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A.T.E.N.A.: EMBODIED THEORY IN AUGMENTED REALITY APPLIED IN DIDACTICS

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Abstract: A.T.E.N.A. represents the evolution of a project that originated earlier, aiming to investigate the use of augmented reality to support education in order to enhance learning processes and consequently academic performance. The research conducted so far, involving university students engaged in acquiring neural correlates related to motor, linguistic, mnemonic and emotional processes, has demonstrated a 40% improvement in learning processes. The proposed contribution aligns within the perspective of embodied cognition, where the role of purposeful gesture becomes crucial. This is because it seeks to harness the potential of motor acts and, consequently, brain activation at the motor cortex level, in synergy with frontal and prefrontal activation, generating greater synaptic connection to support the learning process. In light of this, the research hypothesis aims to explore the real connection between the potential of purposeful gesture to facilitate the manipulation of the studied object and the generation of a more meaningful learning process, specifically in the mnemonic component, through the use of Augmented Reality.

Keywords: Manipulation, semantic memory, visuo-spatial memory, Innovative Lessons

1. Introductions

The A.T.E.N.A. project (Augmented Tool for Enhancement of Neural Activation) emerges as an evolutionary phase of a previous initiative focused on exploring the potential of augmented reality (AR) applied to education. In previous research, AR has been used as a support tool both in academic lectures, where the teacher acted as a knowledge mediator, and in individual student study, with the goal of enhancing

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learning processes and consequently improving academic performance (Lembo et al., 2023; Cipollone et al., 2023; Lembo et al., 2023; Cipollone et al., 2023). In this new incarnation, A.T.E.N.A. represents a qualitative leap in the digital educational landscape, where the digital nativity of students is now an intrinsic characteristic.

Digital evolution has revolutionized education, demanding constant adaptation to fully exploit the potential of emerging technologies. A.T.E.N.A. fits into this context, acting as a bridge between traditional pedagogical methodologies and digital advancement. AR thus becomes a key element, bringing pedagogical and educational innovations that go beyond superficial technological integration, defining the learning context as a fundamental element in the development of the individual within a biopsychosocial perspective (Kranzler et al., 2020; Giorda & Rosmo, 2021).

Previous research has focused on university students, addressing neural correlates related to motor, linguistic, mnemonic, and emotional processes, concretely highlighting the fundamental contribution made by AR in favor of a better understanding of abstract concepts (Lembo et al., 2023).

However, the A.T.E.N.A. project aims to extend this exploration to a broader range of educational levels, from primary school to university, with the goal of fully understanding how AR can influence learning in all its facets.

In the following contribution, we aim to examine in detail the experimentation that has brought to light the benefits of manipulating models in AR in learning contexts. This involves analyzing how its integration has influenced student participation, understanding of concepts, and active engagement in the educational process. In this context, the research explores the importance of purposeful gestures as a means to facilitate the understanding and assimilation of theoretical content. Previous studies have suggested that the conscious use of gestures during teaching and studying can lead to greater information retention and a deeper understanding of abstract concepts (Cipollone et al., 2023).

Purposeful action, experienced in this context through the manipulation gesture on models, creates stronger and more robust connections in the neural circuits involved in memorization and understanding.

Through a critical review of previous investigations and the analysis of data collected during previous research phases, the goal is to draw solid conclusions on the effectiveness of AR as an educational tool.

In conclusion, A.T.E.N.A. is not just a research project; it is an innovative response to the challenges of digital education, an attempt to translate the potential of AR into tangible benefits for students at every level. The following article aims to trace A.T.E.N.A.'s journey, outlining its current impact and projecting how it can contribute to the future of digital learning.

2. Theoretical Background

2.1 Learning processes from a constructivist and embodied cognition perspective

Scientific literature provides a detailed overview of the revolutionary potential inherent in directing learning styles towards the adoption of technologies in educational contexts. This emerging direction is based on solid constructivist theoretical foundations, advocating for the active involvement of students in the construction of their knowledge. These theories, in particular, emphasize the crucial importance of anchoring the content to be learned in the cultural reality of the individual (Panciroli & Macauda , 2018).

The integration of technological and digital supports in education goes beyond the mere use of digital devices; it is about creating a learning environment in harmony with the students' culture. This connection between educational content and cultural context not only makes learning more relevant and engaging but also amplifies the opportunity for students to understand and apply knowledge meaningfully in their daily lives (Cipollone et al., 2023; Lembo et al., 2023). In this way, the student becomes capable of generalizing the acquired notion, making learning meaningful (Peluso Cassese et al., 2023).

Therefore, the digital technological support envisaged by the A.T.E.N.A. project, in light of constructivist theories, represents not only an innovative adaptation but a true pedagogical transformation. This approach not only takes into account the cultural diversity of students but also promotes greater participation and active learning, thereby improving the overall quality of the educational journey (Panciroli & Macauda , 2018).

Simultaneously, this research is anchored in a solid theoretical framework based on two fundamental pillars: constructivism and embodied cognition (Gomez-Paloma et al., 2017; Tsulaia, 2023). Constructivism asserts that individuals construct the meaning of what they learn through experiences and active interactions. In this perspective, the learning process involves the student in an active construction of knowledge, making them the protagonist of their own understanding.

AR fits into this context as an innovative educational tool that provides the basis for improving educational offerings and enhancing learning styles. Thanks to its intrinsic characteristics, AR creates conditions that anchor students to their cultural reality, especially those belonging to the digital generation. These students, as digital natives, are immersed in technology from birth, making AR, with its digital interface, a familiar ground for learning.

A key aspect of AR is its ability to facilitate student interaction (Tomassoni, 2021) (Tarasenko, 2022). Designed to coordinate action and perception through the direct manipulation and multitouch of virtual objects, it presents lesson content in an engaging manner. This level of interactivity creates an engaging learning environment where students can actively explore, discover, and understand (Ibili, 2019). The use of motor actions significantly contributes to the development of conceptual knowledge, in line with the perspective of embodied cognition. In other words, through physical action in the virtual environment, students can consolidate and deepen their understanding of complex concepts, offering a rich and multisensory learning experience.

In summary, this research aims to explore the educational potential of AR based on the principles of constructivism and embodied cognition. By leveraging active interaction, students' digital familiarity, and the engaging nature of AR technology, the goal is to create a authentically meaningful, culturally relevant, and pedagogically effective learning environment.

2.2 The role of gesture in the learning processes

The approach to the educational landscape has undergone significant transformations in the context of embodied cognition, a theoretical perspective that considers the human body and its actions as natural aspects of learning and central elements for understanding abstract concepts (Gomez-Paloma, Angelino, Pastena, Raiola , Lipoma, & Tafuri, 2016). In this context, purposeful gesture emerges as a crucial element in making theoretical content more accessible and meaningful.

Embodied cognition suggests that the human mind does not operate in isolation but is closely connected to bodily experiences and physical actions. Purposeful gestures, movements with a specific purpose, become vehicles through which the body actively participates in the learning process (De Freitas, Piai, Farias, De Moraes, De Moraes Rossetto, & Leithardt, 2022). This approach deviates from the traditional Cartesian view of the mind as separate from the body, encouraging the complete involvement of the organism in understanding theoretical concepts.

In light of what has been discussed so far, the research explores the importance of purposeful gesture as a means to facilitate the understanding and assimilation of theoretical content, specifically in mnemonic processes. Previous studies have suggested that the conscious use of gesture during teaching and studying can lead to greater retention of information and a deeper understanding of abstract concepts (Cipollone et al., 2023).

The act of consciously managing one's body while learning can serve as a physical anchor for information, creating stronger connections in the neural circuits involved in memorization and understanding. This investigation aims to explore how purposeful gesture can be implemented to support semantic and visuospatial memorization processes. Through studies and observations, the intention is to analyze how students respond to the integration of purposeful gesture in lessons and how this influences the learning process, specifically in the mnemonic component. The implications of this research go beyond the classroom, laying the foundation for new educational approaches that take into account the close interconnection between body and mind.

The goal, therefore, is not only to highlight the effectiveness of purposeful gesture in embodied cognition but also to propose practical strategies for implementing this methodology in daily teaching.

3. Memory system and gesture

The accelerated development of mobile technologies and AR is revolutionizing the learning landscape, sparking interest in studying the learning processes associated with the use of AR through mobile devices such as smartphones and tablets. The A.T.E.N.A. project, aiming for a synergistic integration between such devices and AR, which overlays virtual elements onto the real world, aims to enhance the learning experience, hypothesizing an improvement in the memory system. In particular, attention is focused on analyzing the role played by manipulation through gestures performed on the virtual object, evaluating whether this methodology can make a significant contribution to deepen and enhance the learning process, especially at the mnemonic level (De Freitas, Piai, Farias, De Moraes, De Moraes Rossetto, & Leithardt, 2022). This approach is anchored in the principles of embodied cognition, which argue that actively involving the body during learning leads to more effective acquisitions.

A significant branch of gesture research has highlighted the positive impact of gestures on working memory. Numerous studies have indicated that gestures facilitate working memory, and this effect is observable in both internal and external tasks (Marstaller & Burianovà, 2016). The integrated approach of eye and hand movements has been shown to exert a selective and beneficial effect on visual working memory concerning specific goals, as revealed in previous research (Hanning & Jonikaitis, 2016; Ohl & Rolfs, 2018; Heuer & Crawford , 2017).This synergy between eye and hand movements appears to be guided by attention, as suggested by the associated attentional involvement during such movements (Hanning & Jonikaitis, 2016). In particular, the synergistic coordination between eyes and hands positively reflects on visual working memory, indicating a complex interaction between visual and motor systems (Hanning & Deubel, 2018).

In light of the above, the A.T.E.N.A. project aims to explore how the interaction between mobile devices, AR and the activation of gestures in terms of object manipulation studied can optimize learning, favoring mnemonic processes and pushing beyond the limits of conventional methodologies (Lim & Lim, 2020; Squires, 2018). It is hypothesized that the ability to manipulate 3D objects, explanatory of topics covered during lectures or individual study, may promote the memorization of information, relying on brain activation not only in the frontal and prefrontal areas but also in the motor cortex, the latter due to the integration of purposeful movement on the object. This synergistic activation between different areas necessarily involves increased brain communication, which facilitates various stages of the learning processes. The innovative approach proposed by A.T.E.N.A. could open new perspectives in the educational field, providing fertile ground for further research on the relationship between movements, mnemonic processes, and learning in the digital era.

4. From 3D models to A.T.E.N.A.

The practical and technological component of this investigation materializes in the generation of three-dimensional models for educational purposes. For the creation of such models, we used .GLTF files, which encapsulate a 3D model saved in the glTF transmission format. An advantageous aspect of this format lies in its ability to incorporate a comprehensive scene description in JSON format within the file, including node hierarchy, cameras, materials, and providing detailed information about animations and meshes. After being uploaded to the repository, the 3D models are invoked by a JavaScript script that associates them with ArUco markers. These markers can be easily used in web pages, presentations, PDFs, and any other digital or printed document. Their remarkable detectability through smartphone cameras, even under conditions of high angles or rotations relative to the vertical position of the device, constitutes an additional advantage. The binary encoding of these markers makes them particularly robust, allowing for error correction during the detection and decoding phase.

Once displayed on the student's smartphone through these markers, the 3D models become manipulable through touchscreen commands. The effect of visualizing a three-dimensional model in the immediate context of the surrounding reality amplifies attention towards AR integrated into the time and space dedicated to study. The choice of using ArUco markers proves particularly suitable for students due to their resilience in situations of rotation and perspective or trapezoidal distortion. These markers maintain their effectiveness even in low-light conditions, making the AR experience accessible in any context and moment, in line with the goal of making the research easily usable and accessible.

Considering variations in the student's position during the lesson, where the perfect perpendicularity between the device and the physical support is not always guaranteed, the choice of using these markers resolves any challenges and effectively aligns with the project's objectives. The embodied cognition approach emphasizes the importance of overcoming Cartesian dualism of mind and body, giving the body a central role in learning processes. This implies the need to make the AR experience overall experiential, endowing the models with scalability and rotation functionalities through touchscreen gestures, allowing for an information manipulation experience for learning. The use of the Aframe framework has made this implementation possible, enabling the easy manipulation of models. The overlay of the 3D model on the student's physical reality results in deeper engagement, transforming the learning experience into a highly emotional and engaging occasion, with positive effects on the internalization of concepts anchored in the surrounding reality.

5. Research Project: A.T.E.N.A.

This research is an evolutionary phase of a research project called "Augmented Didactic," which in-volved 296 students from the departments of Education, Psychology, and Engineering. In the previous research, a 40% of learning improvement was find out thanks to AR.

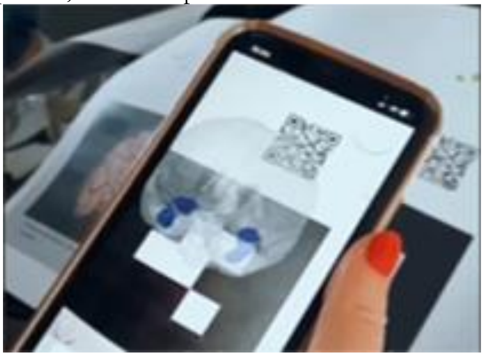
This research hypothesis is an extension of a previously conducted investigation that assessed the impact of manipulation on memory processes in general. For more information on the previous analysis, please refer to (Cipollone et al., 2023), where a general enhancement of mnemonic processes by 53% compared to a control group was observed. Having established that the possibility of manipulation has a significant impact on memorization, today we specifically investigate which component has a greater influence.

This research aims at exploring if the manipulation of 3D models through goal-directed gesture facilitates meaningful learning by enhancing the mnemonic component. Specifically, our research investigated two types of memory: semantic memory, which involves memory of concepts and their respective meanings, and visuo-spatial memory, which involves the perception of spatial relationships between objects or their parts, the orientation of stimuli, and the relationship between the person and the object (Nicoletti & Rumiati, 2011). Our goal was to understand if the possibility of manipulation could influence these two types of memories differently, as they are highly involved in learning processes.

5.1 Sample, methods and materials

The sample, composed by students of Niccolò Cusano University, was randomly divided into two groups, an experimental group of 51 subjects (from now on, referred as Manipulable) and a control group of 29 subjects (from now on, referred as Unmanipulable), both from Bachelor's Degree and Master's Degree of the Educational and Psychological Department. The proposed teaching activity was conducted by two different teachers through frontal explanation and the utilization of AR stimuli.. Specifically, the lesson involved the explanation of the neuronal correlates of certain cognitive functions, such as memory and language. AR was presented through qr code which, as in Figure 1, allowed to view the notions presented in class in 3D. The qr code has been inserted in the reference manuals of the subject of "Didactics and Neuroscience" (Peluso Cassese et al., 2022) and "General Didactics and Neurodidactics" (Peluso Cassese et al., 2023).

Figure. 1 AR, through qr code, on smarthpone



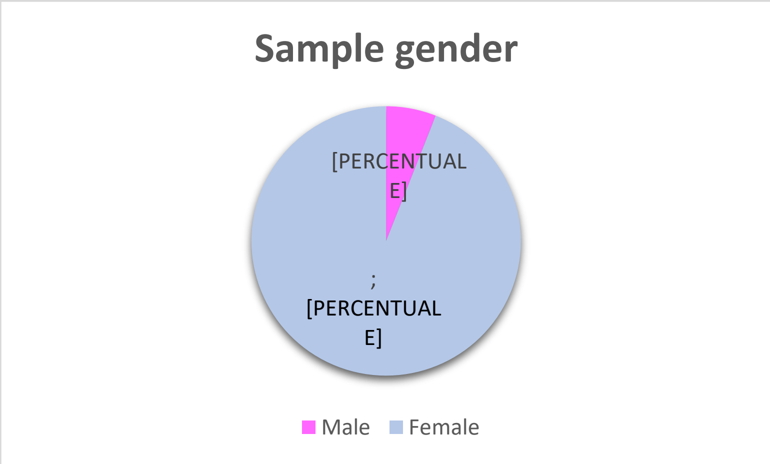
The experimental group was able to manipulate the brain in AR, touching the touchscreen to see it on different point of view. The control group, instead, was able just to see the brain in AR, without interacting with it.

A consent form and information sheet was provided to all participants. Pseudonyms have replaced the names of participants. Participants were given the opportunity to withdraw from the study at any time.

At an early stage of the trial, we administered the Rey Auditory Verbal Learning test (RAVLT), a mnemonic test used to exclude the presence of memory disorders within the sample, and a questionnaire about general personal information. No one had mnemonic disease so the sample taken into account was composed by 80 students. At the end of the activity, we administered to the two group a spontaneous recall questionnaire aimed at investigating the level of memorization of the concepts explained. The questionnaire was created based on a traditional free recall test and provided to the sample through a Google Form, which was accessed via a QR code. The test included a series of open-ended questions about the topics just explained, to which the sample had to respond without consulting any additional material, in order to assess the memorization of concepts. The questions investigated both the ability to memorize semantic content, such as "What is the role of the amygdala?" and visuospatial content, through questions like "Where is the hippocampus located?". The last question in the questionnaire presented an image of the brain, and students were required to identify the location of all the explained cerebral areas. A time limit was not set, and during the completion of the questionnaire, experimenters monitored to ensure that students did not access any additional material.

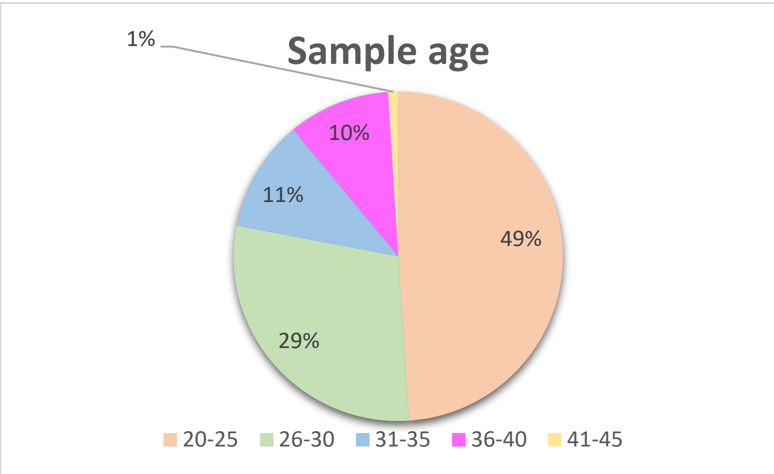
5.2 Results

Graph. 1. Sample gender



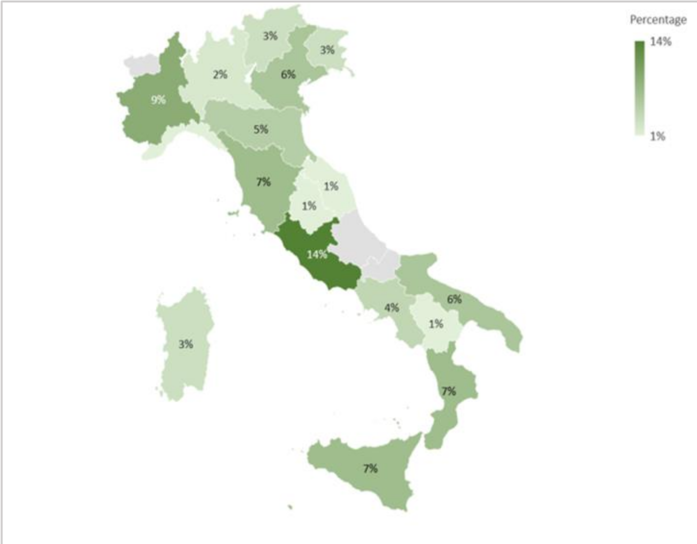
The sample displays a predominance of female subjects, accounting for 94%, while the percentage of male subjects is 6%, both from the Department of Education and Psychology at Niccolò Cusano University (Graph. 1).

Graph. 2 Sample age



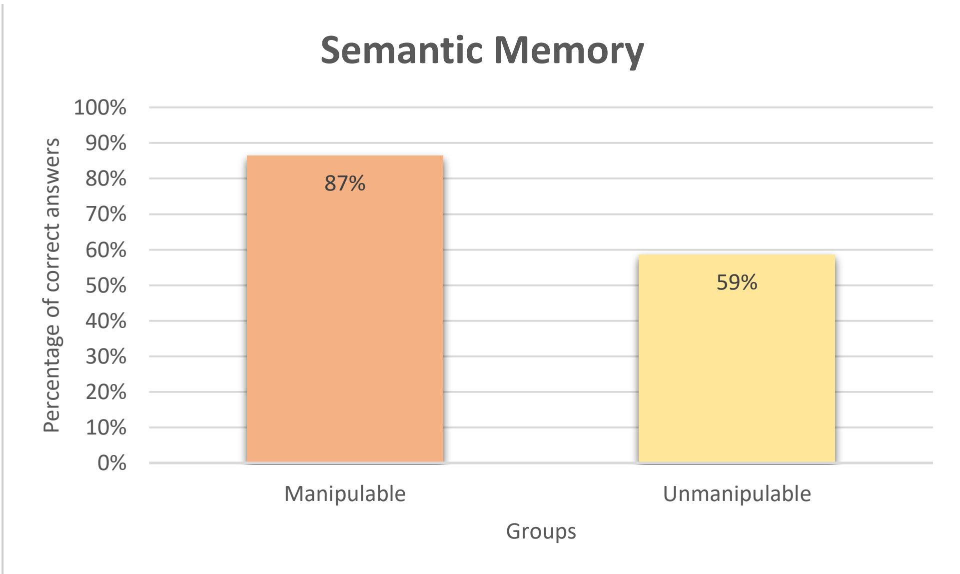
On the other hand, the sample is fairly distributed across age groups, with an average age of 27 years. (Graph 2).

Graph. 3 Sample origin



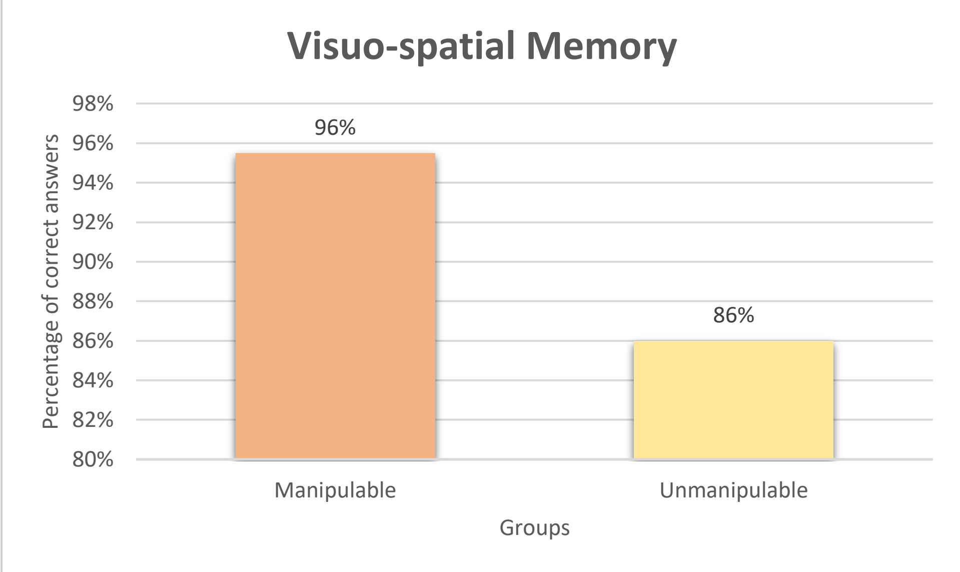
The sample has a heterogeneous origin from the north, central and southern Italy (Graph. 3).

Graph. 4 Percentage of memorization on semantic memory



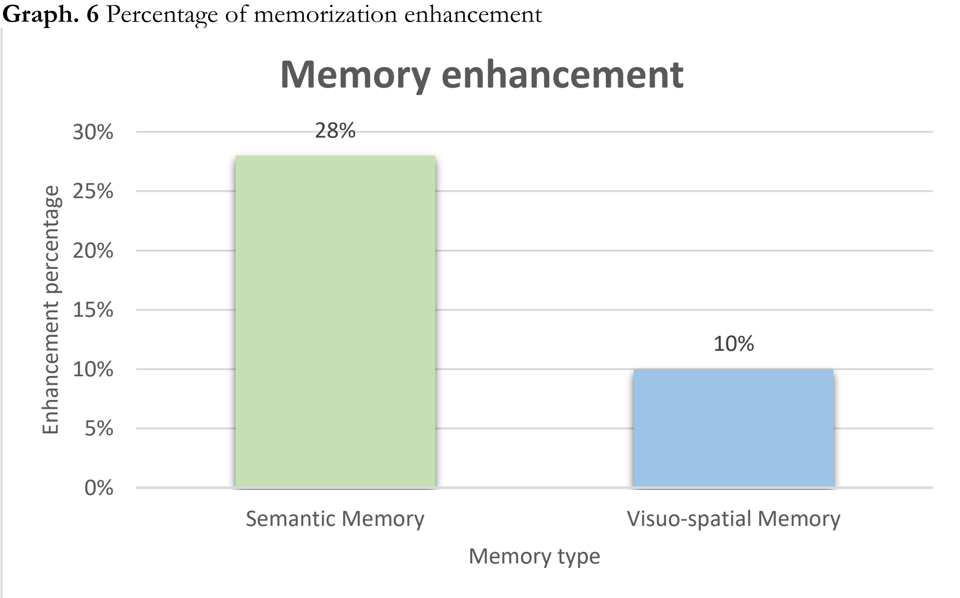
In Graph. 4 there are the results obtained by the two groups on the semantic memory level. To create this graph, we considered all responses to content-related questions, revealing the acquisition of information in semantic memory. As shown in the graph, the experimental group demonstrates better memorization, with 87% of correct answers, while the control group achieved only 59%.

Graph. 5 Percentage of memorization on visuo-spatial memory



The results regarding visuospatial memory are presented in Graph 5. In this case, the responses to questions related to visuospatial content and the final question about the visual localization of brain areas was used. Once again, the experimental group showed correct responses in 96% of cases, whereas the control group achieved 86%.This section may be divided by subheadings.

Graph. 6 Percentage of memorization enhancement



In Graph. 6, the memorization enhancement divided by the two type of memory was reported. In this case, the difference in memorization levels between the two experimental groups was analyzed. This summary graph highlights how there has been an actual enhancement of the two mnemonic processes, specifically 28% on the semantic memory and 10% on visuo-spatial memory. As evident, in both cases, the experimental group benefited from the ability to manipulate the stimulus.

5.3 Data analysis

In this section, the descriptive statistics and details of the data analysis were reported. In order to perform the statistical analyses, JAMOVI software (version 2.3.26) was used.

Table. 1 ***Groups descriptives***

Groups descriptives

Groups	N	Average	Median	Variance	SD	SE
Unmanipulable	29	19.5	22.0	30.3	5.51	1.02
Manipulable	51	27.1	29.0	14.3	3.78	0.529

The above Table 1 displays descriptive statistics for the experimental group, labelled as Manipulable (N=51), and the control group, namely Unmanipulable (N=29). Specifically, the variability indices are shown. As indicated in Table 1, the groups exhibit unequal variances, necessitating the utilization of Welch's t-test to investigate the research hypothesis. The Welch's t-test, also known as the t-test for unequal variances, is a two-sample location test employed to assess a null hypothesis that assumes equal means in two populations with different variances. This test involves a qualitative independent variable (A.T.E.N.A. Methodology) with two categories: Unmanipulable and Manipulable. The necessary conditions for applying the test were met in the current study. Specifically, each statistical unit represented a distinct subject (independent observations); the dependent variable followed a normal distribution in the population (normality); and the variance of the dependent variable differed between the groups (heteroscedasticity).

The data underwent analysis using the Welch's t-test to compare results between the control and experimental groups. A significance level (α) of $p < 0.05$ was selected, signifying that statistical significance was considered when the p-value was less than 0.05.

Table. 2 Welch's t test

Welch's t test

DoF	statistics	p	effect size	
43	6.5973	0.0001	Cohen's d	1.7

As depicted in Table 2, the test statistic T is 6.5973, surpassing the critical value range of [-2.021:2.021], thereby signifying the significance of the observed difference.

Furthermore, Cohen's d was employed to assess the effect size for the pairwise comparisons. The effect size index is classified as small ($0.20 \leq d < 0.50$), moderate ($0.50 \leq d < 0.79$), or large ($d \geq 0.80$). In this context, the index is large ($d = 1.7$), indicating a substantial impact of the independent variable (methodology) on the dependent variable, represented by learning outcomes.

The null hypothesis posits no statistically significant differences between the two groups, while the alternative hypothesis suggests the presence of statistically significant differences. Given that the p-value < α, we reject the null hypothesis. The average of Group-1's population is deemed unequal to the average of Group-2's population. This implies that the difference between the sample averages of Group-1 and Group-2 is statistically significant. Additionally, the p-value falls below the level of significance (α) ($p < .00001$), indicating an extremely statistically significant difference. Consequently, the sample data support the acceptance of the experimental hypothesis.

6. Discussion

The digital transformation in education, adapting continuously to emerging technologies, stands at the core of educational evolution. A.T.E.N.A. plays a pivotal role as a bridge between traditional pedagogical methodologies and digital progress. The use of AR emerges as a crucial educational tool, enhancing educational offerings and enriching learning approaches. The integration of technological and digital tools in the educational context goes beyond device usage; it aims to create a learning environment in harmony with students' culture. This connection makes learning more engaging and relevant, allowing students to apply knowledge meaningfully in their daily lives. In this process, students can generalize acquired notions, providing deeper meaning to overall learning (Lembo, Cipollone , Oliva & Monteleone, 2023) (Cipollone E. , Lembo, Oliva, & Peluso Cassese, 2023) (Peluso Cassese & Lembo, Manuale di didattica generale e neurodidattica, 2023).

Additionally, the educational approach has undergone significant changes within the realm of embodied cognition, a theory that considers the human body and its actions as natural aspects of learning and fundamental for understanding abstract concepts (Gomez-Paloma, Angelino, Pastena, Raiola , Lipoma, & Tafuri, 2016). In this context, purposeful gestures have emerged as a key element in making theoretical content more accessible and meaningful. This research focuses on the importance of such gestures in facilitating the understanding and assimilation of content, especially in mnemonic processes. Previous studies have suggested that conscious use of gestures during teaching can improve information retention and understanding of abstract concepts (Cipollone E. , Lembo, Oliva, & Peluso Cassese, 2023). The coordination between eye and hand movements has shown to positively influence visual working memory, suggesting a complex interaction between visual and motor systems (Hanning & Deubel, Independent affects of eye and hand movements on visual working memory, 2018) (Imenkamp, 2022). In light of this evidence, it was hypothesized that manipulating 3D objects during lessons can enhance memorization, involving not only frontal and prefrontal areas but also the motor cortex, thanks to the integration of object-focused movement.

Specifically, the aim was to verify whether manipulable AR had a different impact on semantic memory and visuo-spatial memory, two central elements in the learning processes. Particularly in the use of AR, research highlights how it positively affects visuo-spatial memory, thanks to the ability to view stimuli in 3D. In this context, the investigation sought to determine whether, in addition to enhancing visuo-spatial memory, viewing and manipulating stimuli in 3D had any influence on semantic memory.

The results highlighted an improvement in both types of memory. This outcome was consistent with expectations, confirming our research hypothesis. The data analysis revealed a statistically significant improvement facilitated by the manipulation opportunity, with a p-value $< .00001$. This value strongly indicates the potential of the presented methodology.

A very interesting finding was the difference in memorization between visuo-spatial memory and semantic memory. Indeed, as revealed by the data, visuo-spatial memory was less enhanced by manipulation compared to semantic memory. This result could be attributed to the fact that the control group still viewed the stimuli in AR, and this, in itself, already affects visuo-spatial memory, aligning with existing literature (Imenkamp, 2022). Instead, these data seem to suggest that the manipulation variable has a greater impact on semantic memory. These results could be attributed to the central role of purposeful gesture, which is a key element in making theoretical content more accessible and meaningful. Literature tells us that conscious use of gesture during teaching can improve information retention and understanding of abstract concepts (Altmeyer, Kapp, Thees, Malone, Kuhn, & Brunken, 2020) (Buchner, Buntins, & Kerres, 2022) (Cipollone E. , Lembo, Oliva, & Peluso Cassese, 2023) (Gargrish, Mantri, & Deepti , 2020). Thus, this could positively influence especially semantic memory, thanks to the role of gesture aiming to harness the potential of motor acts and, consequently, brain activation at the motor cortex level, generating more synaptic connections to support the learning process.

Certainly, this data does not allow us to establish a stable connection between semantic memory and manipulation in AR. This research was conducted on a university sample, mainly composed of female subjects from almost the entire national territory, affiliated with only two university faculties. Additionally, the educational activity focused on a specific topic and was carried out by only two different instructors, with a sample size too small to establish a stable connection between the variables under consideration. Therefore, this research can be considered a starting point, but it becomes necessary to replicate it, adjusting the methodology and expanding the sample.

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7. Conclusions

In light of this and the emerged results, the research hypothesis can be confirmed: the manipulation capability offered by the use of AR within the A.T.E.N.A. methodology enhances the memorization both on visuo-spatial and semantic level.

A.T.E.N.A. once again demonstrates itself as an innovative and contemporary methodology, keeping pace with the rapid changes that technology is bringing to education.

The digital transformation in education, facilitated by tools like A.T.E.N.A. and AR, enhances learning experiences by integrating technology into traditional pedagogies. The emphasis lies on prioritizing the student's central role in the educational process, acknowledging them as a collaborator in their learning journey. Most importantly, the student is viewed holistically, not fragmented into separate elements such as mind and body but considered as an integrated entity. This strategy leverages the full potential of an Embodied pedagogy. Consequently, guided by these principles, the capacity to interact with educational stimuli using AR becomes a cornerstone of the progressive A.T.E.N.A. approach. It stands as an extra asset for fortifying the student's memory retention and overall learning experiences.

This research highlights the importance of purposeful gestures in making theoretical content more accessible: manipulation of 3D objects in AR positively influences both semantic and visuo-spatial memory, with a significant enhancement demonstrated. Notably, this study suggests a stronger impact on semantic memory, emphasizing the need for further research with an expanded and diverse sample to validate these findings and draw more conclusive connections.

It is our intention to continue with the research in order to explore all the possibilities and potentialities that this new methodology can offer, being aware of the need for multidisciplinarity. Specifically, our goal is to explore: (1) other age groups; (2) other cognitive components involved in learning; (3) other faculties or subjects in which to apply the methodology.

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