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Visuospatial processing improvements in students with Down Syndrome through the autonomous use of technologies

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Abstract

The main purpose of our study was to examine whether autonomous training through the use of technologies could be associated with improvements in selective attention, visuospatial short-term memory and visuospatial processing in students with Down Syndrome (DS). In addition, our study aimed to analyse how the improvements in selective attention and visuospatial short-term memory tasks could predict improvements in visuospatial processing. Twenty-six children and adolescents with DS who belong to specialized schools for ID participated in the study. Three different mobile applications, Bubbles (selective attention), Pairs and Learn (visuospatial short-term memory) and Tangram (visuospatial processing) developed by Smile and Learn were used during a three-month period by the students. The results showed significant improvements through training in both, Pairs and Learn and Tangram, whereas there was no significant improvement in Bubbles. The results also showed that Pairs and Learn performance could predict a 36% variance in Tangram one. Cognitive and educational implications of these results are discussed.

Introduction

Although emerging technologies have created a big impact on our entire society, those that are directed at people with Intellectual Disabilities (ID) have not evolved in the same way (Istenic y Bagon, 2014; Stock, Davies, Wehmeyer and Lachapelle, 2011). In this sense, Wehmeyer, Smith and Palmer (2004) pointed out the existence of some barriers which could limit the use of technologies by students with disabilities, such as locating equipment, lack of time for training students and teachers and lack of funds to access devices or services, among others. This study is focused on the possible improvement of the selective attention, short-term memory and visuospatial processing abilities through the autonomous use of specific tablet applications during a

Practitioner Notes

What is already known about this topic

- Educational value of technology
- Cognitive limitations in Down Symdrome population
- Limited use of technologies in population with Intellectual Disabilities

What this paper adds

- Autonomous use of technologies by Down Syndrome students
- Cognitive improvements in Down Syndrome students through technologies
- Need to develop adapted or specific technological tools for Down Syndrome students

Implications for practice and/or policy

- Use of Technology in Down Syndrome education
- Development of autonomy for learning in Down Syndrome students
- Development of technologic educational tools based on games

period of three months in Down Syndrome (DS) students. This Syndrome is one of the most common neurodevelopmental disorders caused by the trisomy of chromosome 21 and characterized by a number of physical, cognitive, and behavioural atypicalities (Laws and Gunn, 2004; Steele, 1996).

Cognitive profile of Down's Syndrome

From a cognitive perspective, it has been suggested that performance of DS could be predicted upon overall intellectual disability (Silverman, 2007). For instance, it has been described generalized executive function deficits both in adolescents (Lanfranchi, Jerman, Dal Pont, Alberti and Vianello, 2010) and adults (Rowe, Lavender and Turk, 2006). In addition, developmental studies have shown impairments associated with poorer auditory and verbal processing and relative strengths in visuospatial processing, non-verbal memory (Chapman and Hesketh, 2001; Chapman, Schwartz and Kay-Raining Bird, 1991; Jarrold and Baddeley, 1997), and non-verbal reasoning (Abbeduto, Warren and Conners, 2007; Chapman, 2003; Chapman and Hesketh, 2001), together with an increased difficulty to stabilize the acquisition of new skills (Fidler and Nadel, 2007). However, even when it has been widely assumed that visuospatial abilities are relatively preserved in DS subjects, impairments in visuospatial processing have been described (Bellugi, Bihrle, Jeringan, Trauner and Doherty, 1990).

Visuospatial processing involves the integration of global and local information from the context, in order to understand its structure and to make generalizations to other contexts (D'Souza, Booth, Connolly, Happé, & Karmiloff-Smith, 2016). Typical development allows for processing both, local and global aspects without disruption (Porter and Coltheart, 2006). DS subjects have been described as "global processors" with a holistic processing style focused on global information at the expense of the local one (eg, Bihrle, Bellugi, Delis and Marks, 1989). Some previous research focused on the analysis of construction tasks has corroborated this characterization by showing that DS subjects had difficulties with some aspects of drawing and block construction, producing the global configuration with impairments in the local details (Bellugi *et al.*, 1990; Bellugi, Lichtenberger, Jones, Lai and St. George, 2000), whereas subjects with other neurodevelopmental disabilities such as Williams Syndrome or Autism would be focused on the production local details, showing difficulties in global processing (eg, Farran, Jarrold and Gathercole, 2003; Mottron, Belleville and Ménard, 1999). However, this categorization as local or global processors was recently put in doubt by D'Souza *et al.* (2016). They found that DS participants made as many local as global matches and fewer global matches than Williams Syndrome participants did in Navon-type task, which contradicted the results obtained in previous research. The authors concluded that the kind of task or stimulus used could be taken into account to reconsider the characterization of "local" and "global" processors in the field of neurodevelopmental disorders. Moreover, other authors such as Costanzo *et al.* (2013) suggested that, in order to achieve a better knowledge of the difficulties in visuospatial processing, it could be necessary to analyse the existence of impairments in other underlying processes in which DS subjects have been impairments, such as selective attention (eg, Clark and Wilson, 2003; Cornish, Scerif and Karmiloff-Smith, 2007; D'Souza *et al.*, 2016; Wilding, Cornish and Munir, 2002) and visual or short-term memory (eg, Bower and Hayes, 1994; Costanzo *et al.*, 2013; Jarrold and Baddeley, 1997; Lanfranchi, Carretti, Spanò and Cornoldi, 2009; Lanfranchi *et al.*, 2012)

Technologies, learn and Down´s Syndrome

Several studies have shown the benefits of the emerging computer technologies to improve cognitive skills in people with ID. For example, Wii gaming technology has demonstrated the improvements of motor proficiency, sensory integrative functioning, visual-integrative abilities, limits and postural stability in children with DS (Berg, Becker, Martian, Danielle and Wingen, 2012; Wuang *et al.*, 2011). In addition, computer technologies might be effective in reading and writing therapies (Felix, Mena, Ostos and Maestre, 2017), and computerized visuospatial memory training has demonstrated to improve the short term memory performance in children with DS (Bennett, Holmes and Buckley, 2013). Moreover, the benefits of combining computer technologies with traditional therapies were shown in a research of Akhutina *et al.* (2003). In this study, participants who received a visuospatial training and a traditional therapy based on executive functions and verbal regulation of spatial functioning improved their visuospatial skills better than the groups that received only one of them. Finally, it has been posted that the use of technologies by ID subjects could improve their productivity and quality of life (Hammel, Lai and Heller, 2002).

A population with ID for which the use of emerging technologies is increasing, is people with Down´s Syndrome (DS). Considering the described characteristics of people with DS, the use of the emerging computer technologies is even more important. In this sense, computer´s tools increase their motivation (Ortega and Gómez, 2006), facilitate their perception using a multimedia approach and offer them the possibility of increasing autonomy and personal independence (Felix, Mena, Ostos and Maestre, 2017).

The present study

This study is part of a European Union's Horizon 2020 Research and Innovation Programme (H2020) that acted as the financial support and the ethical grant which has allow to develop this study by promoting an educational innovative proposal through empirical research. Specifically, our research has been developed as a cooperative work between university-company, and has been focused on the educational use by DS students of mobile applications based on cognitive abilities. In this context, we selected three applications presented as games that were developed with the advice of specialists in psychology and education by Smile and Learn® to design an intervention program with two main aims. In this context, we selected three applications presented as games that were developed with the advice of specialists in psychology and education by Smile and Learn® to design an intervention program with two main aims: (1) to explore how performance of DS subjects in visual selective attention, visuospatial short-term memory and construction tasks could improve through new technologies autonomous training (Autonomous training meant that students were free to choose which application to use at each training time and that, although they were supervised, they did not receive help in the execution of tasks.) and (2) to analyse to what extent training in tasks associated with visual selective attention and visuospatial short-term memory could explain the improvement in a construction task. Even when it has been described difficulties in DS subjects to stabilize the acquisition of new skills (Fidler and Nadel, 2007), we expected an improvement associated with training in all the three tasks. In addition, we expected that the enhanced performance in both, selective attention and visuospatial short-term memory tasks, could predict the expected improvements in the more complex construction task.

Method

Participants

Twenty-six children and adolescents with DS took part in this study (15 boys and 11 girls, age range 7–17, $M = 9.1$, $SD = 1.5$). All the participants were diagnosed as moderate intelligence disability. No participant had any associated physical deficit that might have compromised the experiment. All the participants of this study belong to specialized schools for ID. All participants carried out the tasks at school as part of their daily activities.

Truly informed and parental permission for research participation was obtained prior to testing.

Materials

Three applications presented as tablet games for the participants were the tasks used in our study:

Bubbles: Selective attention was evaluated by the bubbles game. The goal of the game is to explode all the bubbles that contain a certain element inside (Figure 1). Bubbles fall from the top of the screen and the player has to explode those with the selected element inside. When all five rounds have been played, the result is scored. Each player gets 50 points per round played (bonus). When a player explodes a right bubble the score grows up 10 points. As evaluation metric, we have employed the score obtained in each game without the bonus point. Therefore, the scores only

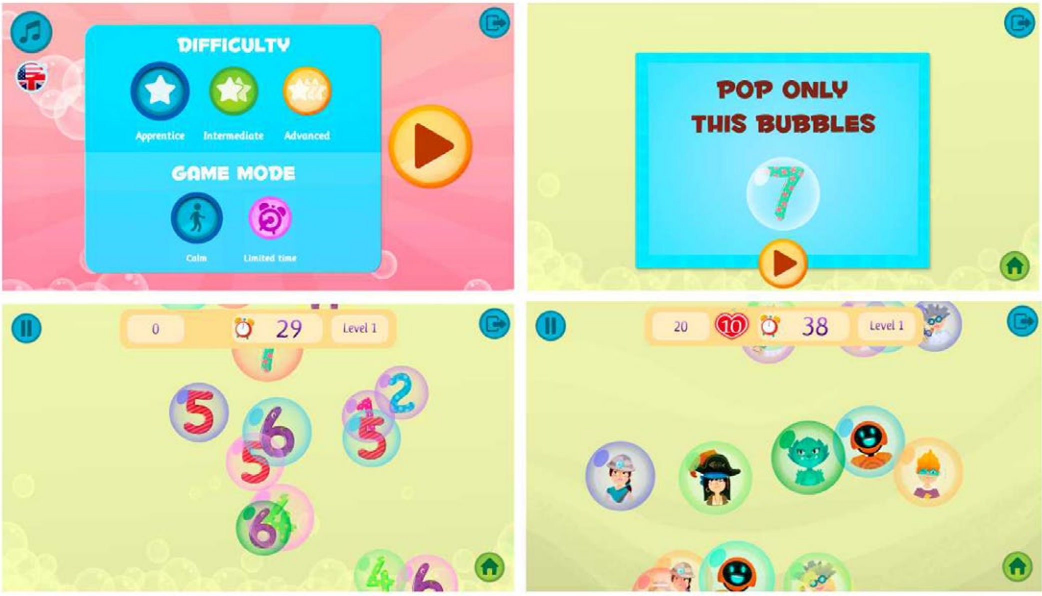

Figure 1: Screenshot of the bubbles game

reflect the successes and failures. The game has three difficulty levels (apprentice, intermediate and advanced) and five rounds in each level. In the apprentice level, every 2 seconds appears 3 new bubbles appear. In the intermediate level, every 1 second 5 new bubbles appear. Finally, in the advanced level every half second 7 new bubbles appear. Notice that the Bubbles game has two game modes: one chance and no rush. The element to explode is fixed in the initial screen of the game. In our study, all the participants played in the apprentice level and no rush mode. During the game, the player receives visual feedback of correct or wrong. Once all rounds are completed, the game displays a compliment message with enthusiastic sounds. Additionally, it evokes a congratulation sound and materializes multiple fireworks upon the completed game.

Pairs and learn: Short-term visuospatial memory was evaluated by Pairs and Learn game. This game is based on the famous games Pairs or Memory. “Pairs and Learn” is a card game in which all cards are laid face down on a surface and two cards are flipped face up over each turn. The goal of the game is to turn over pairs of matching cards (Figure 2). We can find cards of six categories (animals, fantasy, flags, fruits, musical instruments and jobs). At the beginning the participant selects the category to play with. In each round the player has a few seconds to see all the cards before they are faced down. The player selects a card to flip it over. If the next card selected by the player matches the first card, both cards disappear from the screen and the player wins 30 points. If they are not the same card, they are turned face down again and the player loses 10 points. If the player passes the round without fails it wins 50 extra points. If the player match two pairs of cards in a row it wins 30 extra points and if the player hit four matches in a row it wins 120 extra points. The round ends when the last pair has been picked up. The player will pass to the next round, if matches all the cards. The goal is to clear the tableau with the maximum possible score. “Paris and Learn” has three difficulty levels (apprentice, intermediate and advanced). The apprentice level has four rounds and the number of pairs at the two first rounds is two. The last two rounds have three pairs for matching. The intermediate level has 8 rounds, and the advanced level has 12. In our study, all the participants played in the apprentice level and, and the scores only reflect the successes and failures without extra points.

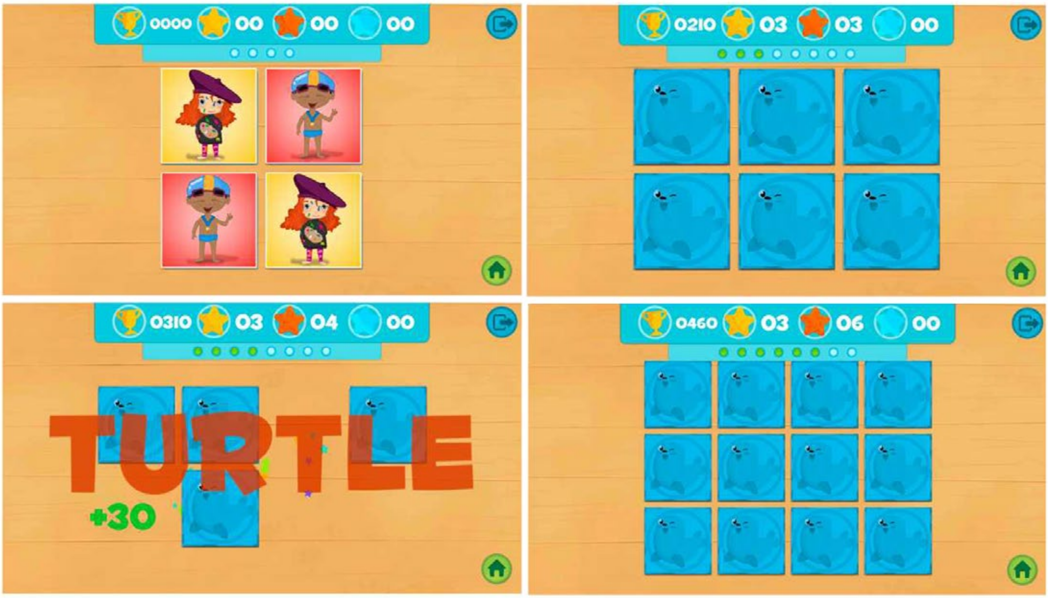

Figure 2: Screenshot of ‘Pairs and Learn’ game

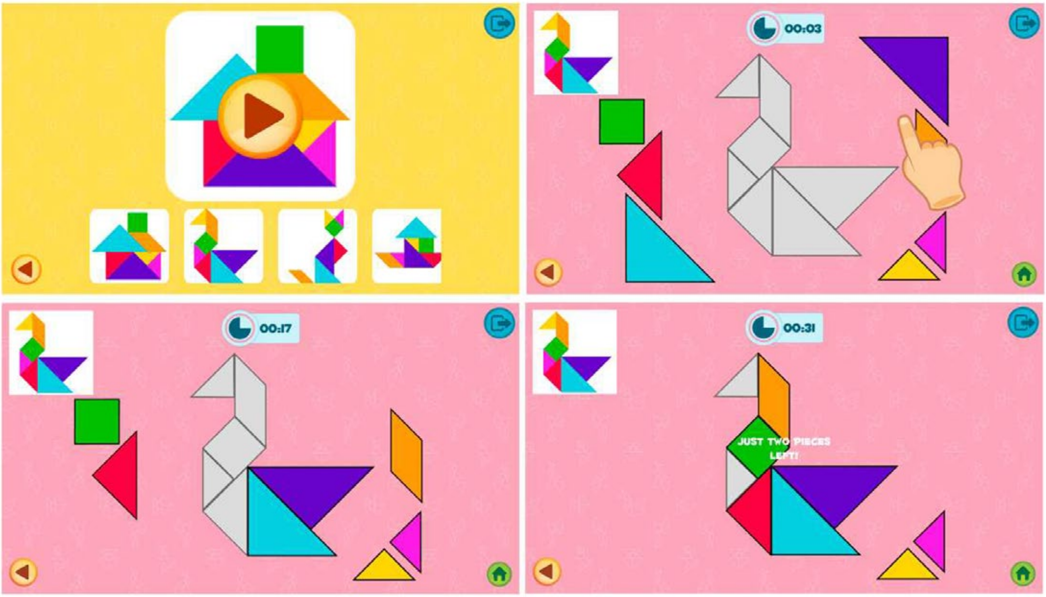

Figure 3: Screenshot of Tangram game

Tangram: Tangram is based on seven geometrical figures (a square, rhombus, rhomboid, two big triangles, two small triangles and a medium size triangle). The players have to put them together to form different shapes (given only an outline or silhouette) using all seven pieces, which may not overlap. During the game, the players have to drag the pieces to the right places. When all the pieces are placed, the puzzle is completed. The game includes a wide selection of figures throughout 3 different levels (apprentice, intermediate and advanced) (Figure 3). In the apprentice level each figure has a different colour, and the shape to form is shown as an outline. At the beginning of the play all the figures are distributed over the screen and then, the player has to rotate each one and moving into its position. In our study, all the participants played in the apprentice level. We assess player's progress by registering the time spent on completing a shape.

Procedure

All the participants were recruited from two specialized ID schools that decided to participate in the study by incorporating the use of the selected applications into the daily classroom activities. The families were informed and parental consent was obtained in all cases. Ethical approval was granted by H2020.

The participants were instructed to use the described applications at least one hour per week during a period of three months. Each participant had his own tablet with a personal username and password and was instructed to use the apps autonomously. It was established a minimum of three periods of 20 minutes per week of use to each application. Although the students were instructed to use the three applications (one per period), they could freely choose the order of use. Teachers were involved in their motivation and supervision by controlling that the students accessed correctly with their personal username and password and that they used the three applications at least 20 minutes each one, but without interfering or lending help to the students in the execution of tasks.

The intervention was designed to carry out a longitudinal study in which two types of analysis were to be developed: on the one hand, we planned paired *t* comparisons to analyse the existence of a possible improvement effect associated with training within each application; on the other hand, both correlational and regression analyses were planned in order to study the relationship among all the three applications and how the selective attention and short-term visuospatial memory tasks could predict the construction ones.

The tasks run as it follows:

Bubbles: during the game, the player receives visual feedback of correct or wrong. Once all rounds are completed, the game displays a compliment message towards the child with enthusiastic sounds. Additionally, it evokes a congratulation sound and materializes multiple fireworks upon the completed game.

Pairs and learn: during the game the player receives visual feedback of correct or wrong according to the result of the round. Visual feedback of correct or wrong is also displayed at the top of the screen according to the result of the all rounds. Once all rounds are completed, the game transmits a compliment message towards the child with enthusiastic sounds. Additionally, it evokes a congratulation sound and materializes multiple fireworks upon the completed game.

Tangram: during the game, whenever the player places a piece in the right spot, the game gives positive feedback through congratulations and/or some other sounds (Figure 3d). Also, the game reacts negatively, but only with sounds. Once the puzzle is completed, the game transmits a compliment message towards the child with enthusiastic sounds. Additionally, it evokes a congratulation sound and materializes multiple fireworks upon the completed puzzle.

Results

Table 1 shows the scores obtained by the participants in the tasks. As it can be seen, all the participants used the Bubbles and Pairs and Learn tasks but only 16 used the Tangram app. In addition, only 14 participants used the three apps whereas 8 participants did not comply with all the training time requested to each application because they stopped playing without finishing the game or changed among applications several times. Thus, to be more rigorous with the possible training effect, we decided to select for the subsequently analysis those 14 participants who used all the three applications completely following the established time rule.

Taking into account our first aim, we analysed if there were improvements in performance across the three tasks used. Student *t* by pairs was carried out between the first score obtained and the mean of scores (Mean scores was calculated by controlling for the number of attempts of each participant. Taking into account the duration of the training, we decided to use this measure as a final index of global performance during the three months), in which the number of attempts was controlled. As it can be seen in Table 2, the results showed that improvements in performance were significantly in Pairs and Learn and Tangram tasks, whereas there was no significantly improvements in Bubbles one.

Table 1: Scores obtained in all the tasks through the three months training

	N	*Min. score*	*Max. score*	*M*	*SD*
Memory	26	190.00	780.00	448.78	176.90
Bubbles	26	26.54	193.65	87.03	62.91
Tangram	16	5.00	1202.00	199.00	278.61

Table 2: Differences between the first score and the mean one

		Mean score	*t*	*df*	*p*
Pair 1	Bubbles first	156.07	–1.48	25	.15
	Bubbles mean	199.00			
Pair 2	Memory first	358.08	–2.45	25	**.02***
	Memory mean	448.78			
Pair 3	Tangram first-	37.85	–2.94	15	**.01***
	Tamgram mean	87.04			

[1]$n = 14$, *$p < .05$. Significant results are in bold.

Table 3: Pearsons'correlations among the three tasks

	Memory_mean	*Tangram_mean*
Bubbles_mean	.46 **.03***	.50 .07
Memory_mean		.64 **.01***

[1]$n = 14$, *$p < .05$. Significant results are in bold.

Table 4: Regression analysis

	Final Model	*A R2*	*F*	*β*	*t*	*D-W*
Tangram	Memory_mean	.36	8.34	.64	2.89	1.5

[1]$n = 14$.

Correlational analysis

In order to analyse how the three tasks were related, Pearson´s correlations were carried out. To control for false positives in the context of multiple test, and following Costanzo *et al*, (2013), we applied a False Discovey Rate procedure proposed by Bejamini & Hochberg (1995) with a *q* value of .05. As it can be seen in Table 3, the results showed a significant positive correlation between Bubbles and Pairs and Learn tasks ($r = .46$, $p < .05$), and Pairs and Learn and Tangram tasks ($r = .64$; $p < .05$). No significant correlation was found between Bubbles and Tangram tasks ($r = .50$; $p > .05$).

Regression analysis

A stepwise linear regression analysis was conducted to appraise the way in which Bubbles Task and Pairs and Learn Task impacted on Tangram Task. Only 14 subjects played to all three tasks. The results show that 36. 1% of Tangram task performance was explained by Pairs and Learn task. This variable established a positive relationship with Tangram performance. Bubbles Task was excluded on the regression analysis. Table 4 shows the linear regression equation.

Discussion

The aims of this study were to explore how performance of DS subjects in a visual selective attention, visuospatial short-term memory and construction tasks could improve through new technologies training and to analyse to what extent training in tasks associated with visual selective attention and visuospatial short-term memory could explain the improvement in a construction task.

In relation to our first aim, we had hypothesized that training could be associated with an improvement of performance in all the three tasks. The results showed that the participants significantly improved their performance through training in both, Pairs and learn and Tangram applications, partially corroborating our hypothesis. Although not all the participants used the three applications during the time of training, those who did it showed an increase in their performances regardless of the number of attempts that was controlled in the mean score used as final index of performance. At this point, one could suggest that the use of the first and last score should change the results obtained, but it is not the case. A subsequent analysis in which the first score and the last score x number of attempts were considered as indexes of final performance across the three months training was carried out. The results corroborated the enhancement of performance both in Pairs and Learn ($t = -4.21$, $p < .01$) and Tangram ($t = -2.74$, $p < .05$) applications.

However, the results showed no significant improvement in Bubbles task. Even when the average of attempts using the three applications did not show significant differences among them (all *ps* > .05) the participants did not increase their performance in Bubbles in the significantly expected way, which contradicted our expected results. To explain this result, it is necessary to take into account the specific demands of the Bubbles task: although the main aim of the task was to select and explode the bubbles with a concrete object, which required selective attention, the bubbles appeared three by three every two seconds, which could involve response time demands. In this sense, it has been suggested that DS subjects tend to show slower rates of response, which could be more responsible of a decreasing efficiency than the cognitive abilities (Silverman, 2007). Thus, we suggest that more than the attentional demands of the task, the demands of response time may be related to the lack of a significant improvement in their performance. Our result could corroborate those obtained by D'Souza *et al.* (2016) who had already found a decreased performance in DS subjects which could be associated with the speed of presentation of the stimuli.

In summary, our results corroborated that the use of technologies could allow to DS students to improve their visuospatial skills (Akhutina *et al.*, 2003; Bennett *et al.*, 2013) through autonomous training. However, it could be necessary to control the difficulty of those tasks which require a response time to better adapt them to each target population.

Regarding our second aim, we had hypothesized that the enhanced performance in both, Bubbles and Pairs and Learn tasks, could predict the expected improvements in Tangram one. The results of the correlational analysis showed that the performance in Bubbles and Pairs and Learn, and Tangram and Pairs and Learn tasks were significantly related, whereas Bubbles and Tangram were not.

First, it is possible that the lack of relationship between Bubbles and Tangram could be associated with both, the time response differences and the cognitive processes involved. Although the Tangram task required selective attention to discriminate and select the shapes and colours, the efficient performance of the task was no-time dependent and could involve other kind of processes related to the accuracy in the rotation of each shape before placing it in its position (Nelson and Strachan, 2009).

Second, the relationship between Bubbles and Pairs and Learn could be explained by taking into account the underlying cognitive processes involved in the tasks, that is, selective attention and short-term visuospatial memory. It has been suggested that selective attention could reduce memory load through filtering relevant information from the environment (Downing, 2000). Moreover, the maintenance of a spatial location in memory should generate an attentional shifting to each novel location (Awh, Jonides and Reuter-Lorenz, 1998). Thus, even when Pairs and

Learn could be affected by time response performance, both tasks could share underlying cognitive processes to some extent.

Third, the significant relationship between Tangram and Pairs and Learn tasks could reflect the described requirement of a temporal storage mechanism necessary when visual information is used to guide behaviour (Phillips and Christie, 1977). In addition, this result could corroborate the involvement of short-term visuospatial memory in construction tasks, which had been yet showed in previous research with DS subjects (Costanzo *et al*., 2013). Importantly, the subsequent regression analysis showed that performance in Pairs and Learn could explain a 36% variance in Tangram, which suggests that training in tasks associated with basic cognitive processes could have a transfer effect that would be reflected in more complex tasks. However, this idea needs deeper research.

To conclude, this study not only contributes to knowledge about the cognitive functioning of DS subjects, but also to how technologies could allow them to improve its cognitive abilities through autonomous training. However, our study had two main limitations: the reduced sample size which limited the generalization of the results obtained, the autonomy of the students, which reduced the number of participants who used all the three applications and limited the control of the attempts of each student. Finally, it could be suggested that a control group would allow to analyse if the described use of technologies could be more or less effective than other methodologies. Nevertheless, the aim of our study was not to compare educational tools, but to analyse how the autonomous use of technology could improve performance in DS subjects through a training period.

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Statements on open data, ethics and conflict of interest

Data can be accessed by contacting Smile and Learn®.

As part of an H2020 project, this study meets the necessary ethical requirements and does not include activities or results that pose safety problems for the participants. In addition, the personal data required were treated confidentially for the registration and initial control of the participants and were treated anonymously in the study.

No conflict of interest declared.

References

Abbeduto, L., Warren, S. F., & Conners, F. A. (2007). Language development in Down syndrome: From the prelinguistic period to the acquisition of literacy. *Developmental Disabilities Research Reviews*, *13*(3), 247–261. https://doi.org/10.1002/mrdd.20158

Akhutina, T. Y., Foreman, N., Krichevets, A., Matikka, L., Narhi, V., Pylaeva, N., & Vahakuopus, J., (2003). Improving spatial functioning in children with cerebral palsy using computerized and traditional game tasks. *Disability and rehabilitation*, *25*(24), 1361–1371. https://doi.org/10.1080/0963828031000161635 8

Awh, E., Jonides, J., & Reuter-Lorenz, P. A. (1998). Rehearsal in spatial working memory. *Journal of Experimental Psychology: Human Perception and Performance*, *24*(3), 780.

Bellugi, U., Bihrle, A., Jernigan, T., Trauner, D., & Doherty, S. (1990). Neuropsychological, neurological, and neuroanatomical profile of Williams syndrome. *American Journal of Medical Genetics Part A*, *37*(S6), 115–125.

Bellugi, U., Lichtenberger, L., Jones, W., Lai, Z., & St. George, M. (2000). The neurocognitive profile of Williams Syndrome: a complex pattern of strengths and weaknesses. *Journal of cognitive neuroscience*, *12*(Supplement 1), 7–29. https://doi.org/10.1162/089892900561959

Benjamini, Y., & Hochberg, Y. (1995). Controlling the false discovery rate: a practical and powerful approach to multiple testing. *Journal of the royal statistical society. Series B (Methodological)*, 289–300.

Bennett, S. J., Holmes, J., & Buckley, S. (2013). Computerized memory training leads to sustained improvement in visuospatial short-term memory skills in children with Down syndrome. *American journal on intellectual and developmental disabilities*, *118*(3), 179–192. https://doi.org/10.1352/1944-7558-118.3.179

Berg, P., Becker, T., Martian, A., Danielle, P. K., & Wingen, J. (2012). Motor control outcomes following Nintendo Wii use by a child with Down syndrome. *Pediatric Physical Therapy*, *24*(1), 78–84. https://doi.org/10.1097/PEP.0b013e31823e05e6

Bihrle, A. M., Bellugi, U., Delis, D., & Marks, S. (1989). Seeing either the forest or the trees: dissociation in visuospatial processing. *Brain and cognition*, *11*(1), 37–49. https://doi.org/10.1016/0278-2626(89)90003-1

Bower, A., & Hayes, A. (1994). Short-term memory deficits and Down syndrome: a comparative study. *Down syndrome research and practice*, *2*(2), 47–50. https://doi.org/10.3104/reports.29

Chapman, R. S. (2003). Language and communication in individuals with Down syndrome. *International review of research in mental retardation*, *27*, 1–34.

Chapman, R., & Hesketh, L. (2001). Language, cognition, and short-term memory in individuals with Down syndrome. *Down Syndrome Research and Practice*, *7*(1), 1–7. https://doi.org/10.3104/reviews.108

Chapman, R. S., Schwartz, S. E., & Bird, E. K. R. (1991). Language skills of children and adolescents with Down syndrome: I. Comprehension. *Journal of Speech, Language, and Hearing Research*, *34*(5), 1106–1120.

Clark, D., & Wilson, G. N. (2003). Behavioral assessment of children with Down syndrome using the Reiss psychopathology scale. *American Journal of Medical Genetics Part A*, *118*(3), 210–216. https://doi.org/10.1002/ajmg.a.20007

Cornish, K., Scerif, G., & Karmiloff-Smith, A. (2007). Tracing syndrome-specific trajectories of attention across the lifespan. *Cortex*, *43*(6), 672–685. https://doi.org/10.1016/S0010-9452(08)70497-0

Costanzo, F., Varuzza, C., Menghini, D., Addona, F., Gianesini, T., & Vicari, S. (2013). Executive functions in intellectual disabilities: a comparison between Williams syndrome and Down syndrome. *Research in developmental disabilities*, *34*(5), 1770–1780. https://doi.org/10.1016/j.ridd.2013.01.024

Downing, P. E. (2000). Interactions between visual working memory and selective attention. *Psychological science*, *11*(6), 467–473.

D'Souza, D., Booth, R., Connolly, M., Happé, F., & Karmiloff-Smith, A. (2016). Rethinking the concepts of 'local or global processors': evidence from Williams syndrome, Down syndrome, and Autism Spectrum Disorders. *Developmental science*, *19*(3), 452–468. https://doi.org/10.1111/desc.12312

Farran, E. K., Jarrold, C., & Gathercole, S. E. (2003). Divided attention, selective attention and drawing: Processing preferences in Williams syndrome are dependent on the task administered. *Neuropsychologia*, *41*(6), 676–687.

Felix, V. G., Mena, L. J., Ostos, R., & Maestre, G. E. (2017). A pilot study of the use of emerging computer technologies to improve the effectiveness of reading and writing therapies in children with Down syndrome. *British Journal of Educational Technology*, *48*(2), 611–624. https://doi.org/10.1111/bjet.12426

Fidler, D. J., & Nadel, L. (2007). Education and children with Down syndrome: neuroscience, development, and intervention. *Developmental Disabilities Research Reviews*, *13*(3), 262–271. https://doi.org/10.1002/mrdd.20166

Hammel, J., Lai, J. S., & Heller, T. (2002). The impact of assistive technology and environmental interventions on function and living situation status with people who are ageing with developmental disabilities. *Disability and Rehabilitation*, *24*(1–3), 93–105. https://doi.org/10.1080/09638280110063850

Istenic Starcic, A., & Bagon, S. (2014). ICT-supported learning for inclusion of people with special needs: Review of seven educational technology journals, 1970–2011. *British Journal of Educational Technology*, *45*(2), 202–230. https://doi.org/10.1111/bjet.12086

Jarrold, C., & Baddeley, A. D. (1997). Short-term memory for verbal and visuospatial information in Down's syndrome. *Cognitive neuropsychiatry*, *2*(2), 101–122. https://doi.org/10.1080/135468097396351

Lanfranchi, S., Carretti, B., Spanò, G., & Cornoldi, C. (2009). A specific deficit in visuospatial simultaneous working memory in Down syndrome. *Journal of Intellectual Disability Research*, *53*(5), 474–483. https://doi.org/10.1111/j.1365-2788.2009.01165.x

Lanfranchi, S., Jerman, O., Dal Pont, E., Alberti, A., & Vianello, R. (2010). Executive function in adolescents with Down syndrome. *Journal of Intellectual Disability Research*, *54*(4), 308–319. https://doi.org/10.1111/j.1365-2788.2010.01262.x

Lanfranchi, S., Baddeley, A., Gathercole, S., & Vianello, R. (2012). Working memory in Down syndrome: is there a dual task deficit? *Journal of Intellectual Disability Research*, *56*(2), 157–166. https://doi.org/10.1111/j.1365-2788.2011.01444.x

Laws, G., & Gunn, D. (2004). Phonological memory as a predictor of language comprehension in Down syndrome: a five-year follow-up study. *Journal of Child Psychology and Psychiatry*, *45*(2), 326–337. https://doi.org/10.1111/j.1469-7610.2004.00224.x

Mottron, L., Belleville, S., & Ménard, E. (1999). Local bias in autistic subjects as evidenced by graphic tasks: perceptual hierarchization or working memory deficit? *The Journal of Child Psychology and Psychiatry and Allied Disciplines*, *40*(5), 743–755.

Nelson, R. A., & Strachan, I. (2009). Action and puzzle video games prime different speed/accuracy tradeoffs. *Perception*, *38*(11), 1678–1687. https://doi.org/10.1068/p6324

Ortega-Tudela, J. M., & Gómez-Ariza, C. J. (2006). Computer-assisted teaching and mathematical learning in Down Syndrome children. *Journal of computer assisted learning*, *22*(4), 298–307. https://doi.org/10.1111/j.1365-2729.2006.00179.x

Phillips, W. A., & Christie, D. F. M. (1977). Components of visual memory. *Quarterly Journal of Experimental Psychology*, *29*(1), 117–133.

Porter, M. A., & Coltheart, M. (2006). Global and local processing in Williams syndrome, autism, and Down syndrome: perception, attention, and construction. *Developmental Neuropsychology*, *30*(3), 771–789. https://doi.org/10.1207/s15326942dn3003_1

Rowe, J., Lavender, A., & Turk, V. (2006). Cognitive executive function in Down's syndrome. *British Journal of Clinical Psychology*, *45*(1), 5–17. https://doi.org/10.1348/014466505X29594

Silverman, W. (2007). Down syndrome: cognitive phenotype. *Developmental Disabilities Research Reviews*, *13*(3), 228–236. https://doi.org/10.1002/mrdd.20156

Steele, J. (1996). *Epidemiology: incidence, prevalence and size of the Down's syndrome population. New approaches to down syndrome*. (pp. 45–72). London: Cassell.

Stock, S. E., Davies, D. K., Wehmeyer, M. L., & Lachapelle, Y. (2011). Emerging new practices in technology to support independent community access for people with intellectual and cognitive disabilities. *NeuroRehabilitation*, *28*(3), 261–269. https://doi.org/10.3233/NRE-2011-0654

Wehmeyer, M. L., Smith, S. J., Palmer, S. B., & Davies, D. K. (2004). Technology use by students with intellectual disabilities: an overview. *Journal of Special Education Technology*, *19*(4), 7–21. https://doi.org/10.1177/016264340401900402

Wilding, J., Cornish, K., & Munir, F. (2002). Further delineation of the executive deficit in males with fragile-X syndrome. *Neuropsychologia*, *40*(8), 1343–1349. https://doi.org/10.1016/S0028-3932(01)00212-3

Wuang, Y. P., Chiang, C. S., Su, C. Y., & Wang, C. C. (2011). Effectiveness of virtual reality using Wii gaming technology in children with Down syndrome. *Research in developmental disabilities*, *32*(1), 312–321. https://doi.org/10.1016/j.ridd.2010.10.002