Augmented Reality for Rehabilitation of Cognitive Disabled Children: A Preliminary Study

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Abstract— **We have designed a non-immersive recreational and educational augmented reality application (ARVe - Augmented Reality applied to Vegetal field) that allows young children to handle 2D and 3D plant entities in a simple and intuitive way. This application involves a task of pairing and provides visual, olfactory or auditory cues to help children in decision making. 93 children from a French elementary school (including 11 cognitive disabled ones) participated in a preliminary study. The objectives of this study were: (1) to investigate children performance and behaviour in using AR techniques, and (2) to examine specific attitudes of cognitive disabled children confronted to such techniques. We have observed that disabled children were very enthusiastic when using the application and showed a high motivation compared to most other pupils. Moreover, autistic and trisomic children were able to express some positive emotions when confronted to the application. These very encouraging results promote a widespread use of such tools for cognitive disabled children.**

I. Introduction

USING Virtual Reality (VR) technologies for educational and entertainment purposes (recently called edutainment) is getting more and more common [1]. VR applications for teaching disabled children are also getting introduced [2, 3]. Indeed, characteristics of VR are useful in recovering process where users have varying needs and capabilities. Thus, some projects have been designed specifically to treat autism [4].

However, some aspects of full immersion may play a substantial role in denying usage of VR, particularly for children who are more sensitive to immersive VR exposure compared to adults. As an alternative tool, Augmented Reality (AR) provides safer and more intuitive interaction techniques that offer the opportunity to interact with 3D objects in real world [5-9]. Moreover, in AR set-up, social communication channels such as natural speech and paralanguage are not blocked, breaking down mental barriers applying such a technology to specific problems or disabilities [10].

Researchers working with AR systems have proposed solutions in many application domains. For about fifteen years, areas that have been in focus include: training in manufacturing [11]; military training [12]; entertainment [13]; storytelling [7, 14]; product design [15, 16]; and computer aided surgery [17], etc. However, AR applications intended for young children, typically 5-12 years old, are few and very few among them provide experience feedback [18], [19].

During the elementary cycle of school, in the field of natural science teaching and learning, pupils must be able to reconstitute the image of an animal, or a plant starting from distinct elements, to recognize signs of animal or vegetable life and to connect them to great functions (growth, nutrition, reproduction, etc).

In addition, the object sorting and matching tasks allow the child to coordinate his visual competences with his driving competences. In their simplest forms, that relates to the ability to look at an object, to reach it and to grasp it. In a more complex way, he can handle it, and place it in some indicated place. Object matching tasks can include activities consisting in matching identical or different objects or entities. Such tasks may be also used to evaluate the children abilities in understanding significance of objects or entities. In more complex forms, these tasks allow conceptual training of the object categories that can be visually taught from images.

In this paper, we present a non-immersive recreational and educational augmented reality application called ARVe (Augmented Reality applied to Vegetal field) that allows young children to handle 2D and 3D plant entities in a simple and intuitive way. It is a more or less complex matching task of vegetable entities. It offers the possibility of playing with the virtual entities and their supports, to work out a dynamic to-and-from between play and effort. Moreover, it allows the children to discover some characteristics of the plants but also to handle the entities and adjust the gestures according to an intention.

In section 2, we present the design and the implementation of the AR application (ARVe - Augmented Reality applied to Vegetal field). Section 3 is dedicated to the description of a preliminary study that aimed at: (1) investigating children performance and behaviour in using AR techniques, and (2) examining specific attitudes and behaviours of a few children with cognitive disabilities confronted to such techniques. Results and discussion are given in section 4. The conclusion of the paper provides some perspectives.

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II. Design and Implementation

The ARVe (Augmented Reality applied to the Vegetal field) application is a non-immersive recreational and educational augmented reality application that allows young children to handle 2D and 3D plant entities such as fruits, leaves, flowers and seeds in a simple and intuitive way. These entities are presented in a Magic Book–like user interface [7]. Rigid paperboards with eight printed square marker patterns are used (Fig. 1*a*).

The ARVe application involves a matching task and provides visual, olfactory or auditory cues to help children in decision making. Indeed, users have to put in correspondence the 2D and 3D entities displayed on mobile patterns positioned on the right-hand page with corresponding 3D fruits displayed (on stick patterns) on the left-hand page.

When the application starts, four fruits (apple, strawberry, peer, and raspberry) appear on the left-hand page, in a random position. These fruits remain permanently on this page. They are reference entities for the pairing task. The application proceeds in four stages. The first stage consists in pairing the fruits of the right-hand page with those of the left-hand page (Fig. 1*a*). Following stages consist in correctly pairing, flowers (second), leaves (third) and finally seeds (fourth) with the corresponding fruits. Users may reach for and handle a given entity (position on a tangible marker) and position it to the right location with or without the assistance of visual, auditory or olfactory cues.

Completion time is recorded at each stage and finally the total time is calculated using intermediate times. The experimenter may stop the chronometer between each stage in pressing on the space-key.

Sensory cues (visual, auditory or olfactory feedback) may be provided to help children in decision-making:

(i) Visual cues: as illustrated in Fig. 1*b*, mobile entities are surrounded by a red circle when not well positioned and surrounded by a blue circle when correctly placed.

(ii) Auditory cues: fruit names were audio recorded and are provided as the user brings a given entity closer to his/her face.

(iii) Olfactory cues: similarly, odor of the corresponding fruit is displayed as the user brings a given entity closer to his/her face.

The application ends as the user has passed through the four stages of the task.

The application was developed with Microsoft Visual C++ 6.0 and the OpenGL Library. Pattern detection, recognition, and tracking were achieved using ARTag 1.0 software library [20], and a Logitech QuickCam Pro3000 video camera. 3D Fruits (apple, peer, strawberry and raspberry) were modeled using 3DstudioMax and exported in .3ds format so as to be correctly loaded in the AR application. Sounds were added using the Fmod 3.74 library [21].

A commercial olfactory display (SyP@d™ display from Osmooze) [22] was used to provide the specific odors of the selected fruits. This olfactory display is based on to a technology of gels, conceived from essential oil and stored into cartridges. The device is controlled in real-time using a C/C++ program and is connected via a USB port.

(a) (b)

Fig. 1. Top-view of the AR interactive multi-media book with the reference left-hand page and the right-hand page allowing selection, displacement and repositioning of the 3D plant entities. A child performing the fruit task of pairing (a) and two bad-located 3D plant entities (b). Visual cues (red or blue circles) are used to help the child carrying out the task.

III. Method of the Experimental Study

This section describes the method used in the experimental preliminary study. Ninety-three children from an elementary school (Saint-Antoine primary school in Angers, France) participated in the experimental study.

Four classes of different primary school levels: K-2 (age 7-8); K-3 (age 8-9); K-4 (age 9-10); and K-5 (age 10-11) took part in the study, as well as a specific class, called CLIS[1] (Classe d'Intégration Scolaire). The CLIS of the Saint-Antoine elementary school accommodates eleven

[1] The objective of CLIS is to accommodate motor, sensory or cognitive disabled pupils within a traditional school framework so that they partially or completely attend school courses adapted to their ages and their capacities.

children (age 7-11) having important cognitive functions disorders: light mental deficiencies, trisomy, elective cognitive difficulties, psychological disorders (psychosis), autism, and development invading disorders.

Through a matching task, we investigate children performance and behavior in using AR techniques, and examine specific attitudes of disabled children. Parents and teachers of the school were asked to give their agreements, for the experimentation.

A. Task and Protocol

At the beginning, each child was asked to perform the first stage of the matching task using real fruits. This was done to ensure that all children had understood the task they would have to perform in the AR set-up. Then, after 5 minutes of rest, children were asked to do the task in the AR set-up. The experimenters gave instructions to all children in a similar way. The task consisted in performing the four stages of the pairing. However, disabled children where asked to perform the first stage only. For other children, time was recorded at each stage. Task completion time was therefore calculated by adding the time taken to achieve each stage.

Each child was free to handle, move and reposition the 2D and 3D entities with his/her own way. He/she also could question the experimenters, move in the room or express him/herself.

B. Experimental Set-up

As mentioned above, the experimental set-up (illustrated in Fig. 2*a*) used for the study does not use any head-mounted display or stereoscopic goggles. It is completely safe, inexpensive and highly portable.

The study was carried out in a dedicated classroom equipped with camera and video recording facilities; so that many pictures and video of the children could be taken when performing the task.

Each child was led in this room where two experimenters accommodated and explained them the course of operations. The experiment was performed without the presence of the teachers. Each child sat in front of a table where the Magic-Book–like user interface was presented. The web-camera was placed vertically above the book and out of his/her reach. While the child handled the patterns, he/she looked at the video-projected mixed scene on a large screen, in front of him (Fig. 2*b*). To help the disabled children in making decision, visual cues were provided. Moreover, if difficulties or lack of understanding appeared, the experimenters intervened to guide or reformulate the instructions.

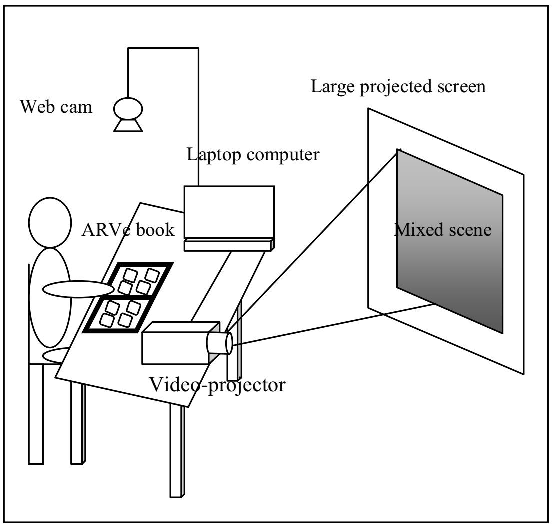
C. Observation and Recording Data

Grids of observation and a post-handling discussion with each child were made for further analysis of children attitudes and behaviors and to take into accounts his reactions and comments. Thus, various features related to hand movements, displacement, glances, and verbal elements were put in the grid. Significant elements concerning children strategies undertaken to achieve the matching task were also noted. For each child, two pictures (one at the beginning and one at the end of the task) were taken. Moreover, each child was video-taped during one-minute when performing the task. In order to increase data for observation, additional photographs and video-recording were taken while the handicapped pupils carried out the experiment.

IV. Analysis and Discussion

Some previous studies highlighted that the use of AR was a key element in moving children away from apathy, lack of involvement and that AR had very important features for optimal learning activities, particularly it can stimulate users emotionally across a full range of senses in a potentially great number of scenarios and environments [23]

We have analyzed the various features gathered in the observation grids and the recording data in order to highlight the attitudes and the behaviors of disabled children. This produced two levels of analysis. A first aspect relates to the



(a)

(b)

Fig. 2. Experimental set-up (a) and a pupil performing the ARVe matching task (b).

attitude of the children in terms of emotional and behavioral answers, which are verbally expressed concerning the AR set-up. A second aspect relates to children performance in completing the task and includes some cognitive elements. Finally a third aspect concerns the interest of parents and teachers.

A. Comparative Analysis of Attitudes and Behaviors

Children were put at ease by the experimenters. The ARVe application allows framing and guiding strongly the activity of the pupils by reformulating with them for example the instruction, by inciting them to proceed by analogies, to describe the entities, by seeking and sorting relevant information, and by leading them to evaluate what they have learned or understood. It also offers the child many opportunities to hear the verbal expression associated with a visual indication.

Except for the K-5 pupils, most of them have expressed themselves easily (i) to make comments on what they were seeing and what they were doing, (ii) to request information (approximately 7% of the non-disabled children asked for details and precisions concerning the matching task) (iii) to speak about anything else. 82 % of the disabled children established an easy verbal contact with the experimenters against 43.8 % for K-5 pupils and 97 % on average for K-3 and K-4 pupils.

The ARVe application allows the children to express themselves about the virtual entities, and to facilitate the formulation of questions. Moreover, it also allows exceeding the school framework and therefore expressing some difficulties or suffering.

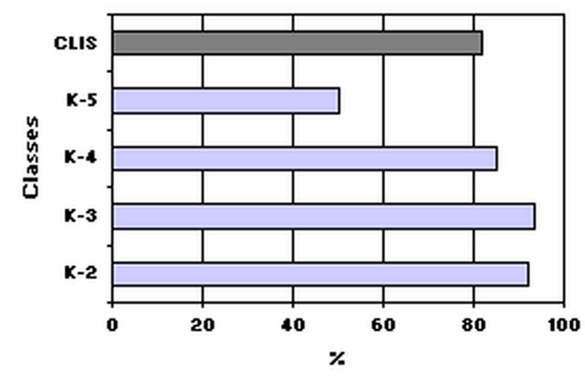


Fig. 3. Percentages of well-motivated children from different primary school levels : K-2 (age 7-8) ; K-3 (age 8-9) ; K-4 (age 9-10) ; K-5 (age 10-11) and CLIS.

The application usability was also evaluated in term of motivation of the children confronted to the AR tool. The observation grids and the various recordings allowed an evaluation of their interest and their focus throughout all the experiments. The question of their interest was also recorded in the post-observation questionnaire.

Recorded data allow pointing out that the AR tool generates enjoyment, focused attention and positive involvement feedback. About 82% of the children were interested in the experiment (Fig. 3). However, only half of the K-5 children were interested. This difference was also perceived in term of focus when performing the task. A higher degree of difficulty of the proposed task should definitely increase their interest and their curiosity. Indeed, 86% of the K-5 children have already practiced computer activities and 95% of them used it for educational purposes as strategy or doom-like video games. So we make the assumption, the ARVe application did not have the same interest for the youngest and the disabled children. All the children, including disabled, easily handled the markers and had no difficulty with technical elements (Fig. 4). Also, the perception and understanding of the 2D and 3D virtual entities, was effective for all children including the disabled ones.

B. Specific Behaviors and Attitudes of the Disabled Children

The AR tool offers several interesting cognitive aspects, such as the smooth transition between real and virtual worlds, the use of a tangible interface metaphor for object manipulation that eliminates the problem of interaction using keyboard and mouse that can result for children with cognitive disabilities, in significant difficulties.

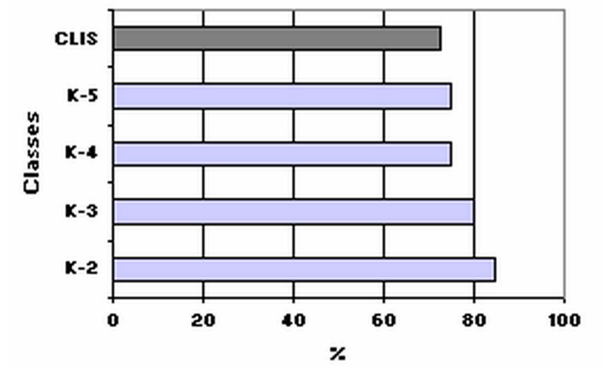


Fig. 4. Percentages of children from different primary school levels : K-2 (age 7-8) ; K-3 (age 8-9) ; K-4 (age 9-10) ; K-5 (age 10-11) and CLIS, using with facility the AR tool.

Nine disabled children (82 % in Fig. 3) developed a keen interest in the ARVe application. The study highlighted particular behaviours concerning the virtual fruits. Some of them tried to shake the marker patterns to make some fruits fall down. Others simulated their tasting. This finding is very important and reveals some interesting tracks of reflection concerning mental perception of virtual entities considered as real fruits by some disabled children.

The 11 pupils of the CLIS, confronted to the ARVe application, reacted differently. Two children's behaviors and attitudes, in particular allow illustrating this point.

(i) Let us relate the specific case of an autistic child who arrived in the classroom while being trailed by ground. He systematically put his hand on his face, tried to hide. A few minutes later, he slackened and did not hide himself any more. He kept asking the same question: "*what's that?*" by indicating and touching all the objects which constituted the AR application or which surrounded him. He closed the laptop computer and started to turn the pages of the Magic-book. At the end of the first stage of the task, he absolutely wanted to start again and repeated to the experimenters: "*you start again!*".

It is recognized that the visual approach for the autistic children is very important, for the acquisition of new knowledge and competencies [4]. The thought patterns of autistic children are mostly visual, which can be effectively exploited by the AR tool. In the ARVe application, matching is an activity that the autistic children like because their visual aptitude is used for a precise goal, with some discovery pleasure and curiosity that are sources of motivation for these children.

(ii) As illustrated in Fig. 5, a trisomic child was very motivated by the ARVe application and handled with ease the patterns. During the experiment, she discovered specificities and possibilities of the AR application. For example, she hid successively the four virtual fruits on the screen with her hand with her hand, she turned over a chart to know what there was behind, she passed the hand under the patterns, she was delighted to see her hand appear on the screen when it passed in the camera focus, etc. She exploited different possibilities of the AR tool while playing with the patterns and proposed to use the application in other ways. For example, she hid two to two the paired fruits, and simulated also the tasting of a virtual fruit while showing great satisfaction. Another disabled child performed the same game by hiding two to two the paired fruits.

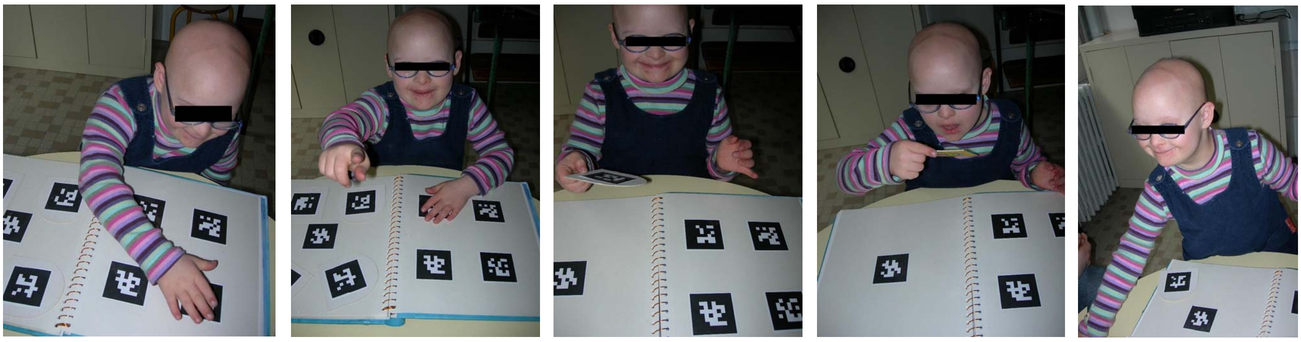


Fig. 5. The specific case of a trisomic child: Discovery, interest in and motivation for the AR tool.

C. Comprehension and Achievement of the AR Matching Task

Comprehension of the AR task is a significant indicator to work on the future development of the ARVe application. Most children used the static fruits on the left-hand page model to pair the vegetal entities on the other page. It was interesting to note that in the first 30 seconds of the task, more than 80% of the K-2 up to K-5 pupils were particularly reactive and established the link between the models and the entities to be paired.

As illustrated in Fig. 6, half of the disabled children needed an adaptation and reflection time before establishing the link between the static entities of the hand-left page and the mobile entities to be paired of the right-hand page. Some K-2 and disabled pupils have a tendency to pose the marker patterns on the models and not on the right-hand page. This was attributed to a bad comprehension of the instructions particularly, by the disabled pupils or to a carelessness of younger children rather than difficulties resulting from the design of the ARVe application.

It appears that 97 % of the K-2 up to K-5 pupils achieved the four stages of the task with a more or less fast training as illustrated in Figs 7 and 8. Younger and disabled pupils spent more time to succeed in the first stage of the task and needed external assistance. Although specific problems appeared for the disabled children, for example speech difficulties of misunderstanding of the instructions. After 10 minutes, 8 of them were able to succeed in pairing the fruits (Fig. 8). Results obtained by disabled children offer interesting and contrasted prospects. A thorough analysis could offer tracks of reflection as for the use and the possible evolution of the application.

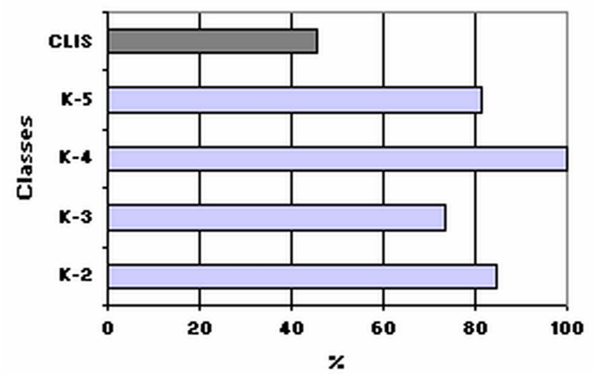


Fig. 6. Percentages of children from different primary school levels: K-2 (age 7-8) ; K-3 (age 8-9) ; K-4 (age 9-10) ; K-5 (age 10-11) and CLIS, making the link between the mobile and static entities during the first 30 seconds of the AR matching task.

D. Interest of the Teachers and the Parents for the ARVe Application

The ARVe application represents a fertile support to propose improvements or new axes for pedagogical purposes while teachers or parents themselves can easily implement it. Attractivity of the AR tool can be made profitable to develop pedagogical or training applications that allow for example repetition of actions and scenarios while limiting the risks that the bad handling of some objects could generate.

The application can be used in an autonomous way by the oldest pupils or in a more or less guided way by the youngest or the disabled children. The teacher can reduce the level of difficulty, by arranging the complex task and aiming at one kind of entities for example.

The teacher responsible for the CLIS was particularly interested in the experiment feedback "to apprehend its pupils differently". It is necessary to take into account the heterogeneity of the CLIS and not to maintain a completely identical teaching for all the disabled children, by proposing tasks which can submerge some of them because they exceed their data handling capacity and/or require knowledge still incompletely acquired. Moreover, given the possibility of adjusting the task, the AR tool is valuable to offer to the cognitive disabled pupils the same training as the other pupils of the elementary cycle.

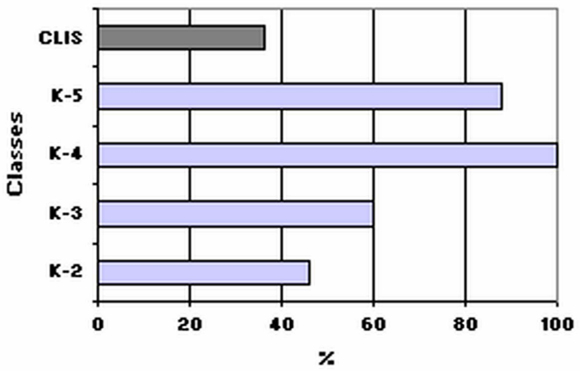


Fig. 7. Percentages of children from different primary school levels: K-2 (age 7-8) ; K-3 (age 8-9) ; K-4 (age 9-10) ; K-5 (age 10-11) and CLIS, having succeeded the first stage after 1 mn.

Furthermore, analysis of the results allowed finding the age bracket to which the AR application seems to be most relevant. Characteristics of the AR application are well suited with some teaching objectives of the K-1 up to K-3 levels in the field of natural science as (i) to learn how to question in handling, building, observing, classifying, or testing, (ii) to find and understand the growing process of an animal or a plant, and (iii) to discover the world of life by sensory exploration.

Each family was also asked to deliver an opinion of their perception of virtual and augmented reality technologies. Feedbacks from families and teachers reveal that virtual reality and augmented technologies are well perceived. Thus, 90 % of the parents considered it positively for their teaching aspects, a stronger implication of the child in his training and for making the child aware of a new technology that they had never seen and experienced before.

The 11 families of the disabled children primarily emphasize ideas that these tools may involve their children more deeply in the learning process. Moreover, they consider that these tools enhance interest in and attraction to new technologies. Finally, they do consider that such tools may offer an efficient teaching aid. Comparative percentages underlined in first virtual reality and augmented technologies as a teaching aid: (25,8 %). Only one family of the CLIS answered negatively for the taking part of its child in the experiment considering that “it was a useless gadget”.

V. Conclusion and Perspectives

A non-immersive recreational and educational augmented reality application (ARVe - Augmented Reality applied to Vegetal field) was presented along with an experimental study involving cognitive disabled and non-disabled young children. The proposed application allows children to handle 2D and 3D plant entities in a simple and intuitive way through a matching task and provides visual, olfactory or auditory cues to help children in decision making. 93 children from a French elementary school, including 11 pupils with cognitive disabilities, participated in the study that aimed (1) to investigate children performance and behavior in using AR techniques, and (2) to examine specific attitudes of disabled children confronted to such techniques.

We observed that disabled children were very enthusiastic when using the application and showed a high motivation as compared to most of the other pupils. Moreover, autistic and trisomic children were able to express some positive emotions when confronted to the application. Our very encouraging results promote a widespread use of such tools for disabled children and reveal some interesting tracks of reflection concerning mental perception of virtual entities by some cognitive disabled children.

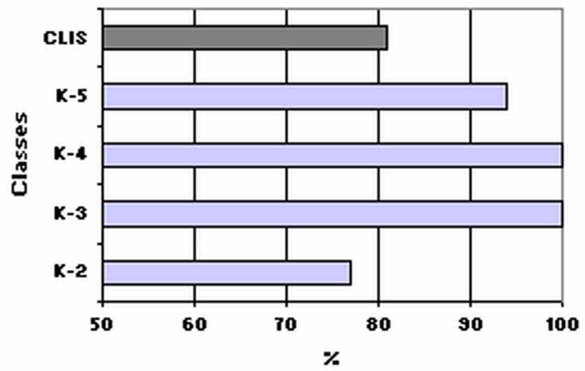


Fig. 8. Percentages of the children from different primary school levels: K-2 (age 7-8) ; K-3 (age 8-9) ; K-4 (age 9-10) ; K-5 (age 10-11) and CLIS, having succeeded in the first stage of the AR matching task, after 10 mn.

New teaching methods can be imagined to take into account pupils having cognitive disabilities and to make them progress towards training and learning objectives while respecting their various needs.

Further experiments will be carried out in order to investigate the effect of auditory and odors cues. This can offer very interesting aspects in perception, motivation and learning process. An interactive computer program encourages the users to active participation and gives them the experience of control over the learning process [24].

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