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Indice

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Experience Augmented Reality: From Education and Training Applications to Assessment Procedures

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Abstract

Augmented Reality (AR) is a technology that makes it possible to enrich the information deriving from stimuli of the real world. AR is in the process of changing the methodology of how we learn and teach; although this adoption is not yet widespread, there are several examples of successful developed applications adopted in education and training. This paper proposes a preliminary study on an AR tool aimed to assess and train spatial skills.

Keywords: Augmented Reality, Education, Training, ArUco Markers, Tangible Interfaces, Spatial Skills

1. Introduction

Nowadays, the rapid evolution of technology involves several fields in which its utilization has become crucial, including education and training (Goodyear & Retalis, 2010). Although digitalization encompasses many aspects of human society, some educational programs are

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still struggling to adapt their methodology to the demands of modern times (Buckingham, 2007; Selwyn, 2016). Although reluctance and reservations persist against new *hi-tech* pedagogical approaches (Selwyn, 2016), several learning methods contemplate the adoption of new technologies. Technology Enhanced Learning (*TEL*; Goodyear & Retalis, 2010) offers new opportunities in the educational field, incorporating digital technologies in innovative ways. TEL provides a new set of educational and training methodologies, that promote dynamic learning process, active experimentation of knowledge and collaborative behaviors, and it aims to design new learning experiences that connect formal and informal contexts.

Dynamic learning (Iran-Nejad, 1990) relies on the concept of training students to become self-determined learners. There is a mutual exchange of feedback between teachers and students, able to trigger a mechanism in which information and knowledge are transferred through the indirect process of observing, reflecting and researching. Dynamic learning processes do not exclude traditional teaching methods but active participation of the teacher is key. Moreover, in this approach students independently seek knowledge, finding the necessary tools to pursue their goal of learning.

The *active experimentation of knowledge* refers mainly to the experiential learning (Kolb, 1981, 1984) and consists of a process of constructing knowledge that is responsive to contextual demands. Hence, the act of learning is seen as a transformation of experience, a result derived by the combination of what a person studies theoretically, and then applies in practice. Several scholars (Bransford, Brown & Cocking, 2002; Keeton, Sheckley & Griggs, 2002) promote the importance to educate students to become active learners, with relevant meta cognitive skills. By developing their self-efficacy as learners, students can take responsibility for their own activities, understanding which is the most suitable "way of learning" for them, and what kind of skills they need to manage difficult disciplines with concrete improvements.

The *collaborative behaviors*, from an educational point of view, concern a situation in which two or more students learn something together (Dillenbourg, 1999). According to Gokhale (1995), individuals can acquire more knowledge and achieve higher levels of learning when they work in a small group rather than when they are alone. People adopting collaborative behaviors to learn something, enhance one another's resources and skills; for example, asking one another for information, evaluating one another's ideas, monitoring one another's work, etc. Collaborative behaviors can be analyzed considering Lev Vygotsky's concept of learning called zone of proximal development (Chaiklin, 2003): there are tasks that learners can and cannot accomplish; the zone of proximal development lies between these two areas, with concepts that a learner can learn only with the help of guidance. In a position like this, it is important to learn through communication and interactions with others, aiming to achieve a collaborative learning, which can guarantee better results than independent work.

These relevant aspects of the learning process can be supported and empowered by TEL programs, which can boost its magnitude on education and training through another important feature that is the gamification. *Gamification* consists in applying game characteristics to a non-game situation, with the aim to increase individual engagement (Zichermann & Linder, 2013). Moreover, gamification regards the concept of *flow*, a mental state in which the person performing a certain activity is completely absorbed by it, experiencing a deep enjoyment by doing that specific work.

In the next section, there will be described the evolution of TEL methodologies, outlining Augmented Reality applications.

1. The evolution of TEL applications

The adoption of TEL applications in education and training started from WEB tools expanding potentialities offered by e-learning (Bell, Hoadley & Linn, 2004), to the development of Serious Games (Charsky, 2010), that consist in (video)games with very specific educational purposes.

Serious Games promote higher engagement levels compared to traditional teaching methods, and individuals experience a low-effort learning process, due to the leisure characteristics of *playing a game* (Skalski, Dalisay, Kushin & Liu, 2012). Serious games can be adopted with children (Ferrara, Ponticorvo, Di Ferdinando & Miglino, 2016), for example to train their visuospatial skills (Spence & Feng, 2010), or by examining their favorite pre-school activities (Cerrato, Ferrara, Ponticorvo, Sica, Di Ferdinando & Miglino, 2017; Cerrato & Ponticorvo, 2017), but they can also be successfully applied with adults, investigating and assessing soft-skills in digital environments (Broz et al., 2014; Dell'Aquila, Marocco, Ponticorvo, Di Ferdinando, Schembri & Miglino, 2016; Di Ferdinando, Schembri, Ponticorvo & Miglino, 2015; Ponticorvo, Di Ferdinando, Marocco & Miglino, 2016).

Furthermore, the use of TEL based programs is increased by the diffusion of specific digital environments, such as Multiplayer Virtual Worlds and Augmented Reality Systems, that made even more challenging the design and the developing of *edutainment* applications.

Augmented Reality (AR) involves the enrichment of human sensory perception through simulated information, conveyed with electronic devices, which would not be perceivable with human senses (Milgram, Takemura, Utsumi & Kishino, 1995).

The idea of blending/augmenting *real* data with *virtual* ones is attractive, but AR shouldn't be misunderstood with Virtual Reality (VR), inasmuch as VR provides a whole computer-based experience, able to be experienced only in virtual environments.

Conversely, AR uses a real environment, in which information are "virtually" expanded through different electronic devices: AR, in other words, brings together real and virtual aspects, guaranteeing a unique and combined source of information (Burdea Grigore & Coiffet, 1994).

AR systems came out in 1960s and the initial applications adopted both AR and VR technologies (Johnson, Levine, Smith & Stone, 2010), but the label "Augmented Reality" was first used in 1990, by the Boeing researcher Tom Caudell. Although back in the 90s only big companies could have the possibility to afford AR systems, now, with modern technologies, AR can also be experienced at home with personal computers or through mobile devices such as tablets or smartphones.

Mainly, there are two types of AR applications (Zhou, Duh & Billinghurst, 2008): marker-based and marker-less applications. The former works through an input device (e.g. a camera) able to recognize specific visual clues that enrich the information, while the latter adopt positional data such as GPS or compass.

The potentialities of AR are related to the fact that information provided to people can be linked to specific contexts (*in situ*) but can also depend on the autonomous exploration of the real world. Moreover, sometimes AR requires the interaction of users with concrete objects and their physical manipulation, in order to have access to their complete source of knowledge (the physical information and the one virtually enhanced).

These aspects are crucial from a pedagogical point of view, considering for example the theory of learning based on Constructivism (Fosnot & Perry, 1996); the constructivist theoretical framework defines the learning process as being complex and nonlinear, and it implies an active reorganization (or an active "*re-construction*") made by the learner. Following this theory, people have no access to the "true reality", because they build their own version of it, and establish a reciprocal exchange relationship between them and the object they are about to learn.

Smartphones, PCs, tablets and tangible interfaces represent the tools that, through AR, individuals use to start the "reconstruction" phase of the reality that they want to learn. Using concrete objects to access knowledge is also related to Vygotsky's theory, according to which the entire learning process is not direct, but rather mediated by signs and by the use of instruments (Vygotsky, 1978).

Thus, even though one of the main fields for AR applications is the entertainment sector, education and training fields could take huge advantages of AR technologies, and one of the principal reasons is because with this system people are more involved in the learning experience feeling themselves completely absorbed in the activity.

As a matter of fact, Chang, Morreale and Medicherla (2010) claim that many studies have demonstrated higher motivation and participation for learning in students using AR and VR environments. Despite the noticeable progress made in the field of AR, this technology is not so popular for educational and training purposes due to several issues, such as the integration of this new instrument with traditional educative approach, the price to develop and maintain AR applications and the needed expertise to use this kind of system (Selwyn, 2016).

Even among dissenting voices, nowadays the adoption of AR in education and training could be easily carried out with new low-wage technologies. Also educational AR applications designed not in recent times, could be used now with new perspectives exploring its potential (Kerawalla, Luckin, Seljeflot & Woolard, 2006); moreover, keeping motivated and engaged students is another important benefit of integrating AR with traditional teaching methods. In the next section some successful AR applications in education and training will be addressed.

2. Successful AR applications in education and training

Currently, AR systems are mature enough to be applied to a wide range of sectors, including education and training, whereby technological innovation is particularly appreciable. According to Billinghurst (2002), AR diverges from other education approaches for three reasons. Firstly, AR brings the connection of physical and virtual environments, guaranteeing a common working space for learners in which they can recreate a face-to-face collaboration. Secondly, tangible interfaces adopted in AR convey a double message, a concrete one, based on their real physical characteristics and spatial relationships, and a semantic one, based on the information contained in them that can be accessed through the virtual environment. Lastly, the transition between reality and *virtuality* places AR in the middle point of the continuum between the real and the virtual world.

In recent years, several AR applications have been developed with education and training purposes showing the positive impact of augmented reality experiences on different disciplines.

For instance, some of them are developed to teach science, as shown by Sannikov and colleagues (Sannikov, Zhdanov, Chebotarev & Rabinovich, 2015) proposing a game-like framework able to keep the students engaged and involved while performing applied physics tasks in AR, with the goal to increase their interest in learning.

Other AR applications are used to teach inorganic chemistry (Núñez, Quirós, Núñez, Carda, Camahort & Mauri, 2008), and scholars claimed that students had a better comprehension and understanding of the fundamental chemical concepts and structures with an AR tool, increasing their attention and their interest in the learning process. This outcome is confirmed by other researches (Maier, Tönnis & Klinker 2009) sustaining that the understanding of chemistry increases by adopting AR technology, since the fear and reserved attitude in respect of chemistry decreases, because students have a more playful way of controlling and interacting with spatial relationships of molecules.

Another field of AR educational application is represented by the study of biology; Juan, Beatrice and Cano (2008) developed an Augmented Reality system for learning the interior of the human body. Their tool was tested with Spanish children confirming that young students enjoyed learning with the AR system and considered it a useful tool not only for learning the interior of the human body but also for learning other subjects.

Another research compared college students learning geography under AR versus computer-based conditions (Hedley, 2003). The study indicates that students in AR condition constructed more detailed mental representations than the computer-based group.

The traditional learning of history can also be enhanced by AR, as stated by Kysela and Štorková (2015), considering that history teaching is limited to books, historical films, photos, interviews with contemporary witnesses and school trips related to important historical events. With mobile AR technology, students can be guaranteed a much more interesting information at one place in a real space and time. Each student owning a mobile device (tablet, smartphone) can work with multimedia content enriched for the element of augmented reality; for instance, software can detect the location and orientation of electronic devices and place images of a local multimedia content providing various information (audio and text) about it.

Furthermore, mathematical and geometrical concepts are successfully channeled with AR technology. In different works (Kaufmann (2002; Kaufmann & Schmalstieg, 2003) an AR software, named Construct3D, was adopted to train spatial abilities, which are crucial in individuals' spatial intelligence (composed by spatial perception, spatial visualization, mental rotations, spatial relations and spatial orientation). This AR software promotes and supports exploratory behavior through dynamic geometry, for example all geometric entities can be continuously modified by the user, and dependent entities retain their geometric relationships (for instance, moving a point lying on a sphere results in the change of the sphere's radius). Kaufmann collected encouraging evaluations of the project, with the plan to integrate his software in Austrian high schools.

As far as geometry education is concerned, another research (Martín-Gutiérrez, Contero & Alcañiz, 2015) shows the positive use of augmented reality for improving spatial abilities. Authors sustain that the AR technology had a measurable and positive impact on students' spatial ability. Moreover, learners considered AR tools attractive and easy to use, with a user-friendly interface in a pleasant environment, and with a very useful technique for training spatial skills.

Another example of the adoption of AR for training purposes, is the study presented by Okimoto and colleagues (Okimoto, Okimoto & Goldbach, 2015) that developed an AR Application for Welding training. The purpose of this AR system is to support future welders through an augmented environment in which people can develop the necessary skills for welding, familiarizing with the spatial relationships of concrete objects to weld, and then use them in real contexts. They used a real welding helmet as an AR viewer and they coated the welding torch with AR markers interacting with other markers that simulate the welding procedure. The welding teacher can take advantage of this application, studying relevant indexes useful to plan a better organization of training, identifying the needed welding techniques to transfer real-life scenarios.

The latest AR applications described in this section focus on the spatial abilities that can be improved and trained in an AR environment; in the next section there will be presented a tool that aims to evaluate and train the spatial cognition of individuals, that exploits both the physical environment and AR technology.

3. Using AR to develop a tool assessing and training spatial cognition

As already mentioned, AR applications can be marker-based or markerless. A recent AR system, belonging to the marker-based applications, is the one represented by the ArUco *library* (Garrido-Jurado, Muñoz-Salinas, Madrid-Cuevas & Medina-Carnicer, 2016).

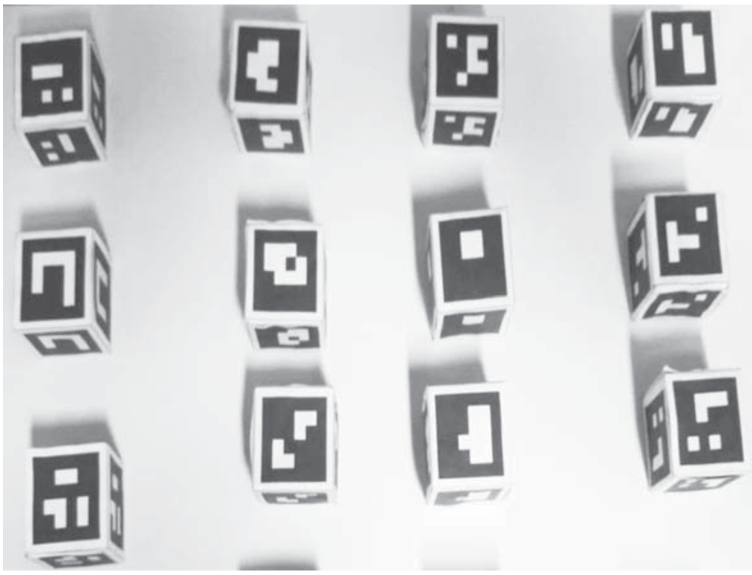

Figure 1. AuRuco markers examples

ArUco markers (Fig. 1) are represented as black-and-white squares that contain a binary matrix consisting in their identifier (id); the black part represents the "0" bits of the matrix, conversely the white part represents the "1" bits (Fig. 2). The black border allows an easy detection for an external detecting device and the binary codification permits the markers' identification. The size of ArUco Markers is determined by the dimension of inner matrix (e.g. a marker size of 4x4 is composed by 16 bits).

Even if ArUco markers are rotated in the environment, the detection process identifies their original rotation, thanks to the binary codification. The detection involving ArUco markers will return the position (as coordinates) and the id of each recognized marker and the device (usually a Camera) scanning the markers is able to recognize them through an algorithm that prospectively rotates the markers to the original form.

Despite the several existing AR applications, the use of ArUco markers is not widespread. This work proposes a study on ergonomics and usability of a tool designed to assess spatial cognition adopting ArUco markers as tangible interfaces, shaped as cubes, to be used and manipulated physically like normal objects of the actual world, able to "augment" their rate of information, once scanned by a camera, through the interaction with an electronic device (Pc, Laptop or Tablet).

Figure 2. An example of cubes (with AuRuco markers) dispostion

The main idea behind this tool is to enhance, technologically, a test aimed to assess spatial cognition named the Baking Tray Task (*BTT*; Tham & Tegner, 1996). BTT represents a neuropsychological assessment tool to evaluate the Visual Neglect (*VN*; Bartolomeo, 2007; Halligan & Bartolomeo, 2012), a consequence of right hemisphere damage, that lateralizes the spatial attention of individuals on their right side, making them unaware and unable to explore the left side space. BTT consists simply of disposing 16 cubes on a surface, as evenly as possible, as if they were cookies to be cooked in the oven. People with VN usually tend to not consider the left side of the surface, not creating a uniform placement of the cubes.

The technologically enhanced version of BTT includes a software and a camera able to detect the cubes' position and has several advantages. First, it provides an automated scoring of the task performance. In addition, the performance of the subject can be stored in the software database and successively consulted. Moreover, differently from the original way to score the individual performance (a simple comparison of how many cubes are placed in the left and right side of the surface), the enhanced version allows, in real time, the determination of other additional source of information related to the cubes disposition, such as the running time and the temporal order of the cubes placement.

These data could be useful for deepening some aspects related to spatial cognition of people, highlighting, for example, the preferred starting and ending point of an objects' placement in a defined space, and what kind of constructional strategy people adopt, looking for preferred dispositional patterns in the cubes disposition. A preliminary data collection with the BTT enhanced version is still ongoing, recruiting healthy participants; one of the goals is to discover common patterns in the cubes disposition among the normal population. For instance, preliminary data with 50 subjects shows something related to the preferred starting point; considering the surface in which the cubes are disposed as six cells (two rows: top and bottom space; three columns: left, center and right space), the preferred two starting points have been individuated in the Top Right and Top Left position (Table 1).

Table 1. Observed frequencies of the first cube disposition in 50 subjects

	Left	Center	Right
Top	18	2	23
Bottom	1	2	4

It is certainly necessary to collect more data among healthy participants before inferring something related to how individuals dispose objects in a delimited space, but initial outcomes show a specific tendency.

In future directions, the use of cubes with ArUco markers can not only be extended, as above described, in recreating a spatial cognition assessment tool, but also used as a tool to train and not only assess spatial skills; the software performing the task could provide an adaptive tutoring system, able to give recurring feedback about participants' performance and able to adapt test requests on the users specific requirements, keeping trace of their improvements. Starting from this point, it would be possible integrate a training and rehabilitation program for people with impaired spatial cognition skills.

Moreover, the adoption of cubes as a tangible interface could support mathematics and geometry lessons in elementary schools (e.g. using cubes to compose patterns and different shapes, asking students how many cubes are necessary to build a rectangle of a certain dimension etc.), enabling also collaborative behaviors among students, which are crucial in the learning process (Chaiklin, 2003; Gokhale, 1995). Furthermore, it has already been shown the benefits deriving from the manipulation of physical objects to improve spatial abilities in children, giving them the possibility to understand the spatial relationships among concrete objects (Casey, Andrews, Schindler, Kersh, Samper & Copley, 2008).

4. Discussion and conclusions

In the present paper, several applications adopting AR technology have been described, which are becoming more and more widespread in research, in both academic and industry fields. The main characteristic of AR is that it allows a unique multisensorial-experience, combining stimuli from the real world with technology enhanced information. This means to interact with real objects, stimulating spatial skills, and it is important also in virtual environment (Lok, Naik, Whitton & Brooks, 2003). In fact, merging the physical dimension with the virtual brings the activity to perform in augmented/virtual reality closer to real-world tasks. Handling real objects recreates real-life experiences and enhances the learning of spatial relationships.

In this study, the general functioning of AR technologies is highlighted, because to better understand how AR works, it's necessary to know the methodology behind AR applications. For example, defining which are the concrete objects that have to contain enhanced information, how AR markers works and how they have to be posed, and also defining what are the other aspects to be taken into account for the correct experiencing of an AR session.

With regard to the educational aspects of AR applications, it has been shown that AR matches with Constructivism's theory (Fosnot & Perry, 1996): the act of learning as a nonlinear process where an individual "reconstructs" the piece of reality that they want to know with instruments and tools (the same process used by AR applications). In addition, Vygotsky already claimed in 1978 that students consolidate learning through signs and instrument mediation.

According to the review proposed by Saltan and Arslan (2017), although increasing students' motivation, satisfaction, and engagement are important aspects of learning, it is also critical to improve, through AR technology, students' higher order thinking skills such as problem solving and creative thinking. AR applications in formal education reach noticeable educational outcomes, but technical thresholds are recognized amongst one of the most critical boundaries for learning efficacy; a common thought of people adverse to the massive use of AR who claim that there is too much technology in educational fields, and sometimes it distracts students from their learning path.

However, AR potentialities are preparing to be enormous, and they will change the conventional educative and teaching methods, making the whole learning experience more interesting and more satisfying. In addition, AR methodology represent a possibility to integrate new form of exercises with classical pen and paper exercises, capturing the attention of students on the task and reducing their cognitive effort in doing exercise in a more agreeable way. Furthermore, the scope of AR can be extended also to other fields, such as the development of new tools for assessment purposes, as it has been highlighted by the technologically enhanced version of BTT.

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