



Case Report

Case Report: Using Eye-Tracking as Support for the TEACCH Program and Two Teenagers with Autism-Spectrum Disorders

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Abstract

Mobile eye-tracking can be a powerful tool to help in designing strategies to improve learning in individuals with autistic spectrum disorders. The two teenagers studied in our project, both with autism disorders, use less fixation points to look at these scenes and are slower than peers with normal development. After one year of individualized treatment, the teenagers' competencies in eye contact with target points were improved.

These preliminary results show that the intervention should take place in ecological conditions and the evaluation using Mobil eye-tracker, something which bypasses language deficits, could be integrated into clinical routines in order to increase generalization.

Keywords

Autistic disorder; Intellectual disabilities; Eye-tracking; Individualized educational program

Introduction

TEACCH (Treatment and Education of Autistic and related Communication Handicapped children) is an educational program for children and adults of all ages with ASD (Autism Spectrum Disorder). The TEACCH approach is called "formal education" and is based on the fact that people with ASD suffer from neuropsychological deficits [1]. It is important to remember that the goal of this approach is to teach the person to live with his disability, not to cure it. Although people with ASD are heterogeneous, it seems however, as demonstrated by Mesibov et al. [1] and confirmed by many writers like Dawson [2], Ozonoff et al. [3,4] and Tsatsanis [4], constant characteristics which are described as follows: (1) a significant preference for visual information; (2) more attention to detail with sequencing difficulties and integration signals; (3) strong attentional variability due to hyperacusis or contrary to the extreme focus on specific interests (reduction of sensory gating); (4) the major problems in social functioning with marked impairment in social interaction (5) difficulty with abstract concepts and especially with

the concept of time, which includes fast activities, early recognition of problems and the end of an activity and its duration; (6) tendency to cling to routines and rituals, which induces a learning disability and generalization. Disturbances generate a negative state of stress in the learning condition.

The formal education of TEACCH is to change the environment to meet the needs of people with ASD and its effectiveness has largely been demonstrated [1]; However, to use the TEACCH program as efficiently as possible, it is essential to develop a therapeutic intervention cognitive behavioral orientation as cognitive remediation. In the case of ASD accompanied by severe mental retardation, cognitive remediation will reduce the deleterious impact of cognitive impairment in learning. To increase the widespread, intervention must take place in ecological conditions [5-8]. Finally, assessment instruments are an important starting point for individualized plans of teaching and support emerging skills [9].

Sample Course of TEACCH

The school takes care of children and adolescents (4-15 years of age) from 8.30 am to 12 noon: followed by the midday meal until 1:00 p.m., a break between 1:00 p.m. and 2:00 p.m. is programmed. The school starts again from 2:00 p.m. to 3:45 p.m. Monday through Friday. On Wednesday, the schedule is from 9:00 to 11:45. The schedule for the day is accurate. The student consults his schedule that is adapted to his level. Below an example of the daily schedule, showing the progress of activities.

Figure 1 shows the example of daily schedule. According to the level of understanding, the schedule is the real object for students at a lower level of development, then from a picture, to a drawing, to a pictogram and to a word for students of higher level. Thus the student has a notion of temporality in relation to its day and with respect to the elements shown in his schedule numbers. The schedule also allows announcing the changes; the unexpected (such as a speaker or a sick student) becomes predictable. When the teenager reaches his desk (Figure 1), his work pattern (always adapted to his level) shows him the list of tasks to perform (Figure 2).

Figure 2 is the description of the work table. The student starts work by combining the color put on his desk and the corresponding locker. The last card is the transition card that brings him back to his schedule or game (indicated by the arrow in the illustration above). The program TEACCH consists mainly of autonomous work in which the student understands the task with a target clarified immediately understandable. On the other hand, whilst job training where the activity takes place in duo (student and teacher). In this case, the teacher shows the student what he expects of him and indicates the time it would take with a similar work pattern to that in class. Working schema associated with colored lockers (bottom right) for the work to be done during work independently.

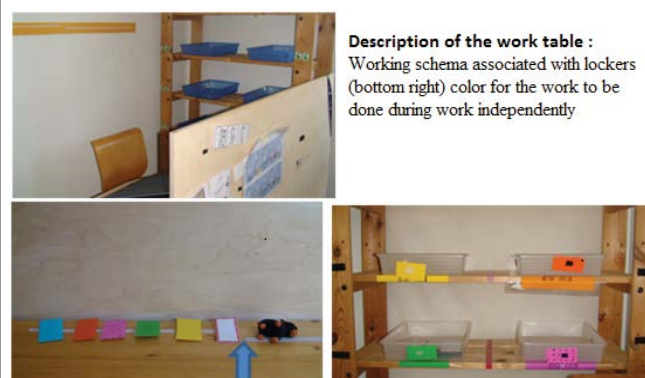
Figure 3 is the example of suggested exercises. The exercises have always "manuals" and clarified guidelines. The activity is taken for granted if, for example, for a week, the activity is successful and that the student is able to generalize. After a two-month break, the activity can be reassessed to verify the purchase. During the day, there are times without beginnings and clear ends (wait for the taxi, play free,

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Figure 1: Example of daily schedule. On the left, the schedule uses real objects for students at a lower level of development; In the center, the zone operates photos and drawing for students with a more advanced developmental level; Right, time use pictograms and password for students of higher levels.



Description of the work table :
Working schema associated with lockers (bottom right) color for the work to be done during work independently

Figure 2: Description of the work table: Top left, place of work. Bottom left, scheme of work associated with lockers (bottom right) color for the work to be done during work independently.



Figure 3: Examples of suggested exercises. Left, sorting exercise; Right form of exercise distinction regardless of color.

go on the swing, stay seated when meal is finished etc.) which require the use of visual aids to indicate the time (various timers or songs).

Presentation of Lea and Tom, whose first names are fictional. Perrenoud [10]

Lea is a 14-year old girl. When she was born, a Tetralogy of Fallot's cardiac malformation was detected. The genetic report performed

when she was 3 months old indicates a female-type karyotype with 47 chromosomes (additional chromosome 15, partial tetrasomie 15 q). Lea was able to sit up around 10 months and began walking at eighteen months. From the beginning she was clumsy and still today she exhibits considerable problems with balance. At the age of 4, a "Psychoeducational Profile" evaluation (PEP, [11]) revealed an severe ID with emergencies. Also, the following diagnosis was made: severe ID, dysmorphogenetic syndrome, developmental disorder, hypotonia. The PEP conducted when she was 7 years old estimated a developmental age of between 16 and 19 months. Around the age of 9, she was diagnosed with Irlen's syndrom. She also suffers from a divergent strabismus. Currently, she sometimes associates cubes, colors and images, but not in a systematic way. As a result, her schooling never results in acquired learning. She is not able to follow soap bubbles because her visual follow-through is nearly inexistent and does not follow what she is doing. Currently, the suitable image-learning level for Lea involves a simple image, presented in stark contrast with a uniform background. She is a highly impulsive adolescent with unstable emotions. Only rarely does she go about on her own.

Tom is a 16 year old boy. At birth, he was diagnosed with a significant hypotonia of unknown origins. The medical exams conducted at that time did not ever reach a precise diagnosis. At 4 years old, he exhibited an autism-like disorder, hypotonia of the lower limbs, an asymmetry of the upper limbs and difficulties manipulating tactile stimulations. At 10, he exhibited a severe ID and he is not able to dress or undress himself. When he walks, he drags his feet on the ground and is at risk of tripping. His PEP-R indicates a developmental age of between 10 and 16 months. At the age of 15, the PEP-R indicated a developmental age of between 12 and 17 months, only a slight improvement compared to the test conducted 10 years earlier. Today, this adolescent does not speak. On the visual level, he associates cubes and green disks, but no other colors. He does not pay attention to soap bubbles. He does not look at what he is doing and does not visually track an object that crosses the median line. He does not show any interest for picture books.

Lea and Tom live at home and go to specialized school every day (EEAA, LE FOYER). We received informed consent from their parents for the use of eye-tracking (ASL's Mobil Eye, Bedford) as well as for publication.

Results of the initial assessment LEA: We took into consideration the latest assessments conducted by the school, at the PEP-R where she reached a developmental age between 1 year and 4 months and 1 year and 7 months, as well as the revised Checklist Profile sensory [12] which enabled to clarify the sensory profile by drawing sensory strengths and weaknesses. His profile gave the results from possible forms according to the sensory experience in autism listed by Bogdashina. We draw the attention of the reader that the score obtained would not split between strengths and weaknesses sensory, so that senses that collect the most points can be as much by the addition of disturbances than by the sensory positive peculiarities (Table 1).

Eye tracking, meanwhile, confirmed the absence of visual-motor coordination deficits in proprioceptive integration (balance, position, body movement), the preferential use of peripheral vision and an exclusive use of proximal indices.

This initial evaluation will modify its existing structured curriculum. Priorities are given to the level of cognitive performance compared to the understanding of tasks and situations as Lea needs a clear and simple visual aid to keep her attention on the task.

Results of the initial assessment TOM: The latest assessments conducted by the school or the PEP-R shows a developmental age of 12 to 17 months. Checklist Revised sensory profile [12] shows the following results (Table 2).

Eye tracking has highlighted the difficulties of integrating dynamic visual signals; an integration and slowness of processing all the visual signals; lack of visual-motor coordination, preference for the peripheral vision at the expense of the focal vision.

With Tom, there is a difficulty in processing visual information characterized by a perceptive and integrative vision disorder of physical and biological movements. Tom uses his peripheral vision to perform the task. This is seen by the combination of the fixing points at the center of the support; This is widely described by the term “functional fovea” which is the ability to sweep across the world without the eyes moving. With this operation, obviously there is not visuo-motor coordination. As an indication, we are taking as an example a young person without autism spectrum disorder.

Evaluation Tool: Eye-tracking

The material used in this study was the “Mobile Eye” from the Applied Science Laboratories in Bedford, MA, USA (ASL – declaration of conformity, 10.2004). An infrared beam was projected onto the fovea of the right eye. The beam is 880 nanometers, which satisfied the requirements [13] for a light beam that does not harm the eye. The three-point corneal reflection was 0.50 mW/cm² and made it possible to transmit the duration and fixation points without having to immobilize the head. Pupil diameter calibration provided information regarding attention through changes in pupil size [5]. The parallax was reduced by calibrating the distances. Furthermore, a second camera was integrated into the glasses in order to record the visual scene in color as well as the sound. What the camera records of the visual field (50 degrees horizontally by 40 degrees vertically) is nonetheless reduced compared to the eye’s actual visual field (180 degrees horizontally and 150 degrees vertically).

Physiological Response

The parameters studied were fixation points and their duration. Measuring fixation points and their duration enables us to measure a patient’s perception as well as perceptive identification.

Prescription of the TEACCH Program

Given the severity of the handicaps of the two adolescents in this study, as well as their low developmental progress, our work involved adapting their school activities to the particularities of their vision. In this way, we hoped to promote perceptive development and organization, something which is absolutely necessary in cognitive development and therefore in learning.

For Lea, eye-tracking confirmed the lack of visual-motor coordination, the deficit in proprioceptive integration (balance, position, body movement), the preferential use of peripheral vision as well as an exclusive use of proximal clues.

This initial evaluation resulted in a modification of her existing structured teaching program. Priorities were given at the cognitive performance level with respect to task and situational understanding since Lea needs clear and simple visual support in order to maintain focus on a task.

For Tom, eye-tracking highlighted his difficulty in integrating dynamic visual signals; a slowness at integrating and treating all

visual signals; an absence of visual-motor coordination, a marked preference for peripheral vision to the detriment of focal vision. Here are the adaptations proposed in terms of their TEACCH program.

The Eye-Tracking evaluations were related to certain school tasks: (1) learning to follow a moving target (2) matching contrasted images Lea and Tom were evaluated three times with Eye-tracking, with an interval of 1 year between evaluations. The evaluations were conducted at school by the author, an Eye-tracking specialist, a low-vision and corporal therapy specialist, as well as the student’s specialized teacher.

Results

Our results show a quality increase of visual scanning in the image matching task after the development of the individualized program.

Figure 4 shows how both adolescents followed a moving target (candle or light) with their eyes for 1 second before any changes were made in the individualized program. In order to help readers understand, we also provide, for illustrative purposes, the data showing how an unimpaired adolescent follows a moving target. The blue dots correspond to gaze fixation, in chronological order of appearance. The instructions given for this task are to follow the light with the eyes. For Lea, the light was brought as close as possible to her face to get her attention. Both Lea and Tom have a deficit of dynamic visual signal integration, something that is broadly recognized and written about in the literature [14-16]. Nevertheless, it is interesting to note that there is a functional difference between the two teenagers. In essence, Lea is unable to follow the target, her gaze is deviated and fixed; this is expressed by two static fixation points (1,2). In Tom’s case, he has delayed visual tracking; this can be seen by 3 fixation points that move but are far from the target (the light source) (Figure 4).

In Figure 4 the blue dots correspond to gaze fixation, in chronological order of appearance. The data shows that Lea and Tom have a deficit of dynamic visual signal integration. Their handicap is not the same; Lea follows the moving target with her peripheral vision (static fixation points) while Tom uses his central vision but

Table 1: Lea; checklist sensory profile.

Sens	Score	Chek list sensory profile LEA
Vision	7	poor perception, distorted depth and space; 2D world, deformation of the shape, size
Audition	10	hearing overload
Touch	3	sensitive only to certain textures
Olfaction	4	fascination for odors
Taste	1	inability to distinguish between strong flavors or tastes slightly pronounced
Proprioception	5	fluctuation between hyper and hypo between connection and disconnection
Vestibular	9	delayed interpretation head / body movements

Table 2: Tom ; checklist profile sensory profile.

Sens	Score	Chek list sensory profile TOM
Vision	10	Visual Overload
Audition	16	Hears thoughts
Toucher	10	Touch Overload
Olfaction	5	Fluctuation between hyper and hypo"; between connection and disconnection
Taste	5	Fluctuation between hyper and hypo; between connection and disconnection
Proprioception	12	proprioceptive perception périphérique
Vestibular	7	distorted perception of body movements

has difficulty following movement (dynamic fixation points, but far from the target).

Figure 5 shows a school exercise given to Lea and Tom. The instructions for this exercise are to match the image from the container on the left to the identical image on the central support. The blue numbered points correspond to the chronological appearance of visual tracking undergone to match the two images. The blue arrow indicates where the matching image is located. Both Lea and Tom have difficulty treating visual information characterized by a perceptive and integrative disorder of seeing physical and biological movements as suggested by Gepner [17-19]. Lea's visual scanning is disordered and interrupted by saccades which do not work to resolve the task at hand. She also does not have visual-motor coordination. In Tom's case, he uses his peripheral vision to complete the task. This can be seen by the way the fixation points move in toward the center of the support; this has been described by the term "functional fovea" [20] which is the ability to scan one's surroundings without moving the eyes. This functioning obviously also implies a lack of visual-motor coordination. For illustrative purposes, we can see that the teenager without an ASD anticipates the forthcoming task through eye movements. There is a guiding of the forthcoming task (Figure 5).

In Figure 5, the blue dots correspond to gaze fixation, in chronological order of appearance; the blue arrow indicates where the matching image is located. Neither Lea nor Tom is able to complete the task without errors. Furthermore, their visual scanning is not effective enough to complete the exercise and neither of them have visual-motor coordination. On the one hand, Lea's visual tracking is disorganized, and on the other, Tom uses his peripheral vision.

Following the eye-tracking evaluation, the various parties involved determined certain adaptations to the individualized schooling program as described above. A year after these adaptations were established, a new eye-tracking evaluation was conducted to get a sense of the teenager's visual progress by studying their visual signal integration in a quantitative way using the average duration of their

fixation points. This was followed by a quantitative evaluation of their visual scanning by looking at the chronological displacement of their fixation points. A final evaluation was conducted six months later to see whether they had maintained the skills acquired.

Figure 6 describes the quantitative evaluation of visual scanning through the visual signal integration, meaning the average duration of the fixation points during the entirety of completing the tasks. As we noted during the initial phase, Lea and Tom do not integrate visual signals in the same way. Lea's initial evaluation indicated that the duration of her fixation points is very long as she follows a moving target. This data supports the hypothesis of a fixed stare under dynamic conditions. By working to slow down the displacement of the moving target, we were able to get Lea to follow the target's movement. Our initial observation of Tom brought us to the hypothesis that he was capable of following the movement but with a delayed movement of his gaze. Slowing down the target also helped him improve the speed of his visual scanning because we were able to decrease the duration of the fixation points. In terms of the matching task, Lea had trouble keeping her attention and her gaze on the task, and this was noted by a very short duration of the fixation points. By inclining her working space and bringing the exercises both closer to her and centering them, we were able to increase the length of time her gaze remained on the working area. In this way, the duration of her fixation points largely increased. All in all, these new results showed us that now Lea can better fix her attention on her working area, but she still uses her peripheral vision as shown by the very high duration of the fixation points. What remains is to work on the switch from peripheral vision to central vision. Our initial observation of Tom brought us to hypothesize that he was using his peripheral vision to resolve the task at hand. The adjustments suggested—working in the morning in order to compensate for his slowing down, work on contrasts and use vertical presentations of the work to be done—made it possible to reduce his strategy of relying on peripheral vision instead of his central vision. The results demonstrated a decrease in the duration of his fixation points, which is a movement toward the use of his central vision (Figure 6).

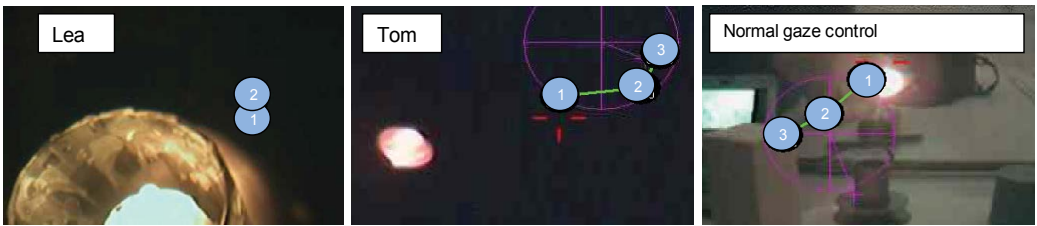


Figure 4: Description of visual tracking for 1 second for Lea, Tom, and, for illustrative purposes, an individual with no dynamic target visual tracking difficulties.

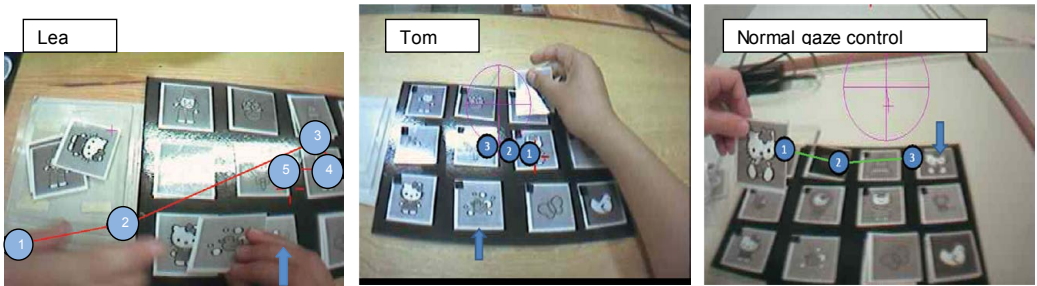


Figure 5: Description of visual tracking over 1 second for Lea, Tom, and, for illustrative purposes, an individual with no difficulties in the task of matching identical images.

Figure 7 shows the qualitative evolution of the visual scanning in the task of matching images following the changes made to the personalized program. We can see that the use of (1) an inclined working space, (2) contrast as well as (3) a reduction in the amount of information given to Lea enabled her to center and organize her visual scanning of the work space. For Tom, by giving him each card that must be matched (1) vertically, as well as using (2) contrast enabled him to reduce his strategy of using his peripheral vision to complete the task and increased the movement of his gaze over the task to complete (Figure 7).

In Figure 7 the blue dots correspond to gaze fixation in chronological order of appearance and the blue arrow indicates where the matching image is located.

Discussion

Professionals find themselves at a disadvantage when working with polyhandicapped individuals, with ASDs and sever ID because the possibilities for researching the resources or weaknesses of the person are restricted. This is why using eye-tracking can lead to new research paths, understanding and therapy perspectives for these individuals who are often ignored due to a lack of resources. Currently there are no published studies showing a similar approach to this work where the originality of this work. With this approach, we were able to demonstrate what supports and enhances the infra-school activities (given the seriousness of the disorders, obviously the normal requirements of school according to age, the reason why it

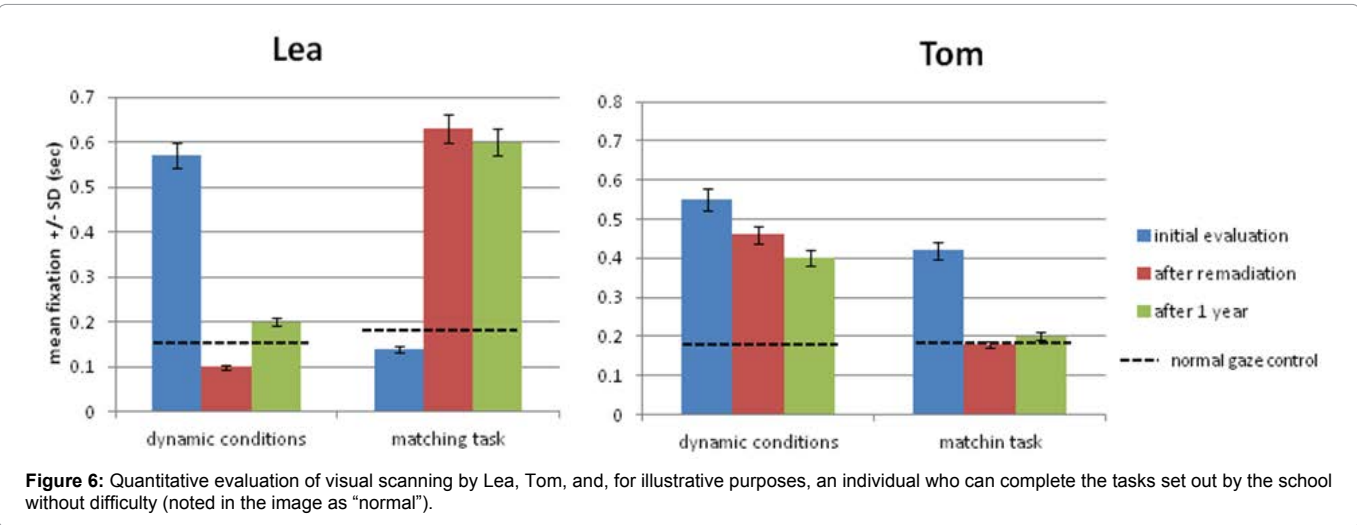


Figure 6: Quantitative evaluation of visual scanning by Lea, Tom, and, for illustrative purposes, an individual who can complete the tasks set out by the school without difficulty (noted in the image as “normal”).

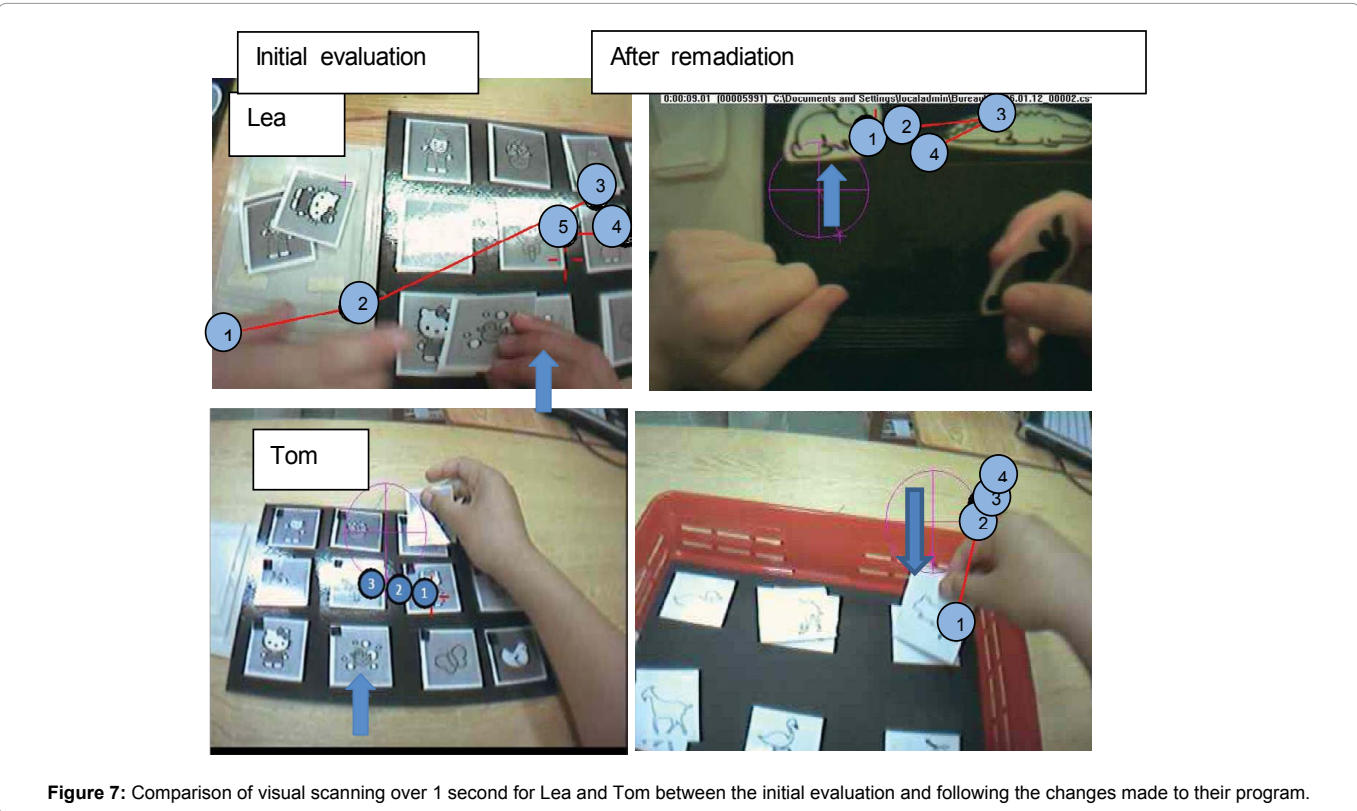


Figure 7: Comparison of visual scanning over 1 second for Lea and Tom between the initial evaluation and following the changes made to their program.

is in infra-school) and develops the visual and cognitive functions despite the severity of mental retardation and multiple disabilities of these future adults.

In this article, we have tried to demonstrate the usefulness of using eye-tracking for investigating the integration of visual signals. For the school, learning is a major challenge in the development of these children with such major handicaps. Because of this, the visual aspects of their handicap are fundamental, since all the theoretical principles of the TEACCH program are based on using visual clues. This makes an evaluation of the abilities and deficits of these students essential, in order to make use of the information gathered. Using this approach, we were able to highlight that which supports and improves their schooling activities and develops both visual and cognitive functions despite the severe ID and polyhandicaps of these future adults. In essence, the re-adapted program helped Lea to better integrate dynamic clues. We were also able to help her reduce the atypical saccades linked to autism and increase her visual signal integration through a better scanning of her visual field. For Tom, we were able to take his slowness into account and integrate the visual signals and we made him use his central vision more frequently. The support for these two students is necessarily interdisciplinary because of their numerous handicaps and this is exactly what complicates the task as this requires more patience, more courage, more creativity, as well as more coordination between the professionals and more communication. This also asks the professionals involved to develop their own humility with respect to their incapacity to find a single solution. Essentially, each professional brings only a small piece of understanding to the larger picture. Gestaltism [21], states that “the whole is more than the sum of its parts,” a notion that applies to interdisciplinarity. One of the biggest difficulties when working with these students is not being able to see progress, because progress is, in essence, quite subtle and therefore not always visible. For those involved, this can be quite discouraging. Eye-tracking is thus useful in that it highlights the subtle improvements achieved and also makes it possible to adjust the program with precision. Something which adds some optimism in cases of profound deficiency. Also, eye-tracking uses cognitive-behavioral concepts because we establish a cognitive evaluation that enables us to highlight the mode of functioning. The therapy offered will be clearly behavioral because we work from the premise that by changing behavioral response triggers we will affect cognition. This corresponds to the therapeutic field of cognitive remediation [22-25]. Eye-tracking is becoming one of the neuroscience-originated technologies used in cognitive behavioral therapy [6].

Similar to schizophrenia for which the CBT therapy is based on cognitive deficits for reducing symptoms [26], current research on Autism Spectrum Disorders also indicates a certain number of cognitive deficits responsible for symptoms such as sensory hypersensitivity, need for ritual and visual contact anomalies [20,27-38].

Conclusion

These case studies indicate that despite a severe ID, an autism-spectrum disorder and a polyhandicap, there are possibilities for learning new skills and generalization. This study shows that we used the TEACCH program to research the most effective evaluation, adaptation and results, as suggested by Mesibov et al. [9]. Our study shows the importance of the evaluation of individualized treatment in the effectiveness of structured teaching. The originality of the study is the use of neuroscientific ways in evaluating the individualized

program to support emerging skills when we are dealing with serious deficits for which the traditional tools are not sensitive enough.

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