User experience of digital dioramas for interactive whiteboards

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USER EXPERIENCE OF DIGITAL DIORAMAS FOR INTERACTIVE WHITEBOARD

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ABSTRACT

This paper presents the methods and procedures applied to evaluate a Digital Diorama: a multimedia product for Interactive Whiteboards, designed to support science teaching in primary schools and specifically regarding environmental issues.
The study is part of a wider interdisciplinary research conducted through the collaboration between Academia (Politecnico di Milano, Dipartimento di Design; Università degli Studi di Milano-Bicocca, Dipartimento di Scienze Umane per la Formazione; Università di Roma Tor Vergata, Dipartimento di Scienze e Tecnologie della Formazione), primary schools and other public institutions for scientific knowledge diffusion.
Its overall purpose is to investigate whether Digital Dioramas, used with Interactive Whiteboard Technology, can improve the teaching of some fundamental aspects of biology (with special reference to the ecology), geography, and other scientific content. The applied method is innovative as it combines qualitative behavior observation with eye tracking methodology, which represents a quantitative and objective evaluation tool.
Preliminary experimental results seem to indicate that the fruition of Digital Diorama is fairly easy and it stimulates the interaction among kids and their curiosity through emotional and cognitive captivation. Furthermore, Digital Diorama can support teachers in their classroom activities, even more than the typical tools of formal learning such as readers.

KEYWORDS

User interface, eye tracking, behavior observation, usability, interactive whiteboard.

1. INTRODUCTION

Digital Diorama (DD) is an adaptive-learning educational model based on the use of computers and interactive teaching devices, able to turn the learner from passive receptor of information into collaborator in the educational process. The interest in developing digital dioramas to reproduce the experience of dioramas' exploration in museums is already stated in literature (Narumi et al., 2011).

Previous studies regarding the use of physical dioramas to elicit ecosystem complex thinking in children demonstrated the strength of affective learning (Gambini et al., 2008). Dioramas, as scientific models of natural ecosystems, lead users from virtual environments to real-life learning situations.

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Their digitalization and fruition through Interactive Whiteboards (IWBs) dedicated platforms is intended to permit a wider exploitation of these resources for learning and teaching, inside and outside the classroom (museums, parks and public workstations).

Nowadays IWB device is an increasingly global educational technology and a further rapid growth is expected in the next five years. The market research company FutureSource Consulting, considering 34 million teaching spaces, found that one in eight classroom across the world now has an IWB device and, by 2015, one in five will have one (Avvisati et al, 2013). However, few multimedia products have been specifically designed for this type of technology up to now. Furthermore, usability and acceptability are crucial for their effectiveness.

Data collection and analysis regarding primary school children behavior is relevant to support the development of the interactive DD system (Nesset and Large, 2004; Andreoni et al., 2010). To this purpose, users can be observed while interacting with digital prototypes in laboratory and in the real context of use (Hanna, 1999). In order to study user experience and behavior, experiments were conducted within laboratory recreating similar conditions to the classroom environment.

An innovative method was applied combining the observation of physical behavior and the analysis of eye tracking. The use of eye tracking represents a methodology able to provide experimental evidence for objective and quantitative analysis of subjects' visual exploratory behavior in many situations of everyday life (Hayhoe and Ballard, 2005; Zambarbieri, 2003; Zambarbieri and Carniglia, 2012). In fact, clear vision of an object is guaranteed only when its image falls within the central part of the retina, which is called fovea. Therefore, in order to explore a visual scene, the eyes have to move in such a way as to bring the image of an object of interest onto the fovea. During visual exploration, the eyes make saccades and fixations. Since visual information is acquired by the central nervous system only during fixations, whereas saccades are used to shift the gaze from one point to another, it is reasonable to infer that the eye tracking methodology represents a powerful tool for the study of exploration strategies and the underlying cognitive process. Thus, when a subject is exploring a visual scene eye movements supply information about the focus of subject's attention.

The contemporary use of videotaping technologies permits to apply a behavior analysis model regarding different interaction modes and to work in interdisciplinary groups composed by engineers, designers, social scientists, usability experts. The analysis of the kid's spatial behavior, as well as psycho-perceptual and emotional expressions, is performed through a software for video annotation, to create a structured database of the different types of interaction.

The aim of this paper is to describe the methodology and the results of a preliminary experimental phase designed to verify usability of the interface and observe children's behavior. The following steps of the project will include the extension of the examined population of children; the adjustment of the interface to improve the usability of control keys and finally the experimentation of the DD within the real context of use in the classroom.

2. THE DIGITAL DIORAMA

The Tursiope DD (from Museo di Storia Naturale of Livorno) analysed in this study, represents a cut of Mediterranean Sea with its specific animals and vegetation. The DD is a digital photographic reproduction of the real diorama and it consists of a multimedia interface containing touch-screen hotspots that give the possibility to explore DD. The hotspots provide three different types of fruitions, based on an active and captivating interaction with the user: scientific in-depht analysis, link with aspects of everyday life, contents for teachers.

The DD is structured in four levels:

- Level 1, Imaginary Trip ("Viaggio Immaginario"): emotional exploration of DD through the listening of audio descriptions;
- Level 2, Crossover Topics ("Tematiche Trasversali"): scientific multimedia contents (videos, diagrams, photos, short taglines) that lead to reasoning about the relationships between individuals, other biological elements and everyday life;
- Level 3, Identity Card ("Carta di Identità"): specific information organized in FAQ and related answers about the DD elements;
- Level 4, Practical Activities ("Attività Pratiche"): suggestions for practical experiences to be unrolled at school.

These levels mix different models of intentional and non-intentional learning, taking advantage of non-formal and informal learning, (Trinder, 2008) embedding learning in planned daily activities, that are not explicitly designed as learning tools.

The development of the Tursiope DD is based on an iterative prototype evaluation process, a consolidated methodology largely applied in the field of computer interfaces (Bury, 1984) comprehending free user exploration, expert analysis and user tests which led to the development of the first release of the DD, now in use in the first test elementary school. The different phases of prototype development concerned the solution of technical problems and the improvement of functional performances required for an easy use of the DD. A relevant phase in this process are the experiments described in this paper.

3. MATERIAL AND METHODS

3.1 Experimental Protocol

Four primary school students (two girls and two boys) aged between 7 and 8 years, have been involved. This number of test users seems to be enough to detect around 70% of the existing usability problems and to achieve a 60% ratio of benefit to cost (Nielsen and Landauer, 1993) which is a result coherent with the goal of this preliminary experimental phase.

The experiments were organized in two steps:

- Step 1: each kid, wearing eye tracking glasses, stood up in front of the IWB device. The experimenter guided the diorama exploration by asking the kid to execute 29 specific tasks. The test lasted about 10 minutes per kid;
- Step 2: the four kids were together in front of the IWB device and the experimenter asked them general questions about the contents of the diorama. The test lasted about 25 minutes.

Throughout the entire experiment, the subjects were video-recorded by means of a camera placed in the upper corner of the experimental room, behind the children.

3.2 Eye Movements Recording

Eye movements are recorded by video-oculographic technique (VOG). VOG makes use of the image of the eye taken by a digital video camera to compute gaze direction. In order to make this data processing fast enough to be performed in real time, the image of the eye is illuminated with infrared light to create corneal reflexes. The infrared light is not visible to the subject so it will not cause a distraction, however it is visible to the camera.

Eye Tracking Glasses (SMI – SensoMotoric Instruments GmbH, Germany) are used in this study (Figure 1). Within the lightweight frame of the glasses six infrared light emitting diodes illuminate the eye to create the corneal reflexes. In the frame, also a digital camera is embedded to collect the eye images. A further camera, placed in the front of the glasses is applied to record the scene in front of the subject, allowing the correlation between gaze position and the environment.

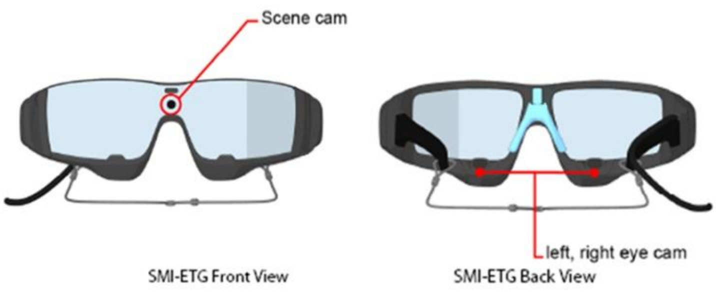

Figure 1. Front and back view of the SMI eye tracking glasses, showing cameras position

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3.3 Eye Movements Analysis

Eye movement analysis was performed offline by using the BeGaze software. The first stage in the analysis consists of the identification of saccades and fixations within the recorded eye movements. To identify fixations, BeGaze makes use of a dispersion-based algorithm with a maximum dispersion threshold set at 100 pixels, and a minimum fixation duration of 80 msec.

Gaze displacement between two successive fixation positions are identified as saccades. Once saccades and fixations are recognized from the temporal sequence of eye position data, the correlation between gaze position and the scene taken from the camera is established. From the position and duration of all fixations, the scanpath is reconstructed: fixations are represented by circles whose diameter is proportional to fixation duration, whereas straight lines represent saccades. Within each screenshot of the Diorama, areas of interest (AOI) can be defined and BeGaze calculates for each AOI several eye movement parameters.

3.4 Physical Behavior Observation

The main objective of the Step 2 is to define what attitudes can be identified among the four children, in order to understand whether the DD can help them to improve network learning and their capacity to connect topics and develop content in group. The secondary aim is to observe how children behave when they use the IWB interface during test, in particular, to mark any signal of cognitive difficulty, fun behavior, boredom and curiosity during interaction.

Step 2 was organized in two parts: the first part, lasting 20 minutes, was a semi-structured trial to understand whether there was a collaboration among children during the exploration of the DD. The second part was conducted in form of a 5-minute session in which children were completely free to interact with DD. During the exploration of various content of the DD, the researcher submitted open-ended questions to the children, who were free to answer and express themselves.

Qualitative analysis was based on the direct observation performed by a behavior expert, considering: emotional involvement, attention conservation and kids' ability to create discussion on crossover topics. Quantitative analysis was performed examining video-recordings through a software for video annotation called Advene (Annotate Digital Video, Exchange on the Net) in order to identify kids' behaviors and verbalizations.

The identified activities were organized in two classes (Figure 2):

- physical participation of the individual child and the group: spatial behavior (task: move);
- verbal participation of the individual child and the group: oral interaction (task: talk).

Afterwards, the analysis grid was expanded to collect data regarding curiosity elements, stimulation of observation, group interaction and group discussion.

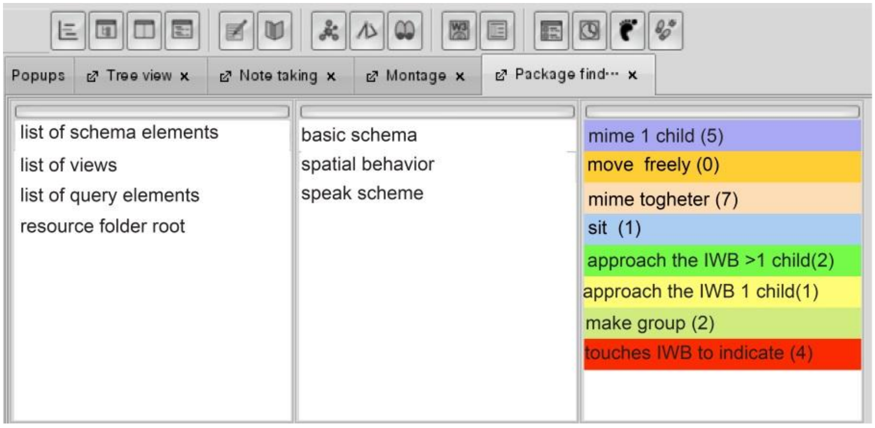

Figure 2. Schemas of verbal interaction and spatial behavior

4. RESULTS

Among the whole 29 tasks requested to the subjects in Step 1, the 11 more comparable ones were deeply analyzed and three of them were selected for detailed results presentation, as the most representative of user interaction with IWB device. Results are described both in terms of gaze analysis and behavior observation. In the last paragraph (4.4 Group test) the behavioral observation of Step 2 is reported.

4.1 Task 1

Subjects were requested to reach one level ("Viaggio Immaginario" or "Tematiche Trasversali") of the DD from the home page. To accomplish the task subjects had to localize the menu control keys placed in the bottom left of the screen, touch it to extend the menu and visualize items (Figure 3). Three subjects correctly reached the goal in few seconds without researcher's support, whereas the fourth subject needed instructions to recognize the menu.

The scanpath in Figure 3 shows an example of subject behavior during the search of "Viaggio Immaginario" level: the subject's gaze first points the requested item, and then it moves throughout all items before going back to "Viaggio Immaginario". Only at that time, the subject selects the requested option.

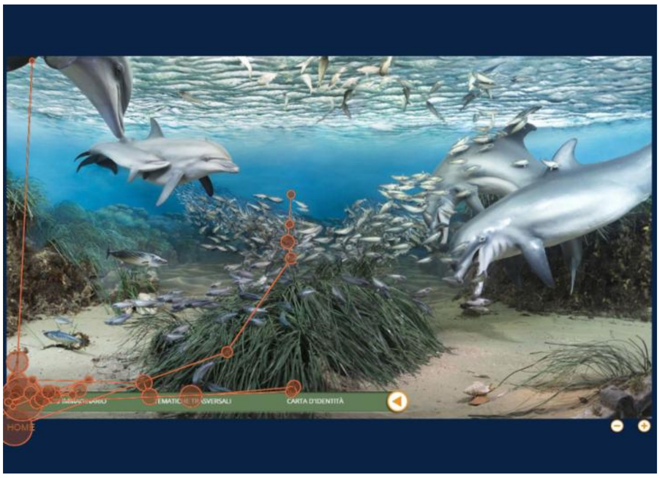

Figure 3. Scanpath of a subject during the execution of task 1. Circles represent fixations, straight lines saccades

4.2 Task 2

Subjects were requested to exit from the hotspot and to return to the level main page. Different options are available to achieve the task:

1. Pushing the zoom buttons, in the lower right corner;
2. Pushing the level title at the bottom of the page;
3. Pushing "HOME" and, from the home page, re-selecting the level.

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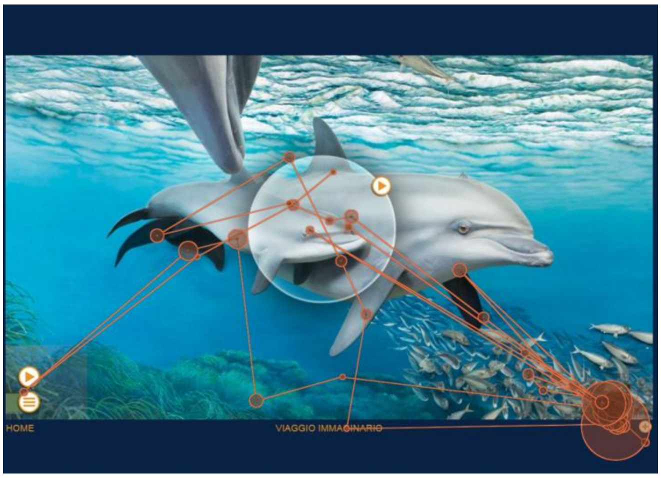

Figure 4. Scanpath of a subject during the execution of task 2

During the experiment, this task was submitted three times. The expected behavior was that the subjects chose option number 1. Actually, they did it, but at the first task's appearance, the execution was not immediate. In fact, it emerged from the scanpath analysis that subjects first explored the lower area of the screen where all control keys are placed and only later, they found the zoom buttons (Figure 4). As the task was repeated, it emerged that the subjects learnt to immediately reach the zoom buttons.

4.3 Task 3

Subjects were requested to exit the actual level and return to the previous. There are different options to achieve the task:

1. Pushing the leftward arrow;
2. Pushing the level title at the bottom of the page;
3. Pushing "HOME" and, from the home page, re-selecting the level.

During the experiment, this task was submitted two times. Three subjects correctly found the leftward arrow in the lower right corner since the first time, as shown by the Scanpath in Figure 5. The fourth subject behaved differently in both tasks presentation, by using option 3 and 2, respectively.

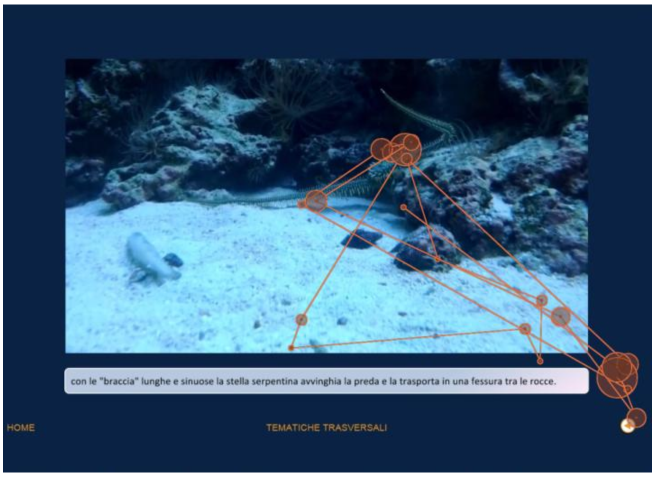

Figure 5. Scanpath of a subject during the execution of task 3

4.4 Group Test

At the beginning of the test, children were gathered and seated around the table in front of the IWB. They remained seated for one minute and then stood up all together and cooperated in the choice of the topic to explore.

In general, all children were actively involved in the test. When a child began to speak aloud or mimed animals' behavior, the mates were stimulated in enjoying the diorama also with body movements. All children coherently answered the questions and they often started spontaneous discussions on different topics.

Children participated for the whole duration of the test with a high interest. Especially during the first part, male children were more active in movement compared to females: males more often motivated others to participate in the interaction.

During the last 5 minutes of the test, an important behavioral change occurred: when the researcher moved away and left children alone, they kept on interacting with the DD. By using controls, they led the exploration of diorama and stimulated discussion on the topics, based on their free choice.

A timeline chart, structured by an expert in psycho-pedagogical sciences, permitted to detect general objectives and related tasks, identifying children verbal and non-verbal behaviors (Figure 6).

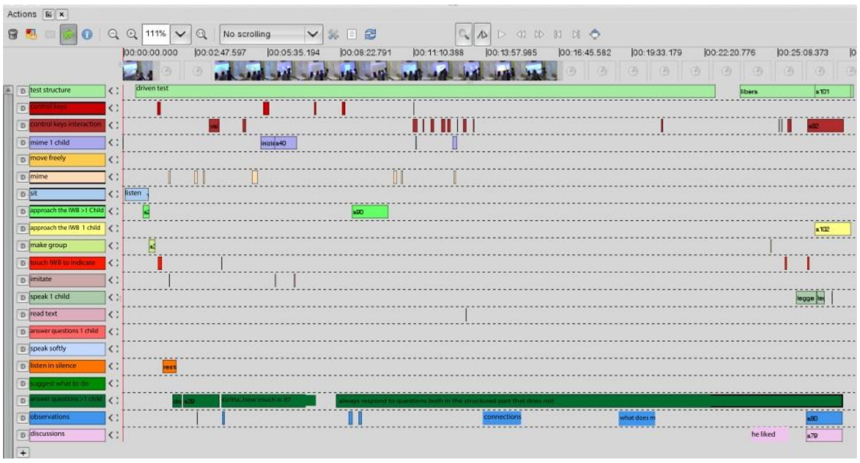

Figure 6. Example of verbal and non-verbal behavior mapping

Comparison of the four subjects shows that to mime animal movements and actions was a recurrent behavior which occurred 7 times during the trial with a total duration of almost three minutes. Another interesting spatial behavior observed was group building. In two annotations of the test, it was obvious that children got together to select or deepen a particular topic (Figure 7).

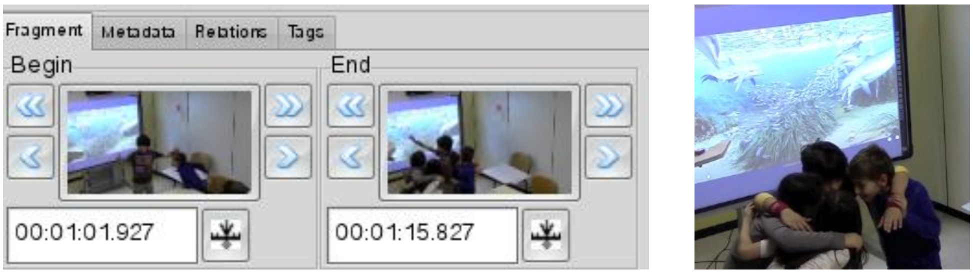

Figure 7. Example of group building and the related picture

Data collected on verbal and non-verbal behavior revealed that kids linked different elements of the DD, jumping from one topic to another, putting them into relationship, reasoning and discussing individually and in group. Several individual observations and group discussion have been recorded for a total amount of respectively 4.40 minutes and 2.50 minutes. Their remarks were ascribable to reflections on the proposed themes, displaying their perception of living systems' complexity.

5. CONCLUSIONS

Experimental evidence about user interaction with DD were obtained by using qualitative and quantitative methodological approaches. Quantitative approach was based on the recording and the analysis of eye movements during the exploration of the visual scene; qualitative approach is based on video-recording analysis for the identification of verbal and non-verbal behaviors.

Data described in this paper represent the result of the preliminary experimental phase of a multidisciplinary research project. Results seem to suggest that kids learn very quickly how to interact with the DD. In fact, children are able to complete tasks execution by locating the correct element within the interfaces as shown by the scanpath of the eyes. In some circumstance they do not identify the requested item (menu key, level title) immediately although they search in the right place, and need suggestion from the researcher to recognize it. This visual behavior suggests that the location is appropriate but their redesign could help to facilitate identification and avoid misleading messages. Another proposal to simplify interaction could be the presence of a back key in every page.

Regarding behavior observation, research findings show that the fruition of digital diorama stimulates the interaction between kids and their curiosity, through emotional and cognitive captivation and otherwise can support teachers in classroom activities even more than the typical tools of formal learning. The engagement produced by video contents suggests to replace static images with videoclips in the hotspots to support group discussion and reasoning. A difference in male and female engagement has also been observed.

The evaluation of this finding together with the validation of possible adjustments in the interface is planned in the following steps of the project involving more children and experimenting the DD in the real context of use.

Recent results in the literature have examined reading activities and comprehension on IWBs (Shams and Dabaghi, 2014; Megalakaki et al., 2015) and the learning effects (Şad and Özhan, 2012). Our results, focused on the user experience with DD provide further evidence about usability and effectiveness of IWBs underlining the potentialities offered by IWB device in didactic contests.

To spread the diffusion of the DD as an innovative learning resource, alternative IWB open source hardware technology can be designed and realized to lower the cost of installation in schools. and spread the diffusion of “Digital Diorama”. This will provide a valuable tool for the understanding of many ecosystems and the most important basic concepts of ecology, a method using guided participation and collaborative learning in a framework to support responsible attitudes and sustainability practices in everyday life. The DD can also be deployed on the web or thanks to workstation located in public places such as urban parks, municipalities, museums, since it is important that the learning of new concepts continues beyond school, throughout life to make each individual a true member of the society of knowledge.

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