THE POTENTIAL OF AUGMENTED REALITY IN THE EDUCATIONAL AND INCLUSIVE DIMENSION.

LE POTENZIALITÀ DELLA REALTÀ AUMENTATA NELLA DIMENSIONE EDUCATIVA ED INCLUSIVA.

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Abstract

In recent decades, educational technologies have grown considerably, not only from a quantitative point of view but also from a qualitative point of view, becoming an integral part of everyone's life and training (Poletti, 2015).In this panorama, Augmented Reality (AR) represents an emerging technology, increasingly at the center of investigations in various research fields, both at an international level (Carrera & Asensio, 2017; Lee, Dünser, Kim, Billinghurst, 2012) and national (De Paolis, 2012; Parola, 2017; Rivoltella, 2010) used in various fields of application, from the mechanical, tourism, to the medical-rehabilitation and psychological fields. One of the most interesting lines of research in recent years is linked, in particular, to the study of the potential of Augmented Reality (AR) in the educational field and its use for the creation of active and innovative learning paths, which present a high level of interaction and customization. The following article intends to investigate and analyze the AR phenomenon to further investigate its application in educational processes, in particular in the field of inclusive teaching with subjects with special educational needs, where the search for AR applications that intend to support people with different levels of ability and/or disability (Sheiderman, 2000).

Negli ultimi decenni le tecnologie educative sono cresciute notevolmente, non solo da un punto di vista quantitativo ma anche da un punto di vista qualitativo, diventando parte integrante della vita e della formazione di ciascuno (Poletti, 2015). In questo panorama la Realtà Aumentata (AR) rappresenta una tecnologia emergente, sempre più al centro di indagini in diversi ambiti di ricerca, sia a livello internazionale (Carrera & Asensio, 2017; Lee, Dünser, Kim , Billinghurst, 2012) che nazionale (De Paolis, 2012; Parola, 2017; Rivoltella, 2010) utilizzata in diversi campi di applicazione, da quello meccanico, turistico, a quello medico-riabilitativo e psicologico. Uno dei più interessanti filoni di ricerca degli ultimi anni si lega, in particolare, allo studio delle potenzialità della Realtà Aumentata (AR) in ambito educativo e al suo utilizzo per la creazione di percorsi di apprendimento attivi e innovativi, che presentano un elevato livello di interazione e personalizzazione. Nel seguente articolo si intende indagare e analizzare il fenomeno dell'AR per approfondire ulteriormente la sua applicazione nei processi educativi, in particolare nell'ambito della didattica inclusiva con soggetti con bisogni educativi speciali, dove è sempre più aumentata la ricerca di applicazioni AR che intendono supportare persone con diversi livelli di abilità e/o disabilità (Sheiderman, 2000).

Keywords

Augmented Reality; learning; education; inclusive processes; disability.
Realtà Aumentata; apprendimento; educazione; processi inclusivi; disabilità.

[1] The contribution is the result of the joint work of the two authors. More specifically, Giovanni Arduini authored paragraphs 1, 2 and 3 and Diletta Chiusaroli paragraphs 4 and 5.

1.Introduction

In recent decades, educational technologies have grown considerably, not only from a quantitative point of view but also from a qualitative point of view, becoming an integral part of everyone's life and training (Poletti, 2015).

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One of the most interesting lines of research in recent years is linked, in particular, to the study of the potential of Augmented Reality (AR) in the educational field and its use for the creation of active and innovative learning paths, which present a high level of interaction and customization.

The following article intends to investigate and analyze the AR phenomenon to further investigate its application in educational processes, in particular in the field of inclusive teaching with subjects with special educational needs, where the search for AR applications that intend to support people with different levels of ability and/or disability (Sheiderman, 2000).

2. Augmented Reality in education

The concept of Augmented Reality (or AR) is relatively new and constantly evolving, and, although there is no univocal and clear definition that allows us to describe it, it is the direct heir of Virtual Reality. The RA, in particular, was born in the early 90s. It is a technology whose peculiarity is that it can exploit any surface of our "real" world, such as a canvas, in order to offer additional information on it (Cantelmi, Pensavalli, Marzocca, 2015, p. 9).

AR, therefore, is a digital representation that superimposes virtual information on the reality perceived through our senses. Its objective is, in fact, to give the sensation that virtual objects are actually present and integrated in the real world: for this reason, it typically uses mobile devices or viewers capable of framing the real environment and augmenting it with additional digital information (Carci, Caforio, Gamper, 2019, p. 278).

"The user's perception of the world is in fact increased, enriched by virtual objects that provide [...] information that the user could not directly detect with his own senses" (Di Martino, 2011, pp. 20-21).

Over time, this technology has become increasingly immersive by increasing the veracity of the interactions between virtual and real components.

For Azuma (1997) AR, rather than replacing reality, as in the case of virtual reality, simply integrates it. In particular, he identified three main characteristics:

- the combination of virtual content with real content within a real context;
- the alignment of virtual contents with real ones through three-dimensionality;
- real-time interaction with virtual elements (Di Martino, Longo, 2019, p.181).

Unlike Virtual Reality, therefore, which places the user completely in a fictitious world, AR superimposes virtual objects onto reality in real time (Cai, Wang & Chiang, 2014; Tekedere, Göke, 2016), so that the user can have the sensation of being physically present in the landscape he sees reflected on the screen.

AR by offering a different way to interact with information can be used to design better learning experiences. In this regard, some international research (Diegmann, Schmidt-Kraepelin, Van Den Eynden & Basten, 2015) has highlighted significant aspects related to the application of augmented reality in educational contexts. They highlight how AR can be used in different contexts, from kindergarten to postgraduate training, highlighting its important potential for the development of fundamental skills such as problem solving, teamwork, critical evaluation and understanding of different perspectives (Di Martino, Longo, 2019).

In this sense, since AR merges any digital information within the real world, i.e. data or electronic information, in various formats (visual, graphical, textual, audio, video and tactile overlays), it has great potential for application in education (Di Martino, Longo, 2019, p.180).

Dunleavy and Dede (2014), in particular, underline how augmented reality can enhance the student experience, multiplying cognitive and socio-relational paths and thus reaching augmented learning (Herrington & Crompton, 2016).

The use of augmented reality in educational technologies, in particular, has the added value of allowing the enrichment of sensory perception through information generated, electronically and semantically connected to the environment, which would not be perceivable with the five senses (Poletti, 2015, p.81).

Santos et al. (2014) in their research use the term experiences in AR to refer to learning experiences facilitated by AR technology and identify the main advantages deriving from the very nature of AR, defined as follows:

- *real-world annotation*, to display text and other symbols on real-world objects;
- *contextual view* that allows you to view the virtual content in a specific real context that helps students build a more elaborate knowledge network;
- *haptic visualization* which allows visual information to be presented in two ways: sense of sight and sense of touch (Di Martino, Longo, 2019, p. 182)

Santos et al. (2014), moreover, identify some strategies to which reference should be made for the design of learning experiences based on AR. Among these are:

- facilitate the exploration of content;
- promote collaboration between students in order to exchange ideas;
- ensure designing AR content that allows students to focus more.

AR technologies are mostly used in scientific sectors such as physics, chemistry, biology, mathematics. In these branches of science, teaching is easier when abstract and difficult to understand concepts are presented in a concrete way with the help of AR technologies (Ozdemir, 2017).

In this context, learning materials prepared using AR offer a means of learning close to the real world (Cai et al., 2014) and allow students to play an active role in the learning process.

In fact, AR makes it possible to create interactive learning environments (Chen, Wang, 2015) and promote innovative teaching methods in which information in 3D format facilitates the acquisition of knowledge and discussion among students (Wu, Lee, Chang & Liang, 2013).

Among the many benefits related to the introduction of AR in teaching, Liou et al. (2016) also highlighted the possibility for teachers to be able to convey concepts more easily and quickly to their students through the use of AR-supported learning materials before their lessons.

This technological novelty has undoubtedly led to innovative procedures in the educational and training field. It has, in particular, contributed to improving the effectiveness and attractiveness of the teaching-learning process, producing real-life scenarios in the classroom, overcoming the theoretical atmosphere that is usually created, creating different styles of thinking and preparing to creative and divergent solutions to the problems of contemporary life. This technology therefore, in addition to enriching what is real with virtual content, allows the activation of the connections that man perceives in the world around him.

3. The inclusive potential of Augmented Reality

As previously noted, Augmented Reality represents a technology capable of enriching our interaction with the real world through additional (virtual) elements, effectively improving the set of information that is received and analyzed at a perceptual level. The addition of interactive digital components can bring information capable of enhancing the processing and understanding processes, which not everyone is able to carry out effectively with natural means (Cottini, 2019). With the integration of virtual contents in the real environment it is possible, in fact, to allow all users to have an immersive and engaging experience, and also to interact with them in real time.

These aspects of AR confirm its enormous potential for inclusion since it manages to simultaneously involve multiple senses within the learning experience (sight, hearing, touch), responding more easily not only to increasingly heterogeneous learning styles, but also to the multiple educational needs of students with and without disabilities (Shneiderman, 2000).

The use of AR, in recent years, in fact, has also found positive results in the field of inclusive teaching and in particular with subjects with special educational needs, where there is increasing attention towards the search for AR applications aimed at supporting people with different levels of ability and/or disability (Sheiderman, 2000). Many educational solutions, to date, exploit the potential of AR to support the processes of acquisition and processing of information, so that the student can experience new ways of exploration and interaction with educational content (Chiazzese, Mangina et. Al, 2019).

For the educational sciences, this is a significant innovation. In fact, in the field of training, important and promising application opportunities can be glimpsed which can contribute to improving the teaching-learning processes by making them more connected with the environment, more engaging and more collaborative through the creation of more plausible interactive spaces capable of promoting greater immersion by students and therefore more effective learning for all.

In this regard, as Di Martino and Longo (2019) point out, the use of AR for educational purposes has the potential to become a powerful tool for Universal Design for Learning (UDL) by providing new tools for multiple ways of representation, action, expression and engagement . Combining AR with UDL principles can help educators create lessons that are accessible and engaging for most students (Walker et al., 2017).

AR can be a new asset to UDL strategies, as it adheres to three core principles underpinning the latter:

- *Multiple Means of Representation*, which emphasizes the importance of adopting flexible methods of information visualization to make learning content available to all students;
- *Multiple Means of Action and Expression*, which focuses on how to provide students with options to demonstrate their knowledge, organize their thinking and interact with content;
- *Multiple Means of Engagement* which underlines the importance of creating interest, enthusiasm and motivation in students who are learning (Walker et al., 2017).

AR tools would be used to enhance instruction by providing access to additional resources and learning materials, as well as scaffolding aids during lessons through different visualization sources that support each student's different forms of learning. An example of using AR to present material in ever-changing and flexible ways is the use of zoomed-in or zoom-out virtual objects. This provides students with the opportunity to explore and gain a deeper understanding of the properties and relationships of objects that are inaccessible in daily life (Walker et al., 2017).

The effective integration of emerging technologies, such as AR, still presents several critical issues that require the need to overcome numerous impediments, such as integration into traditional learning methods, costs for development and maintenance of the AR system and a more general resistance to new technologies (Lee et al., 2012).

However, it is still useful to underline how in fact technology is neither intrinsically limiting nor intrinsically inclusive, but is always subject to the different methods of use in the educational field (Di Martino, Longo, 2019).

Numerous research projects have been born in recent years aimed at analyzing the applications of augmented reality in the field of teaching, to enhance learning and relationship processes in people with different educational needs guided by a totally inclusive perspective.

The inclusive perspective leads to considering everyone's diversity as a basic condition to be taken into account in order to build environments capable of welcoming everyone.

The goal is, therefore, to make inclusive contexts, methods and attitudes starting from an approach that sees inclusion in a dimension of active participation, generator of daily processes in interaction and in practices involving teachers, students , curricula and contexts (Hollenweger, Pantic, & Florian, 2015).

4. Different fields of application of Augmented Reality

This paragraph shows some examples of AR applications useful for people who have difficulty interacting with the environment. In particular, reference is made to applications that are useful for those with ADHD disorder, people with Autism Spectrum Disorder, cases of movement and orientation difficulties, and cases of hearing impairment.

4.1 Augmented Reality and ADHD

ADHD is a neurodevelopmental disorder and indicates a clinical condition with onset in childhood and possibly continuing into adolescence and adulthood.

It is a syndrome characterized by symptoms that can be traced back to the alteration of three major areas: attention, hyperactivity and impulsivity.

The subject is unable to respond adequately to the requests of the external context and finds it difficult to effectively direct his actions and behaviors in the relationship with peers, parents and adults.

More generally, the subject highlights problems for the purposes of a peaceful integration into the social and life context (Zentall et al., 2011).

Students with Attention Deficit Hyperactivity Disorder (ADHD) typically exhibit difficulty managing efforts and cognitive resources to achieve satisfactory performance in selective and focused attention.

Furthermore, a good percentage of subjects with ADHD can present, in comorbidity, a specific learning disorder (DSA) and alterations in the functioning of working memory and in the speed of processing and information processing (Chiazzese, Mangina, Tosto, Treacy, Chifari , Merlo, 2019).

With reference to this, it has been observed that augmented reality can in fact prove to be an important tool for improving the learning outcomes of students with ADHD and DSA through the creation of appropriate teaching contexts that use different visual stimuli. In particular, it is possible to mention the AHA pilot project, funded by the European Commission and conceived by an Irish partnership, which fits into this context with the aim of implementing an AR system capable of facilitating the acquisition of reading and spelling skills and of cognitive-attentive self-regulation processes in students diagnosed with ADHD as a primary disorder (Chiazzese, Mangina, Tosto, Treacy, Chifari, Merlo, 2019, p.1).

The AHA system, created within the project, integrates three tools:

- *the WordsWorth Learning system* (WWL), a web-based program for learning reading and spelling skills;
- *the Web Health Application for Adhd Monitoring* (WHAAM) to monitor the "on-task" and "off-task" times during the performance of WWL activities;
- a series of AR objects to facilitate the learning of some specific reading-writing rules (Chiazzese, Mangina, Tosto, Treacy, Chifari, Merlo, 2019, p.2).

The idea that drives the interest in the use of AR is to test the efficacy of an already validated literacy program (Treacy, 2017) in children diagnosed with ADHD, leveraging on the evidence regarding the effect that RA has in prolonging the times of focused and maintained attention of the subject during the performance of the learning activities.

The objective of the project is twofold since on the one hand it wants to study the effectiveness of augmented reality incorporated into educational contents, on the other it intends to investigate the levels of involvement of children with the proposed educational activities.

A further step involves the involvement of parents and teachers in an active role for monitoring the overall trend in terms of engagement and acquired reading and writing skills, through an update of the student's profile in progress.

In the last step foreseen by the project, all the data collected will be used for the evaluation process of the AHA system, useful for the production of a final report for parents and teachers that includes the outcomes achieved by the child (reading ability and attentive behaviour).

The data analyzes will also allow to answer the research questions and will be the subject of the production of a final report to inform the EC and the political and institutional decision-makers on the results relating to the pedagogical aspects related to the use of AR solutions for children with ADHD (Chiazzese et al., 2019, p. 4).

The implementation of a system that integrates AR content to an already validated program can bring additional benefits to the child's learning through its positive impact on the involvement in the proposed activities. Furthermore, the results of this study could represent for the institutions concerned (political, educational, therapeutic) a useful guide for the development of digital solutions that make the best use of AR technology to facilitate the study and scholastic success of students, in this case, with ADHD (Chiazzese, Mangina, Tosto, Treacy, Chifari, Merlo, 2019).

4.2 Augmented Reality and Autism Spectrum Disorders

AR is widely used in the treatment of Autism Spectrum Disorders since several authors agree on the fact that those abilities, usually lacking in those who experience this disability, but crucial for functional growth, in fields such as social, mentalization, body schema , can be partly developed thanks to "enriched" images, obtained by means of Augmented Reality (Cantelmi, Pensavalli, Marzocca, 2015, p. 13).

Several researches have focused attention on the treatment of Autism Spectrum Disorders with the help of RA tools. In this regard it is very interesting to mention the realization of the MOSOCO Project (Escobedo, Nguyen, Boyd, Hirano, Rangel, Rosas, Tentori, Hayes, 2012) a mobile application that uses AR and the visual supports offered by the Social Compass (Boyd, Chanin, McReynolds, 2011) and which intends to present itself as an intervention and support tool for autistic children to increase the development of social interactions. By obtaining information through their mobile device, each child receives direct assistance, through prompts and reinforcement, during the interaction. The results of the research have shown that the application provides a great quantitative and qualitative contribution to the improvement of social relationships, reducing both interpersonal difficulties and behavioral dysregulations, and also facilitating the integration of autistic children in groups of subjects who do not have this disability (Cantelmi, Pensavalli, Marzocca, 2014).

A further research project dedicated to children with the Autism Spectrum was launched by the Robotics Institute of the University of Valencia (Casas, Herrera, Coma, Fernández, 2012) through the use of a Microsoft Kinect peripheral, which has the The goal is to implement in autistic children body awareness and the ability to understand their own postural patterns. In fact, in a mirror room, together with an adult whose movements are imitated, the child has the opportunity to elicit enriched elements thanks to Augmented Reality, thus acquiring new skills on his own body (Cantelmi, Pensavalli, Marzocca, 2014).

Also in Sicily, the Institute for Biomedical Research and Innovation of the National Research Council (IRIB CNR) has been dedicated for years to experimental projects that intend to help children with autism spectrum, through the use of the most modern technologies.

In this regard Antonio Cerasa, neuroscientist and researcher of the IRIB CNR of Messina and author of "Translational neuroscience. From knowledge of the neuron to applications for health" (2022), explained how currently to rehabilitate and strengthen the main deficits of children with the autistic spectrum linked to social skills, only behavioral therapies are available, and these therapies, in some cases, have low efficacy.

The reason is linked to the great clinical variability with which the symptoms of the autism spectrum can present and to the limited intrinsic potential linked to behavioral treatment. For the scholar, immersive reality systems can allow these limits to be overcome by providing the child with new visual scenarios in which to learn new behavior strategies. However, these systems would be designed to work on one child at a time (Pignataro, 2022).

Instead, the technology imported from the metaverse could make it possible to rehabilitate several children at a time, each immersed in the same scenario, through the creation of a digital avatar of the child.

With the "Primapietra" project (National Research Council, 2011), the IRIB CNR has started a first path for the construction on the Sicilian territory of a space designed to blend the most modern techniques of clinical treatment, at an early age, of children with autism, using the potential of robotics. The last of the projects presented is called InterPares and was funded by the municipality of Messina to allow families, not only to have cutting-edge treatments for their children (Tablet, Virtual Reality, Augmented Reality, Robot) but also to be able take advantage of continuous remote assistance from home (TeleRehabilitation), with a social and work integration project. In fact, within the project, an innovative social reintegration protocol was launched characterized by Autism-Friendly shops where children with autism, via an app downloaded on their mobile phone, can have digital help in performing tasks of daily life (such as go shopping) in complete independence (Pignataro, 2022).

4.3 The support of Augmented Reality for the development of increased autonomy

Another interesting study presented by Don McMahon and David F. Cihak, Rachel Wright (2015), within the Journal of Research on Technology in Education, had the objective of investigating the ability of people with disabilities to autonomously take decisions to move to unfamiliar places where job opportunities exist. The authors state, in particular, that today there are hundreds of AR applications that respond to a wide range of needs including navigation, they also believe that the AR system represents a new technology to be used in teaching processes, capable of bridging the gap between internal and external learning environments.

According to the authors, the researches that have provided suggestions to help students with disabilities through the use of AR technology even outside the school reality are different. They specifically cite studies by Bechett and Shaffer (2005) where they used an augmented reality geographic information system (GIS) to teach planning and organization skills to students with Language Disorders and on the autism spectrum in high schools.

Another example cited by the authors demonstrating the flexibility of using augmented reality through mobile devices is the Layar app, a mobile application that can function as an internet browser to search for local information and can be used across multiple platforms including including IOS and ANDROID. In particular, this AR application can show in real time, to the person who uses it, the list of nearby businesses where it is possible to find job opportunities, the results are provided based on the settings previously chosen by the user.

The purpose of this study carried out by the aforementioned authors and of the use of this application was to examine how this location-based AR technology could help people with Language Disorders and Autistic Spectrum Disorders to move independently to seek opportunities for work in their vicinity.

Indeed, the survey revealed how the use of this app had actually contributed to improving and increasing the decision-making and autonomy skills of people with disabilities. It also allowed them to acquire the ability to access a technological tool, to apply the knowledge necessary to use the application and to make a decision based on the information obtained (McMahon, F. Cihak, Wright, 2015).

As the authors point out, future studies could further investigate these aspects by exploring the advantages or disadvantages of using AR navigation tools for students with disabilities with the aim of assisting students even outside the school context by supporting them towards the development of greater autonomy within the social and relational context in which they will have to move in the course of their lives.

4.4 Augmented reality for a "perceptive narrative" in hearing disabilities

A further and interesting field of research that pays attention to the ability of AR to offer a different way of interacting with various experiential and perceptive information, is linked to the narrative aspect and in particular to the film representation of

forms of experience of disability auditory. In this regard, it is necessary to distinguish and trace two distinct ways of representing deafness:

- a more traditional modality, based on the visual-behavioral aspect, in which the narrative dimension and the multisensory one, typical of cinelanguage, act in parallel;
- a more innovative modality centered on the auditory aspect, in which the perceptive-sensorial dimension becomes a narrative engine instead of the word (Amatori, De Mutiis, 2022).

Within the first modality, the one traditionally present in cinematographic or television products, the representation of the hearing disability in our case coincides with the representation of the person with disability, the visual aspect of the cinelanguage therefore inevitably concentrates on the features more characteristic behaviors. In the second mode, however, the basic paradigm of the representation of the disabled person changes, which is no longer visual-behavioral, but becomes a sensory, immersive experience and a central element of the narrative system, leading the viewer into the sound world of the character.

All of this is linked around a new way of thinking about cinema, a cinema that intends to become an immersive experience, in 5D, syncretic and synesthetic. The film Sound of Metal, in particular, succeeds in this aim because through a series of sound subjectives, the universe surrounding the protagonist who has a hearing disability is not only seen with his eyes but perceived with his hearing.

On the same front of immersive involvement in a potentially pedagogical and inclusive key, there is the technology of Augmented Reality (AR) which helps to develop spatial (Kaufmann & Schmalstieg, 2003) and psychomotor skills, thanks to the combination of tactile experience, visual (Feng, Duh, & Billinghurst, 2008) and auditory.

Also in this case, the ability of AR to offer a different way of interacting with information of an experiential and physical type makes it possible to achieve better, facilitated, engaging learning that is less based on the linguistic channel alone (Di Martino & Longo , 2019).

In Sound of Metal, thanks to a series of AR sound subjectives, we can perceive what a deaf person hears, experiencing directly with our hearing the closed and muffled world in which the characters move and experiencing the difficulties from their point of view, not limiting ourselves to "looking" at deafness, but "hearing" it. In this sense it is possible, contrary to a summative perspective typical of AR, in which perception is "enriched" with virtual information through technological devices, to adopt a subtractive logic in which technology is used to remove parts of perceived reality (Amatori, De Mutiis, 2022).

The enormous potential for inclusion of augmented reality, therefore, capable of simultaneously involving multiple senses within the learning experience (Di Martino & Longo, 2019) are in this case also transported within the context of what is defined as a reality diminished, in which multi-sensory is reduced to become a narrative element able to tell the experience of the person with disability without the linguistic contribution, thanks to the immediacy of an "embodied" sensitivity (Amatori, De Mutiis, 2022 , p.108).

5. Conclusions

As previously noted, the use of technologies related to Virtual Reality and Augmented Reality, which present a high level of interactivity, sensory involvement and immersiveness, is demonstrating considerable effectiveness in many educational and experiential contexts and also in the treatment of various forms of disabilities such as those related to Autistic Spectrum Disorders (Cantelmi, Pensavalli, Marzocca, 2014).

Currently, both internationally and in Italy, various educational experiences are underway that focus on the possible applications of Augmented Reality in teaching-learning processes, even if significant data about their concrete effects are not yet available.

We have previously reported the results of various researches that recognize the potential of AR application for people with various physical and cognitive disabilities, which deserve a more in-depth evaluation that takes into account not only the technical aspects, but also the pedagogical ones, with the objective not only to improve teaching-learning processes through the development of new digital solutions in an inclusive perspective, but also to support people with different forms of disability and those who are close to them in their daily lives.

AR can only represent an effective tool if strategies and action plans are defined that are aware of the objectives to be achieved, it is certainly a new frontier that must be further explored and implemented because it is able to provide an educational and existential importance.

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