12. Hearing and touch for seeing: Instructions to promote mental representation of geometric shapes in visual impaired people when constructing a moving toy

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Introduction

This case study aims to describe the processes developed for adapting and expanding the Jellybird guide and resources designed for the **AutoSTEM** project for seeing students and teachers https://www.autostem.info/wp-content/uploads/2020/06/Jellybird-for-AutoSTEM-PT-v3-def-3.pdf to

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allow educational inclusion for blind or visually impaired children. The instructions and resources are intended to complement the general guidelines already developed by the **AutoSTEM** project, to promote mental representations of geometric concepts with visual imagery.

The Jellybird is a bird made from paper and cardboard, that has wings that can make bird-like movements, when constructed. Following the general aims of the project, STEM subjects can be introduced when the children are constructing an automaton, including geometric shapes, types of motion, and/or biology concepts. A pedagogical guide has been developed, with examples of how the educator or teacher can talk with the children about STEM subjects and ideas. For instance, with the Jellybird, educators can talk about the different parts, their shapes and placement, for example, 'The body is round, but not a circle. It is oblong and pointed at one end. There is a left-hand side and a right-hand side of the body' or 'The wings are rectangles. A rectangle has four sides and is oblong. There will be one wing on either side of the bird'. In the Resource section of the AutoSTEM website the guides are available in 5 EU languages.

Sight is a fundamental sense for human beings to obtain information. When people cannot access information through sight, hearing and touch become more crucial'. **Hearing (distant analyser**); for the visually impaired, is the sense for information and orientation, it enables them not only to orientate in space and the environment but also in the time and history. A visually impaired person perceives by hearing the surrounding world and people, whose voices and sounds are characterizing in the ambient space and actual social climate or story's situation. However, they do not respond to visual communication such as facial expression, gestures, gesticulation and body expression, which are important accessories to verbal communication. Markedly they feel handicapped in non-verbal communication (Kohanová, 2006).

Touch (contact analyser); compensates for sight in the area of graphical communication. Haptic sensation (touching) replaces non-verbal expression of information that is accessible by touch - models, relief and other typography pictures (Kohanová, 2006). Although blind people use tactile information as a substitute for the eyes to explore the environment, the sense of touch has limitations in range, distance, and size so that the introduction of blind students to an object is often incomplete. This has caused the teaching of blind students to primarily be verbal. They tend to have verbal delusions about a thing, though the imagined is not experienced or seen directly. 'The imagery of something that does not exist during the process of imagining is commonly called imagery. For blind students who become suddenly blind, it is still possible them to do visual imagery because they have received visual information and stored it in their memory' (Zahra, Budayasa & Juniati, 2018, p. 2).

Researchers in mathematics education have emphasized the importance of visualization in mathematical learning and the mental imagery in the mathematical meanings construction and in the conceptual development. Visualization and visual thinking are the essence that makes geometry a special case in mathematics (Costa, 2005). The imagery is defined as a collection of images and the power of imagery is that it can result in visualization, which helps students to make relations and meanings in learning geometry (Solano & Presmeg, 1995). Also Zahra, Budayasa and Juniati (2018,p. 2) stress the importance of visualization, stating that "In elementary school, visualization becomes one of the important abilities used to help students in understanding spatial concepts, shapes, sizes, and distances'.

Students who are blind or with impaired sight have limitations in developing their spatial conception. 'Loss of vision in the blind has an impact on the development of cognition, especially the formation of concepts through sensory experiences to perceive the environment, an essential distinction between blind and sighted students is the conceptual development of blind people in visualizing objects through tactile experience, while sighted students use their visual experiences" (Zahrai, Juniati & Budayasa, 2018, p.90). The loss of visual experience in blind students causes some difficulties in understanding of the concepts of geometry directly.

Blind students take a long time to construct a mental representation of spatial concepts making the learning of geometry difficult (Thinus-Blanc & Gaunet, 1997). In the same way, Vianna et al. (2006) also showed that students with visual impairment, such as blind students, have difficulty understanding geometrical images. The difficulty of learning and teaching geometry to sight impaired students is experienced by the students and their teachers. Although using tools like physical models, many teachers still have difficulty teaching geometry to blind students who cannot use their visual senses (Vianna et al., 2006; Pritchard & Lamb, 2012).

While seeing people have a major advantage in this area, blind people have other important abilities in their favour, capabilities that cannot be developed by people with good vision, no matter how hard they try. Based on the brain's capacity to rewire and distribute resources from affected areas, the sensors migrate from vision towards touch and hearing, balancing the scale and importance of these senses. Therefore, the brain area responsible for sight and hearing develops higher abilities (Pritchard & Lamb, 2012).

Context, approach, and implementation

This work analyses the processes and modifications introduced when adapting the pedagogical guide and construction instructions for one of the automata of the **AutoSTEM** project. The Jellybird is designed for children from 4 to 7 years old. The teacher can adapt suggestions to their own class and context, plan their own activity, and adapt the idea for other ages. The pedagogical guide and construction instructions can be found at: https://www.autostem.info/jelly-bird/ (Figures 1 & 2).

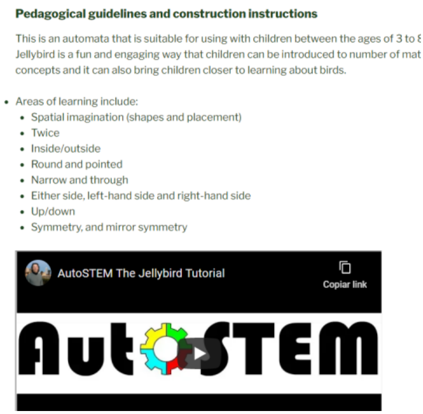


Figure 1. Overview of the webpage for the pedagogical guidelines.

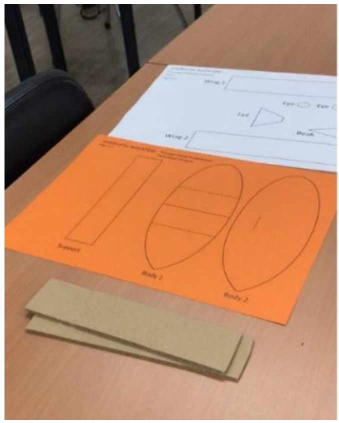


Figure 2. Parts of the Jellybird before construction.

The pedagogical guide adaptation was carried out by a multidisciplinary team, taking in to account the literature about difficulties in teaching and learning geometry experienced by blind children and teachers and embodiment in the blind students mind.

As a result, several steps were taken. Some of these steps are integrated in the general pedagogical approach of the **AutoSTEM** project, others directly address the adaptation of the guidelines itself and the analysis of the processes and changes introduced.

Overview of the process developed

The starting point is the **AutoSTEM** project that has developed pedagogical guidelines and construction instructions for a number of automata. These guidelines for teachers and educators to use in class are designed to help explore the use of automata to promote motivation in young children for STEM subjects.

Following the development of the pedagogical guidelines and construction instructions, they were used with a second grade class in Portugal. All the children constructed their own automata and the results of a short version of Intrinsic Motivation Inventory (n/d) pointed to a high level of satisfaction among the participants.

To expand the resources and activities into additional areas and promote inclusivity, the Jellybird pedagogical guidelines and instructions were adapted for children with visual impairment, by adding descriptions of the geometric shapes and the motion involved in the moving toy. This work was developed by taking into account previous evidence about the difficulties experienced by blind children in understanding the concept of geometry directly, and the difficulties faced by teachers in explaining the shapes.

Blind children cannot use visual aids to learn geometry and many teachers have difficulty giving instructions even by using physical models, because blind children take a long time to construct a mental representation of the spatial concepts. A blind child has to construct in their mind a mental image, and evaluate them, or create a new image.

The development of the adapted guide took in account the perspectives related to the body in the mind and cognition (Johnson, 1987) and the importance of socio- cultural factors for knowledge construction.

It was also produced a typographic version of the shapes that make up the Jellybird and an audio version of the pedagogical guide which was used through the Non-visual Desktop Access (NVDA) (Figures 3 & 4).

It was decided that the shapes of the Jellybird should be prepared and cut out before the session. These adapted resources were used in a session with the participation of the multidisciplinary team, involving Science Education students and teachers, as well as Maths Education teachers and technicians from the Support and Integration Unit of the University of Coimbra, one of them was a visual impaired adult (Figure 5).

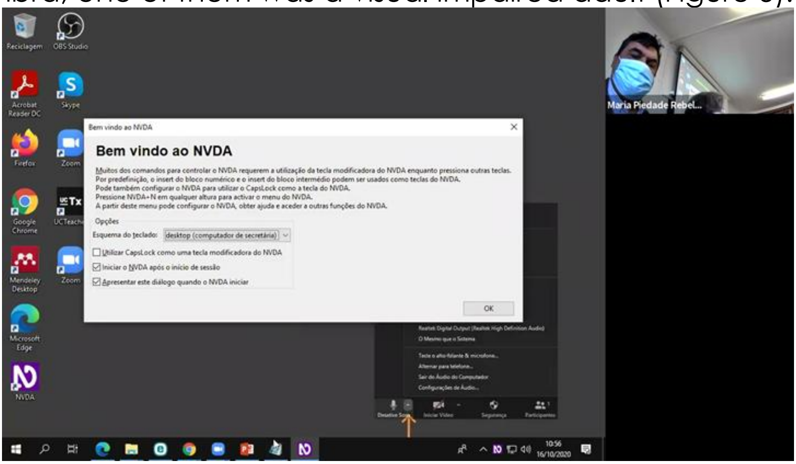


Figure 3. Presentation of the NVDA system.

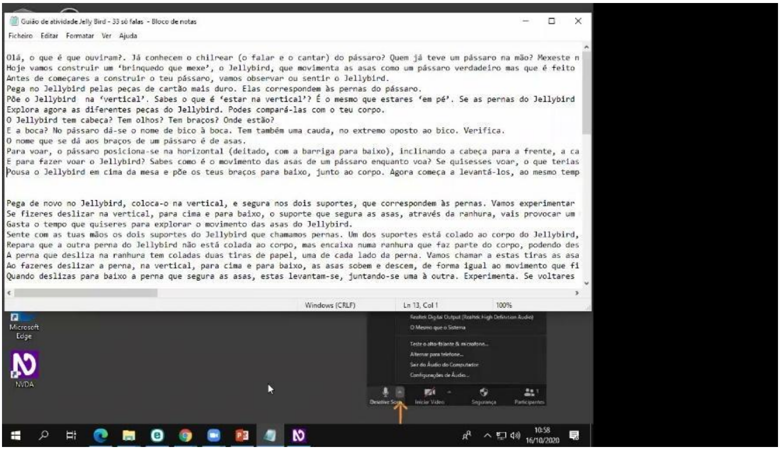


Figure 4. Reading of the audio version of the pedagogical guide.

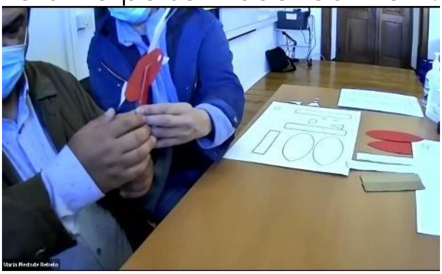
Figure 5. Listening to the audio text with instructions in NVDA format.

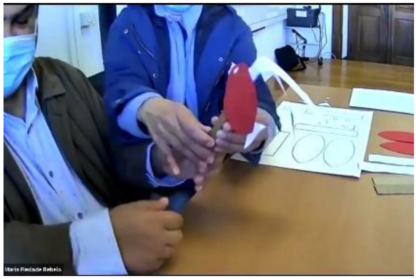
After listening to the audio version of the pedagogical guide with the instructions, the visual impaired adult was given the constructed Jellybird automata (Figure 6) and a typographical version of the shapes of the Jellybird so that they could experience the outline of the shapes (Figure 7).

Figure 6. Presentation of a Jellybird previously constructed.

Figure 7. Presentation of the typographic shapes.

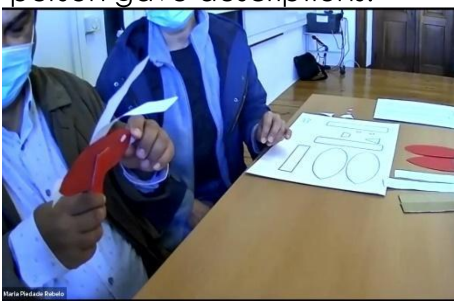
The blind person began by experiencing the Jellybird (Figures 8 & 9), with the help of a sighted person who described the parts as the blind person touched them.





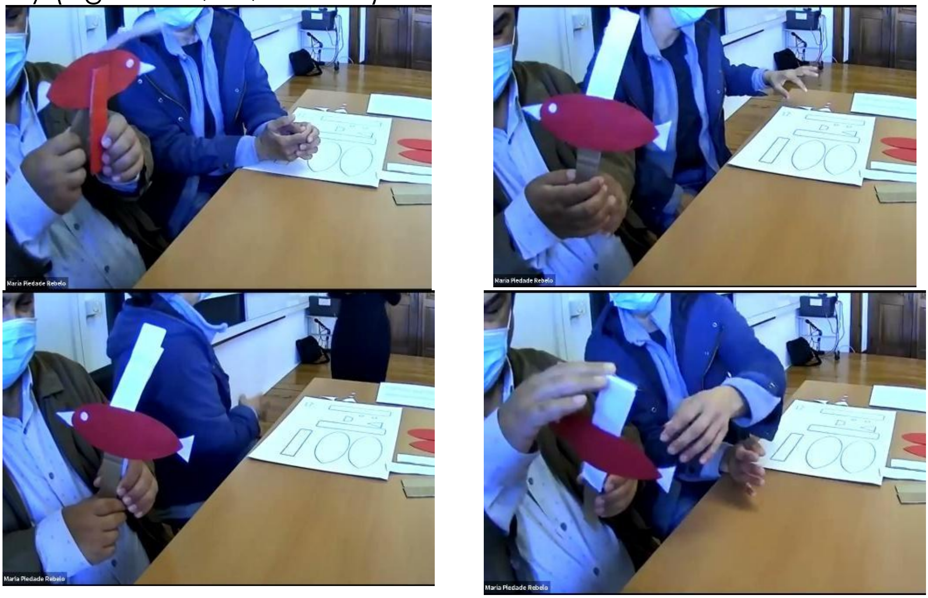
Figures 8 & 9. Blind person handling the Jellybird automata.

The blind person continued experiencing and touching the outlines of the prototype (Figures 10 & 11) while the sighted person gave descriptions.



Figures 10 & 11. Blind people experiencing the outlines of the Jellybird.

Then the blind person tried to experience the movement of the toy (Figures 12, 13, 14 & 15).

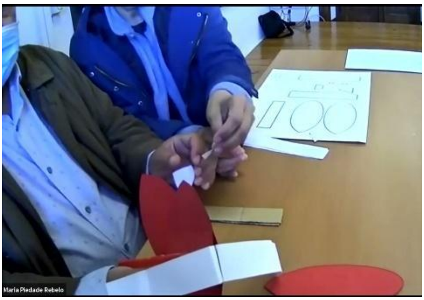


Figures 12, 13, 14 & 15. Blind person trying to experience the movement of the Jellybird.

As this was difficult the student who was helping made a suggestion for a different way to experience the bird movement, by making it go up and down in the air (Figures 16, 17 & 18)

Figures 16, 17 & 18. Blind person finding a new way to produce movement of the Jellybird.

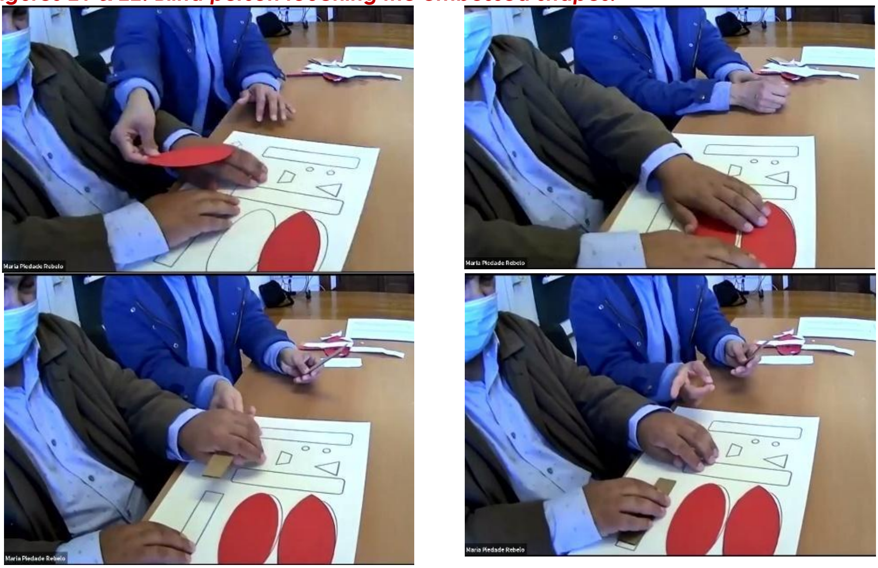
Then, blind person was given the different parts of the Jellybird to touch, while the sighted person described which geometric form each part was (Figures 19 & 20).



Figures 19 & 20. Blind person touching the different parts that constitute de JellyBird.

After experiencing the different geometric forms, the blind person started to touch the typographic shapes (Figures 21 & 22) and then tried to overlap the corresponding parts with their geometric embossed shapes (Figures 23, 24, 25 & 26). In Figure 27 we can see all the geometric forms positioned over the respective embossed shapes.

Figures 21 & 22. Blind person touching the embossed shapes.



Figures 23, 24, 25 & 26. Blind people overlapping the geometric forms with the respective embossed shapes.

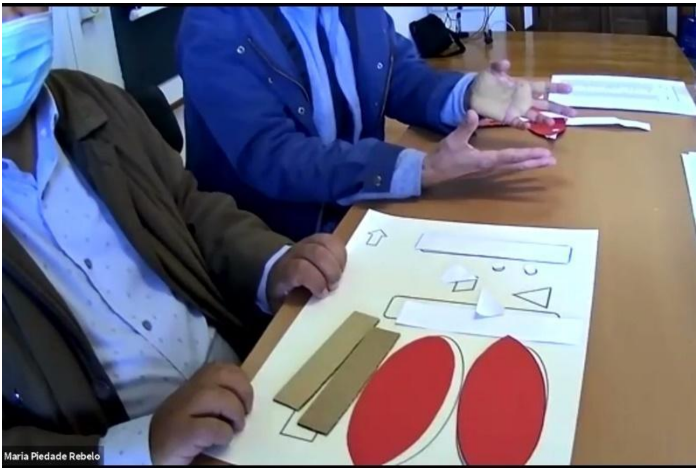


Figure 27. All the geometric forms over the respective embossed shapes.

The resources developed for this session and a further session completed 3 days later were analysed (Figure 28).

Figure 28. Register for the second session.

Both sessions were video-taped and analysed in order to identify the main challenges and ideas. This constituted a category in the results.

Documental corpus and analysis

The documental corpus includes the two guides developed: the general guide and the adapted one to be used by teachers or educators with blind or visually impaired children, plus notes taken during the sessions and their transcriptions.

The two pedagogical guides and construction instructions were analysed and compared in order to identify categories of analysis.

The categories defined to examine and compare the changes between the two pedagogical guides were; similarities, differences and changes.
The Analysis of the sessions where the updated guide was used, as well as the session of reflection allowed additional changes after the first session

Challenges

- Identify the appropriate level of detail in the oral description of the geometric figures of the automata.
- To coordinate audio information with tactile to enable a mental representation of the object/s.
- To test the material and the adaptation of the guide in classes that include blind and partially sighted children, allowing the same experience for sighted children, within the framework of the Universal Design for Learning (UDL).

Results

The analysis of the two pedagogical guides developed for the Jellybird prototype, the general one, and the one adapted for blind and visually impaired children, allowed us to identify the categories: similarities, differences and changes introduced in the adapted guide.

The **Similarities** between the two guides are:

- Framework & aims, play-based pedagogy, learning through automata, STEM.
- Number of sections; both guides include two main sections, one on how the Jellybird can be used to learn STEM subjects and the second on construction instructions.
- Both guides are aimed to teachers and/or educators.

The main **Differences** between the two guides are:

- Development and structure of the sections. The sections in the general guide are developed in a more general way, while in the adapted guide there are examples of detailed specific verbalised instructions
- Pedagogical pathways: teacher role, tasks, materials

The **Changes** introduced in the sections of the adapted guide include:

- Detailed specific verbalised instructions read to the students by the teacher or educator whose aims are, to initiate in the child mental images; and for the child to construct mental images. Both images should be related to the different geometric concepts.
- Tasks involving audio, tactile, embodiment and diary experiences.

- Tasks involving observation were eliminated.

Changes introduced in the adapted guide have a transversal concern to help the child build mental images and to promote their construction, using different tasks and materials. Changes point to additional pedagogical pathways, involving tactile, auditory, embodiment and diary experiences, with the aim that the blind child builds in their mind a mental image or creates new images.

To aid this process;

1. Sounds of birds and/or a story are used to develop mental images through hearing.
2. The bird's body is compared to the child's body, as well as diary activities, aiming to build a mental representation of how the Jellybird is made and how it functions.
3. A sliding motion is presented that is associated with the automata wing motion.

Finally, in order to construct their automata, the child experiences the embossed shapes. During the construction process the child can also, whenever they want, touch and explore a JellyBird that was made previously, or hear the description of the construction process, again.

After the first session, it was possible to see some gaps in the materials and in the adapted pedagogical guide. Based on this experience some additional changes are still to be made, these are:

- Review the description of the geometric figures.
- Select the essential information and make each part shorter by adding pauses between parts when giving the

instructions. Information should be presented in short sequences.

- Importantly, separate and phase the tasks and that the audio is in tandem with each phase.
- Coordinate the audio information with the timings of the tactile exploration.
- The JellyBird automata that is shown to the blind children should have parts that can detach from each other so that the students can deconstruct and reconstruct. It should be more resilient, suggestions include that Velcro and plastic material should be used (Figures 29, 30, 31 & 32).

Figure 29 30 31 and 32. Example of test prototype already prepared.

In Figure 31 are some notes taken during the brainstorming done during the second session with the multidisciplinary team, in which a new timeline was proposed for the activity. In the new proposal it is proposed to start with the embossed shapes, followed by the shapes made from paper and card that are used to construct the JellyBird. Then we move on to the bird that has been built and can also be deconstructed so that the parts can be identified separately.

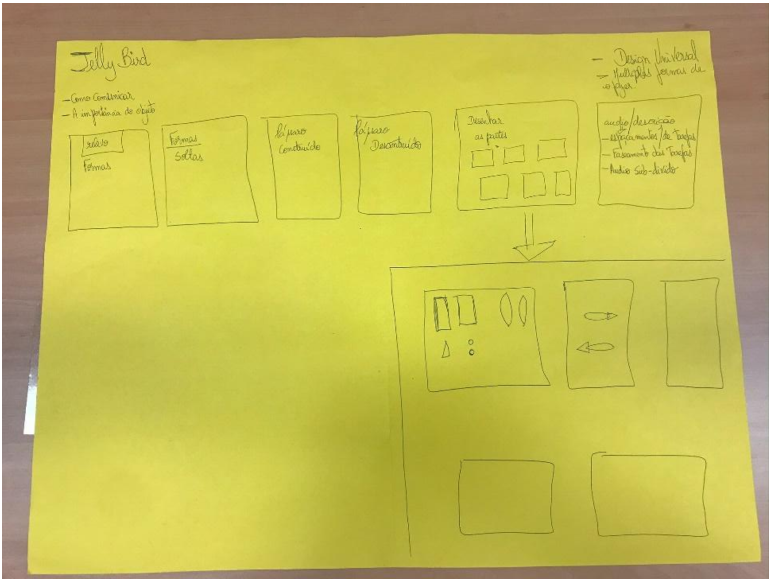


Figure 33. Notes taken during the discussion

Evaluation

The adaptation for blind and visually impaired children of the Jellybird Pedagogical Guide and construction instructions was carried out, to permit mental representation of geometric concepts.

The adaptation involved several iterations. After an initial adaptation, the comparison of the two guides, the general one and the adapted, points to three main categories of analysis: similarities, differences and changes.

The Changes introduced are evidence of a need to bring together multimodal pedagogical pathways that enable the understanding of the mental images of a child and how to build their construction that require; tactile, auditory, embodiment and diary experiences.

Several challenges emerged how to balance between auditory and tactile experiences. Including, the adaption of the teacher guide in to an oral format and the reflective analysis about the process, point to another category.

Additional changes after the first implementation, point to the need to interconnect multimodal pathways and add strategies.

The entire adaptation process was shown to be very complex and has not been completed yet, since many additional changes arose. The opinion and participation of a blind person proved to be very important since it raised points of view that the rest of a multidisciplinary team or a sighted person has no perception of as they are sighted.

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IMI Intrinsic Motivation Inventory – SDT (n/d) https://selfdeterminationtheory.org/intrinsicmotivation- inventory/