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Perceiving Etruscan Art: AI and Visual Perception

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Abstract: This research project is aimed at exploring the cognitive and emotional processes involved in perceiving Etruscan artifacts. The case study is the Sarcophagus of the Spouses at the National Etruscan Museum in Rome, one of the most important masterpieces in pre-Roman art. The study utilized AI and eye-tracking technology to analyze how viewers engaged with the Etruscan Sarcophagus of the Spouses, revealing key patterns of visual attention and engagement. OpenAI, ChatGPT-4 (accessed on 12 October 2024) was used in conjunction with Colab–Python in order to elaborate all the spreadsheets and data arising from the eye-tracking recording. The results showed that viewers primarily focused on the central figures, especially on their faces and hands, indicating a high level of interest in the human elements of the artifact. The longer fixation duration on these features suggest that viewers find them particularly engaging, which is likely due to their detailed craftsmanship and symbolic significance. The eye-tracking data also highlighted specific gaze patterns, such as diagonal scanning across the sarcophagus, which reflects the composition's ability to guide viewer attention strategically. The results indicate that viewer focus centers on human elements, especially on faces and hands, suggesting that these features hold both esthetic and symbolic significance.

Keywords: Etruscan art; AI; neuroesthetics; Sarcophagus of the Spouses; visual perception; eye tracking

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1. Introduction

The term "art object" is defined in a complex and multifaceted manner within the field of material culture [1]. An art object, as defined from a neuroesthetic perspective [2,3], is any artifact that elicits an esthetic response in the observer [4], whether it be a functional object, painting, or sculpture [5]. This response activates brain regions that are involved in reward processing, such as the orbitofrontal cortex and nucleus accumbens, as well as those that are involved in affective processing and self-referential thought [6–8]. Nevertheless, historical and cultural factors have an impact on the definition of an art object. In certain cultural contexts, artifacts may serve as tools, while in others, their principal function may be symbolic or decorative. The cultural milieu in which an artifact is produced and utilized may influence the extent to which individuals regard and appreciate it as an artistic work [9,10].

The subjective evaluation of an art object's esthetic attributes, such as beauty, originality, or technical proficiency, may be a factor in its cognitive characterization. The evaluation is contingent upon the observer's prior knowledge and experiences, as well as their personal preferences and biases. Potential cognitive processes that contribute to the evaluation of an artwork include the assessment of technical quality, the interpretation of its symbolic or metaphorical significance, and the comparison of the object to prior experiences or expectations.

This paper expands the research work on "neuroartifacts" [11] discussed by Giorgi et al. 2023 [12], whose paper was focused mainly on the comparative analysis of artifacts in the museum and in virtual reality using EEG and neurophysiology.

The present research work is focused on the use of eye tracking and AI and a neuroesthetic re-interpretation of the artifact. The main research question relates to the possible

correlation between human perception during the original contextualization of the sarcophagus and contemporary observation by museum visitors [12].

2. The Etruscan Sarcophagus

The case study concerns an iconic and important masterpiece of Etruscan funerary art from about 530-510 BCE: the Sarcophagus of the Spouses [13–15], which is currently on display at the National Etruscan Museum of Villa Giulia in Rome. The artifact is displayed in a separate section of the museum to provide visitors with enough space for a full visual experience from any spatial perspective [16]. The original archeological discovery of this artifact [17] does not allow for a precise identification of its location: it is mentioned in old reports as the eastern necropolis of Cerveteri ("scavi Boccanera", 1874, 1877, 1881 [18]), but the exact topography is unknown [18]. However, it is possible to reconstruct approximately the original context: the sarcophagus was placed inside a funerary chamber in a tufa-block tomb similar to other cases in Cerveteri and in Etruria [15,19].

The artifact is reconstructed from approximately 400 fragments, and it was an urn designed to contain the physical remains of the deceased. It depicts a couple in the traditional banquet position, with their busts raised in front of them while reclining on a bed (*kline*). The man envelops the woman's shoulders with his right arm, bringing their faces in proximity while they maintain their characteristic "archaic smile." The configuration of the woman's fingers and hands implies the potential existence of now-lost objects, such as a miniature vase utilized to pour precious perfume or a cup for sipping wine. This iconography is recurring in Etruscan funerary art, and it recalls a traditional banquet in which a couple showed their symbolic aristocratic power that would be perpetuated in life and death. Because of that, the scene symbolizes the transitional period in between life and the after-life that creates a very specific visual consumption of the artifact (Figure 1). For this reason, it is very likely this tomb was open at specific periods of the year (anniversaries, celebrations, and rituals) in order to allow visitors to celebrate the iconography of this couple. The main scope was to perpetuate power and the symbols of this aristocratic family during and after life for generations.

Figure 1. The Sarcophagus of the Spouses at the National Etruscan Museum of Villa Giulia in Rome.

It is particularly important to emphasize that the comprehension of the sarcophagus depends mainly on its affordances [20], which describe multiple relationships with its original context and its ritual boundaries.

2.1. Methods and AI Approach

I use the concept of "affordance" as developed by the psychologist James J. Gibson and, more recently, by T. Ingold in archeology [21–23], as actionable possibilities that an object or environment offers to an organism, specifically those that are directly perceived. According to Gibson, affordances are properties of the environment that are objectively measurable but are also relative to the abilities of the individual. Gibson's affordance theory emphasizes direct perception without necessitating complex cognitive processing. Here, affordance serves as an interpretative tool, providing insight into how the artifact's visual and spatial elements may have guided ancient interactions and how they influence modern viewers [1].

Gibson's concept of affordance emphasizes direct perception—meaning that humans perceive affordances without the need for complex cognitive processing. The interpretation of an artifact "by affordances" is implicitly connected to its performing power or embodied action. Whereas affordances address "what it is about", taxonomy addresses "what it is". This is a significant distinction, because it emphasizes interpretation over the embodied contact between an object and its viewer/user and may reveal the thought process that went into creating a particular piece of art. In the case of an artifact, the affordance designs its symbolic meaning in space and time. For example, a specific affordance can be identified only during a ritual activity, and it can change or transform significance at the end. In other words, each affordance is transitional because it can recontextualize the human–object interaction in multiple ways [24,25].

Gibson defined affordances as higher-order invariant properties that can be specified in measurable, mathematical, and kinematic terms, rooted in the direct pick-up of information from the environment. Affordances provide perceivers with immediate, actionable information about their environment without requiring complex cognitive processes. In this study, we approach affordance not as an undefined perceptual quality but as a structured concept that describes specific, context-bound possibilities for interaction with the artifact. Affordances, in Gibsonian terms, must be understood as invariant properties that emerge from the relationship between the observer and the object, rather than broadly encompassing any perceptual interaction. For instance, affordances may include directional gaze cues or gestures that suggest interaction, which we interpret through both eye tracking and AI simulations.

This study incorporates AI prompts and Python coding for data processing and visualization, which were essential in analyzing eye-tracking data and mapping gaze directions onto the artifact. Using OpenAI's language model with Python, we generated data simulations to interpret viewer focus areas and to visualize patterns in their gaze fixations. The prompts guided the AI to organize, analyze, and map eye-tracking data onto specific regions of the artifact, such as the faces and hands. Python coding facilitated precise data processing, enabling the creation of visual representations (e.g., heatmaps and vector representations) for detailed analysis.

AI prompts and Python coding are valuable tools in eye-tracking studies, enhancing data processing, analysis, and visualization. Python enables researchers to efficiently handle large eye-tracking datasets using libraries like Pandas and NumPy for data manipulation, while Scipy and Statsmodels support statistical analyses of gaze metrics. Visualization libraries such as Matplotlib and Seaborn allow the creation of heatmaps, fixation plots, and trajectory maps, making it easy to interpret visual attention patterns on specific stimuli. AI prompts streamline this process by generating code snippets, automating repetitive tasks, and offering suggestions for data filtering, AOI (area of interest) segmentation, and the customization of visualizations. By using AI models, researchers can quickly develop and troubleshoot Python code, making analysis pipelines more efficient and accessible. Altogether, Python and AI prompts enable streamlined workflows and deeper insights in eye-tracking research, from data import to visualization and automated analysis.

This process allows us to observe patterns without manual bias, leveraging AI's ability to automate data visualization and enhance analytical accuracy.

2.2. Affordances and Observations

Gibson's theory allows us to identify and analyze these affordances in a quantifiable way, linking them to specific features like the gesture of embracing or the gaze direction of figures on the sarcophagus. This rigorous application of affordance theory highlights how the artifact's design directly shapes perceptual engagement. The theory of affordances complements the concept of embodied simulation in neuroesthetics, where viewers experience a sense of engagement or empathy by simulating the actions, emotions, or intentions depicted in the artwork. Affordances in an artwork can encourage this simulation by presenting cues that suggest interaction, such as reaching, touching, or gesturing.

The observation of an object's affordance might activate neurons correlated with a specific object's affordance or with multiple affordances according to the use and the context. For example, a toy can be used differently in relation to specific narratives or different games. In short, space, time and context can determine the result of the affordance and the meaning of an object. In these terms, we can see the performing power of an artifact as a "transitional" object from its creation to its consumption.

The museum's isolation of the sarcophagus can enable a more precise analysis of its features from various perspectives and prolonged visual observation. However, is this sufficient for a correct interpretation? What are we overlooking in this unguided process?

As mentioned, the sarcophagus is a performing object showing the aristocratic power of a couple in a transitional space, in between life and death. Second, the social context, the banquet/fest, makes these human actors the core of a hypothetical scene in which we should imagine music, sounds, food, beverages, dances, and much more, as documented in several Etruscan painted tombs [13,14]. The functionality of the sarcophagus as an "urn" is hidden by the symbolic iconography that embodies the couple in a spatial projection of gestures and actions. The attitude of the statues to observing and being observed interacts with an imaginary audience standing in front of them. The quality and complexity of this artwork required visual interactions with the public at the time of the funeral but also during periodic visits to the tomb. In this way the artifact becomes both the subject and object of observation: the "spouses" watch a scene, and they are watched as well.

In fact, the gazes of the male and female figures are different, and they interact differently with the surrounding space.

The vector representation in this study models gaze direction by assigning coordinates and orientations to key features on the artifact, particularly on the male and female figures. Each gaze vector is calculated based on the estimated 3D positions of the eyes, using a coordinate system where

- the X-axis indicates the horizontal orientation (left to right),
- the Y-axis represents the vertical orientation (top to bottom), and
- the Z-axis projects depth or the forward–backward axis relative to the viewer.

The male and female figures' gaze vectors were generated by estimating the angle and orientation of each eye relative to the artifact's front view, capturing directed gaze points that suggest focal points or intended visual interactions within the sculpture. This directed orientation allows us to interpret whether the figures' gazes create visual engagement with specific audience viewpoints. To ensure accuracy, we validated the directed gaze orientations of both figures by cross-referencing the eye-position estimates and applying a forward tilt to the Z-axis, which approximates how the gaze might align from a slightly downward angle. This verification step ensures that the gaze vectors provide meaningful data on viewer–object interactions as intended in the original artifact design.

The calculation of the eye gaze of the male and female figures' 3D gaze directions for each eye, considering a slight forward direction on the Z-axis, is the following (Figure 2):

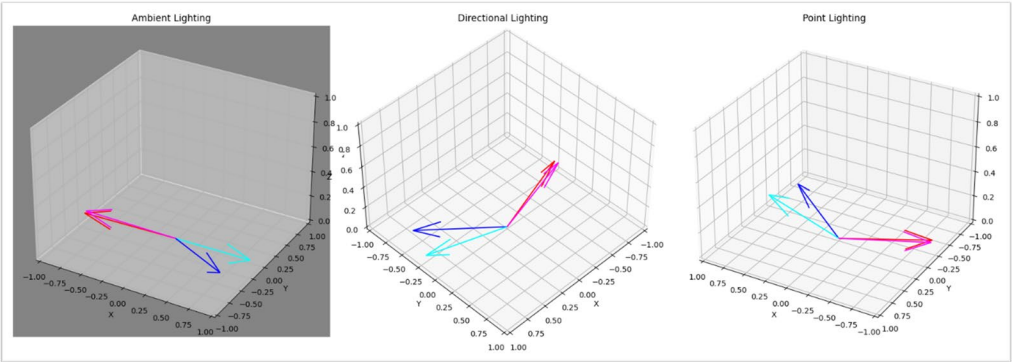

Figure 2. Gaze direction of the male (pink) and female's eyes (light blue and blue) by OpenAI, ChatGPT-4 (accessed on 12 October 2024) via Python coding. This calculation was made on the basis of the 3D model of the sarcophagus. The arrows indicate the gaze direction of each eye for the male and female figures. Each arrow's orientation (i.e., the direction it points to) shows where each eye is directed to in 3D space relative to the sarcophagus. The length of each vector represents the magnitude of the gaze, showing the relative focus distance.

Female figure:

Left eye: Approximately [0.828,−0.552,0.100][0.828, −0.552, 0.100][0.828,−0.552,0.100], indicating a gaze direction slightly to the right, downward, and slightly forward.

Right eye: Approximately [0.976,−0.195,0.100][0.976, −0.195, 0.100][0.976,−0.195,0.100], indicating a gaze more to the right, slightly downward, and slightly forward.

The female figure's gaze is slightly upward and to the right, which could suggest attentiveness, curiosity, or contemplation.

Male figure:

Left eye: Approximately [−0.965,−0.241,0.100][−0.965, −0.241, 0.100][−0.965,−0.241,0.100], indicating a gaze direction slightly to the left, downward, and slightly forward.

Right eye: Approximately [−0.976,−0.195,0.100][−0.976, −0.195, 0.100] [−0.976,−0.195, 0.100], indicating a gaze more to the left, slightly downward, and slightly forward.

***X*-axis**: Horizontal positioning: from **−1.0** (far left) to **1.0** (far right). A value of **−0.5** on this axis, for instance, would mean that the gaze is directed slightly to the left, whereas **0.5** would mean that it is slightly to the right.

***Y*-axis**: Depth or forward–backward positioning. A **−1.0** value here means that the gaze is directed closer to the viewer (or toward the front), while **1.0** means that it is directed further back or deeper into the scene.

***Z*-axis**: Vertical positioning: from **−1.0** (bottom) to **1.0** (top). A positive Z value, like **0.5**, suggests an upward gaze, while a negative Z value, like **−0.5**, indicates a downward gaze.

The male figure's gaze is slightly upward and to the left, suggesting some type of engagement. It may imply a dynamic interaction with his surroundings or a person nearby.

These vectors provide an approximation of the gaze directions in three dimensions based on the estimated pupil positions and a forward tilt on the *Z*-axis. The different gaze directions create visual balance and harmony in the composition, guiding the viewer's eyes across the sculpture. This makes the artwork esthetically pleasing and reinforces the interaction between the figures. By presenting figures with varied gazes and expressions, the artist adds depth to the narrative, allowing multiple interpretations and engaging the viewer's imagination.

Ritual boundaries designed the performing space surrounding the sarcophagus, in which we can identify the main visual region of interest and the space for its affordances. Figure 3 simulates the hypothetical boundaries around the sarcophagus (oval in the central part), where different colors differentiate the main visual entanglement based on the intensity of the visual interaction. This suggests that the viewers' gaze is most concentrated on the sarcophagus itself, with attention gradually diminishing as it moves away from the central object.

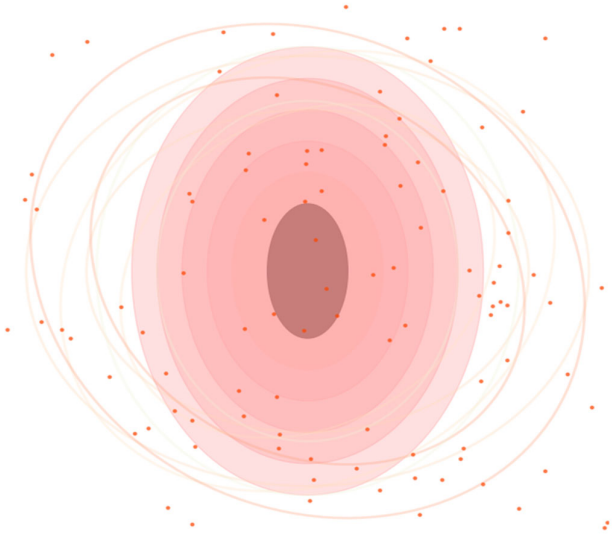

Figure 3. The "aura" of the sarcophagus is depicted with varying degrees of visual attention. The sarcophagus (darker oval) in the center of the funerary chamber is simulated by this AI visual reconstruction (OpenAI, ChatGPT-4 (accessed on 12 October 2024)) based on the intensity of visual interaction. The red dots concern the sounds and acoustic engagement during funerary rituals.

The glowing aura consists of concentric ellipses with gradually shifting colors that pulse over time, symbolizing the ritual–symbolic space surrounding the sarcophagus. Patterned boundaries are formed by ellipses rotated at various angles and in different colors, slowly rotating and changing opacity to represent the ritual boundaries and the passage of time. The dots, distributed both within and outside the ovals, likely represent individual fixation points or areas where viewers' eyes paused. The concentration of dots is higher near the center, aligning with the idea that the sarcophagus itself attracts the most attention.

Below is a list of the main sarcophagus' affordances (Figure 4):

- The act of hugging. This shows the feelings and proximity of the couple. It also unifies the two bodies into one single entity.
- Facial expressions. The two faces (male and female) characterize sex and the eye gazes of the main actor of this scene. They apparently look for eye contact.
- Eyes. The man and the woman's eyes look at different directions, with the intent of engaging a visual connection with different audiences, as discussed above.
- The empty hands. The hands are empty, but they were originally holding cups or other ritual objects. This gesture projects the harms into an imaginary space.
- The two bodies merge into a single shape, which affects the perception of the scene, where the observers are forced to imagine one single body.
- The different feet: bare feet for the man, shoes for the woman.
- Clothing.

Next step of the affordances' analysis was to try a graphic Python simulation through OpenAI, ChatGPT-4 (accessed on 12 October 2024), starting from the original image of the sarcophagus. The results are shown in Figure 4.

The chart emphasizes both individual features (faces, headdresses) and shared elements (pose, decorative features), reflecting the dual nature of the sarcophagus as.

- Hierarchy of detail: The size and placement of affordance areas suggest a hierarchy of importance, with the faces and overall pose being primary focus points.
- Gender distinctions: Differences in headdresses and, potentially, clothing highlight gender-specific aspects of Etruscan culture.

- Symbolic and practical elements: The chart balances elements with symbolic significance (gestures, pose) and those with more practical cultural information (clothing, style, decorations).
- Holistic cultural view: When considered together, these features provide a comprehensive view of Etruscan elite culture, beliefs about death, artistic conventions, and social structure.

The different affordances of the sarcophagus represent various aspects of cultural, social, and symbolic significance. The sarcophagus defies straightforward classification, and upon closer inspection, one feels observed. As an essential element of the initial communicative principle, the gaze of the statues intersects with the symbolic–funeral function of the artistic endeavor.

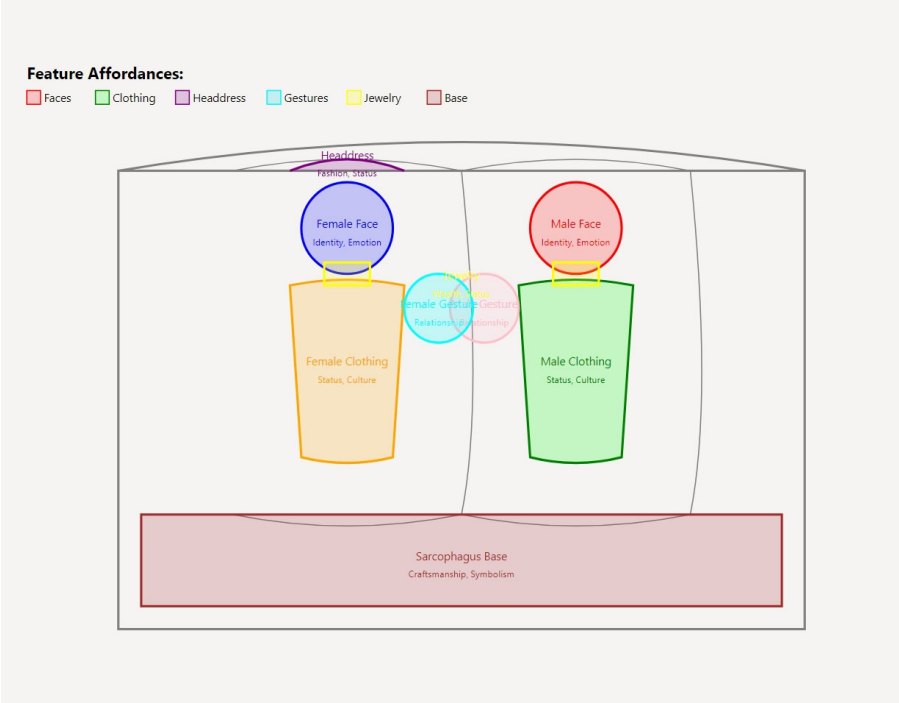

Figure 4. Graphic reconstruction of the featured affordances based on AI identification (OpenAI, *ChatGPT-4* (accessed on 12 October 2024). The schematic graph shows how different elements of the artifact interact with its audience.

3. The Eye-Tracking Experiment

Eye tracking has been a valuable instrument in the fields of neuroesthetic research and art perception, as it enables researchers to examine the ways in which individuals visually interact with artworks and which elements captivate their attention. Researchers can gain a deeper understanding of the cognitive and perceptual processes of observers by monitoring eye movements. This allows them to investigate the factors that attract attention and the way visual information is processed during esthetic experiences.

Yarbus (1967) conducted a groundbreaking study that demonstrated the potential of eye tracking to disclose the gaze patterns of viewers when they viewed intricate images, such as paintings. He discovered that the queries posed to viewers had an impact on their gaze, indicating that the cognitive context influences our perception of art. This principle established the foundation for comprehending the impact of cognitive and emotional states on perception when witnessing art [26].

Locher, Krupinski, Mello-Thoms, and Nodine [27] investigated the perceptions of individuals regarding representational and abstract art. Their findings indicated that representational artworks elicited more structured gaze patterns, whereas abstract art permitted more unrestricted exploration. This discovery implies that the nature of the artwork itself

influences perceptual processing, with representational art promoting open-ended viewing experiences and abstract art encouraging viewers to focus on key visual cues. Based on the mirror neuron theory, Freedberg and Gallese (2007) [3] posited that the act of observing gestures and expressions in art activates similar motor processes in the brains of viewers, as if they were experiencing the gestures themselves. This theory has been substantiated by eye-tracking studies, which demonstrate that viewers tend to concentrate on expressive features in art, such as faces or hands. This suggests that eye movements are a physical response to the emotions and actions depicted in artworks. Heidenreich and Turano (2011) [28] conducted an investigation into the duration of time individuals spent observing various components of paintings. They discovered that individuals have a natural inclination to focus on human figures and features, resulting in extended viewing periods. This temporal focus is consistent with the notion that viewers are attracted to elements that convey emotive or narrative content, which are essential components of the esthetic experience. Eye tracking was employed by Massaro, Savazzi, Di Dio, Freedberg, Gallese, and Gilli [29] to investigate the impact of visual features such as symmetry, proportion, and implied motion on gaze patterns in response to classical sculptures. Their research demonstrated that spectators were attracted to symmetrical and balanced elements, which serves as evidence that the perceptual properties of an artwork are essential for esthetic engagement. The research established a correlation between perceptual affordances and neural responses, demonstrating that eye tracking can be utilized to comprehend neuroesthetic responses to the structural characteristics of artworks.

These studies demonstrate that eye tracking provides valuable insights into the visual engagement of individuals with art. Researchers can infer cognitive and emotional responses, examine cultural and personal influences, and comprehend how viewers' attention is directed by features such as symmetry, implied motion, or facial expressions by capturing gaze patterns. This method is consistent with neuroesthetic theories that suggest that the esthetic experience is rooted in perceptual and motor processes. It demonstrates that eye tracking offers a potent perspective on how viewers perceive and experience art.

In this eye-tracking experiment, 18 participants (10 females, 8 males; mean age = 30.76, SD = 12.78) were exposed to the artwork at the National Museum of Villa Giulia (Figures 5 and 6 [12]). They observed the artifact for 60 s at the distance of circa 2 m from the museum case (front side of the sarcophagus) under the same lighting conditions. The museum room used the same light settings for the duration of the experiment.

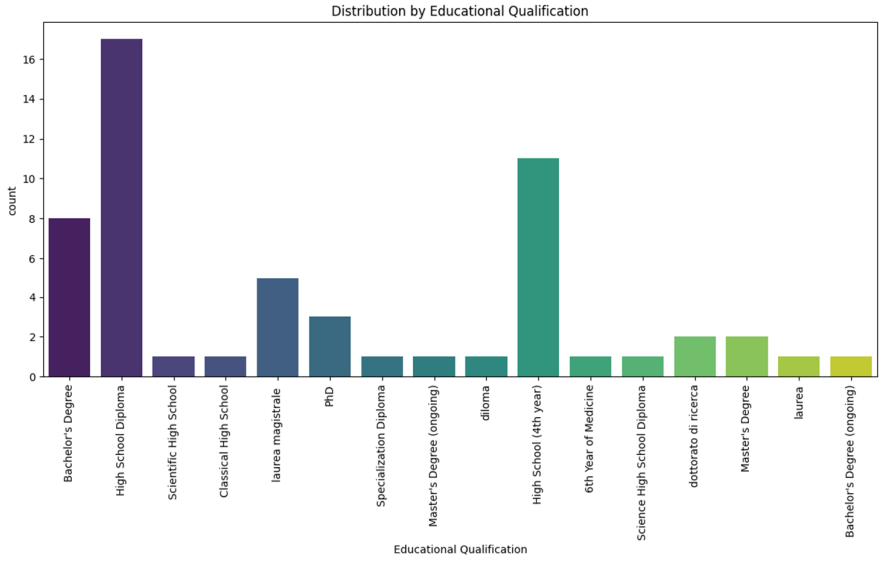

Figure 5. Participants distributed by background and education.

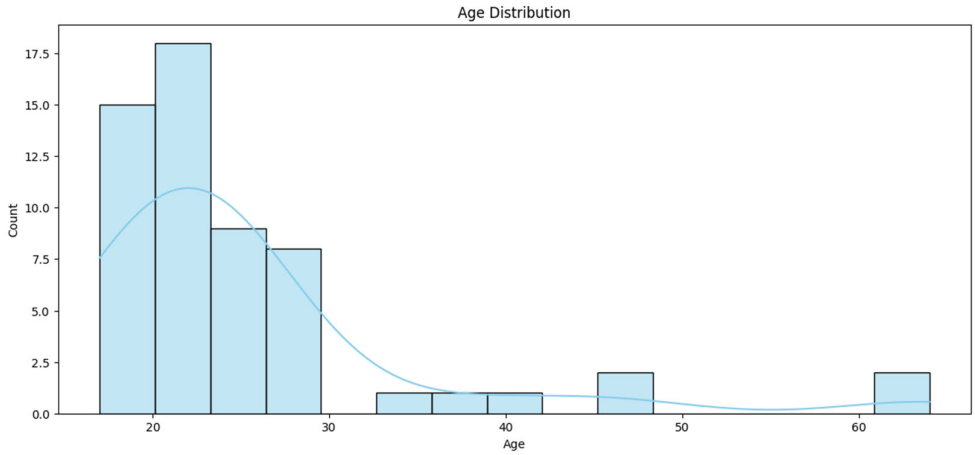

Figure 6. Participants distributed by age.

The esthetic and visual study of the artifact by affordances is important for cultural and artistic contextualization, but it should be also compared with scientific and more empirical experiments based on contemporary human observations. For achieving this goal, eye-tracking analysis is a powerful and effective tool. In fact, eye tracking [30] involves precisely measuring and recording the movement of a person's eyes as they examine an artifact or artwork, typically using specialized cameras, tools, and software [31]. In the context of archeological artifacts and artwork, eye tracking allows researchers to understand several key aspects of visual interaction:

- Gaze patterns: These reveal which specific areas of an artifact or artwork attract the most attention, showing how viewers navigate the object visually.
- Fixation duration: The technique measures how long an observer's gaze remains fixed on features, indicating areas of heightened interest or complexity.
- Saccades: These rapid eye movements between fixation points can show how viewers connect different elements of the artifact or artwork.
- Scan paths: The overall sequence of eye movements provides insight into how individuals construct their understanding of the object.
- Areas of neglect: Eye tracking can also reveal which parts of an artifact or artwork receive little to no attention.

Eye-tracking studies can inform museum curation strategies, helping to optimize the display of artifacts for maximum engagement. In archeological research, it can aid in understanding how ancient viewers might have interacted with artifacts or structures, providing clues about their intended use or significance. Moreover, when combined with other cognitive research methods, eye tracking can offer insights into the cognitive processes involved in artifact interpretation, esthetic appreciation, and the formation of historical narratives. In essence, eye tracking serves as a bridge between the physical attributes of archeological artifacts or artworks and the cognitive processes of those who observe them, offering a unique window into the complex interaction between viewer and object in the realm of cultural heritage. Experiments conducted at the National Etruscan Museum, visual observations, and statistical data analysis of the gathered data, are evidently essential for resolving the research questions that have been posed thus far. In this case, the experiment involved 42 human subjects observing the sarcophagus for 60 s from the same distance and from the same position. The device Pupil Invisible [32] was used for all the experiments. It resembles a pair of glasses and uses cameras positioned near the eyes to capture gaze data without obstructing the wearer's view. The device leverages infrared illumination to track eye movements accurately in real-world settings, providing data on fixation points, saccades, and gaze paths. It connects to a smartphone for real-time data recording and analysis, allowing researchers to conduct mobile, hands-free studies across diverse environments. It has an accuracy of 4.6° (uncalibrated) and a Scene Camera of 1088 px 1080 px @30 Hz;

H: 82°, V: 82°. It is equipped with two 2 × IR eye cameras of 192 × 192 @200 Hz. While this fixed perspective aids in data standardization, it might limit the study's alignment with some instance of the affordance theory, which emphasizes perception in motion. We acknowledge that affordances, as dynamic properties, often require observer motion to fully engage with an artifact's interaction possibilities. In this experiment, however, the static observation setup was chosen to provide controlled conditions for measuring visual attention. Future iterations of this research could integrate dynamic elements to explore how movement might influence affordance perception and observer engagement. The current setup is framed as a foundational approach to identifying static affordances—those that can be perceived without physical movement, such as directional gazes or gestures within a fixed viewpoint. We suggest that future research could expand upon these findings by incorporating a dynamic setting, allowing for a fuller exploration of the role of subject/object motion in affordance perception.

However, given the nature of the object, it is presumable that static and standardized observations do not prevent an articulated and spatial interaction with the artifact. For this study, we are not positioning affordances as generic perceptual qualities but as context-bound properties inherent to the artifact itself. Specifically, in the case of the Sarcophagus of the Spouses, we consider affordances in terms of identifiable elements (e.g., the gaze direction, hand gestures, body posture) that provide actionable perceptual cues for engagement and interaction in a ritualistic or symbolic manner. These affordances are framed mathematically in terms of visual fixations and saccadic movements, which are quantifiable through eye-tracking metrics and AI analysis.

Each observer was placed in front of the museum display; therefore, the observation concerns the A side of the artifact (Figure 7). This strategy was adopted in order to avoid visual interferences and other forms of noise but also has the scope to compare and overlap all the eye-tracking results. Despite these efforts, the eye-tracking results show consistent levels of background noise because of interference due other visitors and, very likely, demonstrates a more general need to spatially contextualize the artifact in the museum. Noise and background interference refer to visual areas outside of the region of interest (the artifact).

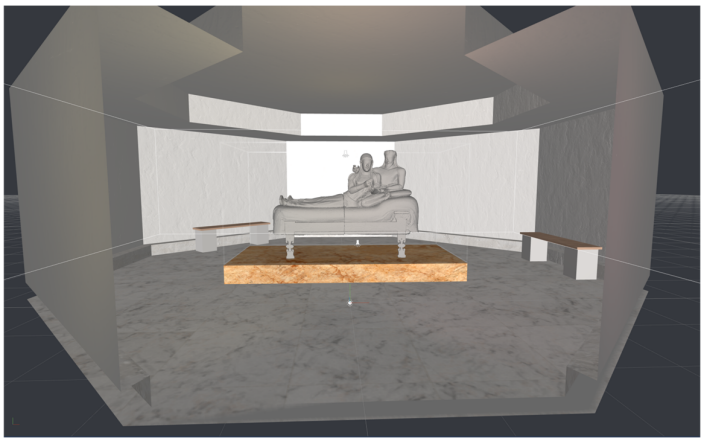

Figure 7. Virtual reconstruction of the museum room with visual simulation of the position of the sarcophagus from the point of view of the visitor (model by Forte, Mencocci).

In other words, the observers tend to target a holistic vision of the entire room before or after an examination of the sarcophagus and its features. In this way, it is possible to classify noise–background interference as an essential part of the experience.

An initial examination of the complete set of eye-tracking data indicates that during the initial 15 s of the experiment, observations are evenly distributed across the entire artwork, with no discernible patterns (Figure 8). Nevertheless, as the experiment progresses, there is an increasing inclination to concentrate on the hands of the couple.

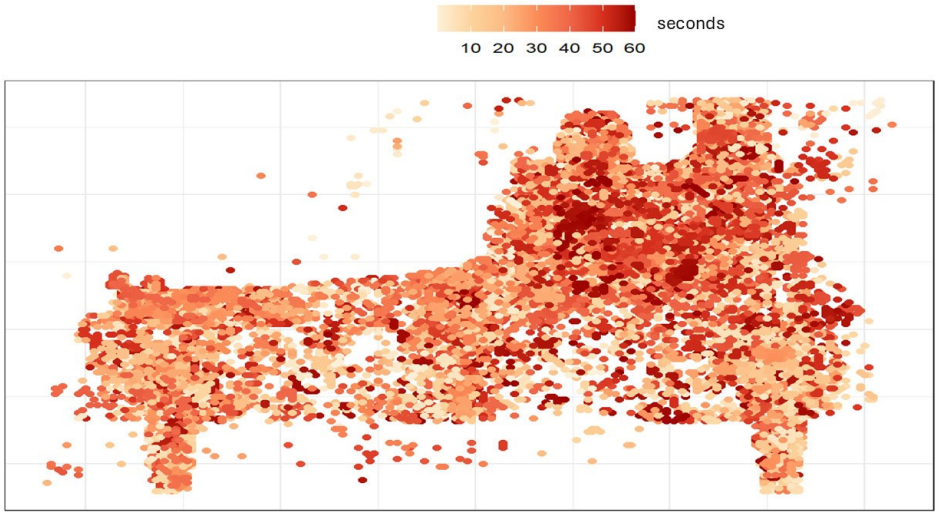

Figure 8. Eye tracking by time of observation, combining the cumulative observations of 42 individuals in 60 s. In this case, the focus is centered on the central part of the sarcophagus, namely the two faces and the hands (processing by Alaimo Di Loro, Mingione).

A more articulated and comprehensive analysis of the eye tracking considers heat maps, saccades, fixations, and scanning paths. The largest concentration of eye-tracking points appears to be on the central part of the sarcophagus, where the two figures of the spouses are located (Figure 9). This suggests that viewers are primarily interested in the human figures, which are often the focal point of such artifacts. There are smaller clusters of focus around the edges and specific details, likely corresponding to the hands, faces, and, possibly, the decorative elements on the sarcophagus. The top portion of the sarcophagus attracts some attention, which may indicate viewers' interest in the facial features or headgear of the figures.

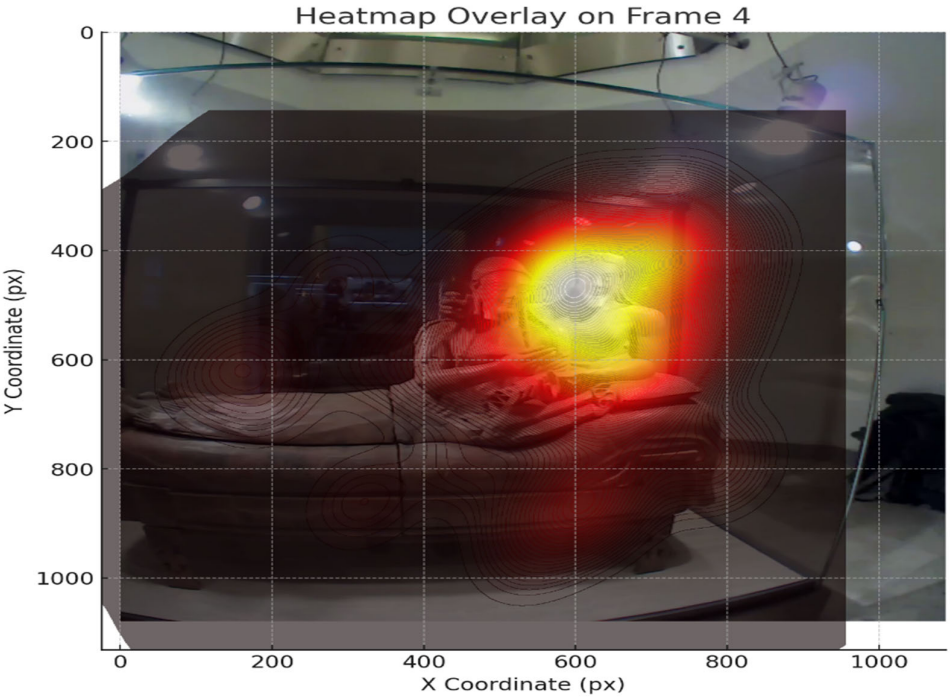

Figure 9. Cumulative heat map based on the 42 visitors and calculated by OpenAI, ChatGPT-4 (accessed on 12 October 2024) Python coding using eye-tracking data.

The base and sides of the sarcophagus have fewer tracking points, indicating that viewers may not be as interested in the structural or less-detailed parts of the artifact. This distribution of points suggests a strong preference for the more detailed and human elements of the sculpture. The average fixation duration (Figures 10–12) indicates that the male face and the female chest are the most relevant features of the artifact. This could be due to the detailed craftsmanship or to the cultural significance associated with these parts of the sarcophagus. The longer fixation durations on these specific features may also reflect an attempt to interpret the facial expressions or the overall posture of the figures, which are central to the artifact's iconography.

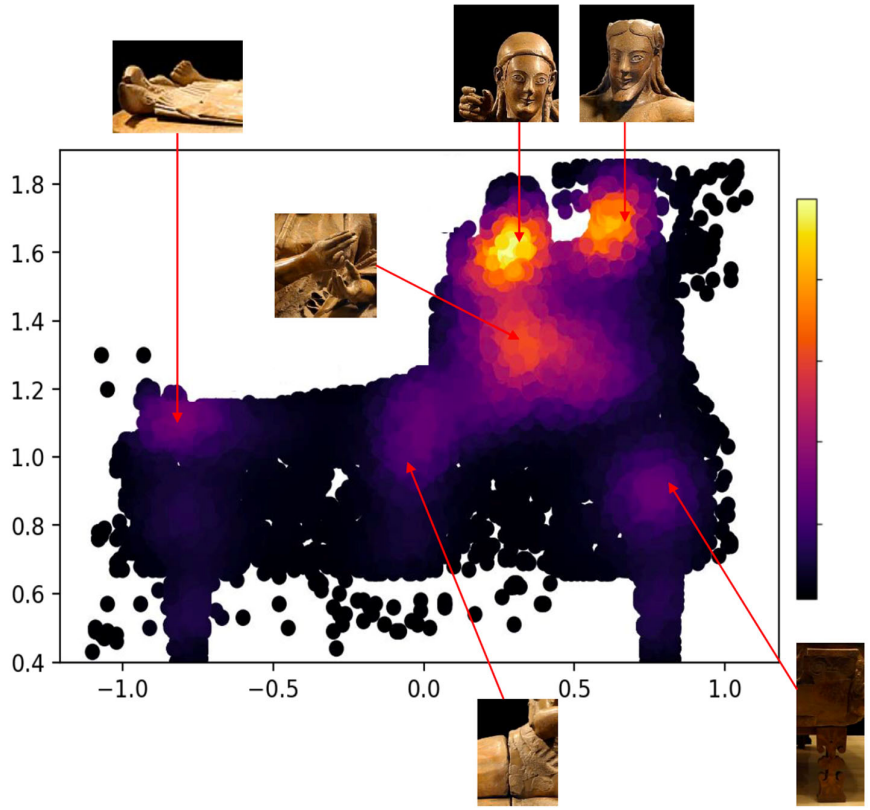

Figure 10. The highest levels of visual concentration on the sarcophagus by ROI (processing by Alaimo Di Loro, Mingione).

Participants interacted with the Etruscan artifact through a combination of focused and exploratory visual patterns. The features most fixated on, such as "noise", "background", "right base", and "female face", suggest that different aspects of the sarcophagus captured varying levels of attention. "Noise" and "background" might indicate areas that were less distinctive or detailed, possibly causing participants to momentarily lose focus or transition between features. The artifact is in the middle of a large room, and it makes sense for any visitor to also visually explore the space around. In contrast, more specific elements like the "female face" and the "right base" drew concentrated fixations, possibly due to their visual or symbolic significance in the context of the artifact.

Regarding saccade behavior (Figure 13), the analysis indicated a predominance of movements in the "southeast" and "northwest" directions, pointing to a diagonal scanning pattern across the sarcophagus. This pattern may suggest a natural way in which viewers explore the artifact's visual space, moving between different focal points like the faces and the surrounding decorative elements. Moreover, the correlation between fixation and saccade metrics shows that participants who engaged in longer fixations tended to have fewer and shorter saccades, highlighting a more deliberate and concentrated engagement with certain features.

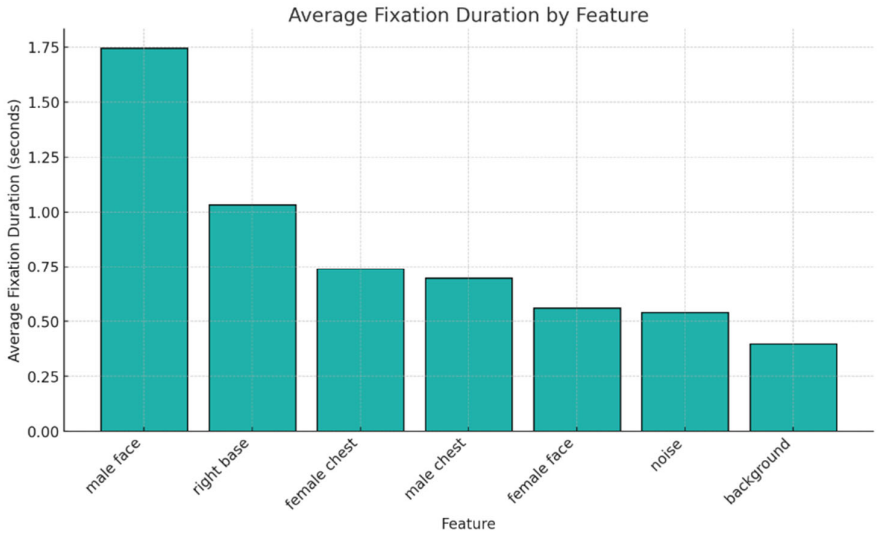

Figure 11. Average fixation duration by feature (OpenAI, ChatGPT-4 (accessed on 12 October 2024) Python coding).

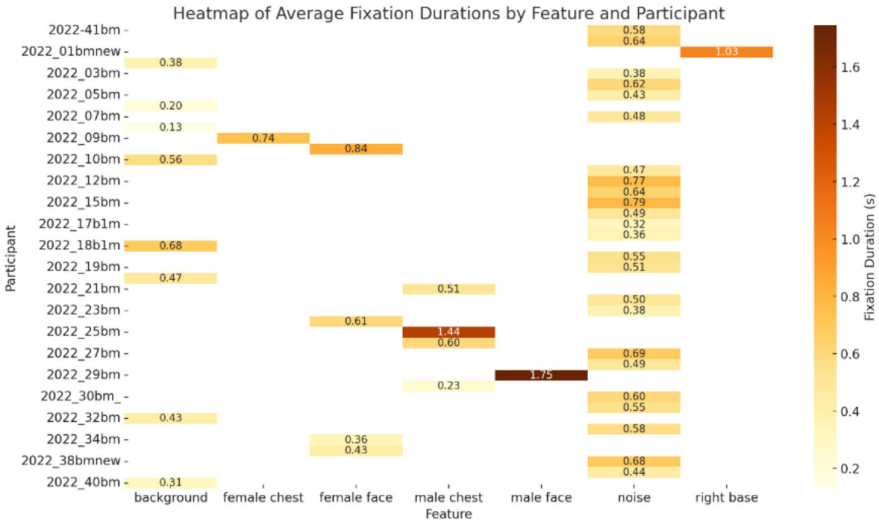

Figure 12. Heatmap of average fixation duration by feature/participant (OpenAI, ChatGPT-4 (accessed on 12 October 2024) Python coding).

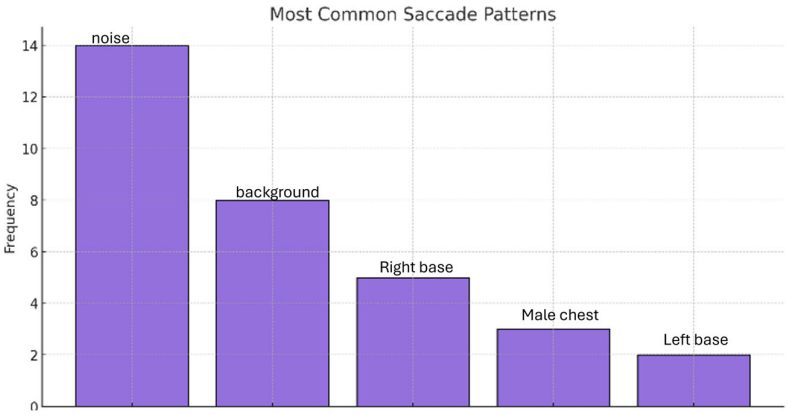

Figure 13. Saccade patterns (OpenAI, ChatGPT-4 (accessed on 12 October 2024) Python coding). Noise concerns all the visual areas out of the region of interest; background concerns the back side of the museum case. It is clear that noise and background are part of the museum experience.

Shorter saccade distances associated with features like "female face" indicate more concentrated attention within a small visual area, whereas longer saccades between broader areas like "background" suggest scanning behavior, where viewers quickly move their gaze across less-detailed parts of the artifact.

Areas such as "noise" and "background" exhibited higher fixation frequencies, indicating that participants' eyes frequently returned to these areas. This could suggest that these features are visually confusing or that they serve as transitional areas as viewers navigate between more detailed or significant parts of the sarcophagus. Features like "right base" and "female face" had lower fixation frequencies but longer fixation durations, suggesting that when participants did focus on these areas, they spent more time there, indicating deeper engagement or interest.

In summary, the key visual differences between features of the Etruscan sarcophagus, as observed in the eye-tracking data, highlight a varied engagement with the artifact (Figure 14).

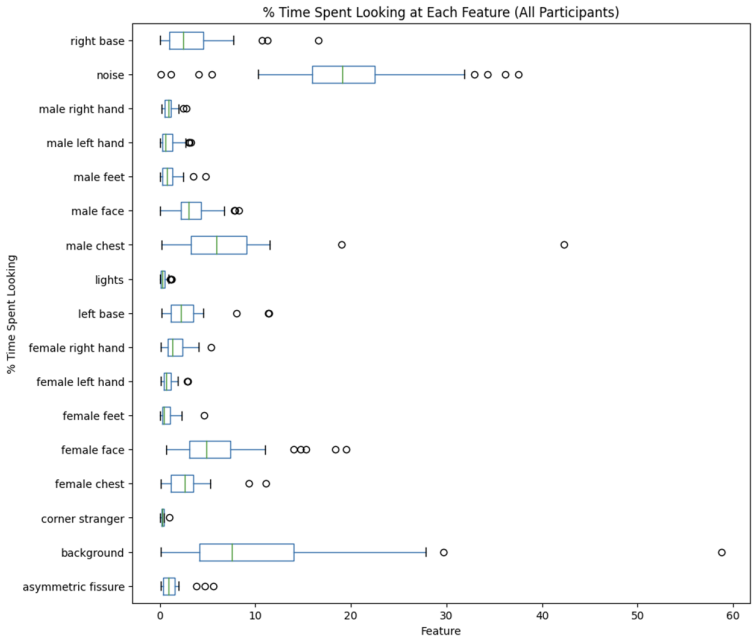

Figure 14. Time spent on each feature (OpenAI, ChatGPT-4 (accessed on 12 October 2024) Python coding). The key features are the male chest, male face, female chest, and female hands. A shorter attention span is observed for male hands. Background and noise are also quite evident in this chart.

Detailed and engaging features (e.g., "female face", "male chest") prompted longer fixation durations and less-frequent but more-focused saccades, indicating deep visual engagement and interest. Less distinct or transitional features (e.g., "noise", "background") attracted more frequent fixations of shorter duration and repetitive saccade patterns, suggesting that these areas were either confusing, less engaging, or served as transitional visual spaces as participants navigated the artifact.

These visual differences underscore how specific elements of the sarcophagus either capture prolonged attention due to their detail and significance or are quickly scanned due to their less compelling nature. Understanding these differences can provide insights into how ancient artifacts are visually processed and appreciated by modern viewers.

To analyze gaze patterns on specific features of the Etruscan sarcophagus, we need to focus on how participants' eye movements (fixations and saccades) differ based on the feature they are observing. This includes looking at metrics like fixation duration, fixation frequency, saccade duration, saccade direction, and the most common sequences of fixations.

The "female face" is one of the features with the longest average fixation durations. This suggests that participants found this feature particularly engaging or that it required more time to process. The detailed representation of the face, likely with specific expressions or cultural significance, might be prompting viewers to spend more time looking at this feature. Saccades to the "female face" might be fewer but more direct, with a focus on specific details of the face, such as the eyes or mouth. The gaze pattern suggests that viewers are drawn specifically to this feature rather than passing over it quickly.

Like the "female face", the "male chest" also has relatively long fixation durations. This attention to human faces shows high levels of empathy in human representation and curiosity toward facial expressions and eye contact.

4. Discussion

The case study of the Sarcophagus of the Spouses is highly relevant and recalls a contemporary concern: the interplay between museums, their visitors, and renowned artworks. Historically, numerous archeological museums have succumbed to fossilization in their intermittent endeavors to secure visitors' assent. To ascertain the popularity or disfavor of their collections, or of the museum in its entirety, these institutions have employed questionnaires and statistics. In many cases, these surveys are focused on museum satisfaction.

The NeuroArtifact initiative [11], on the other hand, investigates the conscious and subliminal associations individuals have with artifacts, alongside their kinesthetic learning and esthetic appreciation. As the investigation centers on the artifact, the museum functions merely as a setting.

The eye-tracking analysis of the Etruscan Sarcophagus of the Spouses reveals significant insights into how viewers engage with this artifact. The data collected include detailed information on fixation points, saccades, and heatmaps, providing a comprehensive view of viewer attention and gaze patterns. Fixations, which indicate periods where the viewer's gaze is stable at a specific point, were notably concentrated on the faces and hands of the figures depicted on the sarcophagus. This suggests that these areas captured the most sustained attention, likely due to their detailed craftsmanship or cultural significance. Particularly, the "female face" showed a higher average fixation duration, indicating that it was a major focal point for viewers.

Saccades, or the rapid movements between fixation points, showed that viewers shifted their gaze between key features of the sarcophagus, such as from one figure to another or from the base to the upper parts. This pattern of gaze movement suggests that viewers were actively exploring the entire artifact rather than just focusing on isolated features. The cumulative heatmaps created from the fixation data further highlighted the regions of the sarcophagus that attracted the most attention. These heatmaps displayed the highest concentration of visual interest around the faces and central parts of the figures, suggesting that viewers were particularly drawn to the most detailed or symbolically significant parts of the artifact.

The overall gaze patterns showed a common initial focus on the faces, followed by explorative saccades to other parts of the sarcophagus. This behavior indicates that viewers are initially attracted to human-like features, which is consistent with typical human visual preferences, before engaging in a broader exploration of the artifact. By defining specific areas of interest (AOIs) such as the "female face", "male chest", "hands", and "base", further analysis revealed that these human features, especially the faces and hands, received significantly more attention compared with other parts of the sarcophagus. This suggests that the depiction of human figures is not only visually compelling but also culturally and artistically significant, possibly conveying messages or telling stories that resonate with viewers at a deeper level.

The variation in fixation durations and saccade patterns between different features indicates different levels of cognitive processing. Longer fixation times on detailed areas

suggest deeper engagement and possibly interpretation, while the rapid scanning of less-detailed areas indicates contextual processing or visual navigation.

Overall, the eye-tracking data indicate a high level of engagement with the sarcophagus, with a clear emphasis on the human elements and a comprehensive viewing strategy that includes both detailed examination and broader scanning. The concentration of fixations on the faces and hands, along with the saccadic movements across different features, highlights the artifact's ability to attract and hold viewer attention, suggesting its cultural and artistic importance.

Overall, these gaze patterns suggest that participants are strategically navigating the visual space of the sarcophagus, focusing intently on features that are likely significant in cultural, artistic, or narrative terms while quickly scanning less-engaging areas. This behavior reflects a balance between detailed examination and broader visual exploration, providing insights into how viewers interact with ancient artifacts.

The data reveal a clear hierarchy in how viewers engage with different parts of the sarcophagus. Human figures, particularly their faces and upper bodies, attract the most sustained attention, while structural elements and less-detailed areas serve as visual anchors or transitional spaces. The eye-tracking study of the Sarcophagus of the Spouses reveals crucial insights into how modern viewers engage with this ancient Etruscan artifact. The results show a clear hierarchy of visual attention, with the faces and upper bodies of the figures attracting the longest fixations and most frequent saccades. This pattern aligns with the artifact's key affordances, particularly the hugging gesture and facial expressions, which were designed to convey intimacy and social status.

The "female face" and "male chest" emerged as areas of intense scrutiny, attracting the longest fixation durations and the most frequent saccades. This pattern of attention underscores the primacy of the hugging gesture and facial expressions as critical affordances, which are designed to convey intimacy, social status, and the complex Etruscan beliefs about the afterlife.

The sustained engagement with these features suggests that modern viewers intuitively grasp their importance, even without explicit knowledge of Etruscan culture. Interestingly, the study revealed that viewers spent considerable time examining the empty hands of the figures. Originally designed to hold objects such as cups or perfume vases, these empty hands continue to draw attention, indicating that viewers recognize them as significant affordances. This finding highlights how the sarcophagus's design successfully projects the intended gestures into space, maintaining their communicative power even in the absence of the original objects.

The observed diagonal scanning patterns, predominantly moving in southeasterly and northwesterly directions, provide valuable insights into how the sarcophagus guides the viewer's gaze. This pattern likely reflects the intentional composition of the artifact, which is designed to lead the eye across its surface in a specific manner. Such a viewing experience may mirror the intended engagement in its original funerary context, suggesting that the Etruscan artisans created a visual narrative that remains effective in guiding modern viewers.

Moreover, the study sheds light on how contemporary audiences interact with the sarcophagus's more subtle affordances. The unified body shape of the couple, gender-specific elements like clothing and accessories, and the overall posture on the *kline* (banquet couch) all received attention, albeit to varying degrees. This engagement demonstrates how the artifact's design successfully conveys complex social and cultural information, transcending time and cultural barriers.

The eye-tracking data also revealed interesting patterns in how viewers navigate between a detailed examination and a broader contextual understanding. Areas labeled as "noise" or "background" showed high fixation frequencies but shorter durations, suggesting that they serve as transitional spaces as viewers move between more significant features. This behavior indicates a sophisticated viewing strategy that balances focused

attention on key symbolic elements with a broader appreciation of the artifact's overall structure and context.

Looking at faces, whether human or sculpted, often triggers emotional responses. This is due to the involvement of the limbic system, particularly the amygdala, which plays a key role in emotion processing [33]. The fusiform face area is a cortical region in the temporal lobe, a cubic centimeter in size, that seems specifically designed to identify human faces. This is just a hypothesis, because fMRI (functional magnetic resonance imaging; not adopted in this study) is the most widely used method for studying the FFA [34,35]. It measures brain activity by detecting changes in blood flow. Researchers can design experiments in which subjects are shown images of faces and non-face objects and the activity in their FFA is compared. Studies have consistently shown that the FFA is more active when subjects view faces compared with other objects.

The expressions depicted in statues can evoke feelings of happiness, sadness, fear, or tranquility, mirroring our reactions to real human expressions.

5. Conclusions

The eye-tracking study of the Etruscan Sarcophagus of the Spouses reveals complex patterns of visual engagement, providing insights into how viewers interact with this ancient artifact. The analysis focuses on various aspects of visual attention, including fixation duration, fixation frequency, saccade patterns, and the relationship between different features of the sarcophagus.

Despite the limitations of a fixed static data recording, the current setup provides valuable data on specific, visually salient affordances that engage attention from a frontal view, such as gaze direction, facial expressions, and hand positioning on the sarcophagus. These elements remain effective in guiding viewer focus, even in a controlled, stationary context. By standardizing the viewing position, we can assess shared patterns of attention across participants, offering initial insights into how affordances are perceived even without physical interaction. While we recognize that a dynamic setup could potentially reveal additional layers of interaction, we believe that the static setup provides meaningful insights into how certain affordances—such as gaze direction, gestures, and symbolic elements—draw attention, even from a single, controlled perspective. Also, a static setup standardizes comparative analyses of all the observations.

It is possible that future research could benefit from exploring affordance perception in a dynamic observational context, perhaps with mobile eye tracking or virtual reality, to capture the full range of affordances in relation to viewer movement.

The hypothetical positioning of the Sarcophagus of the Spouses within its original funerary chamber holds significant implications for understanding its role in Etruscan funerary practices and rituals. Scholars suggest [18,36,37] that like other Etruscan burial artifacts, the sarcophagus was likely placed against the back wall of the chamber or centrally within the space to command visual and symbolic attention. This strategic placement would have facilitated an immersive experience for participants during funerary rituals or commemorative ceremonies. Positioned prominently, the sarcophagus would have interacted with its surroundings, such as with decorative murals, votive offerings, and ritualistic objects, enhancing the overall sensory experience. The faces and gestures depicted on the sarcophagus, especially the act of embracing, would have conveyed a sense of intimacy and unity, drawing visitors into a narrative that transcends life and death. The spatial arrangement would have reinforced the couple's aristocratic status, emphasizing their continued influence and presence even in the afterlife.

The architecture of the funerary chamber itself would likely have been designed to amplify the sarcophagus's visual impact, possibly with a layout that directed light or guided movement toward the artifact. Seasonal openings for rituals or commemorations may have further activated the space, allowing observers to engage in an interactive, ritual–symbolic connection with the sarcophagus.

This spatial context would have underscored the multi-dimensional affordances of the sarcophagus—embodied gestures, directed gazes, and implied actions—which resonated with viewers and stimulated an embodied response. The strategic positioning ensured that these affordances were perceptible and evoked a sense of participation, linking the living with the commemorated deceased and embedding the artifact within a cycle of life, death, and remembrance. Cumulative heat maps and AI simulations show a strong visual attention of the visitors for the statues' faces and hands, because they develop very complex affordances in relation to the surrounding space and its symbolic meaning. There is a clear ranking in the way contemporary observers watch the artifact that very likely reflects what happened in the original Etruscan contextualization. In other words, if the cultural interpretation of the sarcophagus cannot be correctly reformulated by contemporary viewers, we can still measure the bio-cultural/genetic interaction with this artifact. The emphasis on the visual engagement with faces and hand gestures, as well as the holistic perception of the sarcophagus, underlines its ritual–symbolic significance within the context of its original Etruscan society.

Quantitative and qualitative eye-tracking analyses show a significant level of empathy in the observation of the artifact; in particular, in relation to its "body language", facial expressions, gestures, and visual ranking. The findings of the eye-tracking experiments affirm the significance and hierarchy of these features/affordances, allowing reconstruction of the visual–cognitive experience associated with the artifact. The analysis supports that perceiving complex artifacts is a feature-driven process, as specific characteristics activate affordances—potential embodied interactions between the viewer and the object. This study's use of heat maps and defined visual regions of interest demonstrates a dynamic observer–object interaction, despite the static nature of viewing. These results underscore the importance of the following key features and affordances of the artifact:

- The empty hands projected outward imply actions such as offering, drinking, or sharing objects, with the gestures creating affordances linked to motor skill activation [38]. The open-handed gesture might lead to embodied simulation, where the viewer's motor system mirrors the action, creating a subconscious feeling of warmth, welcome, or inclusivity [39].
- The distinct gaze directions of the male and female figures enhance engagement by addressing different observational focal points.
- The male figure's gesture of placing his hand on the female's shoulder merges them into a cohesive, unified composition.

Expanding this methodological approach aligns with Gibson's theory of real-time perception, which posits that affordances are influenced by the observer's interaction with their environment and that they shift based on context. Future research could delve deeper into how the design elements of the sarcophagus—its sculpted details, implied movement, and spatial positioning—invite engagement from multiple perspectives, potentially informing rituals or ceremonies in its original context. This exploration would enrich the understanding of the artifact's multisensory potential and suggest strategies for creating museum experiences that foster interactive and immersive visitor engagement.

Emphasizing movement and varied observation angles would enable scholars to investigate how the artifact's meanings are recontextualized based on physical or social changes, enhancing the discourse on affordances in art perception and supporting contemporary practices that prioritize engaging, interactive museum displays. Expanding research in this way could also contribute to a deeper understanding of how cultural artifacts communicate meaning across time and space, reinforcing the notion that the interaction between viewer and artifact is an evolving, dynamic process.

These results align with neuroesthetic theories, particularly the activation of embodied simulation mechanisms. The viewers' focus on gestures and facial expressions suggests that these elements activate motor skills, allowing for an empathetic connection with the artifact. The integration of AI simulations and eye-tracking metrics deepens this understanding by quantifying the interaction between observer and object.

The study also provides valuable insights for museum curation and archeological interpretation. By understanding which features most effectively capture and hold viewers' attention, museums can design displays and interpretative materials that enhance engagement with the artifact's full range of affordances and cultural meanings.

The methodology employed here, combining eye-tracking technology with a deep understanding of the artifact's historical and cultural context, offers a model for future studies of ancient art. It provides a quantitative basis for understanding how artistic conventions and cultural symbols continue to resonate with viewers across vast stretches of time.

The comparative analysis between the AI simulations of the main affordances with the eye-tracking records shows a very consistent path in the visual interpretation of the object. Heat maps convey the same affordances and ROIs because of the symbolic and ritual power of specific features designed for an Etruscan audience.

In conclusion, this eye-tracking study of the Sarcophagus of the Spouses not only enhances our appreciation of this specific masterpiece but also contributes to a broader understanding of how ancient art functions visually and cognitively. It demonstrates the enduring power of Etruscan artistic conventions and offers new pathways for making ancient artifacts more accessible and engaging to modern audiences. As we continue to bridge the gap between past and present through such innovative research methods, we gain not only a deeper understanding of ancient cultures but also new insights into the universal aspects of human perception and engagement with art.

This deep engagement with the sarcophagus's key features suggests that its design successfully transcends time, continuing to communicate its cultural and symbolic significance to contemporary audiences. These results not only enhance our understanding of how Etruscan art functions visually but also provide valuable data for improving museum displays and interpretative materials, ensuring that the full range of the artifact's affordances and cultural meanings are accessible to modern viewers.

To address this limitation, we propose that future studies incorporate a dynamic observational approach where participants can move around the artifact, allowing for a more comprehensive exploration of affordances. A mobile eye-tracking system or a virtual reality setup could be valuable in capturing how affordances change with different viewing angles, distances, and interactive conditions. This would align more closely with Gibson's emphasis on real-time, interaction-driven perception and would offer richer insights into the sarcophagus's design elements that invite viewer engagement from multiple perspectives.

Initial results suggest that these interdisciplinary studies may have implications for numerous fields, commencing with the evaluation of public perceptions of art and artifacts and culminating in the development of innovative approaches to promoting cultural heritage that cater to the cognitive and emotional requirements of visitors, as well as incorporating insights into the responses of different categories of visitors into the learning sector, including educational environments [40].

The study confirms that the Sarcophagus of the Spouses is deliberately designed to focus attention on the faces and gestures of the figures. These elements resonate universally, evoking emotional and cognitive responses that transcend time and culture. The centrality of human features in commanding visual attention reflects Etruscan artistic priorities, emphasizing interpersonal connection and shared human experiences. The analysis aligns with neuroesthetic theories, suggesting that the viewers' focus on expressive features like hands and faces activates embodied simulation mechanisms. This empathetic engagement allows modern viewers to intuitively connect with the artifact's symbolic gestures and directed gazes. The empty hands and their implied actions invite interpretative engagement, offering a dynamic interplay between the artifact and its audience that mirrors its original ritualistic function.

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Institutional Review Board Statement: Ethical approval for this study was provided by the Sapienza University of Rome Ethical Committee in charge of the Department of Molecular Medicine (protocol number: 2507/2020; approved on 4 August 2020).

Informed Consent Statement: Written informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data will be made available from Maurizio Forte from (maurizio.forte@duke.edu) upon reasonable request.

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