WHEN SOUND TEACHES

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ABSTRACT

This paper presents the Stanza Logo-Motoria, a technologically augmented environment for learning and communication, which since last year we have been experimenting in a primary school; this system offers an alternative and/or additional tool to traditional ways of teaching that often do not adapt to the individual learning ability. The didactic use of interactive multimodal systems, such as the Stanza Logo-Motoria, does not replace the teacher; on the contrary this kind of technology is a resource which offers greater access to knowledge and interaction with others and the environment. This is possible by inventing systems and activities, which bring out inherent values in using technology and in its integration in learning processes. The aim of this paper is to document activities carried out by Resonant Memory, the first application of the Stanza Logo-Motoria, and the relative experimental protocol that we are implementing. In addition, we are going to introduce a new application of the system, the Fiaba Magica, for strengthening gesture intentionality in children with motor-cognitive impairments.

1. INTRODUCTION

The Stanza Logo-Motoria is an interactive space, permanently installed at a school, which allows the assimilation of content by "learning in movement". We started to develop the Stanza Logo-Motoria in 2009 and, on the occasion of the 8th SMC2010 Conference in Barcelona, we presented the first application of the system: the Resonant Memory [1]. From then on, we a) established a validation protocol for its scientific experimentation, b) experimented the Stanza Logo-Motoria at school for a year, c) made the system more user-friendly and flexible and d) developed new applications. We are experimenting the Stanza Logo-Motoria as an innovative way of teaching, which, for scientific research purposes, has also been installed at the Engineering Information Department (DEI) of the University of Padova.

The topic of this work is inherently multidisciplinary: the Stanza Logo-Motoria, an interactive and multimodal environment for learning and communication, is used at school in order to discover and emphasize the enactive approach of learning. By means of new technologies and following the enactive approach we think that it is possible to help school teachers to deal with specific learning difficulties of pupils, from dyslexia to severe motor-cognitive disabilities. In actual fact, these children need to learn by means of alternative methodologies and tools often specifically designed for them. For the child with severe disabilities, it is important to focus on communication skills in order to enhance their quality of life, which can be measured calculating the amount of participation in everyday activities [2]. In order to improve these children's communication skills, they should be able to choose and control their social environment. With this in mind, we have developed a new application for the Stanza Logo-Motoria, called Fiaba Magica, which we are using and enhancing at the same time, with the aim of designing a specific validation protocol.

1.1 Theoretical foundations

The main theories about a child's cognitive development recognize that during infancy the first modality of reality representation is enaction: learning through perception-action-interaction within the environment [3]; this interaction is multimodal because it involves all the senses. There are three ways of organizing knowledge corresponding to three forms of interaction with the world: enactive, iconic and symbolic [4]. Enactive knowledge is based on motor skills: enactive representations are gained "by doing" and, in the enactive context, "doing" is the tool for learning. So enactive interaction is direct, natural and intuitive. If cognition is the process whereby a living organism, interacting with its environment, brings forth, or enacts the world in which he lives, the action is considered as a prerequisite for perception and the sensory input has meaning in relation to effectuated actions. In the enactive approach sensory inputs are used to guide actions, [5] which modify the environment, and/or the relation of the organism to its environment, and hence modify in return the sensory input. Gardner, in the theory of multiple intelligences [6], argues that teaching methods, often based only on logical-

mathematical and linguistic intelligences, disregard whoever uses other cognitive modalities. Gardner believes that schools have to use a multimodal methodological approach. This theory validates teachers everyday experience: students think and learn in many different ways. It also provides teachers with a conceptual framework for organizing and reflecting on curriculum assessment and pedagogical practices. In turn, this reflection has led many teachers to develop new approaches that might better meet learners needs in their classrooms.
In the neurosciences field, the discovery of mirror neurons [7] confirms the motor aspect of cognition: learning is the action performed inside the environment. Many object-related actions can be recognized by their sound through audio-visual mirror neurons that code actions independently of whether actions are performed, heard or seen. These neurons [8] have a) the capacity to represent action contents and b) the auditory access to contents of human language.
Technological systems used in the educational field often do not emphasize the interactivity component that promotes involvement, social interaction and collaboration [9]. Research in the field of Interaction Design rather testify the potentiality of multimodal interactive systems for learning [10], cooperation [11] and interactive storytelling [12].
The disciplines of music therapy and music technology are recent but in the past few years, by means of multiple-media technology, it has been possible to combine them in order to allow people with severe disabilities to gain access to real-time audiovisual interaction. Several important projects such as Care Here [1] and Mediate Project [2] have already used interactive multiple-media technology to improve people's motor and mental skills by producing audiovisual-tactile environments. The main aim of these projects is to develop technological systems whose quality of interaction is so high that the users are not aware that they are using the technology [13].

1.2 The Stanza Logo-Motoria

The Stanza Logo-Motoria is a system with which it is possible to create an Augmented Reality environment [14]; the system takes a broad empty space and, using video tracking techniques, fills the environment with sounds and images. The users presence inside the "reactive space" triggers the playback of sounds semantically connected with the topic of the lesson.
The Stanza Logo-Motoria has been developed by using the EyesWeb XMI platform [3] ; for the overall system architecture see [1]. In the Stanza Logo-Motoria (fig. 1) a webcam is used to acquire the movement of the body in space and gestures; the image stream is processed by an EyesWeb application and a number of low-level features are extracted (e.g. position, velocity and acceleration of the centre of mass) [15]. Space analysis starts from the trajectory followed by each user in the reactive space. The system allows us to define a number of regions within the space and synchronizes the users occupation of a zone with the playback of the audio/video content.
The arrangement of sounds in space captures the pupils' attention and allows them to spatially organize the knowledge acquired. In this way teachers can furnish students with a broad context for understanding the real world and students are more likely to comprehend and remember what they are learning. By exposing students to an experiential, explorative and authentic model of learning, the Stanza Logo-Motoria, may help them shift from passive to active learning modes and thus become more successful learners.

In the following paragraphs we will explain in detail two applications of the Stanza Logo-Motoria called Resonant Memory and Fiaba Magica. In particular in Sec. 2 the Resonant Memory application is briefly introduced, Sec. 2.1 describes its use while Sec. 2.2 presents the validation protocol we are following. Sec. 3 explains fully a new concrete instance of Stanza: the Fiaba Magica application, Sec. 3.1 its aims and Sec. 3.2 the first results of its experimentation. The conclusions are drawn in Sec. 4.

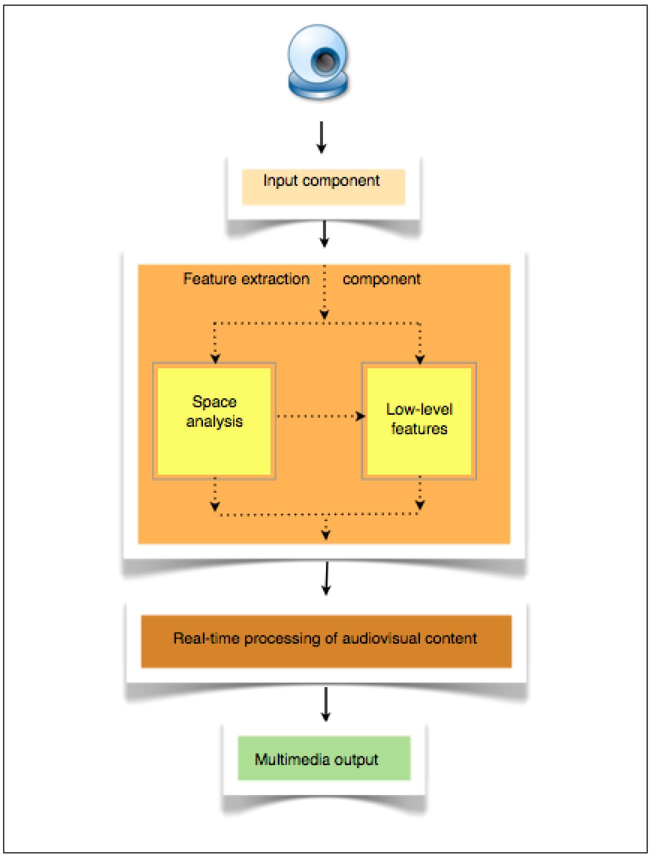

Figure 1. System architecture of the Stanza Logo-Motoria.

2. THE RESONANT MEMORY APPLICATION

The Resonant Memory application allows the creation of a technologically augmented environment [14] to be used within all the subjects taught at school. To explain clearly how the Resonant Memory Application works, we summarize the main points here. The space captured by a webcam is divided into nine areas: eight of these are peripheral

[1] http://www.bris.ac.uk/carehere
[2] http://www.port.ac.uk/research/mediate
[3] www.infomus.org

whereas the ninth is central; the number of areas may vary depending on the didactic needs. Sound information corresponds to each area. The trajectory of the user's barycenter is used to match a sound to a specific position in space. A child explores the “resonant space” in which he/she can freely move without using sensors:

- Noises, environmental sounds, and music are associated with peripheral zones and are reproduced when the child reaches and occupies a peripheral zone.
- The central area is synchronized instead with an audio reproduction of the contents to be taught that contain the elements to be connected with sounds positioned in the various peripheral areas.

The child, listening to the auditory content, enjoys searching for the sounds heard before and, at the same time, he/she creates the soundtrack of the lesson. For the Resonant Memory system architecture see [1].

2.1 Use of the Resonant Memory application

Currently, schoolteachers use the Resonant Memory application to manage lessons in an alternative way, e.g. as a tool to activate the written production of a tale. In this case, the teacher chooses eight sounds and collocates them in the peripheral zones of the Stanza Logo-Motoria. The child, by exploring the physical and auditory space, is encouraged to invent a tale using those sounds. Then, the tale invented by the child is converted into an audio file and located in the central zone of the Stanza Logo-Motoria. Finally the child “reads the story again”, moving by himself within the sound-augmented space.
The Resonant Memory application is used also in order to study a school subject such as History: the teacher records the text of the lesson and puts it into the central area; whereas the sounds connected to the recorded text are collocated in the peripheral areas. The child listens to the content reproduced in the central area, reaches the different peripheral areas experimenting with the sounds and finally, enjoying the game, “fills the content of the lesson with sounds”. Teaching contents, by becoming “physical events” which occur around the child by means of the child, activate the motor aspect of knowledge [16]. The environment has acquired, in this case, a dynamic role: it becomes a dynamic space, a space of knowledge and logic, a map where knowledge grows. The Stanza Logo-Motoria becomes a map of knowledge: the spatial map of knowledge.
We are also experimenting the use of Resonant Memory application as a tool to develop the spatial ability on the part of students with severe visual impairments. We are checking if it is possible to use the Stanza Logo-Motoria as a means to develop orientation and mobility training for blind people. If movement is a basic element for learning, at the time that a child physically discovers his world, then learning takes place. Children with visual impairments typically need encouragement to explore the environment. To them the world may be a surprising and unpredictable place, but also non-motivating. Orientation and mobility training usually helps a blind or visually impaired child to know where he/she is in space and where he/she wants to go (orientation). It also helps him/her to be able to carry out a plan to get there (mobility). It is important to begin to develop orientation and mobility skills in infancy, and continue during their adulthood in order to improve autonomy in moving [17]. This is the reason why we are experimenting the Stanza Logo-Motoria with pupils and adults, as a tool to develop interactive training for mobility and orientation, by working in the following way: starting from the centre of the Stanza Logo-Motoria, the user has to move in a certain direction to trigger a specific sound. He/she can move forwards, backwards, towards the right and left, diagonally forwards and backwards. The sound informs the user if he/she is following the right direction. When the user keeps to the correct direction, the sound represents an auditory reinforcement. Before carrying out this task, the child with visual impairments has to memorize the spatial localization of sound by means of a tactile map and/or the physical exploration of space.

2.2 Validation protocol of the Resonant Memory application

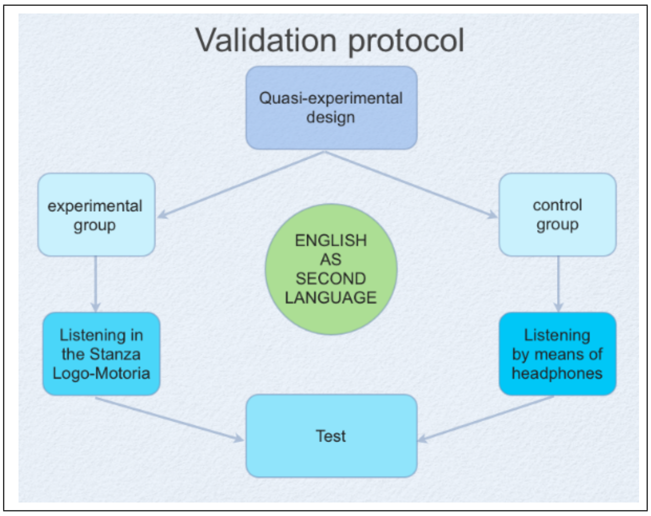

Figure 2. Validation protocol of the Stanza Logo-Motoria.

At school we have been testing (fig. 2) the Stanza Logo-Motoria in Resonant Memory modality since February, following a quasi-experimental design [18] (between subjects) with two comparable classes: two Third Classes. The quasi-experimental design requires a pre-test (February), an intermediate-test (April) and a post-test (June) for a treated (experimental) and comparison (control) group. Every test consists of two tasks: “listen and tick the right picture” and “listen, draw and color”. We intend to verify (experimental hypothesis) if pupils, by using the Stanza Logo-Motoria as a listening tool for learning English as a second language, improve significantly in word recognition and language comprehension than those who use passive listening by means of headphones or the 5.1 sound system. The dependent variable is: a significant improvement of listening comprehension ability in English as a second language. The independent variable is: use of the Stanza

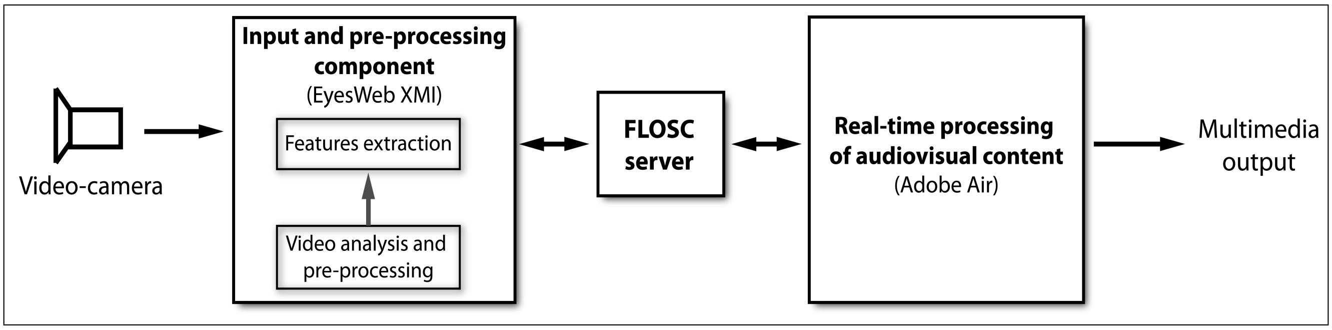

Figure 3. System Architecture of the Fiaba Magica application.

Logo-Motoria, in Resonant Memory modality, as listening tool. For two hours a week the control group is using the language laboratory equipped with headphones for binaural listening while the experimental group is using the Stanza Logo-Motoria.

3. THE FIABA MAGICA APPLICATION

In Fiaba Magica, the space captured by the web-camera is divided into three areas (fig. 4); each area is synchronized with a) the audio reproduction of a sequence of a tale and b) the screen projection of the corresponding image. The video stream is processed in order to extract several low-level features related to the users movements. Background subtraction is achieved via a statistical approach: the brightness/chromaticity distortion method [19]. Extracted features include the trajectory of the centre of mass, the Motion Index, and the Contraction Index. Using these parameters, the system recognizes the following actions performed by the user:

- raising their arms laterally one at a time;
- their body position in space.

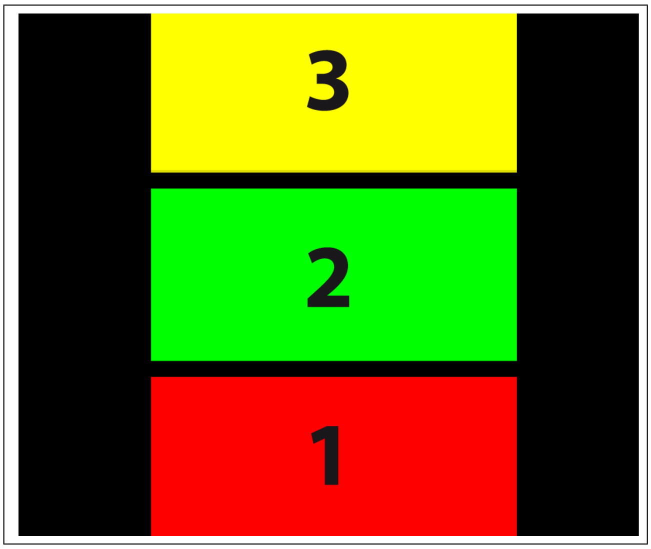

Figure 4. How the space is organized by the Fiaba Magica application.

When the user reaches the first zone, the Fiaba Magica application a) triggers the projection of two characters on the screen and b) activates the audio reproduction of the first part of the tale. During this phase no other event is triggered. After having listened to the first audio track, the user animates the corresponding character on the screen by raising his/her arms laterally, one at a time. The graphic animation consists of two "animated talking characters" (fig. 5). Once both characters have been animated, the user reaches the second area to listen to and see the second part of the audio/video tale. Consequently, two other characters to be animated appear on the screen. The interaction modality in the second and third zones is "managed" as well as the first one.

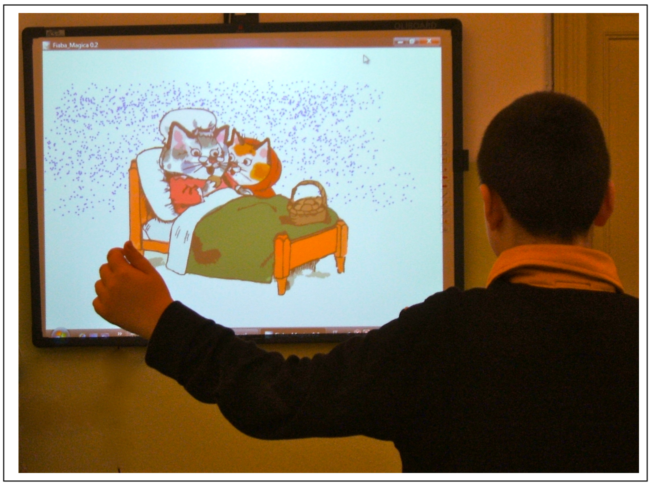

Figure 5. The user animates the corresponding character on the screen by raising his arms laterally, one at a time.

Figure 3 shows the overall system architecture of the Fiaba Magica. It consists of two major components described below.

1. The input and processing component which receives the video stream captured by the webcam observing the space; this component is responsible for:
   - processing video data (e.g. denoising and background subtraction techniques to extract the users silhouette);
   - the motion feature extraction which enables a) the analysis of input data in order to get information about how the user occupies the space (e.g. where he/she goes; how long he/she re-

mains in a given area) and b) the analysis of gesture features.

A software patch developed in the EyesWeb XMI environment performs the video analysis and feature extraction tasks.

2. The real-time processing of audio visual content component, which is responsible for the real-time control and processing of audio/video material, depends on the features extracted in the feature extraction stage. This task is performed by an Adobe Air application that also provides a user GUI to configure the system.

A Flosc server allows bidirectional communication between EyesWeb and Adobe Air. Flosc is a communication gateway, which enables communication between Adobe Flash and any software recognizing UDP data. Flosc a) converts Actionscript data into OSC format, via XMLSocket of Actionscript, and b) sends out the OSC data in UDP format at the other end of the server.

3.1 Use of the Fiaba Magica application

We use the Fiaba Magica application to explore how augmented reality can provide positive and enjoyable leisure experiences for pupils with severe disabilities. Due to limitations in their physical and mental abilities, these children have few opportunities to engage in independent leisure activities. This lack of opportunity often leads to the development of dependent behavioral patterns and learned helplessness [2]. At school, for children suffering from severe disabilities, there are specially trained teachers who have to teach them sign language, how to walk, keep their balance, feed themselves, and exercises that improve their muscle co-ordination and their speech. Simple activities like brushing their teeth, arm movements, cutting with scissors, writing or drawing are taught to make these children self-reliant. By interacting with a multimodal environment, their self-esteem and sense of self-empowerment potentially increase. With the Fiaba Magica application, the teacher could teach spatial concepts, personal awareness of the different body parts, how to move their body in relation to others and objects and the understanding of where the body is in the environment.
The Fiaba Magica application is also used to help strengthen the gestural intentionality of children with multi-disabilities. Often these children express communicative intentionality only by means of simple gestures and vocalizations, which can be enhanced thanks to technology. Fiaba Magica "augments gestures" by synchronizing movement with visual and sound stimuli, in order to bring out the intentional feature of action [20].
Since the children suffering from severe disabilities cannot walk properly and require a wheelchair or supports, the Fiaba Magica application can cater for two users at a time, or a user in a wheelchair accompanied by a helper.

3.2 Early assessment of the Fiaba Magica application

Currently two pupils with severe impairments are experimenting the Fiaba Magica application:

1. A 6-year-old child with left-sided hemiparesis (paresis on the left side of the body) who cannot walk and uses a wheelchair; he has learning difficulties due to a lack of development of motor skills.
2. A 12-year-old girl with cerebral palsy - a persistent, but not unchanging, disorder of posture and movement caused by a non-progressive disorder of the brain - which includes the loss of physical capabilities for walking, standing and sitting (disequilibrium syndrome), using hands and speaking abilities.

Up to now we have observed that both pupils have the opportunity to:

- be motivated to move in space;
- improve their voluntary movement of arms laterally, which - in such a situation - is disturbed by synkinetic movements (involuntary muscular movements accompanying voluntary movements) in order to develop the intentionality of gesture;
- enhance their capability to hold their head up high in order to follow the images with eyes;
- improve their balance in standing and walking;
- increase their attention span;
- interiorize the temporal concepts (before, now, after).

In particular, the child with hemiparesis, who is also in a wheelchair, has used the Fiaba Magica application with the help of his teacher; whereas the mother physically supported the girl with cerebral palsy. These users demonstrated an exceptional degree of enthusiasm, fun and enjoyment during each augmented reality experience. It will soon be possible to measure, by video analysis, the quantity and quality of upper extremity movement over a long period of time in order to check if they have had functional improvements in motion.

4. CONCLUSIONS

The Stanza Logo-Motoria, by using standard hardware and simple strategies of mapping, has sparked the interest of students and teachers in more innovative ways of learning and teaching. The system is suitable for the school environment thanks to its easy implementation; moreover, teachers are immediately involved in the design of activities due to the simplicity of mapping, which makes it instantly comprehensible. In fact, for over a year now, the use of the Stanza at school has shown that, by using the same basic scheme, it has been possible to develop in collaboration with teachers a great deal of educational activities involving several school subjects, such as English, History, Science, Music.

For children with severe disabilities, such as hemiparesis, cerebral palsy and blindness, who are placed in the Stanza Logo-Motoria, it is possible develop particular learning paths by means of specific applications of the system, which can meet their needs of autonomy and communication with the others and the environment.
These early results truly convince us that this is but the beginning of a path, which could lead to the introduction of technologically augmented learning in schools.

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