VISUAL LEARNING AND EDUCATION FOR AUGMENTED REALITY ENVIRONMENTS

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Studies on the neurosciences and the cognitive sciences have shown the existing interconnections between visual perception and cognition in the knowledge/interaction with the world. It is recognised in particular how the perception of the information in the multimedia format can improve the teaching-learning processes. With reference to the neuro-cognitive and cognitive aspects, I will focus my attention on visual learning, with particular regard to the use of augmented reality technologies. The present contribution aims specifically to identify the elements of tangency between visual educational perspectives and the construction/use of augmented digital environments.

NEUROSCIENCE, VISUAL PROCESSING AND DIGITAL TECHNOLOGY

Within the scope of the scientific literature, the most recent studies on neurosciences and didactics converge towards some aspects and principles that redefine the knowledge acquisition processes in relation to a style of visual and multimedia learning. In fact, the workings activated for the understanding of the world involve sensorial, visual, perceptive, motor, empathetic and emotive aspects. The visual channel is controlled and oriented by the movements of the body and interacts with other sensorial forms within a common environmental field (Damiani, Santaniello & Paloma, 2015).

An active comparison with the new scientific models can therefore impact the design of 'neurodidactic' interventions (Rivoltella, 2012; Damiani, 2012; Compagno & Di Gesù, 2013), also in the light of the practices initiated in diversified learning contexts through the use of the digital technologies. In the exploration of the body-environment interconnections, there emerges an ever-greater recognition of the rooting of knowledge in the body-brain. In that sense, Varela (1990) underlines how cognition is founded upon the motor-sensorial system: the world is not something that is 'given' to us from the outside, but we take part in it through the way in which we perceive and move in space. As shown by the developments in the neurosciences, cognition can be identified as 'enation': sensation, perception and action constitute a unitary device of the body-brain addressed to knowledge and interaction with reality (Varela, Rosch & Thompson, 1992; Gallese, 2007; Chemero, 2009). In this regard there is talk of embodied cognition, that is 'embodied' knowledge and based on the integrated and multisensorial experience with the world (Sozzi, 2015). The theory of multiple intelligences of Gardner (1983; Gardner & Hatch, 1989) and Beauport (1994) refers to this conception; they recognise the presence of multiple intelligences connected to different specialised cerebral areas. Hence, alongside the logico-mathematical and linguistic intelligence, tied to the activity of the parietal lobes, the left frontal lobe and the Broca area, there is the musical intelligence, mainly located in the right hemisphere and the corporeal-kinaesthetic, which depends on the activity of the cerebellum, the thalamus, ganglia of the base and from which depend the body's posture and movements. Last but not least, the visual-spatial intelligence allows us to recall images and pathways and is correlated with the activity of the right hemisphere. Specifically, the neuroscientific studies have detected the relationship between visual strategies and spatial strategies: the visual narrative representations without visuo-spatial, schematic and sequential references, do not allow for the construction of a mental model of the problem to be resolved, while the dynamic schematic-visuo-spatial representations turn out to be adequate to the problem-solving capacity (Passolunghi, Vercelloni & Schadee, 2007).

These studies refer to a specific branch of the neurosciences, the Visual Neuroscience that focuses on the visual system of the human body, with the aim of understanding the neural activities with respect to the processes of visual perception, besides the behaviours dependent on vision (Gegenfurtner, Kok, Van Geel, de Bruin & Sorger, 2017; Chen, 2019). In regard to this sector, some research into perception and visual learning style have focused on how the visual information can have an impact on the acquisition and the transmission of knowledge (Feldges, 2016). Specifically, the concept of learning style (Falcinelli, Gaggioli, & Capponi, 2016) refers to an individual way of acquiring information that privileges a certain sensorial channel. The plasticity of the brain means that it is capable of adapting to the different stimuli that it receives from the outside in wholly personal ways (Wolf & Barzillai, 2009). As a matter of fact, the information on a given argument are not necessarily acquired holistically by the student, but rather the preferences for some sensorial modes is recorded. Fleming (2009) defines four learning styles, that is four modes of information take-up: visuo-verbal (based on the written language), visual-non-verbal (based on images, figures, diagrams, schemes), auditory (based on listening); kinaesthetic (based on the direct experience of things through manipulation and movement). Petty (2009), instead, identifies a modality of information acquisition of a visual, auditory and kinaesthetic nature. The former thus stresses the cognitive elaboration at a linguistic/semantic level. The second underlines the receptive capacity to perceive internal (kinaesthetic) and external (visual/auditory) stimuli. Particular attention has been reserved to the study of the visual learning style to assess its educational impact in terms of the reinforcement of knowledge acquisition. Indeed, the capacity to see is the dominant sensorial system in man, occupying between 20 and 30% of the cerebral cortex area (Van Essen & Drury, 1997; Van Essen, 2003). Human beings elaborate visual-non-verbal elements faster as compared with the verbal ones and every day they come into contact with a huge number of images and visual representations: digital charts, infographics, maps, signs, videos, diagrams, illustration, etc. (Salvetti & Bertagni, 2019). One tends to remember about 10% of what one listens to, about 20% of what one reads and about 80% of what one sees (Rizzolatti & Sinigaglia, 2008; Collins, 2015; Gazzaniga, 2009; Kandel, Schwartz, Jessell, Siegelbaum & Hudspeth, 2013).

Specifically, Feldges (2016), investigating what happens inside the nervous system when one's eyes receive visual stimuli, points out how learning derives from the fusion of two neural perceptive processes based respectively on the recognition of objects and the representation of forms (Bear, Connors & Paradiso, 2006) and on the perception of moving objects. This distinction reported in the educational contexts, refers to forms of learning supported by two different visual flows: fixed images and dynamic images. Indeed, the former flow of information allows one to understand the aspects linked to the visual perception of a static image, but does not provide accurate explanations as to how we actually perceive the world that presents as a continuously evolving and ever-moving environment. Thus, it is shown how the educational practice that pays particular attention to the use of fixed images should also stimulate the student by recovering the action of the body within a given space (Lumbelli, 2012; Bruni, 2013). In relation to these themes, the centrality of the neurosciences emerges in the study and in the implementation of the augmented reality technologies (AR), with particular reference to the knowledge both of the possibilities and the limits of our sensorial systems, and the cerebral responses deriving from the interaction of forms of mixed technology which in turn can give new information on cerebral functioning. The immersive experiences realised in an AR environment pose precise questions as to the perceptive mechanisms that underlie it. Indeed, AR is recognised as having an important action of mediation between the brain and the physical world thanks to the sensorial and cognitive wealth of the user's experience. In a continuous reciprocal exchange, neuroscience provides an understanding of how the use of AR technologies can influence the brain by allowing for the reconstruction/integration of reality starting from the sensorial perception, at the same time augmented reality provides neurosciences with new ways of testing theories and concepts relating to complex cognitive and perceptive phenomena, in particular visual, spatial and kinaesthetic, simultaneously recording and monitoring the changes in the cerebral activities and behaviours (Baldassi, Kohno, Roesner & Tian, 2018).

VISUAL LEARNING

Visual learning lies at the heart of a long debate on its cognitive implications and potentialities (Arnheim, 1969; Cardarello & Contini, 2012; Clark & Lyons, 2010; Landriscina, 2011, 2012; Mayer, 2003, 2009; Novak, 2010; Panciroli, Macauda & Corazza, 2020; Paoletti, 2011) which attributes to the images the fundamental role of "didactic catalysers" (Farnè, 2002, p. X) as the principal form of expression and comprehension of the world towards a more meaningful learning.

It is particularly starting from the late nineteen seventies that some sectoral studies have started to deepen the iconic code, the relation between word and image, the audio-visual communication and successively multimedia, paving the way to a tradition of pedagogical reflections on the role and the characteristics of the languages and the audio-visual media in education (Calvani, 2011; Cescato 2017; Galliani, 2014; Rivoltella, 2012; Vivanet, 2015).

Several studies have, however, shown that graphic-visual communication can determine two typologies of interdependent risks: decorativism and cognitive overload. Decorativism refers to the introduction of images not directly correlated to the principal content of the written text or the lesson, capable of producing a cognitive overload (Clark & Lyons, 2010), adding a significant component of distraction. From here the tendency to overlap the written text on the image: the verbal description precedes and even influences the visual reading, to the extent that in different school textbooks a rather limited space is reserved to images. Indeed, a diffuse practice is that of teaching to read and "to analysing the texts of books, but not the illustrations. Although the latter fulfil an illustrative purpose complementary to the graphic-verbal message [...], they are prevalently perceived as some *pleasant interruptions* that segment the reading" (Nuti, 2012, p. 9), thereby deprived of their own semantic autonomy in respect to the verbal content. Far from this position, Ferretti observes how "an illustrated book, also a school textbook, can function through images alone, independently from the text" (2003, p. 40). A controlled use of the images can indeed support the learning process through the adoption of some devices that lead to: focusing attention on the fundamental elements to minimise the cognitive effort and to make prior knowledge emerge; supporting the transfer of knowledge and the construction of mental models; stimulating motivation (Clark & Lyons, 2010).

The images (photos, conceptual maps, charts, graphs) can acquire the characteristics of a scaffold supporting the construction, organisation and re-elaboration of knowledge.

In this regard, the studies on multimedia learning have led to defining some fundamental principles (Mayer, 2003; 2009): words and images are associated (principle of multimediality); contents extraneous to the pre-set objectives are excluded providing contents that are relevant and coherent between them (principle of coherence); words and images that refer to the same contents are situated close together so as to integrate the information in an immediate way (principle of spatial contiguity); the images are accompanied with texts in audio format rather than written so as not to saturate the visual channel (principle of modality); the same informational contents are not presented in different formats (principle of redundancy). In this regard, Laurillard (2014, p. 147) distinguishes n intrinsic load due to the characteristics of each media and an extrinsic load that depends on the quantity and the choice of the visual and multimedia materials and their organisation, suggesting operating towards a pertinent cognitive load. It is not "the number of media present that impacts positively or negatively on learning, but the rationale used in connecting the various media (the graphic organisation in the single media, the choice of media products as a function of the communicative aims and the readers' competencies, the choices topologically adopted to spatially organise the various media) and the attention to the mediation process" (Rossi, 2016, pp. 16-17).

The value of some typical aspects of the visual data is thus recognised, such as: 1. the simultaneity and contextualisation of the information that they enclose in respect to a precise reality; 2. the efficacy of the images, and as source of information; 3. the persuasiveness of the images that catch the eye and evoke emotions (Cescato, 2017). The latter aspect refers to the aesthetic-emotional dimension tied to the "pleasure principle, to the fact that looking at the figures [...] is first of all constituted as sensible experience that activates in the subject visual pleasure, a springboard for fantasy and imagination" (Farnè, 2002, p. XI). Within the scope of the process of mediation (Bruner, 1966; Damiano, 2013) which is born from the need to create a bridge between experience and abstraction, between taught knowledge and learned knowledge (Rossi, 2017), images occupy a significant place as *iconic* mediators, alongside other typologies of mediators: the actives, the analogics and the symbolics. In this way, it is possible to "propose multiple representations of the studied concepts, to reify from one time to the next the studied concept at different levels of abstraction" (Rossi, 2017, p. 14). Specifically in regard to the iconic mediators, the degree of iconicity of an image is a function of the degree of verisimilitude or abstraction chosen in the representation. The images are made up of "elements (lines, forms and colours), organised according to models of similitude with the referent, where it can be a real object (the photograph or drawing of a table resemble the real table) or a mental model, understood as a graphic organiser that visually expresses relations of proximity, inclusion, sequence" (Menichetti & Sarro, 2015, p. 76). The images can transmit knowledge concerning factual objects, but they can also transmit abstract concepts (justice, trust, loyalty, care, etc.) (Feldges, 2014; Feldges & Pieczenko, 2016). Also, the images can be real or fictional, represented and described by and in the verbal texts. In fact also "the texts are always accompanied, in one way or another, by associated images, implied images, latent or inserted in the body of the text [...] and even by images of the 'imaginary museum' of every reader, made up of memories, transpositions seen at the cinema, reportages on the author, images multiplied of his/her portrait, caricatures" (Hamon, 2008, p. 64). In this sense, the image is not only what is perceived through sight, but also through all the other senses (kinaesthetic, auditory, tactile, olfactory, taste). There are indeed different ways of perceiving information.

In this perspective, "the rationales of aggregation and reticularity have allowed for the realisation of artefacts that are ever-more eclectic and spurious" that "make more fluid and continuous the passage from direct experience, to its possible and multiple iconic-symbolic representations, in which the presence of icons, indices and symbols changes almost seamlessly, present in successive representations of the same concept, or in the same representation contemporaneously" (Rossi, 2017, p. 15). The introduction of iconic/visual artefacts of a digital nature has made the mediation increasingly recursive and blended, back and forth from the experience to the symbolic conceptualisation, In fact, the digital, by modifying the relationship between experience and conceptualisation, has introduced a new typology of technological mediators, the synthetic mediators, "whose characterising elements are the co-presence of various media and the interaction between the different languages in the single artefact [...] that is the aggregation, the interaction of different functions within the artifact thanks to the numeric" (Rossi, 2016, p. 17). The transversally of these mediators "that has in particular to do with their multimediality [...], with the convergence to the digital that makes possible the integration of several languages (graphic-verbal, iconic, ...) in a single platform thanks to the codification of these same languages" (Rossi, 2016, p. 17). This form of aggregation leads to the realisation of digital artefacts characterised by a fluid relationship between iconic, symbolic and analogic that makes them difficult to distinguish (Galliani, 2014; Panciroli & Macauda, 2019). In that they are fluid, these mediators escape the traditional classification and contain on their inside different languages that re-sematicize the contents in a different way, overlapping different plans of metaphorization (Pentucci, 2017).

VISUAL LEARNING THROUGH AUGMENTED REALITY

Within the scope of the synthetic mediators, an increasingly important place is occupied by the digital artefacts of a visual nature produced through the augmented reality technologies. Under the umbrella term 'augmented reality' we can group together all those technologies of digital graphics (Ferraro, 2014; Borrelli, 2018) that allow us to visualise virtual contents superimposed upon images of objects of the real world. In fact, framing a given environment through the camera of a smartphone or a tablet or by means of a specific visor, a system of the recognition of the images of reference, the so-called markers, is followed by the visualisation of new and different media contents (texts, images, video, audio, 3D animation). The objects that lie in the real world are augmented by the perceptive information generated by the computer, through multiple sensorial modalities. “The superimposed sensorial information can be constructive (that is, additive to the natural environment) and are perfectly interwoven with the physical world in such a way as to be perceived as an immersive aspect of the real environment” (Salvetti & Bertagni, 2019, p. 243).

In this sense, augmented reality renders an image enriched by new information/graphic re-elaborations that are presented in the observer’s visual field. A tracking system allows the latter to orient itself and to move within the real environment, having an actual perception of the space that changes depending on the movement. A specificity of the augmented reality is given by the new conception of the space inside which the user moves. if the virtual reality technologies are capable of moving us in other spaces and contexts that separate us from the place where we are and from what surrounds us, the augmented reality technologies, through web-devices and geo-tracking systems, are radically inserted in the place and in the context in which we find ourselves (Borrelli, 2018). In regard to the integration/superimposing of virtual/real spaces, there are however different levels of immersivity: we move from the lightly augmented, accessible via the use of smartphone and tablet to the heavily augmented, accessible through wearable devices such as helmets, visors and smart glasses (Salvetti & Bertagni, 2019). This passage accompanies a progressive disappearance of the interface, to the advantage of a more accentuated immersive sensation. “The graphic interface the computer has accustomed us to is substituted by an interface that pretends to be natural, where the interaction through the touch, the gestures, operations like closing and widening one's fingers, ultimately lead to the illusion of having to do with things 'directly'" (Ferraro, 2014, p. 59).

On the cognitive level, the coexistence of physical and digital objects allows us to add and diffuse further informational elements with respect to the ones already visible to have the user interact better with the actual environment. In fact, one of the aspects that most of all characterise the augmented reality is the overlay, that is the activation of an additional level of communication: a perceptive level is superimposed by other strata and levels of perception and information. The user "rapidly obtains more circumstantial information and can use them in his/her communicative interaction with other people" (Barbieri, 2020, p. 201). An aspect that seems particularly significant when the interaction with the world results to be finalised, directed or in Heideggerian terms, projected. The augmented reality images thus act upon the cognitive grasping of the environment by the subject and produce a redefinition of the informational space, as well as a redefinition of the limits of one's own possibilities to act in the world. The user or perceiving subject becomes, through the mobile device or the visor, the point of transit of a dual information flow, one coming from the 'natural' world, the other from the 'virtual' one (Finocchi, 2018). In that sense, augmented reality alters the continuous perception of the actual environment and produces an alienating effect, "a sense of greater distance in respect to the things that end up appearing continuously filtered via the information that is supplied" (Barbieri, 2020, p. 202).

Whilst taking account of these aspects, the experiences conducted in augmented reality environments show how the interaction with the real world turn out to be enriched on the socio-relational and the emotional side, offering original pathways for access and novel spaces for the construction of new forms of knowledge. Specifically, recent studies and didactic experiments (Bini, 2017; Diegmann, Schmidt-Kraepelin, Van Den Eynden & Basten, 2015; FitzGerald, Ferguson, Adams, Gaved, Mor & Thomas, 2013; Gabbari, Gagliardi, Gaetano, & Sacchi, 2017; Macauda, 2019; Miranda & Marzano, 2019; Panciroli & Macauda 2018; Petrucco & Agostini, 2016) have shown how the structuring of a hybrid space, virtual and real, supports the learning processes by valorising the visuo-spatial intelligence of the learners. In particular, it is recognised how the AR environments developed via the techniques of visual storytelling:

- enable the learners to interact directly with the objects, to explore the mechanisms of the physical world and to experience them directly, fostering an authentic and situated learning of a practical nature; the students practice in managing realistic situations, rather than learning facts or techniques out of context (Khanna, 2014);
- facilitate the learning of complex and abstract concepts, because one tends to remember better what one sees as compared with what one hears; the visualisation of the information allows the students to understand better and quickly;
- provide a thorough understanding, via the acquisition of visual information;
- develop effectively the mnemic capacities of the students who recall the information more easily;
- stimulate critical thinking and problem-solving, allowing one to analyse the situations from different points of view;
- develop socio-relational competencies that improve the interaction and the cooperation between students inside the work groups;
- support the students' research process, increasing the attention threshold, developing and stimulating their creative capacities.

Augmented reality thus acts on the process of learning at several levels, at times positioning itself as environment capable of amplifying and enriching the experience, at others as an instrument capable of providing the directives necessary to reach the pre-set objectives. Augmented reality can be considered as one of the technologies that most of all impacts the learning processes through the use/construction of digital knowledge artefacts of a visual nature that transform static expositions into virtual panoramas or rales rich in emotional resonances. These new forms of user experiences make available great quantities of new data, local and delocalised at the same time, which transform the physical spaces into multidimensional realities framing objects/documents within narrative and emotional contexts that enrich the user's experience (Brunelli, 2017; Luigini & Panciroli 2018; Panciroli, Macauda, & Corazza, 2019). Thus, new experiential models are defined that help to create new meaning flows in reference to space, time and subjectivity. The augmented reality is characterised by a continuous shifting between of different discourse universes (visual, textual, audio) that determine new meaning relations between the subject and the reality, accelerating some processes, but slowing down others. Notwithstanding the possible potentials encountered, it is still pointed out that an AR system, akin to a fixed image system, could determine the overload and the cognitive dispersion if not adequately reinforced by a direct experience with the objects of the world and by reflexive and abstract moments supporting an efficacious cognitive experience (Bonaiuti, Calvani, Menichetti & Vivanet, 2017; Miranda & Marzano, 2019). The didactic mediation is thus materialised in a continuous transformation between different mediators: from the real direct experience to the augmented experience seen through the screen of a device; from the physical object of the to the image of the re-constructed/re-elaborated object; from the textual document to the multimedia text (Rossi, 2017). The visual environments of augmented reality indeed act as dense and stimulating mediators capable of offering immersive experiences and bringing together styles proper to other media (Bolter & Grusin 1999; Rivoltella & Rossi, 2019; Salvetti & Bertagni, 2018) through the superimposition of different languages, methods of use, habits of use and relational methods (Borrelli, 2018). Thus, reference is made to a process of re-functionalisation, characterised by the creative use of the functionalities envisaged by the digital environments (Ferraro, 2014). The latter are aligned with the plasticity of multimodal learning styles in the approach to information channelled in a multiple manner, and activate a holistic process of co-construction of meanings and the redefinition of spaces of action/interaction of the subjects, thereby involving complex cognitive and emotional elements.

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