

The Use of an IT-based Cognitive Assessment and Training as a part of a Smart City Program

Implications in Educational, Social, and Healthcare Public Services

Martina Ratto, Keiron T Sparrowhawk, Paul B Cliveden (Author)

MyCognition Ltd.

London, United Kingdom

e-mail: martina@mycognition.com

Abstract—Smart Cities are defined as communities able to improve citizens' quality of life by integrating innovative, technology-based solutions with human potential. This paper aims to evaluate the impact of adopting on a citizenry level a self-administered, online cognitive assessment and training program targeting cognitive health and wellbeing in the process of building a smart community. An implementation of this program across the Peterborough citizenry will be presented, showing the potential outcomes it is intended to produce across the education, social services, workplace, and elderly healthcare sectors. Starting from this pilot study, which is successfully involving Peterborough local communities, possible implementations of the program in other cities' public services will be considered.

Keywords—Smart cities; social services; cognitive health; cognitive assessment & training.

I. INTRODUCTION

Smart Cities, according to the main common definitions, are communities which unite different types of resources to create innovative, technology-based solutions directed towards the community's development and improvement of people's quality of life [1].

As winner of the World Smart City of the Year 2015 award, the city of Peterborough in the United Kingdom is an example of an implementation of a citizen growth, innovation, skill, and sustainability program.

To achieve this, Peterborough City Council and Opportunity Peterborough created the DNA Peterborough program, focused on the creation of smart business environments, on providing a "Living Data Portal" (offering easily accessible census data, crime statistics and health information), on the improvement of employability chances, and on long-term physical and mental health resilience.

As a part of this project, Peterborough City Council has promoted a partnership program with a science-based company specializing in IT-based solutions for cognitive health. Their intent is to promote and enhance cognitive wellbeing across multiple segments of the population, resulting in related outcomes in academic achievement, employability, business soft skills, quality of life, health, and sustainability.

In Section 2 the MyCognitionED assessment and training program adopted by Peterborough citizenry will be presented. Details about the implementation of the program across different sectors of city and the related objectives will be illustrated in Section 3. The expected outcomes of the program in contributing to the creation of a smart community according to the previously provided definition will be evaluated in Section 4, considering citizens' skills enhancement, social outcomes, and public costs saving. In Section 5 further possible implementation in other local communities will be considered, following the Peterborough example. Finally, in Section 6 a preliminary conclusion on the evaluation of the potential of the presented program will be drawn.

II. THE MYCOGNITIONED PROGRAM

MyCognitionED [3] is a program designed to assess and train individuals' cognitive wellbeing in various educational communities, including schools, universities, social and cultural groups, and life-long learning programs.

It comprises a 15-minute, self-administered, online assessment including a digital version of five of the most validated, traditional, paper-and-pencil, neuropsychological tests, designed to assess five key cognitive domains – attention, processing speed, working memory, episodic memory, and executive function. The assessment provides reports for each user, showing the scores obtained in each of the five domains, the trends of improvement over time for everyone, their position relating to the two dimensions of speed and accuracy, and detailed explanations about what the different scores mean and actions they can take to obtain improvements.

The MyCognitionED program then uses the assessment's scores to create a "recipe" that automatically configures a linked training program. The training application is designed to enhance overall cognition, particularly training those domains that showed the greatest weaknesses more intensely. The training program is totally embedded in an engaging video game, which adapts itself to the user's progress.

The game has an aquatic theme in which players must venture into the ocean to undertake various activities. The activities include exploring underwater worlds populated with a range of fish and sea creatures, seeking out and

photographing different types of fish, each with specific characteristics. The training works by encouraging the player to undertake repetitive, and increasingly more challenging, tasks that are designed to train a specific cognitive domain.

Each cognitive domain is mainly trained by a specific “loop,” with some domains trained using several tasks. The game develops on multiple structural levels. At the basic structural level, there are the loops corresponding to different cognitive tasks, which are organized in dives, so that in each dive the user can experience a set of loops.

The ocean map represents a meta-level of cognition. At the map level, users must organize their dive to both achieve the proposed mission and to discover new areas.

The progress of the players on the map, and so the growth of difficulty in the training game, depends on the coins the players collect during their dives. In this way, the game adapts its difficulty to the level of improvement reached by the player.

The intensity of the training depends on the individual assessment’s scores, too, as mentioned above, as the number of loops for each type of task that the user experiences depends on the score obtained in each cognitive domain. In this way, more impaired domains will receive more intensive training. It is generally recommended that users follow the training program for at least eight weeks, playing a minimum of ninety minutes per week, three times a week, to obtain significant improvements.

The program is used in psychiatric populations and in patients having neurodegenerative and various medical conditions [4][5][11][14], as well as in elderly populations and in students of different ages, including those having special educational or learning disabilities/differences (SEND) [7][8][9][13].

The programs are available online and run on the most commonly used web browsers on PC and Mac computers. MyCognitionED is also available as an app for iPad users, and versions for iOS smartphones. Versions of the programs are in development for Android tablets and smartphones.

III. THE PETERBOROUGH PROJECTS

The adoption of the MyCognitionED program as a part of the Peterborough City Council “smart” plan is divided into several projects across various segments of the population. The goal is to grant the entire population access to this time- and cost-saving, digital tool for self-administered assessment and training of their cognitive health.

The pilot stage of the broad project began in 2016 with targeted workshops and with the adoption of the program by large educational and social institutions. The next phase in 2017 will gather early results from the pilot studies and enroll a wider range of schools, families, and institutions for a post pilot study. The shared ambition for the third phase during 2018-2019 is to offer the program to all about 200,000 Peterborough residents, by hosting the program on the Council website, as well as being available in all libraries and on personal devices.

Beginning with the youngest segment of population, the first project involves 13 primary schools and one secondary,

with the aim of improving academic outcomes of those children who are struggling in learning mathematics. The solution proposed is to provide pupils with the MyCognitionED assessment and training programs for an initial period of eight weeks, at the end of which the putative improvements shown in cognition will be compared with official mathematics assessments.

This program will be employed in further projects involving teenagers from the Greater Peterborough University Technical College as an assessment and mentoring tool, and the Peterborough City College, a school specialized in providing educational opportunities for students of all ages, backgrounds, and abilities, particularly focusing on study programs and apprenticeships designed to create employment opportunities for 16-19-year-old students.

Early results from a class of year 5 students have shown an average improvement of their overall cognitive score above 5 points, with a higher improvement in episodic memory, executive function, and attention. Full analyses will be performed at the end of the study; however these early results are encouraging and consistent with the valuable improvements in academic outcomes and behavior, which have already been shown with cohorts of students using MyCognitionED [7][8][13].

A broader educational and social project sees the involvement of the MyCognitionED program in the Early Help Services of Peterborough Council, with particular regard to the Connecting Families program for troubled families. As a first step, the project involves six families with children displaying challenging behaviors, who requested an autism spectrum disorder (ASD) assessment or an attention-deficit/hyperactivity disorder (ADHD) assessment.

This first step is planned to be extended to year 6 students planning to take the Scholastic Assessment Test (SAT) and to unemployed adults at the YMCA, with the aim of improving individuals future professional careers and employability opportunities.

With the purpose of developing a venture able to achieve enhancements in cognitive wellbeing and the consequent improvements in quality of personal and professional life across the entire city’s population, the training program will be adopted by the business owners and entrepreneurs at the Allia Future Business Center. The Future Business Center will become a referring point to incubate, facilitate, and develop innovative ideas for entrepreneurs who are still at an early stage of their own business. Therefore, they will be provided with a specific version of the training program designed to enhance those cognitive functions that are mainly responsible for management and leadership skills.

Finally, the project also aims to reach the homes of the elderly with targeted, user-friendly IT solutions to improve their independence, by recovering those cognitive functions that are essential for managing everyday life tasks.

IV. EXPECTED OUTCOMES

A. Skills enhancement

Since it has been adopted in a number of studies involving hundreds of students from primary and secondary schools, the MyCognitionED program is expected to produce in Peterborough analogous outcomes both in cognitive and learning skills. These outcomes include the ability to focus or to recall information, enhancing academic achievement especially in mathematics, English, and science, as well as in behavioral skills, such as self-regulation and inhibition.

An example of the effectiveness of the cognitive training program in students from 11 primary schools is reported in Figure 1, showing the improvement gained by students engaging in the training program for different periods of time [8].

Strong evidence of the relationship between cognitive functions and academic achievement is reported in the literature, and research is starting to investigate the effectiveness of cognitive training on learning, with some positive results [2].

The program is also designed to enhance the basic soft skills necessary for good job performance, including speed and accuracy in accomplishing tasks, stress management, and leadership skills, the basis of which is executive function.

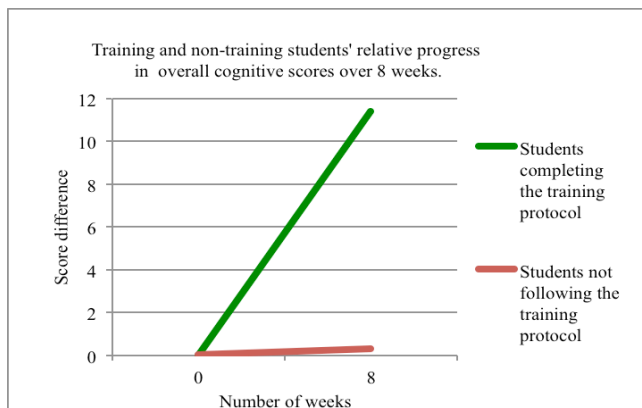


Figure 1. Comparison of improvement in overall cognitive scores between a training and a non-training group of ~50 students.

B. Social outcomes

The main social outcomes expected are related to the employability of the population across different generations and the reduction of the interclass divide.

Recent studies [15][16] have shown that the socioeconomic background of families influences the neuropsychological and cognitive development of children in their early years of life, especially in the domains of executive function and working memory, which are the main ones responsible for both school and work achievement.

Good evidence has been found for the effectiveness of training programs involving troubled families in promoting

healthy childhood development, good cognitive functioning, and long-term outcomes into adulthood [17][18]. Recent studies have shown that 46% of troubled families in the United Kingdom have mental health issues, resulting in anti-social behavior and employability issues [19]. The MyCognitionED program is envisioned to reduce the rate of mental health issues and so produce social improvements for specific segments of the population.

C. Cost savings

A cost-benefit analysis has been conducted of the impact of the MyCognitionED program on the annual costs of interventions described above in the different social sectors of health, education, and workplace. The results show that the annual pro rata cost of cognitive deficit in the education sector amounts to roughly £26M (\$33M), comprising £17M (\$21M) for special educational needs, £4M (\$5M) for youth crime, and £5M (\$6M) for psychiatric disorders. The cost of poor cognitive health in the working population sector is £154M (\$193M) and in the elderly/non-working sector £75M (\$94M). It has been assumed that the MyCognitionED program will reduce the cost by 10% for each sector; therefore, the city could realize combined cost savings of about £26M (\$33M) per annum [12].

V. EXTENSIONS OF THE PROGRAM IN OTHER COMMUNITIES

Following the example of Peterborough, the MyCognition program will be extended to other communities, in particular those represented by the London Councils, aiming to deliver significant benefits for London residents and to pursue innovation, efficiency, and performance improvement across the capital's public services.

The main goals of these interventions will be to increase educational attainment, to enhance employment possibilities, and to support health and wellbeing across the population. By identifying the underlying causes of moderate learning difficulties, primary school pupils will get the support that they need to improve their educational attainment and life chances. Understanding a child's cognitive strengths and weaknesses would allow effective use of teaching assistants (TAs), which accounts for 13% of education budgets. By reducing the number of TAs needed by 0.5 full-time equivalent in each school, this would save the typical school £9,000 (\$11,250) each year.

The program is also aimed to offer support to youth offenders, jobless parents, refugees, asylum seekers, and the elderly segment of the population, since it can be personalized to reflect an individual's needs – job search, skills for life, support for mental health problems, training, mentoring, work placements, or support for creating new businesses or social enterprises.

VI. CONCLUSION

Analyzing the promising expected outcomes of the Peterborough program, it is possible that his type of cognitive assessment and training intervention will be extended to specific cohorts of other Smart Cities and local communities looking for cost saving solutions for the whole community's cognitive healthcare. This would open a new chapter in the Smart Cities' government, by focusing on the prevention of cognitive issues and their long-term consequences in terms of health, learning, employability, competitiveness, quality of life, and sustainability, which ultimately are the key features of a successful "smart" community. Furthermore, the assessment and training program is implemented in a simple, self-administered software tool, which will be available for every type of device, for people of every age and every background. Therefore, it is expected that this program will play a key role in reducing the inter-generational and inter-class digital divide.

Although the adoption of such cognitive assessment and training programs has been increasing recently in the education and health sectors – especially to target learning difficulties in children and cognitive impairment in the elderly – to date, it is not known to the authors that any similar programs are being implemented elsewhere at the city level. The science-based approach which guides the program presented, together with its universality, easy-availability, user-friendliness, and cost- and time-effectiveness, would seem to make it eligible to be a leading innovation tool for future cities aiming to focus their "smart" agenda on their people's potential and wellbeing.

ACKNOWLEDGMENT

We thank the management and staff of Peterborough City Council and the various schools, agencies, and social services organizations in Peterborough.

REFERENCES

- [1] V. Albino, U. Berardi, and R. M. Dangelico, "Smart cities: Definitions, dimensions, performance, and initiatives," *Journal of Urban Technology*, vol. 22(1), pp. 3-21, 2015.
- [2] Peterborough wins Smart City of the Year 2015. (2015, Nov. 20). Peterborough DNA. [Online]. Available: <http://www.peterboroughdna.com/peterborough-wins-smart-city-of-the-year-2015/>
- [3] MyCognitionED. MyCognition. [Online]. Available: <http://www.mycognition.com/education/>. Accessed Feb. 03, 2017.
- [4] A. C. Domen et al., "The validation of a new, online cognitive assessment tool," *European Neuropsychopharmacology*, vol. 25, p. S344, 2015.
- [5] A. Domen et al., "The validation of a new online cognitive assessment tool," *European Neuropsychopharmacology*, vol. 26, pp. S342-S343, 2016.
- [6] J. E. Harrison, J. H. Van Rijswijk, K. T. Sparrowhawk, and D. A. Knight, U.S. Patent No. 20,150,279,226. Washington, DC: U.S. Patent and Trademark Office, 2015.
- [7] P. Shah, R. Kumar, A. McCone, K. Sparrowhawk, and J. Thomas, "The impact of cognitive function assessment and adaptive training on academic performance in students with learning difficulties," Poster session presented at: Copenhagen, DK: 10th Federation of European Neuroscience Societies (FENS) Forum of Neuroscience, Jul. 2016.
- [8] K. Sparrowhawk, R. Kumar, and A. McCone, "Evaluation of cognitive function and training in school children," Poster session presented at: Copenhagen, DK: 10th Federation of European Neuroscience Societies (FENS) Forum of Neuroscience, Jul. 2016.
- [9] A. McCone, R. Kumar, K. Sparrowhawk, and L. Franchi, "Evaluating the impact of cognitive training for SEN children when used at home," Poster session presented at: Copenhagen, DK: 10th Federation of European Neuroscience Societies (FENS) Forum of Neuroscience, Jul. 2015.
- [10] K. Sparrowhawk, R. Kumar, and J. Harrison, "Adaptive Video Games can Assess and Enhance Cognitive Health," *Value in Health*, vol. 17(7), p. A454, 2014.
- [11] D. Nieman et al., "Cognitive remediation in psychiatric patients with an online cognitive game and assessment tool," *European Neuropsychopharmacology*, vol. 25, pp. S344-S345, 2015.
- [12] K. Sparrowhawk, P. Cliveden, M. Ratto, W. Ogle-Welbourne, A. Sunley, "Evaluating the cost-benefit of a cognitive assessment and training program across a smart city population in the UK," *Value in Health*, vol. 19(7), pp. A693-A694, 2016.
- [13] K. Sparrowhawk, J. Harrison, R. Kumar, D. Knight, "Working memory and executive functioning are improved in school students using an applied action video game," Poster session presented at: Milan, IT: 9th Federation of European Neuroscience Societies (FENS) Forum of Neuroscience, Jul. 2014.
- [14] S. C. van de Weijer et al., "The Parkin'Play study: protocol of a phase II randomized controlled trial to assess the effects of a health game on cognition in Parkinson's disease," *BMC Neurology*, vol. 16(1), 209, doi:10.1186/s12883-016-0731-z, 2016.
- [15] D. A. Hackman, R. Gallop, G. W. Evans, and M. J. Farah, "Socioeconomic status and executive function: developmental trajectories and mediation," *Developmental Science*, vol. 18(5), pp. 686-702, 2015.
- [16] K. G. Noble et al., "Socioeconomic disparities in neurocognitive development in the first two years of life," *Developmental psychobiology*, vol. 57(5), pp. 535-551, 2015.
- [17] H. J. Neville et al., "Family-based training program improves brain function, cognition, and behavior in lower socioeconomic status preschoolers," *Proc. of the National Academy of Sciences*, vol. 110(29), pp. 12138-12143, 2013.
- [18] H. Neville, E. Pakulak, and C. Stevens, "Family-based training to improve cognitive outcomes for children from lower socioeconomic status backgrounds: emerging themes and challenges," *Current Opinion in Behavioral Sciences*, vol. 4, pp. 166-170, 2015.
- [19] A. E. Nunn and D. Tepe-Belfrage, "Disciplinary Social Policy and the Failing Promise of the New Middle Classes: The Troubled Families Programme," *Social Policy and Society*, vol. 16(1), pp. 119-129, 2017.
- [20] C. Titz and J. Karbach, "Working memory and executive functions: Effects of training on academic achievement," *Psychological research*, vol. 78(6), pp. 852-86, 2014.