Principles of a self-administered cognitive assessment and training video game and implications in health, education, and wellbeing

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INTRODUCTION

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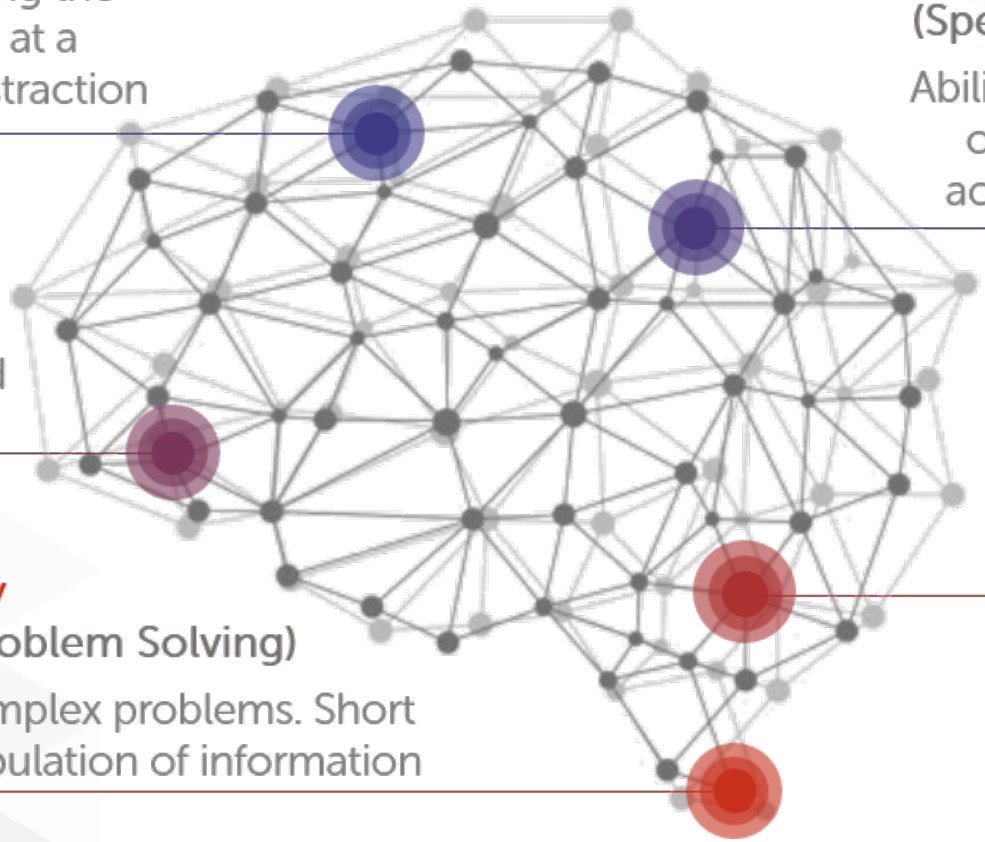
What is cognition?

Attention
(Concentration)

Selectively focusing the mind on one task at a time, blocking distraction

Processing Speed
(Speed And Accuracy)

Ability to perform sequences of tasks with smoothness, accuracy and coordination



Episodic Memory
(Memory)

Recall of times, places, and contextual knowledge

Executive Function
(Planning And Strategy)

Managing all cognitive abilities to plan for the future

Working Memory
(Calculation & Problem Solving)

Finding solutions to complex problems. Short term storage and manipulation of information

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Why should we assess and train cognitive abilities?

Consequences of a poor cognitive health:

- Difficulty with maintaining motivation and drive; difficulty in planning and initiating activities; unable to cope with change or inhibit inappropriate responses
- Unable to comprehend; cognitively paralysed; easily confused; cannot see a work project to the end; decreased resilience to stress
- Forget key points in meetings, key conversations, appointments; loss of wisdom; low confidence
- Can not concentrate in school environment; can not keep track; cannot allow attention to be captured by teacher; easily distracted
- Difficulty in sequencing and coordinating tasks; lack of decisiveness

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Which features for cognitive tools?

- self-administration
- digital access
- real-time scoring system
- automated reporting
- user-friendliness
- adaptive challenge
- engagement

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BACKGROUND

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Principles of cognitive assessment

- Reliability and especially with respect to temporal (aka ‘Test-Retest’) reliability, internal consistency and intra- and inter-rater reliability.
- Validity, i.e. does the test measure the cognitive concepts of interest?
- Sensitivity
- Relative immunity to practice, or when this is an issue the provision of parallel forms
- Concern for successful cross-cultural use

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Traditional, paper & pencil VS digitalized methods

	Conventional **neuropsychological tests**	**Computerised cognitive tests**
Psychometric considerations		
Different forms	None or few	Many
Verbal vs. non-verbal tests	Verbal and non-verbal	Tend to be non-verbal
Randomisation of stimulus	Within test	Within test, between test and between subjects
Test-retest reliability	Wide variability	Generally high for measures of response time
Normative data	Mainly cross-sectional, very little longitudinal data	Very little for most tests
Effects of practice	Large for most tests because of lack of different types	Small because many different forms and randomisation of stimulus presentation
Output	Level of performance	Level of performance and variability in performance

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Traditional, paper & pencil VS digitalized methods

	Conventional neuropsychological tests	Computerised cognitive tests
Practical considerations		
Administration time	Up to 240 minutes	Up to 120 minutes
Support needed	Neuropsychologist or trained technician for administration	Some tests may be self-administered and automatically scored. Interpretation still required by an appropriate professional
Accessibility by users	Poor, requires trained personnel	High, may be accessed via the internet
Data storage and analysis	Time consuming and costly	Automated
Cost	Materials and supplies can be costly	Potential savings with regard to materials and supplies

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Foundations and potential of cognitive training

Brain plasticity, otherwise known as neuroplasticity or cortical remapping, refers to the capacity of the nervous system, essentially the brain to change or to adapt its structure and function over a lifetime.

Changes in the brain occur due to a wide variety of experiences during the lifespan, such as task learning, psychoactive drugs, reward, aging, stress, and diet.

Brain plasticity enables cognitive function to be modifiable in all phases of life – it can be improved, regardless of your age, and cognitive decline can be reversed.

A growing body of evidence supports the protective effects of cognitive stimulation that promotes dynamic reorganisation of higher cerebral functions, thereby helping to maintain function in the elderly [Kelly & Garavan 2005; Boyke et al 2008; Erickson et al 2011] and reduce the risk of incident dementia [Scarmeas et al 2001; Wilson et al 2002].

Foundations and potential of cognitive training

Cognitive training offers retraining in the ability to think, use judgment, and make decisions. Training focuses on correcting deficits in memory, concentration and attention, perception, learning, planning, sequencing, and judgment. Multiple cognitive abilities are involved in everyday tasks, and therefore cognitive training across abilities may be most beneficial.

Cognitive training aims to enhance a person's capacity to process and interpret information and to improve their ability to function and integrate in all aspects of family and community life. Preserving or restoring physical and cognitive function enables individuals to maintain an active and engaging life, and to retain autonomy and independence.

The goals of cognitive training may be considered to be:

- To enhance ‘normal’ levels of cognition
- To avoid or delay cognitive decline due to aging or neurological disease (maintaining current level of functioning appears to be the major goal of many older adults)
- To remediate current cognitive deficits due to aging or neurological disease.

Gamification of cognitive training

- Avatar
- Background music
- Interactive Characters
- Non-interactive Characters
- Competition
- Complex motor control
- Dynamic world growth
- Overarching Goal
- Knowledge tests
- Leaderboard/high score
- Levels
- Lives
- Minigames
- Negative feedback
- Online option
- Positive feedback
- Storyline
- Strong Theme
- Time pressure
- Difficulty Levels

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METHODS

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The MyCognition approach to cognitive assessment and training

- Based on over 40 years of research
- Clinically validated measurement
- Delivers bespoke feedback/ reports from clinical psychologists

- Assessments are self administered in 15/30 minutes and are accurate and repeatable
- Results are immediate
- Detects both enhancement and deterioration of cognitive health

- Dynamically changes based on an individual's MyCQ score

- Training is holistic, but is more intense where there is greatest need
- The training adapts as the individual progresses and is embedded in a video game to maximise engagement

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The MyCQ assessment

Cognitive domain	MyCQ tests
Processing Speed	Simple reaction time test
Attention	Choice reaction time test
Episodic Memory	Visual recognition memory test
Working Memory	2-back test
Executive Function	Alphanumeric trail making test

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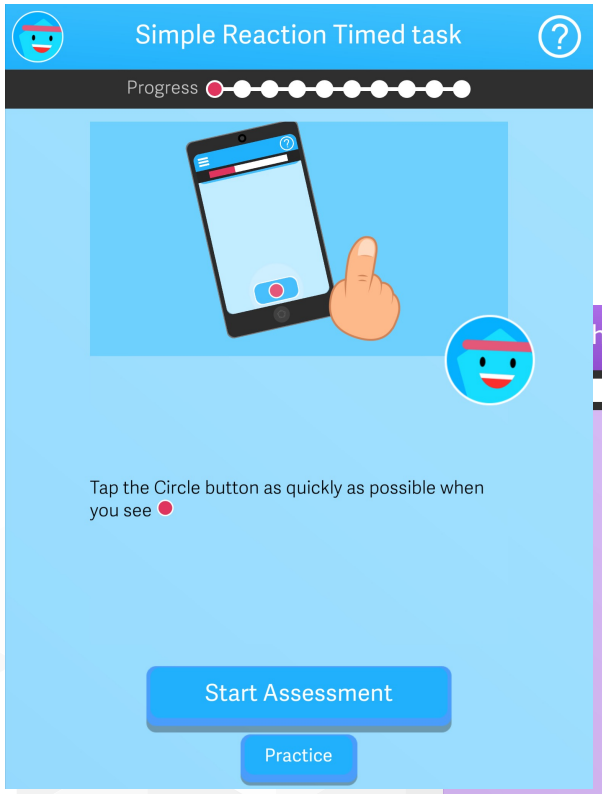
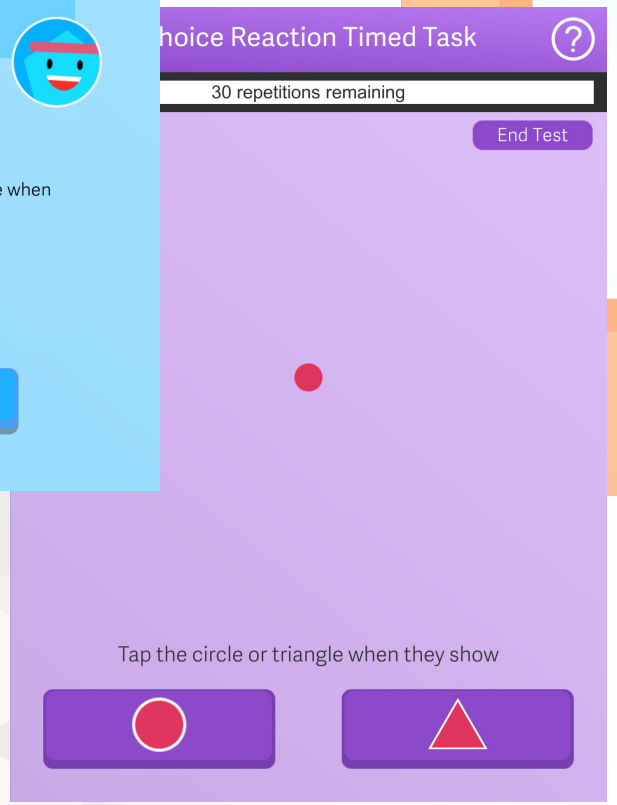
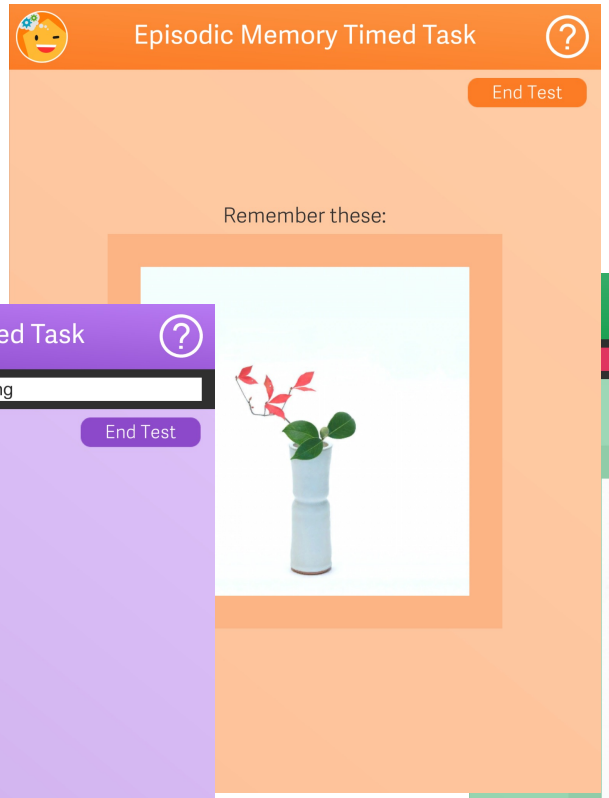
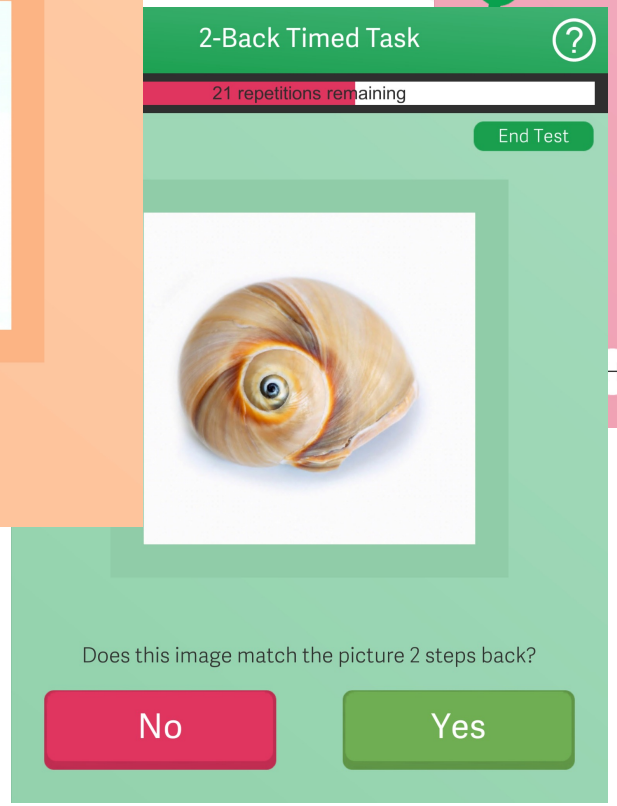
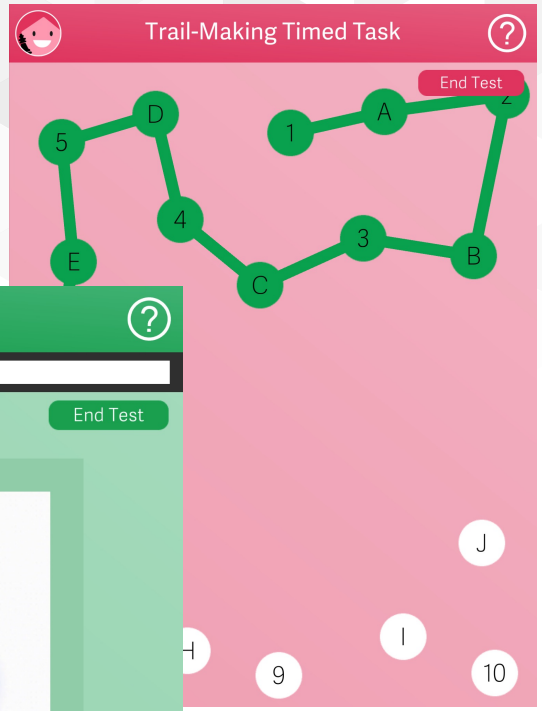
The MyCQ assessment











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Experiencing MyCQ

https://play.google.com/store/apps/details?id=com.mycognition.home&hl=it

https://itunes.apple.com/za/app/mycognitionhome/id1176880537?mt=8

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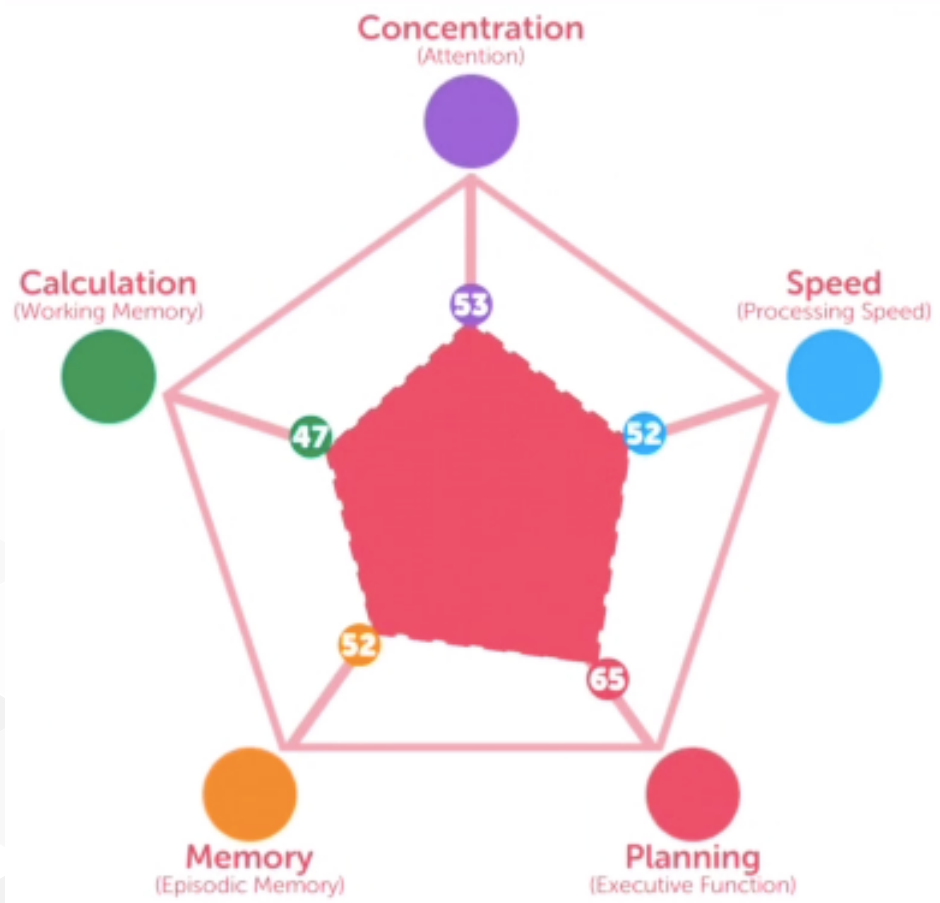
The assessment and reporting system



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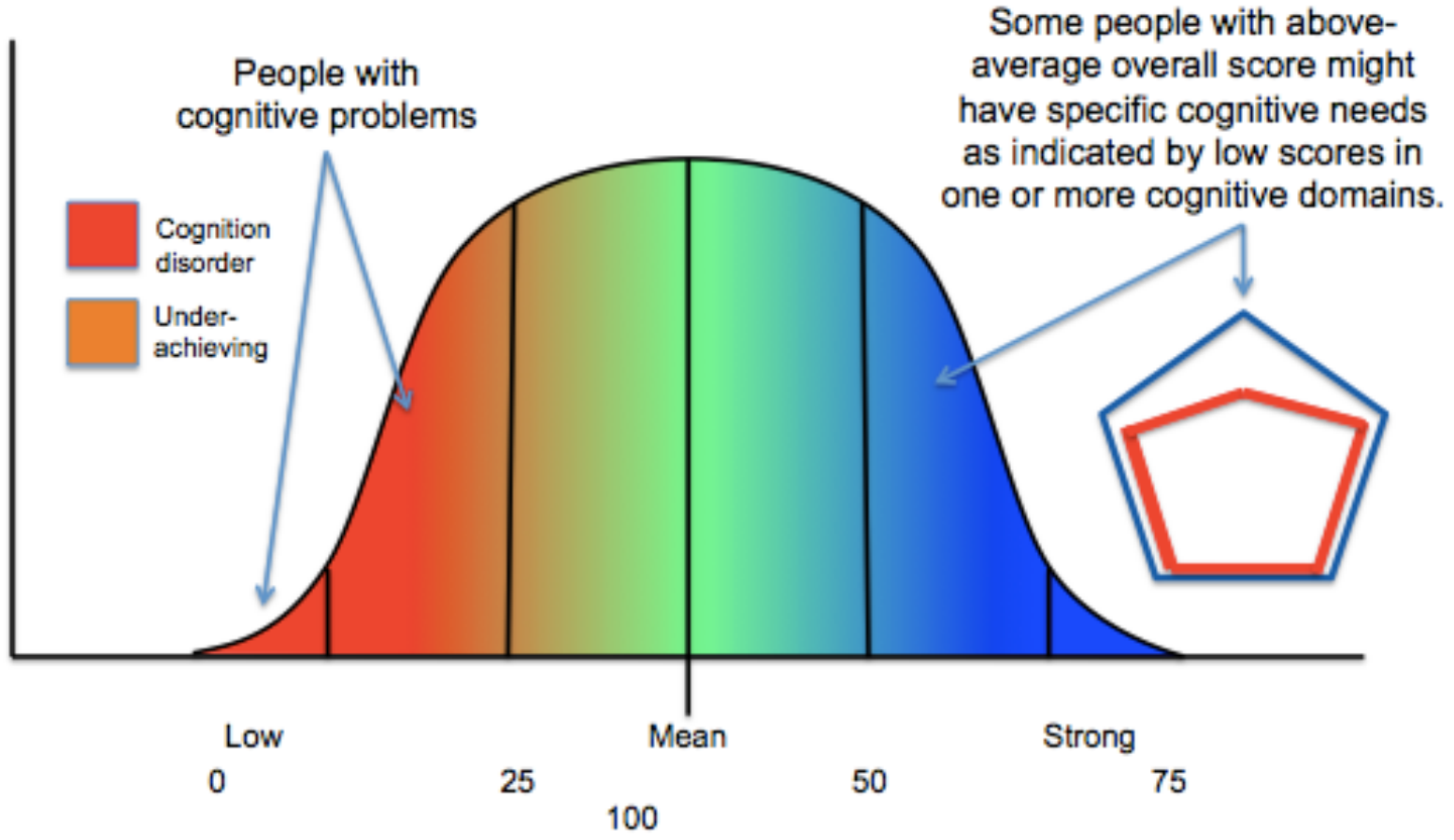

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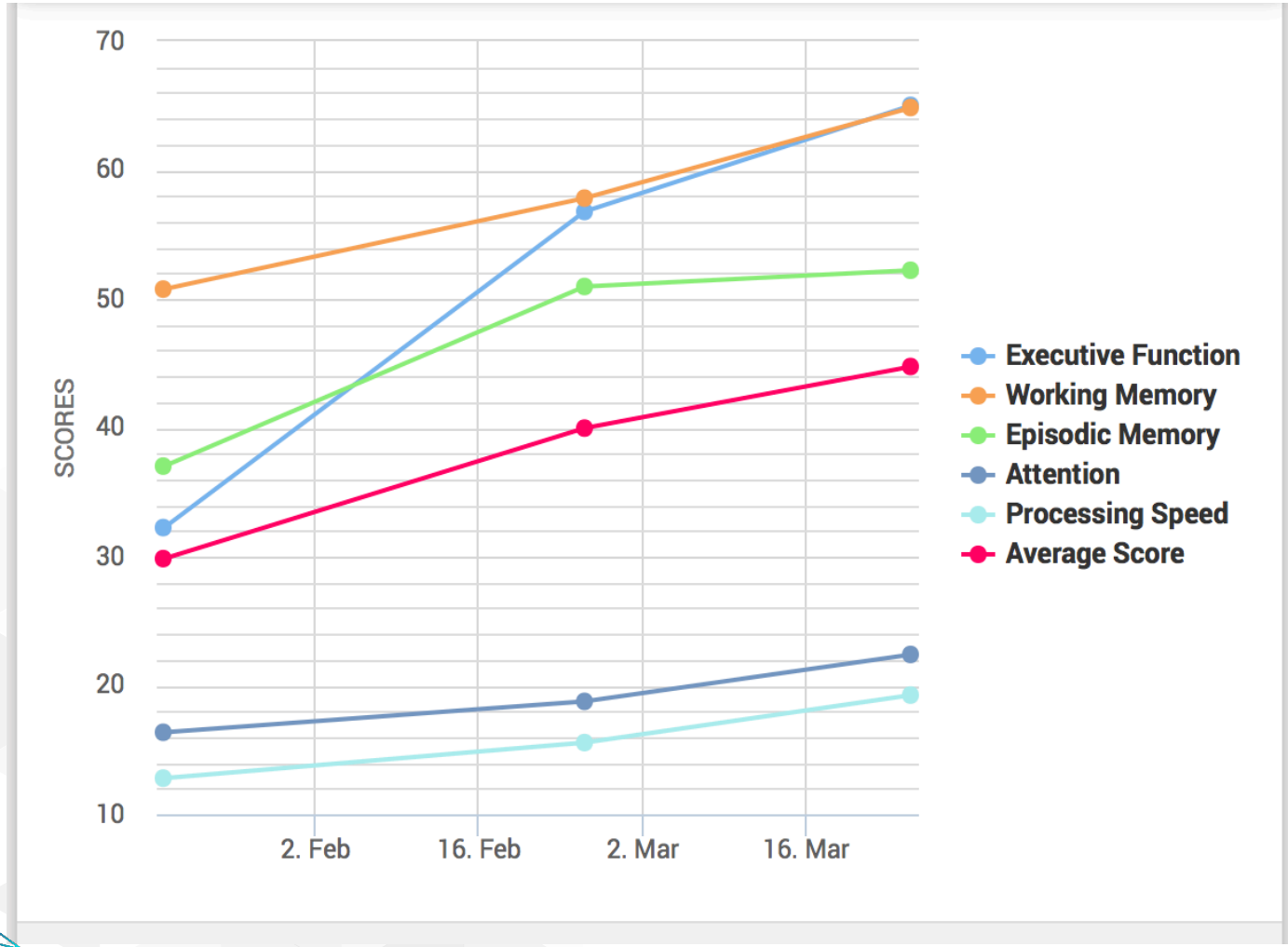

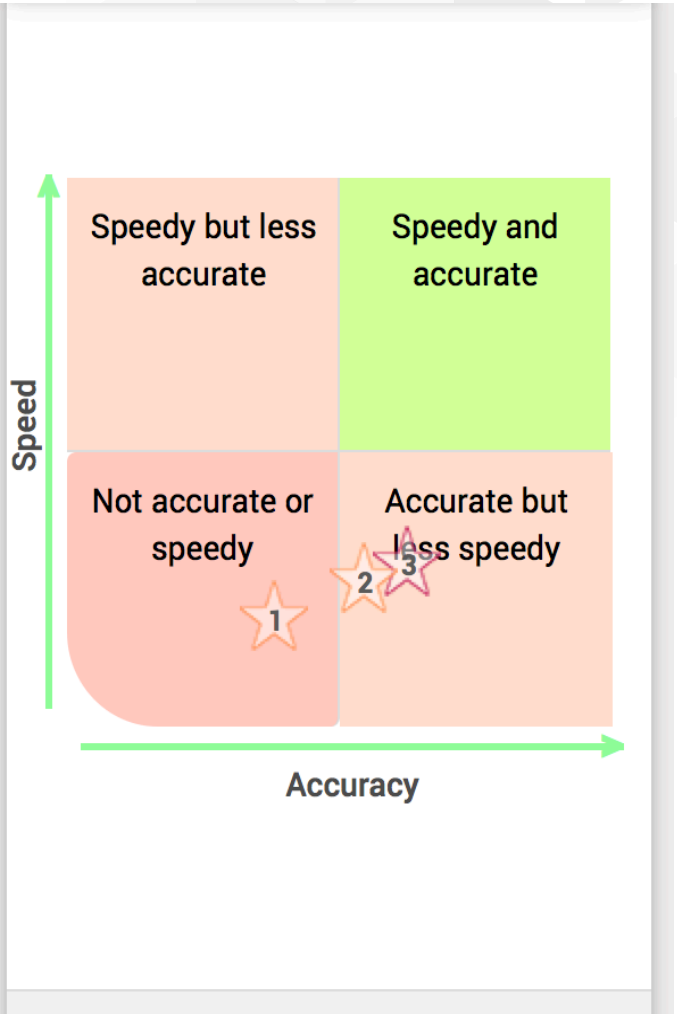

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The training game

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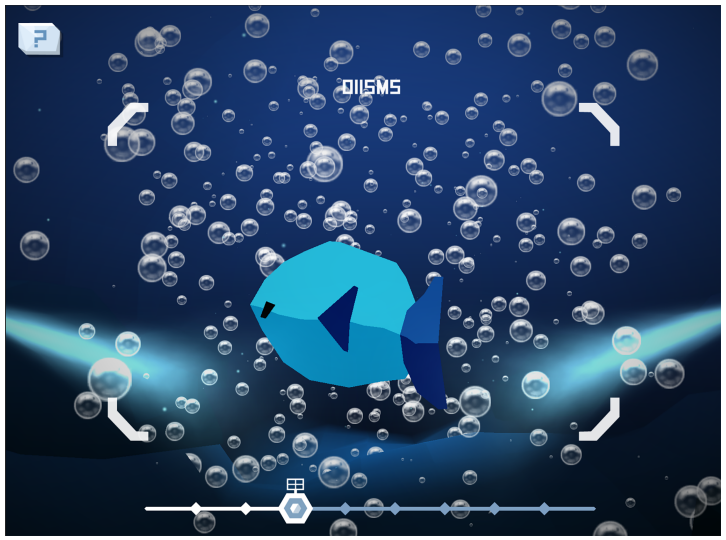
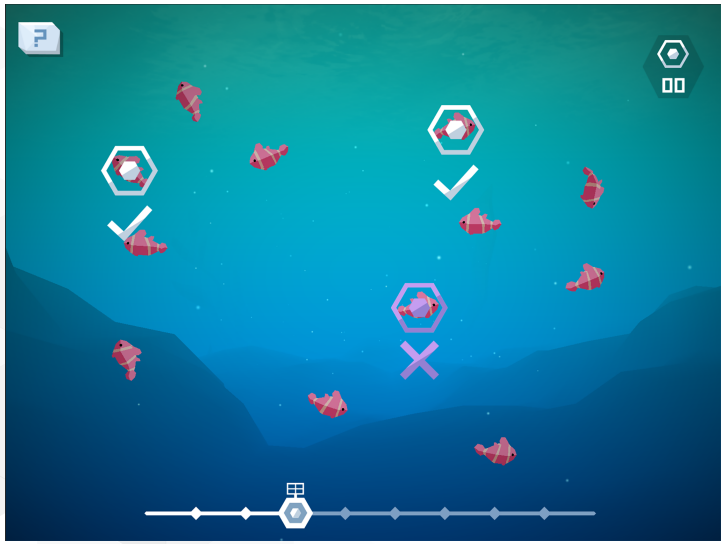
The training game





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STUDIES & RESULTS

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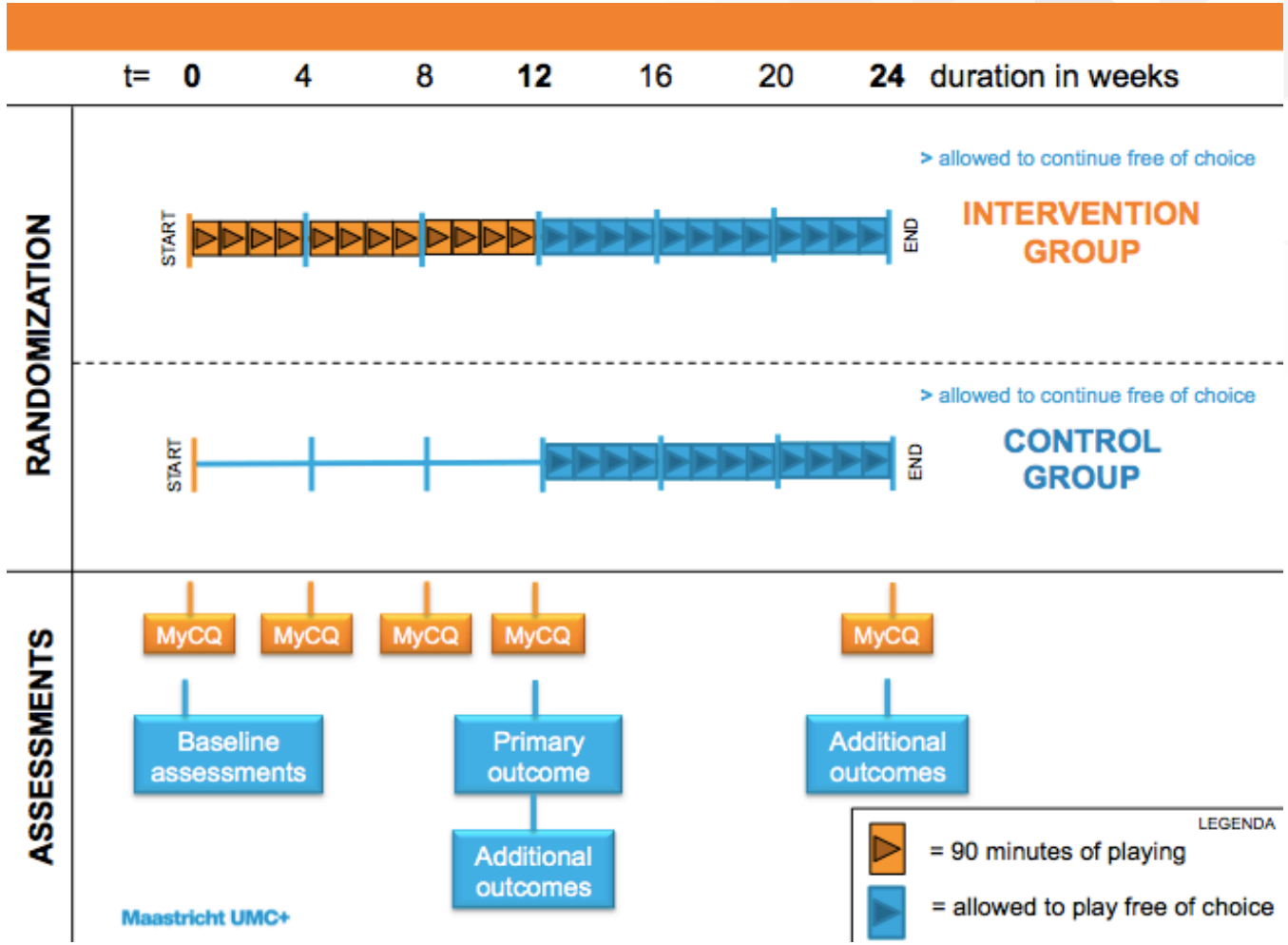
A standard study design

In a standard randomised control trial (RCT) all the patients selected on the basis of specific inclusion/exclusion criteria complete a first cognitive assessment at the baseline, together with any other type of assessment intended for the study.

Then, patients allocated in the intervention group are recommended to play the training game for 90 minutes at week at least 3 times a week for 12 weeks.

On the contrary, the control group follows standard activities for all the 12 weeks without training.

Both the groups are recommended to take follow-up cognitive assessment every 4 weeks to monitor the progress and a final assessment at the end of the study.



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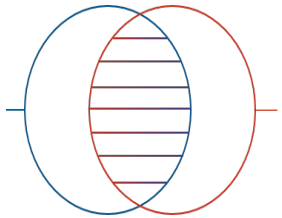
Pilot validation trial with a psychiatric population

Results of our assessment platform



Those of accepted, validated instruments

80 patients with profiling of psychiatric conditions

Statistically significant ($p < 0.05$) & highly significant ($p < 0.001$) correlations were found in all key domains of cognition

77 patients with 3 severe psychiatric disorders provide early evidence to validate that MyCQ scores correlate with well-established and validated Cambridge Neuropsychological Automated Test Battery (CANTAB). MyCQ validation continues until end 2016 in a 3rd randomized controlled trial (RCT) of 120 psychiatric patients at AMC, Amsterdam.

In the above study, patients who trained using the video game for at least 90 min/wk showed significant improvement in verbal memory performance while the control group showed no improvement.

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Main outcomes obtained in education settings

An interim analysis of **588 primary & secondary school students** in 28 schools shows significant evidence that playing the video game for 90 min/wk has improved performance and underlying cognition

In studies with 11 primary & secondary UK schools, there was a 46% increase in cognition scores amongst those who played a sufficient number of hours and no change in scores for those training less than the required minimum amount of time.

In a study in of **43 year 8 & 9 pupils with SEN or learning difficulties** at a London school, the mean cognitive improvement measured at 4, 8, 12 weeks in the video game training group was nearly double that of the control group, with corresponding performance in 10 or 13 teacher-assessed subject including Maths, English, and Science.

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IMPLICATIONS IN E-LEARNING

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Cognition and learning

Special Educational Needs

- Autism
- ADHD
- Executive Function Disorder
- Dyslexia
- Dyscalculia
- General Learning Difficulties
- Behavioral Difficulties

Academic improvements in mainstream, SENs, and gifted & talented students

- Math (calculation, problem solving)
- English (reading, listening, comprehension)
- Science
- General ability to focus
- Behavior

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Processing Speed and fluency

Processing speed has been shown to be predictive of different academic abilities, such as sentence comprehension (Caplan et al 2003) and mathematic skills (Clark et al 2014).

Processing speed primarily influences efficiency of reading fluency among those who can read single words. Reading fluency can subsequently affect further development of more complex academic skills, such as reading comprehension. Reading comprehension is dependent on automaticity, which is a key skill with psychomotor speed. As reading becomes more automatised, less mental effort and attentional resources are required for ongoing decoding and accurate word reading; thus, these resources can be allocated to the task of translating text into meaning.

A good development of processing speed allows higher level cognitive processes which require a greater control to perform better, as less cognitive resources are needed to perform automatised tasks with confidence.

Attention & comprehension

Research findings have shown that attentive resources and reading comprehension abilities are strongly linked, involving in particular sustained attention (Stern & Shalev 2013).

A study (Franceschini et al 2013) has shown that playing action video games, not involving any direct phonological or orthographic training, drastically improve the reading abilities of children with dyslexia.

Reading, phonological, and attentional skills in two matched groups of children with dyslexia were tested before and after they played action or non-action video games for nine sessions of 80 min per day.

It has been found that only playing action video games improved children's reading speed, without any cost in accuracy, more so than 1 year of spontaneous reading development and more than or equal to highly demanding traditional reading treatments. Attentional skills also improved during action video game training.

Episodic Memory and learning

As a component of the long-term memory, episodic memory play a great role in learning.

It is well know that learning styles may individually vary, based on the prevalent sensorial modality.

Finson & Pederson (2011) have highlighted the importance of visual memory, one of the main components of episodic memory, in learning and teaching processes.

Episodic memories influence both how we learn, by providing a multi-modal frame where new knowledge is inserted, and how we retrieve and then use the information learnt.

Working Memory & mathematic skills

Several studies have investigated the relations between working memory abilities and academic achievement, looking in particular at mathematics performances in primary school children.

Working memory has resulted to be involved in different mathematic processes, such as reasoning, numerical operations and problem solving (Meyer et al 2010).

Several randomised controlled trials have shown that working memory skills can be enhanced by adaptive training. A study involved two field trials in which teachers administered working memory training to their own pupils in school.

Following training, children improved significantly in both trained and untrained working memory tasks, and training was associated with significantly greater progress at school across the academic year in maths and English (Holmes 2013).

Executive Function and metacognitive abilities

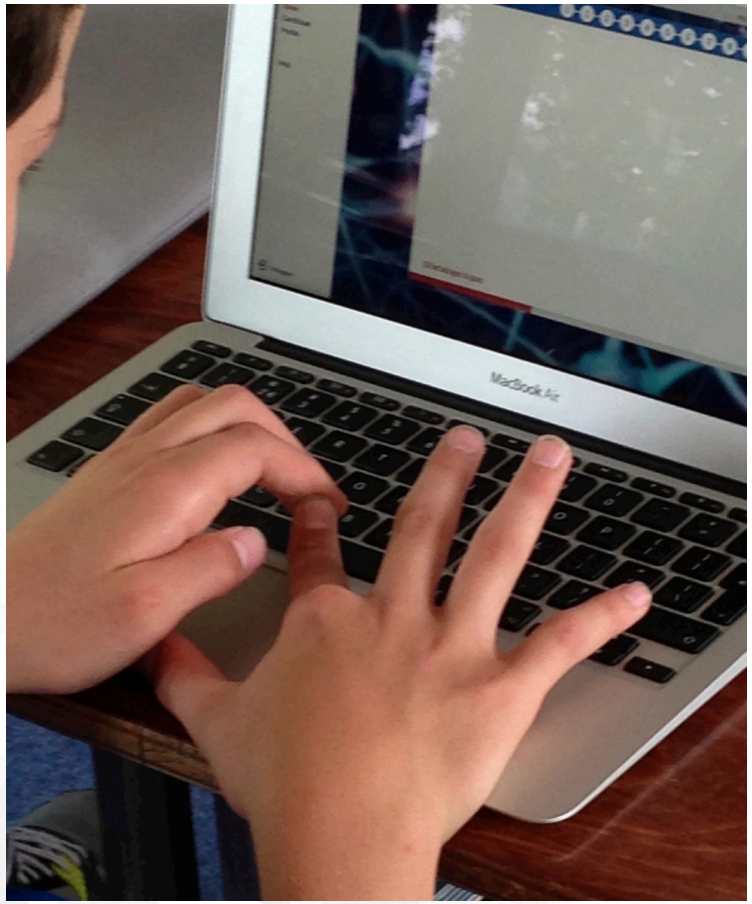
As responsible of the control of different key cognitive processes, executive function have been shown to be involved in multiple domains of learning and school performance.

In addition to core processes associated with attention and working memory resources, which make executive function linked with different domains of learning, such as English and mathematics, executive function are well-known to be responsible for a set a monitoring and self-regulatory processes called metacognitive processes.

Meta-cognition is a the ability to look at, control, and regulate our own cognitive processes.

This plays a fundamental role in learning, allowing to implement adaptive strategies in acquiring new information, to monitoring a task completion, and to inhibit inappropriate processes.

Adoption of a cognitive assessment and training program as a part of an e-learning platform



- An example is the case of a virtual school providing complete education curricula based on an e-learning platform, for students from year 7 to A-levels, coming from different backgrounds and having various life-stories.
- The MyCQ assessment has been used over three years as a screen tool to evaluate the cognitive level of every new student enrolled, coming from very different education and cultural backgrounds and with a variety of health conditions.
- On an individual level, this allows the school to monitor each student's cognitive progression and to provide them with personalized training to enhance cognitive function, especially for those who have low scores in one or more domains of cognition. Since the program is completely self-administered, students can use it with the same conditions required by the e-learning platform, basically a digital device and Internet access.
- The tool can contribute to the identification of specific cognitive issues in children diagnosed as having general learning difficulties, allowing further examinations and diagnoses on the specific type of impairment and consequently allowing a more appropriate treatment.
- On a class level, teachers using the online platform are provided with class reports which allow a remote monitoring of the pupils' cognitive level across time and identify the domains showing deficits, highlighted with different colours. Teachers are also provided with knowledge tips about how learning and teaching are linked with cognitive function.

An example of teacher's dashboard

Bands: Low | Low-Average | Average | High-Average | High

User Id	Name	Assessment Date	Executive Function	Working Memory	Episodic Memory	Attention	Processing Speed	Overall Score
		27/05/2016	44.24	50.13	44.75	53.44	54.03	49.32
		03/06/2016	53.81	53.9	58.55	56.21	57.46	55.99
		25/05/2016	43.82	43.99	53.27	57.26	58.86	51.44
		05/07/2016	47.36	49.59	57.04	54.89	56.26	53.03
		12/05/2016	39.72	35.15	52.88	54.97	56.91	47.93
		12/05/2016	30.99	33.93	41	44.19	44.45	38.91
		31/05/2016	30.99	33.93	41	44.19	44.45	38.91
		06/07/2016	30.77	32.24	47.06	41.04	41.63	38.55
		17/05/2016	35.51	34.91	43.68	39.85	41	38.99
		14/06/2016	34.65	38.2	48.02	26.18	26.71	34.75
		21/06/2016	25.07	37.97	37.6	25.1	25.58	30.27
		14/07/2016	34.91	39	45.62	25.02	28.66	34.64
		16/06/2016	29.03	28.44	39.58	35.77	36.38	33.84
		17/05/2016	26.99	24.21	20.17	39.52	42.2	30.62

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OTHER PERSPECTIVES

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Other implementations of the program in corporate wellbeing programs, elderly support, and smart communities

- Troubled families
- Unemployed parents
- Active Ageing
- Cognitive health in the workplace
- Rehabilitation
- Hospital bed blocking

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The Peterborough projects

Early Help Service, Peterborough

Working with at Key Stage 2 at risk of not achieving their SAT exams and reaching required levels of literacy and numeracy

30

Assess cognition and correlation with test scores and other measurements of behaviour

School Improvement Team, Peterborough

Real-world study of cognitive deficits among primary school population

500

Assess and profile cognitive deficits with aim of overcoming obstacles to learning to improve educational outcomes and enhance well-being

Employee Engagement and Wellbeing, Peterborough

Initial workshop building on UNICEF case study

20

MyCQ Assessment as a measurement tool to assess health and well-being strategies

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Unemployed Vulnerable Adults, Peterborough

Real-world study with YMCA and Job Centre Plus to support adults who have been long term unemployed back into work

40

Assess cognition and measure improvement in **40+ adults** helping them to move closer to the job market

Skills for 21st Century, Peterborough

Study with University Technical College to ascertain cognitive profile of learners at point of admission

150

Assessing and measuring cognition and advocating the value of 'thinking' skills alongside 'practical' skills

Leadership Skills for Innovation in Peterborough

Working with Opportunity Peterborough to identify and enhance the leadership skills in the workplace

115

Assessing and measuring cognition and enhancing leadership and management skills

CONCLUSION

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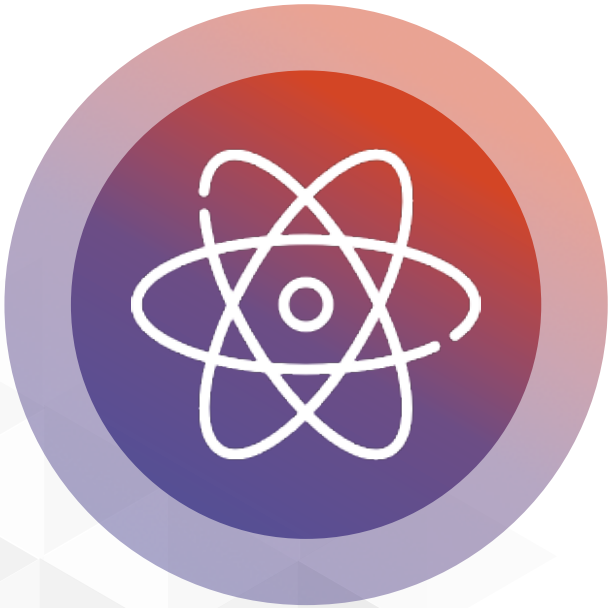
Conclusion



Cognitive assessment and training tools may have a positive impact on education, social services, professional environments and in the health care.

Digital, online tools are able to open new frontiers, making cognitive assessment and training available to everyone in different real world settings.

To develop tools embedding features making the programs further engaging and integrated into a plan of everyday life healthy habits may be a challenge for future research.

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… changing the world one mind at time

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