



# The Use of New Technologies for Cognitive Assessment and Training during Childhood: Risks and Opportunities

---

Luca Pieri, *M.Sc.*

Psychologist, PhD Student

University of Milano-Bicocca

Department of Psychology

Mind and Behavior Technological Center - MIBTEC



# New Technologies?

- Technical innovations → new opportunities for research
  - *Convergence* between previously separated fields



**NBIC**  
Nanotechnology  
Biotechnology  
Information Technology  
Cognitive Science  
(Roco & Bainbridge, 2004)

The screenshot shows a PubMed search results page. The search query is "technology AND childhood development". The page displays 17,811 results. A "RESULTS BY YEAR" bar chart shows a significant increase in publications starting around 2010, with a peak in 2022. The first result is titled "Increased Screen Time: Implications for Early Childhood Development and Behavior." by Radesky JS, Christakis DA. The citation is "Pediatr Clin North Am. 2016 Oct;63(5):827-39. doi: 10.1016/j.pcl.2016.06.006. PMID: 27565361 Review." The abstract snippet reads: "The authors review trends in adoption of new digital technologies (eg, mobile and interactive media) by families with young children (ages 0-8 years), continued use of television and video games, and the evidence for learning from digital versus hands-on play. The authors ..."

# How does Technology Affects Child Development?

## The Dark Side



- Lowers the Attentional Span
  - Reduces Self-Regulation
  - Increases Aggressivity\*
  - Reduces Physical Activity
- Limits Interpersonal Interactions
- Affects Emotional Development

## The Light Side



- Improves Visual-Spatial Skills
- Improves Multi-Tasking Skills
  - Aids Learning
- Useful for Evaluating and Training the Cognitive Skills

\*The evidences are still controversial (APA, 2020)

# The Light Side: New Technologies for Enhanced Learning



Hardware/Software

Tablets/Smartphones  
(0-2 Years Old)

PCs  
(2-6 Years Old)

Virtual Reality  
(6-12 Years Old)

**Users: Students**

- Promote the Engagement to the Learning Process  
(*Serious Games*)
- Promote a Learn-by-Doing Approach

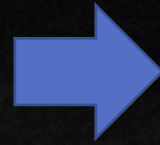
**Users: Teachers**

- Optimize the Evaluation Procedures  
(*Electronic School Register*)
- Common Platform for Sharing the Educational Material  
(*Cloud Computing*)

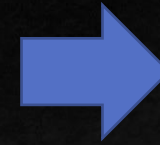
However, these tools can be also useful when there are signs of impaired learning

# New Technologies for Cognitive Assessment during Childhood

During her/his work, a teacher notices that a student is showing difficulties during some educational activities



There is a suspect for the presence of cognitive/behavioral difficulties



**Cognitive assessments** are used in school settings to assess a child's level of overall cognitive ability, learning capacity and identify their cognitive strengths and weaknesses



Attention Deficit and Hyperactivity Disorder (ADHD)

Autism (ASD)

## **Traditional Assessment**

Paper-and-Pencil tasks for assessing different cognitive domains

## **Technology-Based Assessment**

Engaging tasks usually delivered using a gamified approach (tablets and videogames)

**! Cognitive assessment could be valuable also for children who do not show difficulties**

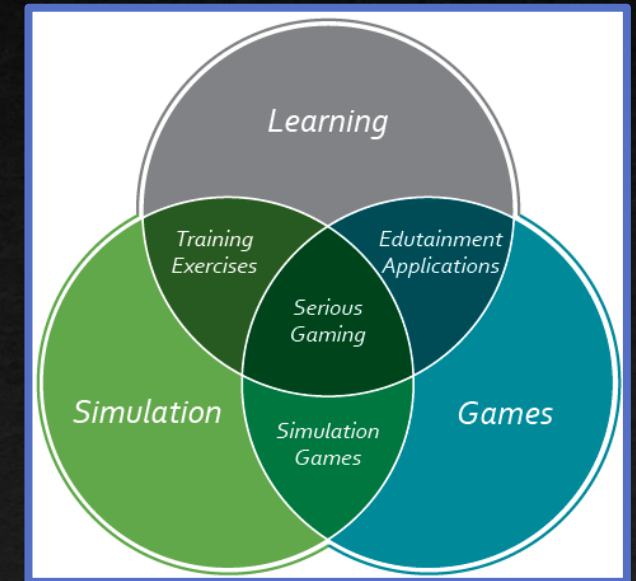
# New Technologies for Cognitive Assessment during Childhood

## ***Serious Games for Cognitive Assessment***

“Serious games are games or applications which are developed not only for fun, but to engage users into an activity → ***meaningful measures of cognitive functioning***”



Types	Diagnosing
Advantages	High participation rate, High accuracy rate, Objective
Disadvantages	Cannot distinguish subtypes clearly

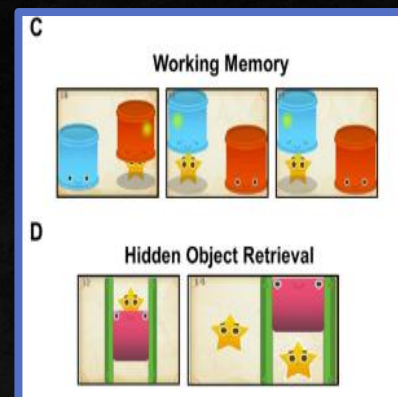
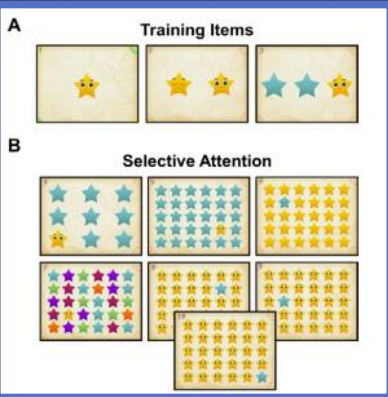


(Zheng et al., 2021)

# New Technologies for Cognitive Assessment during Childhood

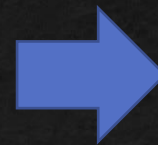
## Feasibility of using touch screen technology for early cognitive assessment in children

Deirdre M Twomey,<sup>1</sup> Conal Wrigley,<sup>1,2</sup> Caroline Ahearne,<sup>1</sup> Raegan Murphy,<sup>2</sup> Michelle De Haan,<sup>3</sup> Neil Marlow,<sup>4</sup> Deirdre M Murray<sup>1</sup>



### What is already known on this topic?

- ▶ Early identification of cognitive delay is critical if developmental interventions are to commence in childhood.
- ▶ Measurement of cognitive ability is currently heavily reliant on language and motor skills and child-administrator interaction.
- ▶ Use of touch screen devices is increasing and children aged 12 months or younger have the requisite fine motor skills to engage purposefully with touch screens.





### What this study adds?

- ▶ Children as young as 24 months old can complete a cognitive assessment on a touch screen device with no verbal instruction and minimal child-administrator interaction.
- ▶ Children can learn how to complete cognitive tasks on a touch screen device.
- ▶ This paves the way for using touch screen technology for language and administrator independent developmental assessment in toddlers.

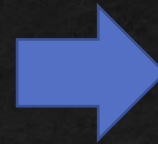
# New Technologies for Cognitive Assessment during Childhood

## Concurrent validity of a touchscreen application to detect early cognitive delay

Deirdre Marie Twomey,<sup>1,2</sup> Caroline Ahearne,<sup>1,2</sup> Emma Hennessy,<sup>2,3</sup> Conal Wrigley,<sup>2,3</sup> Michelle De Haan,<sup>4</sup> Neil Marlow ,<sup>5</sup> Deirdre M Murray <sup>1,2</sup>

### What is already known?

- ▶ Cognitive delay is difficult to detect in pre-verbal children.
- ▶ Standard administered developmental assessments are heavily language dependent.
- ▶ From 12 months of age, children can interact in a meaningful way with touchscreen applications.

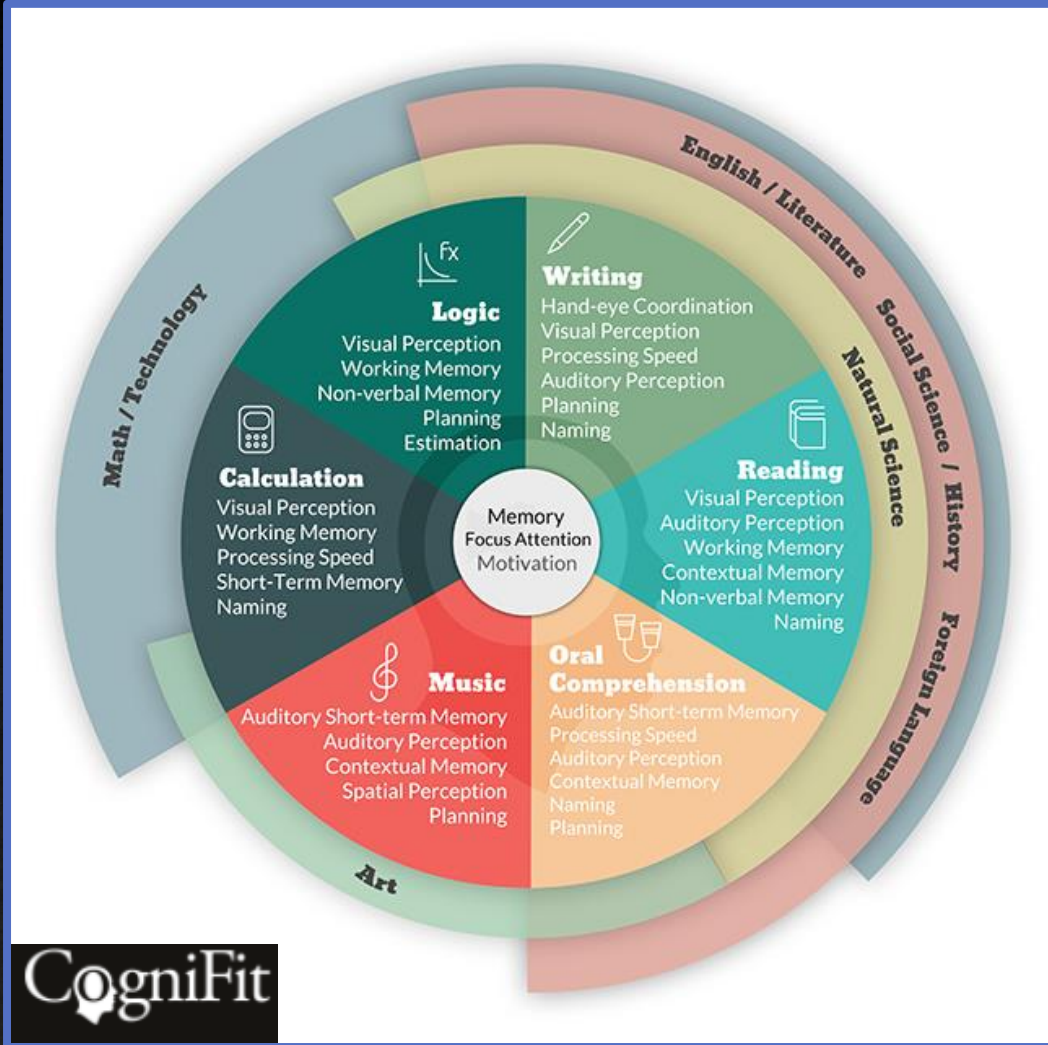


### What this study adds?

- ▶ A touchscreen application designed to test problem-solving ability has good concurrent validity with the Bayley Scale of Infant and Toddler Development—third edition cognitive composite score.
- ▶ Performance on the Babyscreen app has potential to screen for low average cognitive ability at 18–24 months.



# New Technologies for Cognitive Assessment during Childhood



CogniFit

Target Users: 7-18 Years Old Students



## Batteria di Valutazione Cognitiva Online per Scuole (S-CAB)

Valutazione Cognitiva Online per Scuole

La Valutazione Cognitiva Online per Scuole (S-CAB) è un test cognitivo per le scuole, ha il suo fondamento teorico nelle neuroscienze applicato all'ambiente accademico e di apprendimento e all'apprendimento.

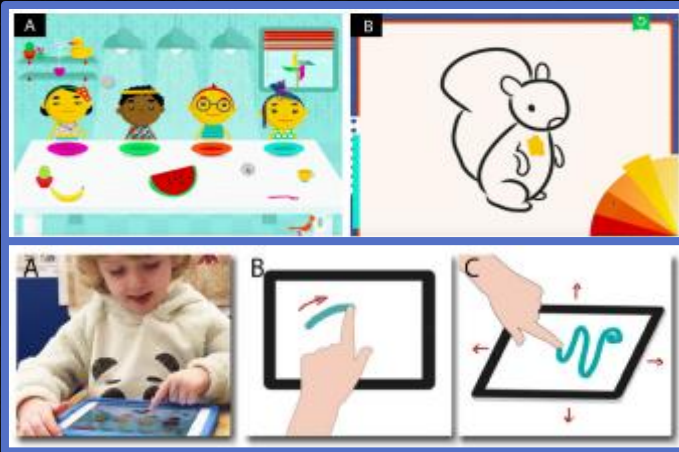
Questa valutazione è stata portata avanti da un team multidisciplinare composto da neuropsicologi, psicologi, medici, ingegneri, disegnatori, programmatori e scienziati coordinati dal comitato di scienza di CogniFit. I progressi in neuroimmagine e le ricerche sulle abilità cognitive in relazione con le competenze accademiche hanno permesso la creazione di questo strumento.

Il test di valutazione S-CAB relaziona le abilità cognitive con le diverse competenze accademiche



20 - 30 minutes

# New Technologies for Cognitive Assessment during Childhood



## Phase 3 diagnostic evaluation of a smart tablet serious game to identify autism in 760 children 3-5 years old in Sweden and the United Kingdom

Lindsay Millar,<sup>1,2</sup> Alex McConnachie,<sup>3</sup> Helen Minnis,<sup>4</sup> Philip Wilson,<sup>5</sup> Lucy Thompson,<sup>5,6</sup> Anna Anzulewicz,<sup>7</sup> Krzysztof Sobota,<sup>7</sup> Philip Rowe,<sup>1,2</sup> Christopher Gillberg,<sup>4,6</sup> Jonathan Delafield-Butt<sup>1</sup>



### Introduction

- ASD is a social and emotional disorder
- Early motor disturbances are the main biomarker for the early detection of the disorder
- Serious games are an attractive and valid paradigm for the assessment

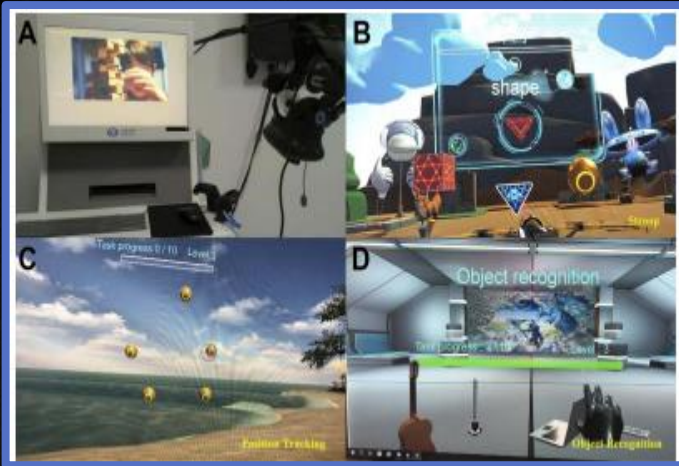
### Methods and Analysis

- Three groups: ASD-OND-TD (Age: 2-6 Years Old)
- iPad application (Play.Care) including two Serious Games
- Data coming from the touch screen and triaxial sensors are analyzed by a machine-learning algorithm

### Results and Conclusions

- Data collection is still ongoing
- Data coming from a pilot study (n=82) are reported
  - Play.Care assessment demonstrated a sensitivity and specificity of 83% and 85%, respectively

# New Technologies for Cognitive Assessment during Childhood



> *Neuropsychiatr Dis Treat.* 2019 Jun 4;15:1517-1523. doi: 10.2147/NDT.S206742. eCollection 2019.

## A virtual reality application for assessment for attention deficit hyperactivity disorder in school-aged children

Yantong Fang <sup>1</sup>, Dai Han <sup>1 2 3</sup>, Hong Luo <sup>1</sup>

### Introduction

- ADHD core symptoms: inattention, hyperactivity and impulsivity
- Diagnosis relies on interviews, self-reports and rating scales (subjective)
- VR advantages: objective and ecologically valid measures of cognitive functioning/higher engagement

### Methods and Analysis

- Two groups: ADHD-Controls (Age: 6-18 Years Old)
- VR-headset application including three tests (visual attention and executive functions)
- VR measures of performance were correlated with traditional questionnaires and attentional tests

### Results and Conclusions

- Significant positive correlation between VR measures and ADHD indexes collected with questionnaires
- VR measures were significantly correlated with neuropsychological measures of attention
- Further studies are needed to confirm and extend the results

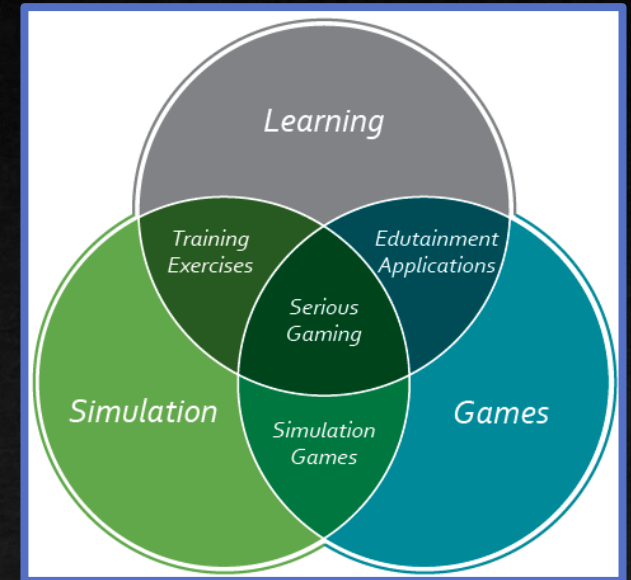
# New Technologies for Cognitive Training during Childhood



***Serious Games for Cognitive Training***  
“Serious games are games or applications which are developed not only for fun, but to engage users into an activity → ***better compliance to the training procedures***”






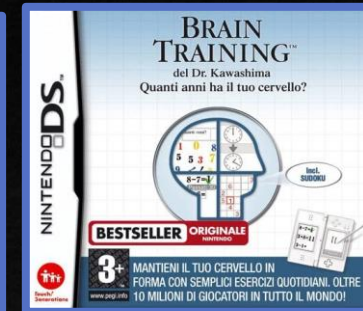
Types	Treating
Advantages	Low side effects, Increase enthusiasm, Improve executive function, Improve daily life skills, Promote social interaction
Disadvantages	The effect is not obvious, Easily addictive, Harmful to eyesight



# New Technologies for Cognitive Training during Childhood

## Brain Training in Children and Adolescents: Is It Scientifically Valid?

 Teresa Rossignoli-Palomeque<sup>1,2\*</sup>,  Elena Perez-Hernandez<sup>3</sup> and  Javier González-Marqués<sup>1</sup>



### Introduction

- Brain Training is a program or activity which purports to improve a cognitive ability or general capacity by repeating certain cognitive tasks over a period of time
- Transfer: benefits in near (target cognitive domain) and far (other cognitive domains) tasks
- Neuroplasticity: structural/functional changes in the brain after the repeated practice of a certain activity
- BT are available widely as commercial products? But are they valid?

### Methods and Analysis




- Systematic review of the literature
  - The resulting pool includes 70 articles
- 1<sup>st</sup> Group: products supported by neuroscience research (*neuroimaging or EEG evidences of induced neuroplasticity*)
- 2<sup>nd</sup> Group: products derived from experimental and quasi-experimental trials (*psychometric measures to evaluate program impact*)

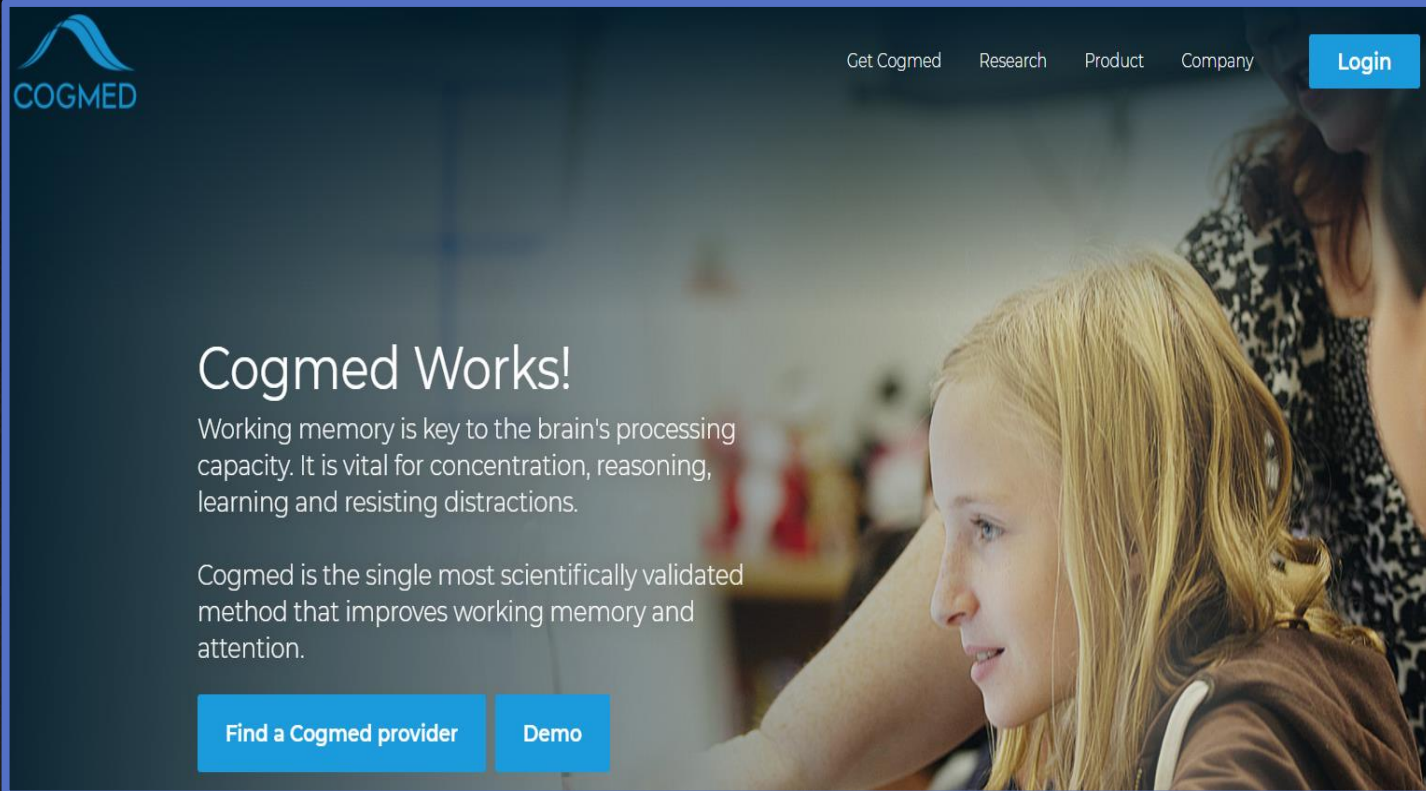
### Results and Conclusions

- Only a few BT products that are commercially available have empirical data that support evidence of neuroplasticity
- Far Transfer: more encouraging for the clinical population than for typically-developing children
- Overall, few independent studies have found far transfer and long-term effects

# New Technologies for Cognitive Training during Childhood

## Brain Training in Children and Adolescents: Is It Scientifically Valid?

 Teresa Rossignoli-Palomeque<sup>1,2\*</sup>,  Elena Perez-Hernandez<sup>3</sup> and  Javier González-Marqués<sup>1</sup>

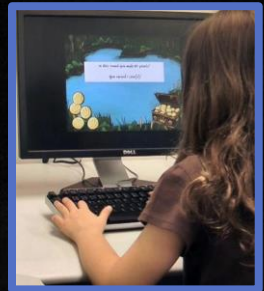


The screenshot shows the Cogmed website homepage. At the top left is the Cogmed logo. The navigation menu includes 'Get Cogmed', 'Research', 'Product', 'Company', and a 'Login' button. The main heading is 'Cogmed Works!'. Below it, a paragraph states: 'Working memory is key to the brain's processing capacity. It is vital for concentration, reasoning, learning and resisting distractions.' Another paragraph follows: 'Cogmed is the single most scientifically validated method that improves working memory and attention.' At the bottom, there are two buttons: 'Find a Cogmed provider' and 'Demo'. The background of the website is a photograph of a young girl with blonde hair looking intently at a screen.

### COGMED

- Efficacy supported by neuroscientific evidences (fMRI-EEG-DNA genotype)
- Correlation between neuroplastic changes and cognitive performance
- Focused on working memory training
- Evidences coming from typically developed and ADHD children

# New Technologies for Cognitive Training during Childhood



Meta-Analysis > Autism. 2014 May;18(4):346-61. doi: 10.1177/1362361313476767.

Epub 2013 Oct 3.

## Innovative technology-based interventions for autism spectrum disorders: a meta-analysis

Ouriel Grynszpan<sup>1</sup>, Patrice L Tamar Weiss, Fernando Perez-Diaz, Eynat Gal

### Improved Skills

Social  
(Facial emotion recognition)

Cognitive  
(Executive Functions)

### Introduction

- Computerized learning procedures include clearly defined tasks and avoid unnecessary sensory stimulation
- Those aspects are crucial for training essential skills for ASD individuals → but different technologies are used
- Emerging or established paradigms?

### Methods and Analysis

- Systematic review and meta-analysis
- Assessment of the efficacy of technology-based training for ASD
  - Identifying the different technologies used for the training paradigms

### Results and Conclusions

- The mean effect size approached the medium magnitude ( $d=0.47$ )
- This result supports the use of technology-based interventions for individual with ASD
- The improvement affects a wide range of different skills

# Technology-Based Cognitive Assessment and Training: Opportunities

## Technology-Based Assessment

### Opportunities

- Engaging procedures → fewer drop-outs, more meaningful measures of cognitive functioning
- Higher ecological validity → better prognostic indexes (specific for virtual reality)
  - Standardized and objective collection of performance measures
- More advanced data collection (e.g., heatmaps)
  - Administrable also from non-experts

## Technology-Based Training

### Opportunities

- Engaging procedures → fewer drop-outs, better compliance to the training procedures, higher retention of the acquired information
- Safe and controlled context with no risks deriving from the errors
- Adaptive responses based on individual performance
- Real-time feedbacks both for the users and for the professionals
- Enhanced accessibility and cost-effectiveness



# Technology-Based Cognitive Assessment and Training: Risks

Technology-Based Assessment

Technology-Based Training

## Risks

- The development is still very time-consuming, and the implementation can be complex
- Might be not appropriate for all situations (e.g., very impaired children)
- Easily addictive and their prolonged use can induce side effects (e.g., eyestrain, motion sickness)
- Must not be taken as entire substitutes of the traditional methods (e.g., therapist-patient relationship is still crucial)



# Thank you for your kind attention!



**Contacts:**

**Mail:** [l.pieri3@campus.unimib.it](mailto:l.pieri3@campus.unimib.it)

**LinkedIn:** <https://www.linkedin.com/in/luca-pieri-942786176/>

**MiBTec:** <https://www.mibtec.it/it/>