NAVIGATION AND EXPLORATION OF AN URBAN VIRTUAL ENVIRONMENT BY CHILDREN WITH AUTISM SPECTRUM DISORDER COMPARED TO CHILDREN WITH TYPICAL DEVELOPMENT

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ABSTRACT:

Autism spectrum disorder (ASD) is a severe disorder therefore the importance to implement targeted interventions in order to improve daily life of children with ASD. For this purpose, Virtual Environments (VEs), i.e. simulations of the real world based on 3D computer graphics, can offer a safe learning environment for them.

This study analyzed navigation and exploration of an urban VE by children with ASD in comparison to children with a typical development.

Sixteen children with ASD and 16 matched control ones were involved. After an initial training phase, children carried out two tasks: the first one was navigating in an unfamiliar urban environment which they could freely explore; the second one was navigating in the same environment but with the goal of finding specific target objects, as in a treasure hunt.

In the first task, children with ASD spent significantly less time in active exploration and explored fewer zones than controls. No differences were found between the two groups in the second task.

Our data indicate that, when freely exploring an unfamiliar VE, children with ASD explore less the environment compared to the control ones. By repeating the exploration with a game-like goal, no differences were found instead. Neuropsychological and motivational aspects should be considered in order to explain these findings.

1. INTRODUCTION

Autism Spectrum Disorders (ASDs) include various conditions such as Autistic Disorder, Asperger's Disorder and Pervasive Developmental Disorder Not Otherwise Specified, that are classified within a clinical spectrum known as Pervasive Developmental Disorders (American Psychiatric Association, 2000). According to the DSM-IV-TR, all of these disorders are characterized by the presence of core deficits in three domains: impairment in communication, reciprocal social interaction and restricted and repetitive patterns of behaviour, interest and activities. Autism spectrum disorder (ASD) is a new category that includes within a single diagnosis several previously separate diagnoses, such as Autistic Disorder, Asperger's Disorder, Childhood Disintegrative Disorder and Pervasive Developmental Disorder not otherwise specified (Diagnostic and Statistical Manual of Mental Disorders (DSM-V), to be released in May 2013). ASD is characterized by the presence of core deficits in two domains: impairment in social communication and social interaction and restricted and repetitive patterns of behaviour, interest and activities.

ASD showed an increase through the ten past years, reaching an incidence of 4 per 10000 to 6 per 1000 children (Faras, Al Ateeqi, & Tidmarsh, 2010). Also if the degree of impairment in individuals with ASD may vary, the impact on affected individuals and their families is generally life-changing (Newschaffer, et al., 2007). For this reason it is important to develop tools in order to improve their skills in performing daily-life activities.

In this context, the potential benefits of virtual reality (VR) for habilitation of children with ASD have been proven by several studies (Bellani, Fornasari, Chittaro, & Brambilla, 2011; Bölte, Golan, Goodwin, & Zwaigenbaum, 2010; Mineo, Ziegler, Gill, & Salkin, 2009; T. D. Parsons, Rizzo, Rogers, & York, 2009; Wang & Reid, 2010). The use of virtual environments (VEs) (i.e. simulations of the real world based on computer graphics) for the treatment of children with ASD is of great help considering the fact that they can be simplified accordingly and depending on the level of input stimuli which are tolerable by an individual (Strickland, 1997). Also, similarity to the real world as well as modification and repetition by means of similar scenes support the generalization to the real world of acquired skills.

Some visual strengths, such as in visual search tasks, have been reported on persons with ASD by several studies (Joseph, Keehn, Connolly, Wolfe, & Horowitz, 2009; Samson, Mottron, Soulières, & Zeffiro, 2011). Accordingly, a preference for visual stimuli, especially if proposed by VR applications, has been noted (Mineo, et al., 2009). Therefore, it is likely that interventions supported by computer technology is useful and appropriate for these children (Shane & Albert, 2008).

Head-mounted displays (HMDs) have generally been used in VR with the objective of increasing the sensation of immersion in the VE. However, this choice is more expensive and less comfortable compared to the use of traditional computer screens. Furthermore, HMDs may cause ‘cyber-sickness’ (S. Parsons, Mitchell, & Leonard, 2004), some of its symptoms are nausea, vomiting, headache, drowsiness, loss of balance and altered eye–hand coordination.

However VEs, can be visualized and explored also using a common computer monitor and a personal computer (desktop VEs), without the need of wearing special equipments (such as HMDs and wired sensors), which could be more troublesome when used by persons with ASD.

The navigation in the VEs is accomplished by the use of common input devices (i.e. keyboard, mouse, joystick, touchscreen) and it is supported by the interactions between the child and the therapist (Holden, 2005; Standen, Brown, Horan, & Proctor, 2002). VEs simulate the real world as it is or they create entirely new worlds. VEs can provide experiences helping participants to understand concepts and to develop strategies when performing specific tasks, which can be repeated as many times as necessary (Chittaro & Ranon, 2007). The realism of the simulated environment, which seems not to be experienced by children with ASD in a different way regarding control subjects (Wallace, Parsons, Westbury, White, & Bailey, 2010), allows the child to learn important abilities that are likely to be applied in their everyday lives too (McComas, Pivik, & Laflamme, 1998; Strickland, 1997).

The purpose of habilitation programs should be to help ASD children to improve their everyday performance skills. Indeed it is recognized in the literature that VEs have a potential benefits in supporting the learning process (Ehrlich & Miller, 2009; Goodwin, 2008; S. Parsons & Mitchell, 2002; Strickland, 1997; Strickland, Marcus, Mesibov, & Hogan, 1996). Research has analyzed the ability of children with ASD to use VEs, and it is demonstrated in several studies that they successfully acquire new pieces of information from their use. Especially, participants with ASD learnt quickly how to use the equipment and achieved significant improvements in required tasks (e.g. identify objects, walk through specific spaces in virtual scenes or show ability to cross a virtual street) after a few trials in the VE (Josman, Ben-Chaim, Friedrich, & Weiss, 2008; S. Parsons, et al., 2004; Strickland, et al., 1996). Further studies using VEs found that social skills (i.e. abilities to recognize and manifest emotions) improved after the VE intervention (Cheng & Ye, 2010; Mitchell, Parsons, & Leonard, 2007; Moore, 2005) and that the competences acquired in VEs were transferred to the real world (Herrera, et al., 2008). These studies employed VEs as diagnostic and rehabilitation tools, but none of the studies have yet focused specifically on understanding the type of exploration (which is a fundamental activity in using VEs) made in the VE by children with ASD. In the real world a reduced environmental exploration, associated with core symptoms of ASD, which include restricted patterns of interests, was reported by several studies in individuals with ASD. Indeed studies of exploratory behavior in the real-world, in children with ASD, have shown atypical object exploration (Ozonoff, et al., 2008) and reduced environmental movement in terms of time spent in active exploration (Pierce & Courchesne, 2001). In addition, a subsequent study, carried out in an experimental room divided into three zones with different levels of visual stimulation complexity, found that the time spent in exploration decreased when visual complexity of the environment was increased (Kawa & Pisula, 2010).

Given the above mentioned extremely good results in the use of VEs and the little knowledge available on VR environmental exploration and space preference in children with ASD, the purpose of this paper was to analyze navigation of VEs by children with ASD compared to children with typical development. Particularly, the aims of the our research were (1) to study the characteristics of navigation in children with ASD compared to children with typical development, (2) to highlight the characteristics of the VE that may affect the ability of navigation, (3) to investigate if stereotyped behaviors also emerge in the VE and what they depend on, and (4) to analyze whether the introduction of motivational elements change the performance in VEs.

2. METHODS

2.1 Participants

Sixteen children with ASD (fourteen males and 2 females) were enrolled. The inclusion criteria were: diagnosis of ASD and age between 7 and 14 years. Furthermore, none of the patients had comorbid attention deficit hyperactivity disorder, seizure disturbance or any other associated disorder known to support ASD features. Fifteen children were diagnosed with Autistic Disorder and one with Asperger's Disorder. Diagnoses were made according to the DSM-IV-TR criteria and were confirmed by consensus meeting including a child psychiatrist, a child psychologist and by the implementation of the Autism Diagnostic Observation Scale (ADOS-G) (Lord, et al., 2000). Children were enrolled from “La Nostra Famiglia”, Scientific Institute IRCCS “E. Medea”, Pasian di Prato, Udine, and at the Child Neuropsychiatric Unit of the National Health Service of Udine. These are social-service organizations that promote and work in favour health care, education and services for people with special needs, essentially in particular children and adolescents. Children with ASD were free of medication, history of traumatic brain injury or other neurological illnesses. Healthy volunteers were 1:1 matched to children with ASD for age, sex, race, language and education.

The participants in the control group were enrolled from the local community in the urban area of Udine. Children with ASD and healthy volunteers were matched 1:1 for age, gender, race, language and educational level. The two groups did not differ in age, educational level, parental education and occupational status as evaluated with the Hollingshead Scale of Socio-Economical Status (Barrat, 2006) (Table 1).

The procedures were approved by the Ethics Committee of the Scientific Institute (IRCCS) Eugenio Medea and have been performed in accordance with the ethical standards laid down in the Declaration of Helsinky. After complete description of the study, written informed consensus was obtained from parents.

2.2 Materials

2.2.1 Neuropsychological and Clinical evaluation

Neuropsychological and clinical scales were administered to both groups in order to get the characteristics of the children with ASD as compared to the control group children (Table 2). Non verbal IQ was evaluated by means of the Raven's Progressive Matrices test (two different versions of the age-appropriate test were used: Standard Progressive Matrices for children aged 12 years or above and Colored Progressive Matrices for children aged 5 through 11 years-of-age) (Raven, 1938, 1984). This test was used as a measure of intelligence because it minimizes spoken instruction, does not require verbal skills and does not refer to particular everyday life's experiences that these children may be missing (Soulières, Dawson, Gernsbacher, & Mottron, 2011). All participants completed the three selected subtests of the visual spatial domain of the NEPSY-II (Korkman, Kirk, & Kemp, 2007). The subtests used were: Block Construction, to assess the visual spatial and visual motor ability to reproduce three-dimensional constructions from models; Picture Puzzles, designed to assess visual discrimination, spatial localization, visual scanning and the ability to recognize part of a whole picture; Route Finding, used to evaluate knowledge of visual spatial relations. The Rey-Osterrieth Complex Figure Test (Osterrieth, 1944) was administered. This test requires the reproduction of a complicated line drawing, first by copying it and then by recalling it in memory after a 3-minutes interval (the test provided two different scores for copy and memory, based on centile scores). Two different versions of the age-appropriate test were used (figure Rey A for children aged nine years or above, figure Rey B for younger children). Many different cognitive abilities are needed for a correct performance and the test evaluated different functions, such as visual spatial abilities, memory, attention, planning and working memory (executive functions).

The Gillian Autism Rating Scale (GARS) (Gilliam, 1995), filled out by the parents, is a behavioral checklist. Items on the GARS are based on the definitions of autism adopted by DSM-IV criteria (American Psychiatric Association, 1994) and provides an Autism Quotient, a standard score (M= 100, SD= 15) derived from four subscales (Stereotyped behaviors, Communication, Social interaction and Developmental Disturbances) which measures the possibility of a child to be diagnosed as autistic.

Achenbach's Child Behavior Checklist for ages 6-18 (CBCL) (Achenbach & Rescorla, 2001) is a checklist of a wide variety of behavioral problems that are summarized by eight syndromic scales with T-scores (M= 50, SD= 10). In our study it was filled out by the mothers of children with ASD and controls.

2.2.2 Virtual environment tasks

The desktop VEs which were used in this research were taken care of by the Human-

Computer Interaction Laboratory (HCI Lab) of the University of Udine. The 3D models were built using the Virtual Reality Modeling Language (VRML) while the Cortona3D (http://www.cortona3d.com/) viewer was used as the interactive rendering engine. Data collection software was written in Java.

Desktop VEs were run on a laptop computer and a mouse was used in order to navigate them. Navigation was controlled according to the conventions adopted by many virtual worlds: mouse movements –right or left - allowed participants to change their orientation in the VE, while holding down the left mouse button and moving the mouse forward or backward activated locomotion within the VE. There were two VEs; the first realistically reproduced the courtyard of a villa in order to get familiar with the use of the mouse during navigation (familiarization task). Children went passed a gate into a garden surrounded by walls, they could see a villa in the front of them. Children could move around the garden, walk under the arcades and go up the stairs (Figure 1 top). The second VE reproduced a small town.There were roads with buildings on both sides, along which children could move to explore different zones containing landmarks such as a fountain, buildings with arcades, a church and a baptistery. Two tasks were carried out with this VE: the first ("free exploration") required to navigate and freely explore this unfamiliar urban environment (Figure 1, bottom) while the second ("treasure hunt") required to navigate the VE and find specific objects (parrots) (Figure 2).

Several previous studies highlighted that the creation of VEs which are every time more similar to the real environment increases the probability that skills acquired in the VEs are transferred or generalized to the real world (S. Parsons & Cobb, 2011; S. Parsons, et al., 2004; Strickland, et al., 1996; Wang & Reid, 2010). In designing our VEs, to maximize similarity between the virtual environments and reality, we (i) considered two existing places (courtyard of a villa and small town), (ii) defined shapes and sizes of the various elements of the two environments by referring to the actual layout and maps of the real places, (iii) took a large set of high-resolution pictures of the real-world buildings and objects in the field and used them to create the textures that were applied to the 3D models in the virtual environment. In addition to the similarity with the real environment, the proposed VEs are specifically designed to study, in children with ASD, the differences between the free exploration and exploration motivated by an aim (respectively “free exploration” and “treasure hunt”).

2.2.3 Procedure

Tasks as well as neuropsychological and clinical scales were administered in two experimental sessions lasting 45 minutes each. In the first experimental session, virtual environment tasks and Raven's Progressive Matrices test were performed; the remaining tests were implemented within one week. The same researcher, a clinical psychologist (L.F.), who knew which group the child belonged to, explained and administered all tasks for all children.

Before participants used the equipment, during virtual environment tasks, the researcher explained and demonstrated how to use the familiarization VE. The researcher showed how to navigate around the VE and then left the children to freely explore it for about two minutes. During the familiarization task, the researcher asked the child to move left and right and forward and backward to see if he/she understood how correctly to use the mouse. All the children were able, after this task, to move around the virtual environment. Furthermore, all participants were familiar with the computer, that they used it at school and at home, as checked by asking parents. After this period of familiarization with the mouse for VE exploration, the computer was switched to the second VE and participants completed the "free exploration" and the "treasure hunt" experimental tasks, in this order for all participants. The instructions about the two tasks given by the researcher were the same for all children. In "free exploration" task, the child was told to freely explore the environment, moving along the streets of the city, until she/he thought she/he had seen it entirely. In "treasure hunt", the experimenter showed the image of an object (parrot) on the screen and explained that there were 5 parrots to search for in the VE and how to select them when found; children had to click the object with the mouse and the object disappeared with a sound. The computer screen continuously displayed a sign indicating how many items were still left to find or if the task was completed (when all 5 parrots had been found). There were no other interactions between the child and the researcher during navigation tasks.

Since we used desktop VEs, that are unlikely to cause cybersickness, we decide to used 8 minutes session for each task (T. D. Parsons, et al., 2009), so as not to cause strain, tiredness and subsequent persevering behavior on the children (Joosten, Bundy, & Einfeld, 2012). The navigation was interrupted before the end of the 8 minutes if the child found all the parrots.

2.2.4 Dependent Measures of "free exploration" and "treasure hunt"

The measures, listed below, were obtained using VU-Flow (Chittaro, Ranon, & Ieronutti, 2006) a tool able to record user's movements in a VE and provide experimenters with visual abstract representations such as navigation paths followed by participants on the map of the VE or heat maps that indicate where in the VE participants walked most.

The VE reproduces an urban area which size is 140 x 275.5 meters. To record subject's positions and movements, the area was divided in square cells and the side of each cell was 0.444 meters long. As a result, 315 x 620 cells detected the position of the plane on which participants 'walked'.

To analyze navigation in both experimental tasks, "free exploration" and "treasure hunt", seven main measurements were used in the present study:

- Number of Zones: Number of zones visited. The VE was divided into 11 areas (as shown in Figure 3).The Number of zones visited was obtained by counting manually the areas crossed at least once by the navigation path of each child.

- Walked-1: Number of map cells on which the child walked at least once.
- Walked-2: Number of map cells on which the child walked at least twice. This indicates how many previously visited cells the child went back to at least once.
- Stationary: period of time in seconds during which the child was standing still.
- Moving: time in seconds during which the child was moving.
- Length: total length of the walked path.
- Number of objects found: number of parrots found by children.

2.2.5 Statistical analysis

All statistical analyses were conducted using SPSS for Windows, version 15.0 (SPSS Inc, 2006). A two-tailed significance level of $p < 0.05$ was adopted. Raw scores for each group were analyzed. Data were tested for normal distribution using the Shapiro-Wilk test. Then Student's t–test or Mann-Whitney test were implemented to compare demographics, neuropsychological and clinical data of children with ASD and control group children. Although Student t-test showed that the two groups did not differ in age (table 1), Pearson test was used to analyze possible correlations between participants' age and performance in the two navigation tasks (these correlations were adjusted by Bonferroni correction). In order to rule out a possible effect of non verbal IQ Raven's Progressive Matrices score was entered as a covariate. Thus one way analysis of covariance (ANCOVA) was used to compare the seven navigation variables between the two groups, for “free exploration” and for “treasure hunt” tasks. Mann-Whitney test was employed to compare the number of visited zones and the number of objects found by each of the two groups. Finally, separate Pearson tests were performed to study possible correlations between performances in the two tasks, “free exploration” and “treasure hunt”, with NEPSY-II subtests and CBCL-ASD profile (correlations were adjusted by Bonferroni correction).

3. RESULTS

3.1 Neuropsychological and Clinical scales

The clinical and neuropsychological data of children with ASD and control group ones are reported in Table 2. Children with ASD had a normal or high IQ, as rated with Raven's Progressive Matrices. Indeed, none of the children had a performance below the 5 percentile corresponding to a subject of “weak” intelligence or to an estimated IQ lower than 75 (Belacchi, Scalisi, Cannoni, & Cornoldi, 2008; Raven, 1938).

The average scores for participants with ASD were lower than control group ones on Raven's Progressive Matrices test and all selected subtests of NEPSY-II. Also, regarding memory and copy abilities, rated by the Rey-Osterrieth Complex Figure Test, average scores of participants with ASD were lower than control group ones. Children with ASD had higher scores than controls in the GARS and in the Internalizing scales and Total scales of the CBCL. The analysis of the CBCL subscales showed that children with ASD had higher scores than control group ones on the Withdrawn/Depressed, Social Problems, Thought Problems and Attention Problems. The CBCL-ASD profile (Biederman, et al., 2010) composed by the sum of the CBCL-Withdrawn, Social and Thought Problems scales was significantly higher in children with ASD than control group ones.

3.2 Navigation in the "free exploration" and "treasure hunt" tasks

During "free exploration" no significant correlations were found between the controls seven VE measures and participant's age. In "treasure hunt", a significant negative correlation, which survived Bonferroni correction, was found in controls between age and Moving ($r=-0.64$, $p=0.01$). Analysis of covariance was performed to rule out a possible effect of non verbal IQ on dependent measures of "free exploration" and "treasure hunt". IQ, as evaluated by means of the Raven's Progressive Matrices test, was not a significant predictor for all dependent measures ($p>0.05$). The analysis of "free exploration" revealed some significant differences instead, between the two groups in Number of Zones (F1,29=6.35, p=0.02, η2p=0.18) and in Moving ($F_{1,29}=7.61$, $p=0.01$, $\eta^2_p=0.21$), i.e. children with ASD visited fewer zones and spent less time moving around the VE than control group ones when the assigned task was to freely explore the environment until they thought they had seen it entirely. The Mann-Whitney test, carried out in each zone, showed significant differences between the two groups in Zone 1 (U=80, Z=-2.41, p=0.02, r=-0.43). No other significant differences between the two groups were found for the other variables considered in “free exploration” task (Table 3). The difference between groups in the averages of Number of Zones and Moving around was smaller and not statistically significant in treasure hunt. More generally, no significant differences for any variable between children with ASD and control group ones (Table 3) were found for the “treasure hunt” task. Lack of significant differences included also the number of parrots found by the two groups which was analyzed with a Mann-Withney test (U=97, Z=-1.36, p=0.19, r=-0.24).

3.3 Correlations

In “free exploration”, the correlations which survived Bonferroni correction were two positive correlations in children with ASD between the CBCL-ASD profile and respectively Walked-2 (r=0.59, p=0.01) and Length (r=0.61, p=0.01).

In “treasure hunt” a significant negative correlation between Route Finding of NEPSY-II and Stationary (r=-0.65, p=0.003) was found for children with ASD.

In “free exploration” as well as in “treasure hunt” tasks, no significant correlations were found within the control group children considering the seven VE measurement and their individual scores in the NEPSY-II subtests and in the CBCL-ASD profile.

4. DISCUSSION

The first aim of this study was to analyze navigation and exploration of virtual environments by children with ASD compared to children with typical development and highlight the features of VEs that influence the ability of navigation. In the “free exploration” task, we found differences in Number of Zones and in Moving around, that were both lower in children with ASD than in the control group. Moreover, the two groups differed in the number of visits to Zone 1, which was lower for children with ASD. An aspect that distinguishes Zone 1 from other areas of the VE is that it has a single entrance which is not highly visible. Therefore, in order to detect it, a more detailed visual analysis of the VE on the participant’s side is required.

It is interesting to note that the above results, obtained with free exploration of a virtual environment, are consistent with studies (Kawa & Pisula, 2010; Pierce & Courchesne, 2001) that analyzed real-world environment exploration in children with ASD. In particular, using respectively one or three rooms with objects distributed throughout the room, these studies found that children with ASD spent significantly less time in active exploration and explored fewer objects than control group children. Moreover, Kawa found that the time spent in exploration decreased with increasing visual complexity of the environment (Kawa & Pisula, 2010).

Another aim of our work was to detect possible stereotyped behaviours in VEs by children with ASD. In our study, the CBCL-Autism Spectrum Disorders (ASD) profile, obtained by adding Withdrawn, Social and Thought Problems scales, showed a positive significant correlation with Walked-2 and Length measurements. Thus, children with higher CBCL-ASD profile traveled for longer distances (Length) and the number of cells of the map on which they repeatedly walked (at least twice) was higher. Interestingly, the correlation between CBCL-ASD profile and Walked-2 confirmed that the core symptoms of autism, such as restricted patterns of interest and repetitive and stereotyped movements, affected the exploration of the unfamiliar urban VE.

Therefore, our results in the “free exploration” showed that the VE was less explored by children whit ASD; especially, children with ASD visited less Zone 1, an area requiring a more extensive visual analysis. Furthermore, reduced exploration of children with autism in “free exploration” could be associated with clinical aspects, as seen by the correlations with CBCL subscales.

Finally, we wanted to analyze whether the introduction of motivational elements would change the performance in virtual environments. In the “treasure hunt” task, which was carried out after “free exploration”, no significant differences in VE measurements were found between the two groups. There were no significant differences in the number of objects found by the two groups either. This result was different from that obtained by Vernazza-Martin (Vernazza-Martin, et al., 2005) who explored goal-directed locomotion in children with ASD, using a real environment (a psychometric room) and found that children with ASD were impaired, compared to the control group ones, in achieving the researcher-imposed goal. In particular, the study concluded that children with ASD were impaired in movement planning and this deficit was caused by typical executive dysfunctions (e.g. attention, planning and inhibition) in autism.

Our results suggest that “treasure hunt” was explored in a more targeted and strategic way by both groups. Two factors could have played a role. First, we could hypothesize that exploring an already visited virtual environment could have helped children with ASD in reducing their performance differences compared to control group ones. This hypothesis is also supported by the fact that previous authors have found that performance of children with ASD improved after repetition using VEs (Mitchell, et al., 2007; S. Parsons, et al., 2004). Moreover, in the “treasure hunt” task, a negative correlation was found between Route Finding of NEPSY-II and Stationary. The route Finding subtest of visual spatial domain was designed to assess knowledge of visual spatial relations and directionality, as well as the ability to use this knowledge to transfer a route from a simple schematic map to a more complex one. Thus, children with ASD, who did best in this subtest, spent less time standing still in the VE.

The second factor concerns the formulation of the exploration goal as a game in the “treasure hunt” task which could have improved the motivation of children with ASD. Restricted and repetitive interests of children with ASD improved in situations of decreased stimulation or lack of things to do, as demonstrated in previous studies (Bright, Bittick, & Fleeman, 1981; Joosten, et al., 2012). Furthermore, during the tasks, the inclusion of motivational elements reduced repetitive behaviors and enhanced learning (Koegel, Singh, & Koegel, 2010). In particular, a study based on the idea that volition is the most important aspect in predisposing persons to engage in tasks, showed that, in children with cerebral palsy, VR created volition and therefore motivation (Harris & Reid, 2005). Moreover, that research highlighted elements of VR that may increase the volition such as variation in the game, level of engagement required by the task and competition. In our task, formulating the goal as a game could have increased also the level of engagement required (children were required to adopt a strategy).

Two recent reviews (Irish, 2013; S. Parsons & Cobb, 2011) showed that VR is a technology with unique potential (i.e. realism, visual input, repeatability) for children with ASD and suggested that future studies should identify how to design VEs that best support learning. Accordingly, we summarize the key points suggested by our study, that can be useful for designing future VEs for children with ASD:

- repeating the task by introducing some elements which required a more detailed visual analysis can lead to a higher number of zones visited by children with ASD;
- the use of some motivational elements which may influence a child's behavior can reduce stereotyped actions and improve performance in general.

Some limitations of the present study should be taken into consideration. First, the relatively small sample size may have limited the generalizability of the data; future studies should thus involve larger numbers of participants. Second, although the navigation in “treasure hunt” was more strategic and targeted, it cannot be completely assessed what was more effective, whether repeating the navigation or presenting the task like a game.

5. CONCLUSIONS

In conclusion, our research indicates that free exploration of an unfamiliar virtual environment could be negatively influenced by characteristics of ASD. When the navigation task is formulated as a game in an already visited environment, we suggest that neuropsychological and motivational characteristics become important in children with ASD and should be further explored in future research.

In particular, our preliminary results may inspire future research that could take into account these variables in the creation of VEs specifically suited for habilitation in children with ASD.

Conflict of Interest: The authors declare that they have no conflict of interest

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Table 1. Demographic information of patients and age matched controls

	Children with autism (N=16)		**Control participants (N=16)**				
	Mean or median	SD or range	Mean or median	SD or range	t_{30}	U	p
Age (years)	9.56	2.16	9.69	1.92	-0.17		0.86
Educational level	3.50	2.16	4.25	2.11	-0.99		0.33
SES education	11.25	6-18	12.00	6-21		123.50	0.86
SES occupation	21.72	9.07	23.12	10.63	-0.40		0.69
SES total	33.44	10.21	35.13	12.80	-0.41		0.68

Independent T test or Mann-Withney test were used (two-tailed). Bold character indicates significant differences.

Mean and SD (Standard Deviation) have been reported for Indipendent T test, while median and range have been reported for the Mann-Withney test.

Table 2. Clinical and neuropsychological features of the sample.

	Children with autism (N=16)		**Control participants (N=16)**				
	Mean or median	SD or range	Mean or median	SD or range	t_{30}	U	p
Non verbal IQ (percentile)	43.50	5-91	83.00	22-100		73.00	**0.04**
Nepsy II (total)	29.25	10.74	42.50	7.81	-3.99		**<0.001**
Nepsy II: Pictures Puzzles	9.58	4.47	15.06	3.17	-4.00		**<0.001**
Nepsy II: Building Blocks	13.07	5.25	18.19	4.85	-2.87		**0.01**
Nepsy II: Route Finding	7.60	1-10	10.00	5-10		39.50	**0.001**
Fig. Rey A or B Copy	35.00	0.5-100	60.00	10-99		77.00	**0.05**
Fig. Rey A or B memory	10.00	1-90	45.00	10-100		66.50	**0.02**
GARS Autism Quotient	75.81	11.87	46.00	10-62	7.49		**<0.001**
CBCL: Internalizing	62.00	50-66	50.00	44-70		46.00	**0.002**
CBCL: Externalizing	51.69	10.68	48.16	10.16	0.96		0.35
CBCL: Total Score	61.00	50-71	49.00	38-72		36.50	**0.001**
CBCL:Anxious/Depressed	57.00	51-70	53.50	50-76		84.50	0.1
CBCL: Withdrawn/Depressed	62.19	6.40	54.46	3.32	4.28		**<0.001**
CBCL: Somatic Scales	55.00	50-67	53.00	50-68		102.50	0.32
CBCL: Social Problems	65.00	56-69	51.00	50-67		**19.50**	**<0.001**
CBCL: Thought Problems	64.00	50-78	50.50	50-71		**40.50**	**0.001**
CBCL: Attention Problems	66.00	53-75	52.50	50-79		**42.50**	**0.001**
CBCL: Rule- Breaking Behavior	52.50	50-67	51.00	50-72		97.50	0.24
CBCL:Aggressive Behavior	52.50	50-79	51.00	50-73		112.50	0.54
CBCL-ASD Profile	191.00	164.00-207.00	156.500	150.00-191.00		**19.50**	**<0.001**

Independent T test or Mann-Withney test were used (two-tailed). Bold character indicates significant differences. Mean and SD (Standard Deviation) have been reported for Indipendent T test, while median and range have been reported for the Mann-Withney test.

Table 3. Performance on "free exploration" and "treasure hunt"

	Free exploration						Treasure hunt					
	Children with autism		Control participants				Children with autism		Control participants			
	mean	SD	mean	SD	F	p	Mean	SD	mean	SD	F	p
Number of Zones	6.50	2.07	8.31	2.02	6.35	**0.02**	7.56	2.10	8.44	1.55	0.94	0.34
Walked-1	11191.63	3188.01	13563.19	3842.92	3.83	0.06	10533.13	2633.48	10593.94	4553.61	0.00	0.94
Walked-2	1422.63	1079.78	1564.56	1153.86	0.35	0.56	978.19	1187.88	1087.88	1516.47	0.05	0.65
Stationary	70.18	63.80	62.43	46.68	0.01	0.94	68.28	60.72	64.96	40.37	0.22	0.68
Moving	255.82	85.91	324.68	72.63	7.61	**0.01**	216.75	93.03	248.77	122.47	0.81	0.38
Length	1477.68	579.20	1711.92	591.82	1.57	0.22	1238.39	502.93	1277.19	796.40	0.05	0.83

Analysis of covariance was performed (df= 1,29)

Fig. 1. Map and pictures of virtual environments (VEs) used for familiarization (top) and for the experimental tasks (bottom)

Fig. 2. Pictures taken from the ‘‘treasure hunt’’ task with parrots to find

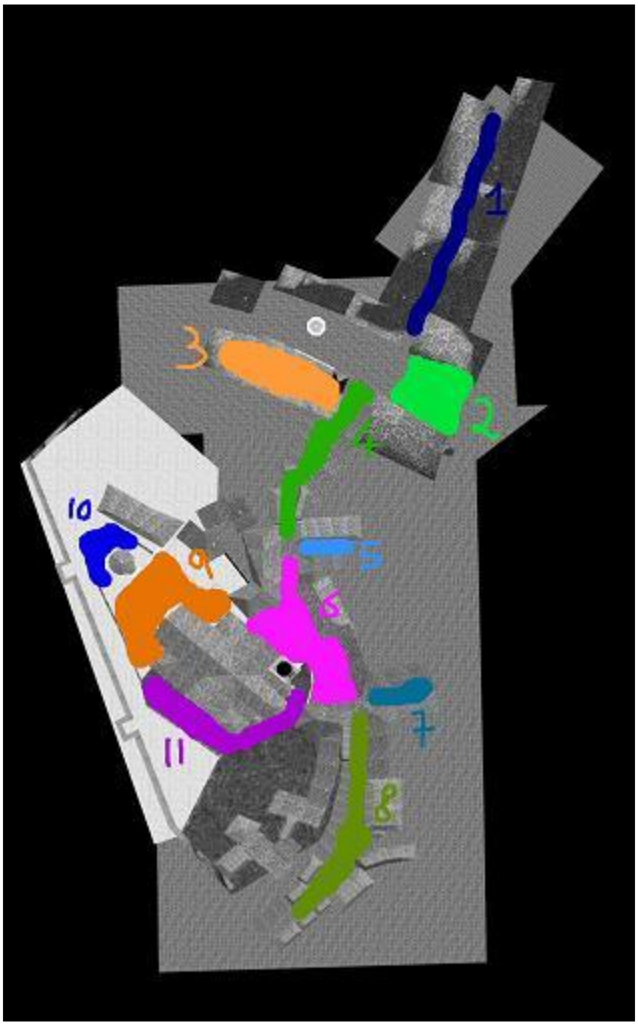

Fig. 3. Areas in which the virtual environment (VE) was divided

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