<td>91.8 [93.6; 97.3]</td>
<td>-0.302</td>
<td>.388</td>
<td>0.05</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>ExerCube</th>
<th>Traditional fHiIT</th>
<th>z</th>
<th>p</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Borg\text{physical}</strong></td>
<td>7.0 [6.0; 8.0]</td>
<td>9.0 [8.0; 9.0]</td>
<td>-3.020</td>
<td>.001*</td>
<td>0.48</td>
</tr>
<tr>
<td><strong>Borg\text{cognitive}</strong></td>
<td>6.5 [5.0; 8.0]</td>
<td>5.0 [4.0; 6.0]</td>
<td>-1.603</td>
<td>.113</td>
<td>0.25</td>
</tr>
</tbody>
</table>

*=p<.05=significant

**ExerCube:**
- Slightly lower physical exertion but average heart rate reached the functional fHiIT threshold
- Subjectively experienced higher cognitive load (dual-domain training)

(Martin-Niedecken et al. 2020)

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Comparison of Attractiveness

<table>
<thead>
<tr>
<th>Questionnaires</th>
<th>ExerCube</th>
<th>Traditional fHiIT</th>
<th>z</th>
<th>p</th>
<th>r</th>
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</thead>
<tbody>
<tr>
<td><strong>SIMS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>intrinsic motivation</td>
<td>6.5 [5.0; 6.0]</td>
<td>5.1 [4.5; 5.5]</td>
<td>-3.566</td>
<td>&lt;.001*</td>
<td>0.50</td>
</tr>
<tr>
<td>identified regulation</td>
<td>6.3 [5.5; 6.7]</td>
<td>6.0 [5.6; 6.7]</td>
<td>-0.029</td>
<td>&gt;.999</td>
<td>0.01</td>
</tr>
<tr>
<td>external regulation</td>
<td>1.3 [1.0; 2.4]</td>
<td>1.8 [1.3; 2.7]</td>
<td>-0.949</td>
<td>.367</td>
<td>0.15</td>
</tr>
<tr>
<td>amotivation</td>
<td>1.0 [1.0; 1.6]</td>
<td>1.3 [1.0; 1.9]</td>
<td>-0.939</td>
<td>.388</td>
<td>0.10</td>
</tr>
<tr>
<td><strong>overall</strong></td>
<td>6.0 [5.6; 6.4]</td>
<td>5.4 [4.9; 5.8]</td>
<td>-3.663</td>
<td>&lt;.001*</td>
<td>0.58</td>
</tr>
<tr>
<td>fluency of performance</td>
<td>6.3 [5.5; 6.5]</td>
<td>5.7 [5.2; 6.4]</td>
<td>-1.708</td>
<td>.088</td>
<td>0.27</td>
</tr>
<tr>
<td>absorption by activity</td>
<td>6.0 [5.5; 6.5]</td>
<td>4.9 [4.5; 5.5]</td>
<td>-3.436</td>
<td>&lt;.001*</td>
<td>0.54</td>
</tr>
<tr>
<td>perceived importance</td>
<td>1.7 [1.0; 2.2]</td>
<td>1.0 [1.0; 1.8]</td>
<td>-2.519</td>
<td>.012*</td>
<td>0.40</td>
</tr>
<tr>
<td><strong>PACES</strong></td>
<td>6.3 [6.0; 6.6]</td>
<td>5.0 [4.7; 5.5]</td>
<td>-3.884</td>
<td>&lt;.001*</td>
<td>0.61</td>
</tr>
</tbody>
</table>

*=p<.05=significant

**ExerCube:** Sig. better results for flow, enjoyment & motivation

(Martin-Niedecken et al. 2020)
Embodied Sketching – Multiplayer Makeover

- Differentially balanced experiences of social immersion, fun & physical and cognitive exertion
- Identification of promising new player formations

(Martin-Niedecken et al., 2019)
Investigation of ....

COGNITIVE(-MOTOR) FUNCTIONS

ANTROPOMETRIC PARAMETERS

PHYSICAL FITNESS

EXECUTIVE FUNCTIONS

ExerCube Training in Young Athletes

AIM: Gathering insights into the training effects of the ExerCube on cognitive(-motor) functions in young game athletes.
Results – Non-Randomized Controlled Trial

• 24 young game sports athletes (15 ± 0.7 years; 46% girls)

• 10 weeks intervention time → shortened to 8 weeks (due to pandemic restrictions):
  – Intervention group: 2x 25min ExerCube training per week + sports-specific training
  – Control group: Sports-specific training only

• Sig. positive effects on cognitive (motor) skills (faster reaction times), especially on concentration (U=-2.483, p=0.013, r=0.51), cognitive flexibility (F=12.176, p<0.001, d=1.488), and divided attention (F=9.776, p=0.002, d=1.404).

(Martin-Niedecken et al., 2023)

ExerCube @School

AIM: Investigation of effects of a school-based exergame intervention on anthropometric parameters and physical fitness
Results – Randomized Controlled Trial

• 58 students (10.4 ± 0.8 years; 48% girls) → only 34 students included in final analysis (due to pandemic restrictions)

• 3 month intervention time:
  – Intervention group: 2x 20min ExerCube training per week + physical education classes
  – Control group: Physical education classes only

<table>
<thead>
<tr>
<th>Outcome</th>
<th>IG (n = 34)</th>
<th>CG (n = 34)</th>
<th>Pre</th>
<th>Post</th>
<th>Pre</th>
<th>Post</th>
<th>p-Values</th>
<th>( \eta^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI (kg·m(^{-2}))</td>
<td>21.7 ± 4.0</td>
<td>21.6 ± 4.2</td>
<td>19.3 ± 4.1</td>
<td>19.7 ± 4.1</td>
<td>n.s.</td>
<td>0.063</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WHR</td>
<td>0.47 ± 0.05</td>
<td>0.46 ± 0.05</td>
<td>0.44 ± 0.07</td>
<td>0.45 ± 0.07</td>
<td>n.s.</td>
<td>0.114</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CMJ (cm)</td>
<td>18.6 ± 5.4</td>
<td>21.1 ± 5.2</td>
<td>20.5 ± 5.2</td>
<td>18.6 ± 3.6 *</td>
<td>&lt;0.001</td>
<td>0.403</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ST (s)</td>
<td>4.12 ± 0.45</td>
<td>4.08 ± 0.47</td>
<td>4.06 ± 0.35</td>
<td>4.18 ± 0.32</td>
<td>0.020</td>
<td>0.157</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SRT (m)</td>
<td>450.0 ± 220.0</td>
<td>507.8 ± 216.5 *</td>
<td>496.7 ± 208.3</td>
<td>469.3 ± 162.9</td>
<td>0.046</td>
<td>0.122</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: Pre—before intervention; post—after intervention; BMI—body mass index; WHR—waist-to-height ratio; CMJ—countermovement jump; ST—sprint test; SRT—shuttle run test; \( \eta^2 \)—partial eta-squared; * \( p < 0.05 \), ** \( p < 0.01 \), and *** \( p < 0.001 \) represent changes from before to after intervention for the IG and CG; p-values represent interaction effects.

CMJ = Counter movement jumps → sig. increase in IG
SRT = Shuttle run test → sig. increase in IG
ST = Sprint test → sig. increase in IG
WHR = Waist to height ratio
BMI = Body mass index

(Ketelhut et al., 2022)
ExerG: Exergame-based Geriatric Therapy

AIM: Adaptation of user-centered soft- and hardware design for the geriatric movement therapy and investigation of acute and long-term effects on motor-cognitive functions (with relation to every day activities).
ExerCube @Home: On-Body Game Elements

**AIM:** Exploration of new physically immersive feedback designs for an @home exergame and investigation of long-term physical and cognitive effects and motivation of a training intervention @home.

ExerUp: Exergame-based Sports Rehabilitation

**DIZH Project**
«Control to Chaos»

Foci:
- Phase 3 of therapy after knee injury
- Return to sports (control to chaos)
The Emotional Journey of Exergames

Further Studies with the ExerCube
FROM THE LAB TO THE FIELD

Application Areas

Gym

Schools

Competitive Sports

Sports Rehabilitation

Cerebral Rehabilitation & Seniors

E-sports
Game Selection – Foci

Motor-Cognitive Assessments

Trail Making
Simple Reaction
N Back
8-Weeks Training Plan

David Habluetzel

CONCLUSION
INCLUSION

EMPOWERMENT

TAKE IT TO THE NEXT LEVEL!