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Eye-tracking support for architects, conservators, and museologists. Anastylosis as pretext for research and discussion

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Abstract

Conservators, museologists, and architects make extremely complex decisions capable of affecting the way people perceive monuments. One might give this idea deeper consideration while pondering anastylosis. One of the things a designer should do when selecting a method of merging together parts of a damaged monument is answer the question whether the chosen method will facilitate the interest of onlookers in the presented object. In which case will the observers spend most of their time looking at the authentic relic fragments and distinguishing between the old and the new parts? The definitions in force do not explain how to approach this topic. By using eye-tracking research, we can learn how observers look at historical objects that have been reassembled again. By combining the observation of visual behaviours with a survey of people looking at such objects, it is possible to see how the process of classifying what is new and old actually works. This knowledge allows for more conscious approach to heritage management processes. In future, results of eye-tracking experiments should help experts plan sustainable conservation projects. Thanks to knowing the reactions of regular people, one will be able to establish conservation programmes in which the material preservation of a monument will reflect the way in which this object affects contemporary onlookers. Such an approach ought to result in real social and economic benefits.

Keywords: Conservation, Visual attention, Eye tracking, Heritage perception, Anastylosis, Participatory methods

Introduction–conservation means design

Designers are well aware that it is not only the form, but also the colours and their combinations that 'play key roles in visual perception, and the strategic use of these can contribute to the effectiveness of visual communications design' [1]. Conservators and museologists are more than restorers of historical forms–at times, for example when reconstructing historical objects, they decide on the nature and scope of contemporary measures that are necessary to make it possible for such a historical object to endure and offer insight into the past. Such people also serve as designers who need to make complex design decisions.

The topics of reconstruction and anastylosis have been discussed and analysed in a number of scientific publications [2–5]. One may find it surprising that anastylosis remains a controversial point in discussions between specialists advocating the prohibition of all forms of reconstruction and those experts who seek alternative ways of presenting relicts of the past to the general public [6]. Since professionals are not univocal on whether objects found by archaeologists should be reintegrated or not, it is easy to assume that other aspects, e.g. aesthetic ones, will be perceived and depicted in a different light depending on the researchers' preferences regarding application of more or less noticeable conservation techniques [2]. Interdisciplinary approach to presentation and management of archaeological relics is exemplified by Kalliopi

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Fouseki in her book *Dispute Management in Heritage Conservation: The Case of* in situ *Museums* [7]. One may also learn a lot about ways of presenting archaeological monuments from *Interpreting the Past: Presenting Archaeological Sites to the Public* [8] by Dirk Callebaut, Neil Silberman, and Ann Killebrew as well as from the ICOMOS Ename Charter [9].

The latter work mentions two issues that seem vital to modern conservation. The first is the need to 'facilitate understanding and appreciation of cultural heritage,' [9] which is directly linked with the satisfaction level of various target groups [6]. The other issue is the development of 'technical and professional standards for heritage interpretation, including technologies, research, and training' [9]. These quotes from the ICOMOS charter are important because the specialists who were responsible for writing the charter apparently felt that it is necessary to invent modern, sustainable and long-term strategies that are adequate to social contexts. Such considerations are in line with the motivation that resulted in conducting the research presented in this paper.

Research goal

The author's intention was to use a non-expert perspective in order to help facilitate the development of an optimal method of filling the gaps in a reassembled architectural detail. What was sought was the most acceptable way to expose this type of monuments to non-professionals, and in consequence the aesthetic boundary for the activities of professionals dealing with this type of projects. The method that made it possible to assess the process of differentiating between the new and the old elements of anastylosis–that is, whether this process is easy or difficult, engaging or tedious–was a series of registrations of visual behaviours of participants intentionally looking at such objects. The author hopes that the analyses, although based on a specific object, will not only serve to solve one individual problem, but that the presented data and their interpretations will be connected with the results of subsequent tests of this type on other technical and aesthetic aspects in the future. Eye-tracking research should make it possible to select methods which enable easy classification of new and old elements in anastylosis.

Anastylosis

Starting point–definition

The following definition became the starting point for a consideration of different types and range of participatory methods applied in relation to archaeological heritage.

'Anastylosis: The reassembly of existing but dismembered parts: the use of new materials should be recognizable' [2].

This definition is consistent with the content of the Venice Charter [3], and its conciseness constitutes its great advantage. However, there are doubts that this short description does not address the question of who is supposed to recognize the newly added elements and how. Is it meant to apply to professionals, i.e. architects, conservators, museologists, and archaeologists, who use advanced research equipment? Or to ordinary observers looking at such an object with the naked eye? Or maybe both perspectives should be taken into account? Moreover, the Venice Charter also provides an excerpt which states that replacements must integrate harmoniously with the whole [10]. The issue of reconstruction of monuments was also discussed in the Charter of Cracow [11], but its contents remain too theoretical and unclear, resulting in tension between experts, potential investors and the society [12]. The same ambiguities are connected with interventions involving archaeological heritage [13]. Many experts, such as Matthew Hardy [14] or John Bold and Robert Pickard [15] suggest that the existing charters and terminology might be flawed and that it is time the assertions made in such documents were looked at closely and verified. Such verification will only prove meaningful if one conducts thorough research using new tools and methods.

Who designs anastylosis and where?

The concept of anastylosis refers not only to museum exhibitions, i.e. reassembled sculptures or ceramic dishes, but most of all to archaeological exhibitions 'in situ,' conserved ruins and architectural objects restored after various types of natural disasters, armed conflicts, and attacks [2, 16]. How can one verify the principles behind such a vast area of conservatory activity? The fact that it has ceased to refer only to real objects, because reconstruction also takes place in virtual and augmented reality [17] requires a careful look at the concept of authenticity in anastylosis and its recipients. The cultural, political, and economic contexts as well as the scale of objects to be reassembled are extremely diverse, hence people who design the appearance of such objects use extremely diverse methods [6].

It is possible that this issue requires a new approach: not one in which we generalize, but rather study particular aspects of the problem; not one in which we concentrate on an expert's point of view, but rather on that of a non-professional. The author suggests that anastylosis should be perceived the same way as any other designing process that results in a creation of a message – a piece of

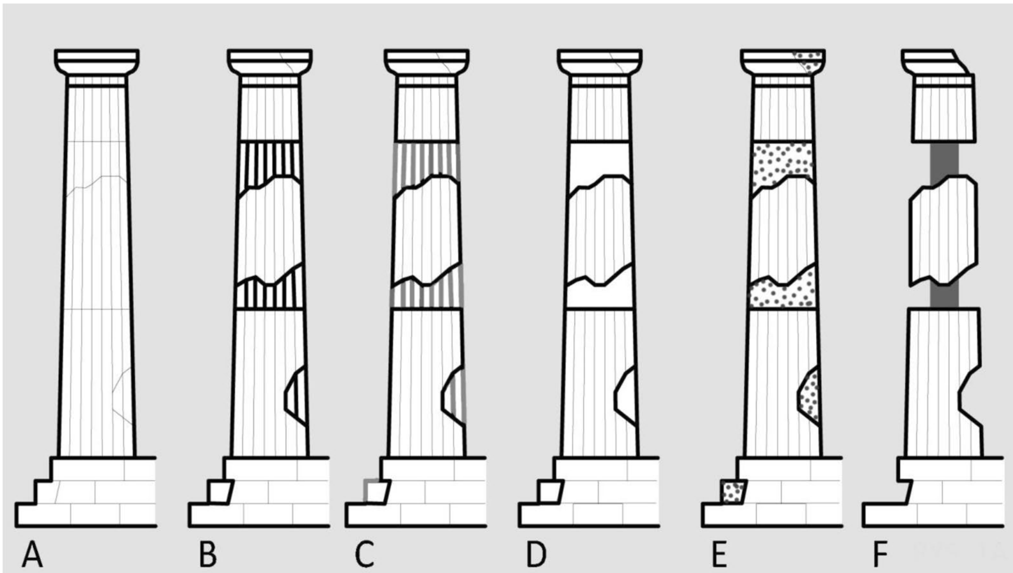

Fig. 1 The diagram presents the idea of different methods of anastylosis. (author). **A** Reassembly done in a way that makes it impossible to visually differentiate between new and old parts. **B**, **C** Reassemblies in which the new parts have been marked with a different colour, but made to resemble the old parts in terms of texture. **D** Anastylosis in which the added parts are simplified in form, but made from the same material as the old parts. **E** Anastylosis in which the new parts are of the same colour as the old parts but differ in texture. **F** Old parts have been placed in their proper positions by means of a frame, but no new parts are added

visual information. If so, the goal of the person creating such a message is to make it easy to comprehend.

Anastylosis in the context of cultural heritage marketing

Nowadays, fewer and fewer people are surprised by the fact that when preserving or planning an exhibition, one should use tools normally applied in marketing [18, 19]. Unfortunately, the range of measures implemented in conservation is often very limited [20] and usually deals only with different ways of attracting visitors. Moreover, these measures are applied in a way chosen by a narrow group of decision-makers, and unfortunately, according to research, do not always serve their purpose [21, 22]. Proposals as to how one might increase the importance of the society's point of view in the process of interpreting historical monuments have been provided by a number of scholars [6, 23–25]. Such research, dating back to the end of the twentieth century in the USA [26], was mostly centred around satisfaction diagnosis based on an analysis of responses to surveys and on observations of experts. In connection with the problems described, the author decided to invite non-professionals to participate in her scientific research, and thus present how observers who lack expertise in the field could participate in the process in which decisions have so far been made only in the privacy of universities, bureaus and offices, by experts whose job does not concern an issue exposed to the media [20]. The search for new methods to increase customers' satisfaction from encounters with architecture and monuments is fully consistent with what is contained in the International Cultural Tourism Charter [27].

When deciding to supplement a monument that is being reassembled again, the researcher or designer must answer the question of the type of cavity filling they should apply in this particular case [28]. After all, there are many methods of emphasizing the original material as required by doctrinal documents [29]. For example, destructs may be joined and stabilized with bar housings, and fillings of a different colour and structure may be prepared (Fig. 1). However, one of the most frequently used procedures is changing the brightness of the introduced elements in relation to the original, while maintaining the similarity of colour and texture. What is important, this method was used in the works done on the Athenian Acropolis.

When choosing a method, a designer should also answer the question whether the method used will facilitate the interest in the presented object. Which method will encourage the observers to spend the most of their time looking at the authentic relic fragments and distinguishing between the old and the new? The more we begin to think in detail about the most important aspect–the purpose of human contact with monuments, the more questions relating to the future perception of the projected anastylosis can be asked. An expert's evaluation of alternative design solutions, on the basis of these questions, should in theory lead, if not to the selection of one best solution, then at least to the indication of the most favourable scope of planned activities [30].

In practice, it turns out that the decisions made by professionals are not always correct. So how to get to know the opinion of non-professionals? We know that a spoken or written 'text may not be a good image of someone's thoughts or knowledge' [31]? In relation to surveying, an alternative way to get to know and understand consumers is a detailed observation of their behaviour [32]. A measurement of physiological reactions seems to be an objective research method because the subjects do not have direct influence on those reactions, for most of them are automatic and unconscious [33]. Such measurement may take on the form of a study of visual behaviours. The use of an eye tracker in order to guide design decisions in architecture and conservation on the basis of responses of regular people appears in the aspect described above to be an innovative solution [22, 34–37].

Eye trackers and their metrics

Eye trackers are devices used to record how observers look at objects presented to them. Thanks to appropriate techniques, it is possible to register graphic trajectories of eye movements along with the point-of-regard on the prepared image [38–40].

There are three groups of eye trackers:

- portable eye trackers, which make is possible to conduct research in real-life surroundings;
- eye trackers connected to VR goggles, which allow research based on spherical stimuli;
- stationary eye trackers, which register how people look at images displayed on a computer screen –this type of an eye tracker was used in the research presented in the paper.

Eye tracking is a complex process but for the purposes of this profile research, it is enough to assign visual behaviours to two general groups. Fixations are short pauses in which the eyeball remains in a relative stillness lasting from 66 to 416 ms [39]. It is during such point-of-regard that the brain collects a dominant part of information about the viewed object. The second type of behaviour are saccades that shift attention between one point-of-regard and another [41]. People perform an average of two to three saccades per second, and they usually last from 20 to 35 ms [42].

In order to analyse eye-tracking data, researchers have to set Areas of Interest (AOI), for which different parameters of visual behaviours are calculated. Fixations are described by a number of values–for example what is measured is the time that passes before the first fixation within a given AOI takes place (time to first fixation), how many fixations take place in a given AOI (fixation count), how long a single fixation lasts (fixation duration) [38–42]. Knowing one's visual behaviours also allows us to state for how long one's gaze stayed within a given AOI (total observation time) or whether the fixations occurring in a given AOI followed one another or if the observer repeatedly moved away and returned to the AOI in question.

Eye trackers and cultural heritage

Application of eye trackers in research connected with architectural heritage and related fields such as painting, sculpture, museology, archaeology [43] or cultural tourism [44, 45] remains innovative. Eye trackers, both portable and stationary, have been used while researching human-oriented strategy for protecting cityscapes or the relationship of architecture and landscape or urban context [46, 47]. These tests showed the gigantic and yet unused research potential of eye trackers as tools supporting architects, landscape designers, conservation officers and civil servants both at the stage of drawing plans and when controlling their effects. One should pay particular attention to the promising results of research regarding application of eye trackers in order to work out appropriate mechanisms of landscape protection in historical cities [34–36]. What is interesting, the search for a suitable methodology in this field continues, which is why the mentioned publications describe applications of all different kinds of eye trackers.

Researchers have also been interested in exhibition interiors and using portable eye trackers in museums [48–55]. The tests carried both in laboratory conditions and in museum interiors made it possible to learn how different age groups look at exhibits and how they use those exhibits to obtain information, to identify visual distractors, and to study the relationship between the arrangement of exhibits and the architecture of the historical interiors in which these exhibits are displayed.

Majority of the aforementioned eye-tracking research diagnoses the behaviours of non-professional observers, but it is also possible to learn how experts assess stimuli presented to them. The striking differences between these two groups of observers can be observed in the experiments done by Tomasz Malik on the basis of aerial photography [56]. Knowledge of research procedures and of the differences in perception of archaeological sites seem to be crucial for the sustainable development of this specific field of science.

Eye trackers can also support scientists, archaeologists, and anthropologists in deciphering the significance of their discoveries. One such example can be seen in the research whose aim was to verify a hypothesis about the reasons why primitive people exhibited such a prolific artistic activity in deep, dark, sound-less caverns [57]. The context of this paper makes it worthwhile to also mention the "Virtual Reality and Neuroarchaeology 2020–2021" project carried out at Duke University.[1]

Methods and measures

In order to conduct the experiment in an effective way, it was necessary to undertake several interrelated measures aiming at obtaining a coherent research procedure. Firstly, it had to be decided what object will be the basis for anastylosis and therefore for the entire research. Only then was it possible to develop proper methodology, linking it with the choice of appropriate research tools, appropriate arrangement of the laboratory and appropriate conditions of registration so that the collected data could be considered reliable. At the same time it was important to choose the correct profile and number of participants as well as to determine how many images will be shown to them and what manner of display will be used.

All these aspects of the research methodology are described in the following parts of the paper. In order to make them clear and comprehensible it was decided that they will be presented in the order in which the decisions were made. This detailed description is necessary since without it one would never be able to redo, verify or expand this research in the future [38].

What architectural element to test?

Due to the desire to put the emphasis not so much on the analysis of a specific case, but on the presentation of a pro-social approach towards management of monuments, it was decided that the object shown in the tests should be related to the most common understanding of anastylosis. The author assumed that, when given a task of selecting one illustration on the basis of which they would explain the concept of anastylosis to a non-professional, most professionals would choose a Greek temple, an ancient portico or a stone column rebuilt from destructs. In order to verify this opinion, an attempt, which consisted in entering the word anastylosis in several languages into the Google browser, was made. What was shown on the screen largely matched the earlier assumptions of the author. Finally, a decision was made that the column would be the subject of the reassembly. Due to the observed popularity of the solution consisting in highlighting new elements by modifying their brightness it was agreed that the survey would employ this method.

Laboratory and apparatus

According to the current recommendations, to ensure reproducibility [58], the research was conducted in a specially prepared, quiet room with the possibility of dimming it and cutting it off from external light sources [59]. The room was devoid of visual distractors [60], unused furniture, its walls were white, and the floor was oak parquet. In the laboratory, there was a place for the subject, a chair, and a desk on which a computer screen was placed, as well as a side computer stand for the person supervising the registration process. Tobii Pro X3-120 eye tracker, which is adapted to the analysis of large images with an accuracy of 0.4°, was used to perform the tests.[2] The stimuli were displayed on a 24″ monitor (DELL Ultra Sharp U2415b). The screen was arranged vertically so that the prepared illustrations were as large as possible. The screen settings such as brightness, contrast and colour balance remained the same throughout the entire experiment. The stationary eye tracker was mounted in the middle of the lower part of the screen housing. The device accumulated data at a frequency of 120 Hz. The observers' distance from the monitor was set in the range from 70 to 90 cm. These two lines were marked on the laboratory floor to facilitate organization. Both the screen and the seat made it possible to adjust the height. It was important because changing their mutual positions for a specific observer enabled to obtain a much better quality of individual 5-point calibration. The calibration was accepted when the average error was not bigger than 0.30° and the maximum error was smaller than 0,50° [38]. If after three calibrations it was impossible to achieve desired values, the team tried to identify the obstacle in 2–3 min. If the following two attempts at successful calibration failed too, the experiment was run nonetheless, in order not to disappoint the participant, but the collected data was not used in calculations. The experiment, data verification and the report-generation process were carried out in the Tobii Pro Lab programme. Participants' responses as well as any problems that occurred were recorded manually.

Participants

Participation in the research was voluntary. Participants received a voucher worth PLN 20 for participating in the tests. Only people who did not have professional knowledge related to the presented topic were allowed to take

[1] https://bassconnections.duke.edu/project-teams/virtual-reality-and-neuroarchaeology-2020-2021. access 10 April 2021.

[2] Technical data, https://www.tobiipro.com/product-listing/tobii-pro-x3-120/ 01/08/2020

part. Architects, conservators, museologists, historians, and even students starting their education in any of these fields were not invited. This is important because it seems unattainable in such tests to determine how such education previous professional experience affect the sensitivity of professional observers, which in turn might alter the way they look at historical monuments [61]. Moreover, the participants were only adult residents of Wroclaw agglomeration (Poland) under 65. Volunteers declaring their willingness to participate in the test filled in a questionnaire available on the Internet, the content of which also indicated which of the volunteers had visual impairments (for example monochromatism) or other diseases that prevented them from participating in the tests. The participants gave their written consent to the anonymous use of the collected data for scientific purposes. It was planned that each of the visual stimuli will be seen by at least 30 participants.

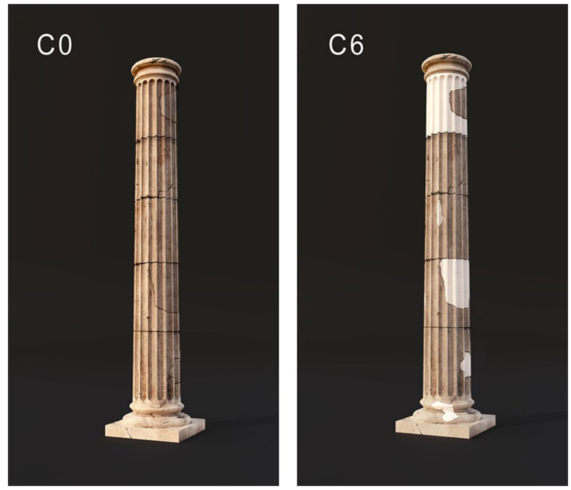

Fig. 2 Extreme examples of the use of contrast anastylosis C0 and C6 (author)

Visual presentation of anastylosis

Once it had been decided what object will be displayed in the experiment and what device will be used to gather data from a group of a certain size, the next step was to prepare suitable images.

Selection of the number of tested stimuli and the brightness of supplements

In order to carry out the analyses comparing different shades of cavity fillings, a model of the reassembled body of a Corinthian stone column was prepared, which was supplemented with five missing fragments of various sizes. In accordance with the guidelines included in the study by Chelazzi, Marini, Pascucci and Turatto [60], the object was presented against a uniform black background. The adopted colour and structure of the stone was to imitate yellowish-brown sandstone from which ancient buildings were often constructed. It was planned to modify only the brightness of the new elements, by adding white, thus obtaining a number of illustrations differing from one another. Only one aspect of the colour characteristic of the added elements was changed, and that was luminance, while hue and saturation were kept unchanged [61]. This way what was altered was the contrast between the adjoining new and original surfaces understood as a modification of the relation in “distribution of luminance, which is the luminous intensity per unit area” [62].

The sequence of stimuli intended for testing was built on the basis of two possible extreme examples (Fig. 2). One of them was the core in which the cavity fillings were made of stone identical to the original one – contrast 0%–(C0), where as the other was a detail in which the complements were white–contrast 100% (C6) (Fig. 2).The stimulus which opened the set intended for the actual tests was a column supplemented with a material slightly contrasted with the original stone (C1–10% contrast). Subsequent complements were gradually lightened by 20%.

Earlier illustrations were made for smaller differences, i.e. 10% and 15%. However, they turned out not to meet the requirements of the study. Ten people were shown all the stimuli and then asked to arrange them in order from the least to the most visible complements. For the smallest contrast differentiation (10%) the arrangement of unmarked examples in the right order turned out to be too difficult for nine people out of ten, and for four out of ten the same problem occurred in case of the differentiation amounting to 15%.

The last examined element was the stimulus which was reconstructed by using almost completely white complements (C5–contrast 90%). In this way, five illustrations to be tested (Fig. 3 and Table1) were obtained, the size and aspect ratio of which, 1620 × 2880 pixels, were adapted to the characteristics of the monitor used in the study.

It should be emphasized that although the entire column was made of the same material, the fluting, the grooves in the midsection, and the different location of the surfaces in relation to the source of light resulted in the old part of the column varying in its luminance. The base of the column is higher in luminance, making the added element in that part less contrasting.

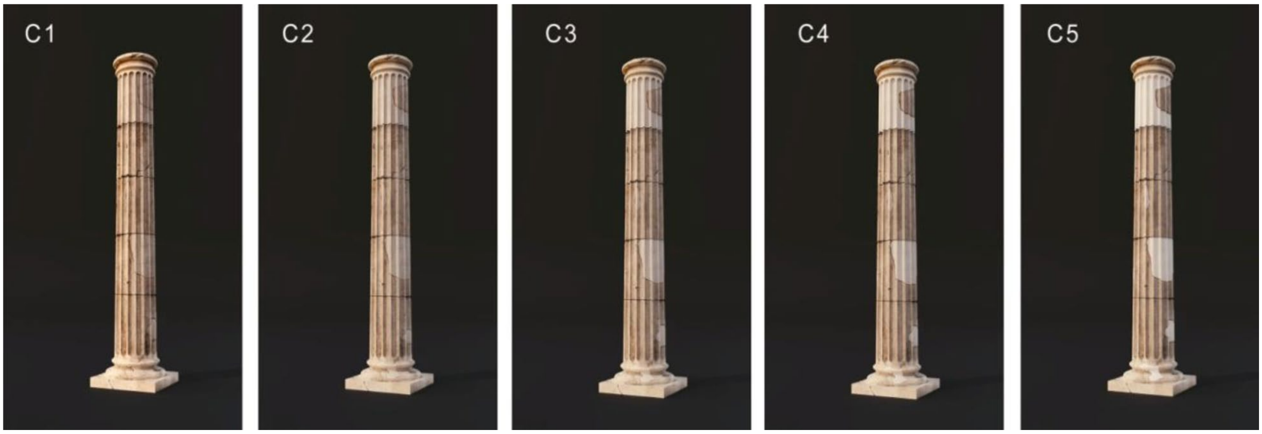

Fig. 3 Comparison of illustrations used during eye-tracking registrations C1-C5 (author)

Table 1 The method of preparing the contrast scale for individual anastyloses (author)

Name of example	C0	C1	C2	C3	C4	C5	C6
New elements	No difference	degree of contrast in the brightness of complements					complete whitening
Degree of contrast	0%	10%	30%	50%	70%	90%	100%

Preparation of the presentation to be shown to the participants

The research also included nine photos of various types of complements to the antique detail. The other images were selected so that they would present different monuments from ancient Greece that involve anastylosis. All of them included some sandstone columns as parts of reconstructed ancient structures. In accordance with what is shown on Fig. 1. these archaeological sites and museum exhibits had added elements of distinct colour, texture or shade.

The illustrations were to be displayed randomly, enabling the subjects to become familiar with the topic before examining the researched image. Stimuli C1, C2, C3, C4 or C5 were shown as one of the last four images. It was important to present only one variant of the illustration to a specific observer, so that the processes of using short-term memory [63] and comparing similar images [64] would not influence the test results. It was significant that the whole group was subjected to the same procedure and that the observers approached the next elements intuitively [65], since people who look at reassembled museum exhibits or Acropolis buildings usually are not familiar with the concept of anastylosis and they do not know what its rules are. By making the research more similar to the real-life situation described, this issue was not explained to the participants of the test either. Had the participants been informed beforehand what anastylosis is, one would have registered visual behaviours that would not have been intuitive but to some extent shaped by the given definition. The purpose of the research was to observe types of visual behaviours that could be later compared to the conscious way monuments are perceived and interpreted by experts. The author feels that such a comparison will add the most to a discussion about conservation of historical monuments and whether experts are willing to include a naïve perspective to modify long-established rules. Many professional environments tend to adhere to assumptions that have not been verified [66] and see taking the perspective of non-professionals into consideration as a scientific fad [67]. However, learning what non-professionals think does not mean that their opinions have to be implemented in an unaltered form over which professionals would have no control [68].

The research had to be designed in such a way that it could be concluded that the participants had the same cognitive intention. If the observers did not follow the command and looked at the pictures freely, their motivation would be unknown, which is presented in the classic eye-tracking experiment by Alfred Yarbus [69]. In order to compare the reception of the prepared examples, it was necessary to come up with a task forcing observers to recognize and differentiate the old elements and the new ones. The task had to be as neutral in character as possible, not demanding specific knowledge or skills, and easy to interpret [70].

The task was formulated as simply as possible, namely 'On the details shown within 10 s, find and count the newly added elements'(Additional files 1, 2, 3, 4, 5, 6, 7, 8). The volunteers were supposed to execute such a command ten times for the examples. On the boards between the illustrations which presented anastylosis, a request was displayed, i.e. 'Say out loud how many new elements there were' (Additional file 6). After the answer was obtained and recorded, the supervisor of the experiment initiated the display of the next image. Numerical answers have the advantage of being independent from the linguistic and social competence of participants or their level of education. Those taking part did not have to assess whether they like the presented image or not because such subjective responses require additional cognitive processes [70]. The above-described combination of this task along with the eye-tracking recording was supposed to enable the interpretation of the data. The eye tracker precisely recorded each participant's eye-tracking route as well as the places where they focused their visual attention [71]. If the numbers quoted by the observers had not been noted, it would not be possible to determine what the effect of looking at the given area was. After all, it is possible to look at an added fragment and not recognize it as a new one for various reasons.

All images were displayed for 10 s. The time was selected by doing a reconnaissance before the tests. Illustrations C1, C2, C3, C4 and C5 were presented to 25 different people (each of the 5 pictures was seen by 5 people) who were then asked to say how many new elements they had seen. The two fastest answers, not necessarily correct, were given after 6 s, the slowest responder gave the answer after 19 s. The median for the reported results was 10 s.

Assignment of AOI

In order to generate appropriate reports on the method of getting acquainted with the appearance of the five prepared stimuli, it was necessary to define Areas of Interest [40, 72] to which individual visual behaviours of the participants, i.e. fixations and saccades, were to be assigned. The method of determining Areas of Interest for the examined images is presented in the following illustration (Fig. 4). The AOI NEW fields were designed to include the boundaries between the old and new parts and the outline was enlarged by a 30-pixel wide envelope. Each illustration had fields designated in the same way. The zone which was a combination of fields 1AOI NEW to 5 AOI NEW was called ALL NEW AOI.

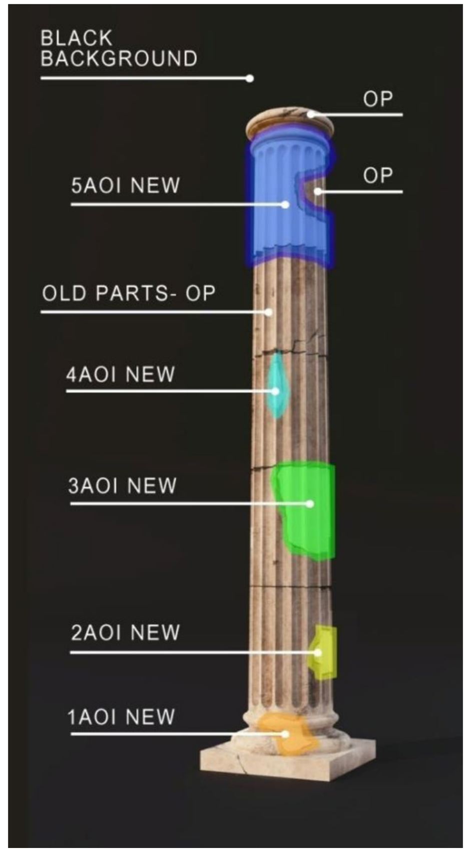

Fig. 4 The method of determining AOI fields (Tobii Pro Lab / author)

Research hypotheses

It was assumed that:

- low contrast will result in few participants correctly recognizing the historical and newly added elements;
- observers will fail to notice some of the newly added complements with too low a degree of contrast or they will look at them but will not be able to classify them as the new ones;
- to recognize new parts, observers of images with lower contrast will make more shifts between the old and the new elements;
- the application of higher contrast will accelerate and make it easier to find new elements and this will increase the number of people correctly performing the task;
- thanks to the additional time, participants looking at sets with more distinct differences between the two types of surfaces will be able to carry out an 'extended investigation of images' [73].
- the fact that the observers will require less time to complete the task will allow them to look more

Table 2 Answers given by the participants in relation to the tested stimuli C1–C5. (author)

Example / stimulus	C1	C2	C3	C4	C5
Respondents	*33*	*33*	*31*	*31*	*33*
Part 1 General response analysis					
Answers					
Correct = well performed task	*6*	*16*	*20*	*21*	*22*
	18%	48.5%	64.5%	67.7%	66.7%
Wrong = badly performed task	*27*	*17*	*11*	*10*	*11*
	81.2%	51.5%	35.4%	32.3%	33.3%

Italic values indicate number of people, the values without italic highligt indicates the percentage in each group

peacefully at the object, including its authentic elements.

Analysis of participants' responses and visual behaviours

Initial data verification

182 people participated in the recordings. Not all data turned out to be implemented in a way that could enable their use later. As a result of the first verification, 161 recordings of the participants were qualified to the stage of interpreting the accumulated data, which in the light of other eye-tracking studies of this type can be considered a large group. Correct recordings were made by 99 women and 62 men (Additional file 9). Some of the eliminated recordings belonged to people who did not receive sufficiently precise calibration results, changed their body positions in a way that disrupted the work of the eye tracker, or for some reason stopped looking at the screen while the tested stimulus was displayed.

Analysis of participants' responses

The first and the simplest part of the analysis was the compilation of the data concerning the answers given by volunteers who tried to count all new fields. The results of the analysis are presented in Table 2.

In accordance with the assumptions adopted, the number of good answers increased for the examples which presented successively more contrastive complements. Only 18% of the participants looking at C1 were able to perform the task correctly. It was the participants looking at C4 that gave the most correct answers. The analysis of the first part of the table makes it possible to see that the greatest improvement in the accuracy of answers, by as much as 29.7%, occurred between examples C1 and C2. Another difference between examples C2 and C3 was significantly smaller, amounting to 16%. The number of

Table 3 Comparison of the number of observers who performed fixations in all five NEW AOIs with the correctness of the answers given (author)

	C1	C2	C3	C4	C5
Eye-tracking results					
Observers who performed fixations in all AOI NEW	*17*	*18*	*17*	*21*	*27*
Correct answers (from Table 2)	*6*	*16*	*20*	*21*	*22*
Classification errors	*11*	*2*	*3 (!)*	*0*	*5*

Italic values indicate number of people

incorrect responses recorded for the observers of examples C3, C4, and C5, remained at a similar level, i.e. around 32–35%.

On the basis of the responses, examples C3, C4, and C5 can be considered similarly favourable. In order to carry out a further interpretation, the obtained results should be connected with the results of the eye-tracking registration.

Observing and noticing complements

The first element that can be directly linked with the oral responses is how many participants looked at all the added items. Table 3 presents the number of people who performed fixations within all AOI corresponding to the new fragments. As expected, their number is gradually increasing. By comparing these results with the answers given by the respondents (Table 2), it can be seen that some of the people who looked at all the elements that were to be counted did not properly classify those elements. It occurred in eleven cases for example C1, in two cases for example C2 and in as many as five cases for stimulus C5. The number of people who noticed an element but were unable to recognize it as new is very high only for example C1, and the level of confusion for the remaining examples is much lower. It seems that an example favouring the correct solution of the task was stimulus C4 because the number of correct answers fully coincided with the results of the eye-tracker registration. It is puzzling why the confusion increased for C5. It should be admitted that it is completely surprising and difficult to interpret that three people who counted the brighter fields for variant C3 did not actually perform fixations in all of the fields but still gave the correct answer.

The doubts arising from the presented comparison prompted the author to undertake a precise comparative analysis as a result of which 10 test participants who gave results exceeding the number of visually visited fields were found. The comparison presents AOI NEW fields that they saw and the recorded content of responses they gave. The Table 4 indicates that participants could be the people who counted these zones seeing them in a

Table 4 Participants with noticed inconsistencies between their answers and the number of AOI in which a fixation was performed

Participant	Visit count					Number of AOI without visit	Verbal responses	Discrepancy between visual behaviour and given answer
	1 AOI new	2 AOI new	3 AOI new	4 AOI new	5 AOI new			
C3								
C3 9	3	–	–	–	1	*3*	*4*	*2*
C3 16	3	2	3	–	–	*2*	*5*	*2*
C3 29	–	2	2	1	1	*1*	*5*	*1*
C4								
C4 2	1	2	1	1	1	*0*	*6*	*1*
C4 23	1	–	1	–	1	*2*	*4*	*1*
C5								
C5 8	3	–	3	–	2	*2*	*4*	*1*
C5 10	3	2	1	1	1	*0*	*6*	*1*
C5 20	4	–	3	2	2	*1*	*5*	*1*
C5 30	3	1	1	2	1	*0*	*6*	*1*
C5 32	1	2	2	–	–	*2*	*4*	*1*

The responses which were considered correct at an earlier stage of the analysis were marked with a italic envelope (author)

Italic values indicate number of people

Table 5 Fragment of Table 2 modified as a result of learning about visual behaviours of the participants and comparing them with the answers given (author)

Example / stimulus	C1	C2	C3	C4	C5
Respondents	*33*	*33*	*31*	*31*	*33*
Well performed task	*6*	*16*	*18*	*21*	*21*
	18%	48.5%	54.8%	67.7%	63.6%

Observed deviation in the number of well-performed tasks should be seen as statistically significant ($p = 0.00015$)

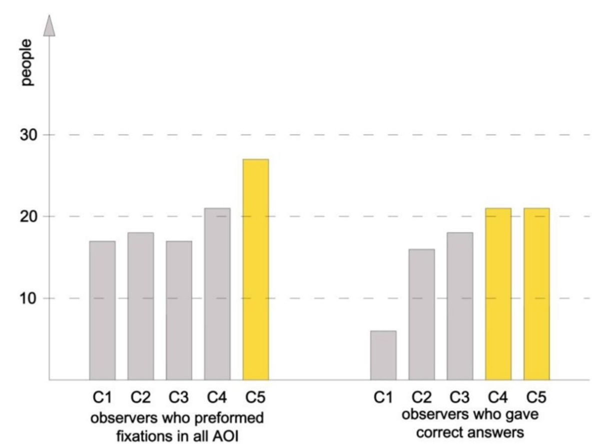

Fig. 5 Graphs showing the number of people who made fixations within all five AOI NEW and the number of people who gave the correct answer (author)

peripheral way [61], however, it is unlikely because AOI fields were intentionally enlarged in relation to the actual limits of the complements to eliminate the influence of this phenomenon. The discrepancy could also result from an unconscious mistake or a hidden desire to 'do better'. The eye-tracking data made it possible to eliminate survey errors of this type.

It is intriguing why such mistakes did not occur when the participants looked at the first two examples (C1 and C2) and as many as 5 people gave too high a result in the example, which is the most obvious. Were those looking at C5 the least focused on the task? Did counting the parts that were too distinctive make the task too easy and result in participants being less focused and thorough? These observations force us to modify the previously provided data. The data for examples C3 and C5 were changed (Table 5). The revised data only deepened the differences between example C4 and the two adjacent stimuli C3 and C5.

The verified data was used to make bar graphs showing the number of people who made fixations within all five AOI NEW as well as the number of people who gave correct answers. By analyzing Fig. 5 one may notice that although in case of C5 a lot of volunteers made fixations within all AOI NEW, not all of them managed to give the correct answer. There must be some reason why the fourth stimulus supported the correct performance of the task in the best way. It was important to examine the remaining parameters of the process of eye tracking over the presented images more specifically in order to better diagnose the reason for the observed relations.

Scale of error

Apart from the number of participants giving incorrect answers, the next parameter that might help interpret the experiment is the total number of unidentified, and

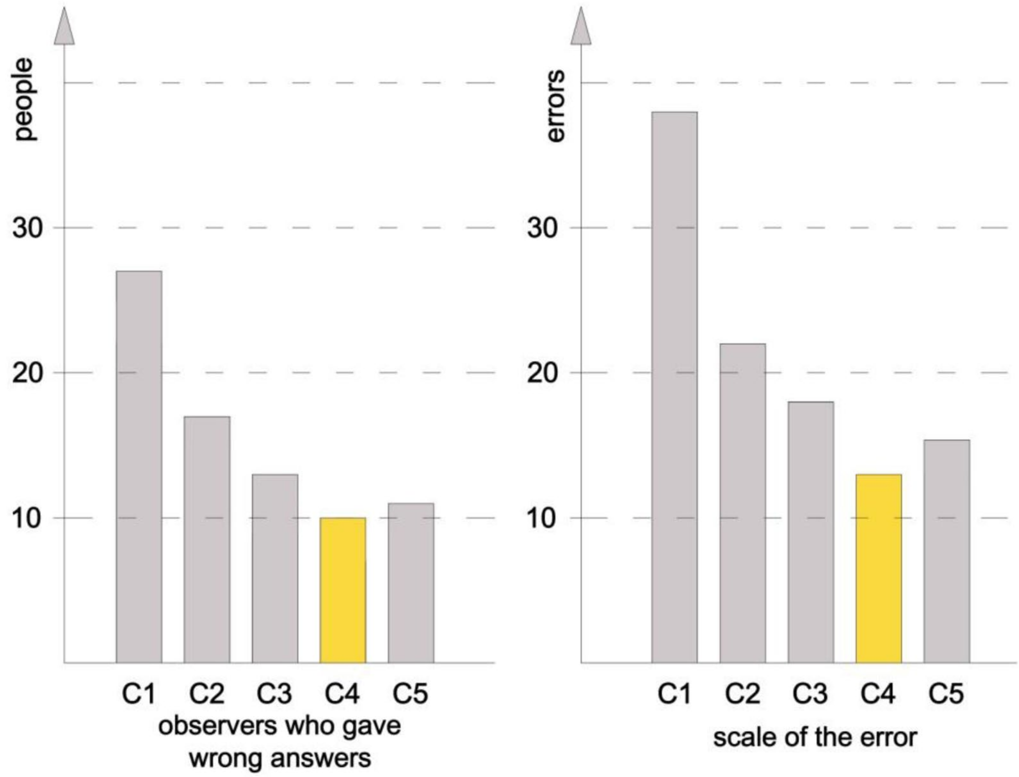

Fig.6 Bar graph showing the number of not counted new elements for each stimulus. (author)

therefore not counted, AOI. For example, 27 participants failed to count all the areas for C1. 22 out of these 27 missed one field, three missed two fields, one person missed as many as four fields, and one another stated that they did not see any fields. Therefore the total number of not counted fields for C1 amounts to 36. The results of similar calculations for the other stimuli are visible in Fig. 6.

One can observe a steady increase in the number and quality of answers. In case of C1 there were participants who failed to notice more than three new areas. There were no such big mistakes in examples C2, C3, and C4. For stimulus C5, no one made a mistake of more than two new fields. It is surprising and difficult to interpret that in examples C4 and C5 (Table 4), there were people who gave results that exceeded the number of added brighter elements presented in the examples, although the contrast visible in these examples, according to the author, should not be misleading. Since the situation in which a participant claimed to have seen more new elements than there really were was also seen as an incorrect answer, the analysis shown below (Fig. 6) suggests that C4 is the option that makes it the easiest to count the added elements correctly.

Heat maps / hot spot plot

The difference in the method of viewing individual examples can be presented by comparing heat maps [73]. This kind of simplified analysis may constitute an introduction to further research. Figure 5 shows thermal maps generated automatically by the Tobii Pro Lab program for the transparency set by the author (50%), the kernel size of 100 pixels and the selected colour model (green, yellow, orange, red).[3] These maps show the places which the participants of the research looked at, valorising the least frequently and most frequently viewed places. The longer more people looked at a given spot, the warmer the colour of this place became (ranging from a dark green shade, through yellow and orange, to red). Figure 7 presents the heat maps for all examples. The object in C2 is observed in the most chaotic manner, and there are few orange dots, while many green dots are scattered. The heat map for C5 shows many more such places, which means that the new AOI were more clearly noticed as separate elements which resulted from the large variations in brightness (salient irregularities) [75]. Such

[3] Tobii Pro User's Manual, Version 3.4.5, https://www.tobiipro.com/siteassets/tobii-pro/user-manuals/tobii-pro-studio-user-manual.pdf/?v=3.4.5.

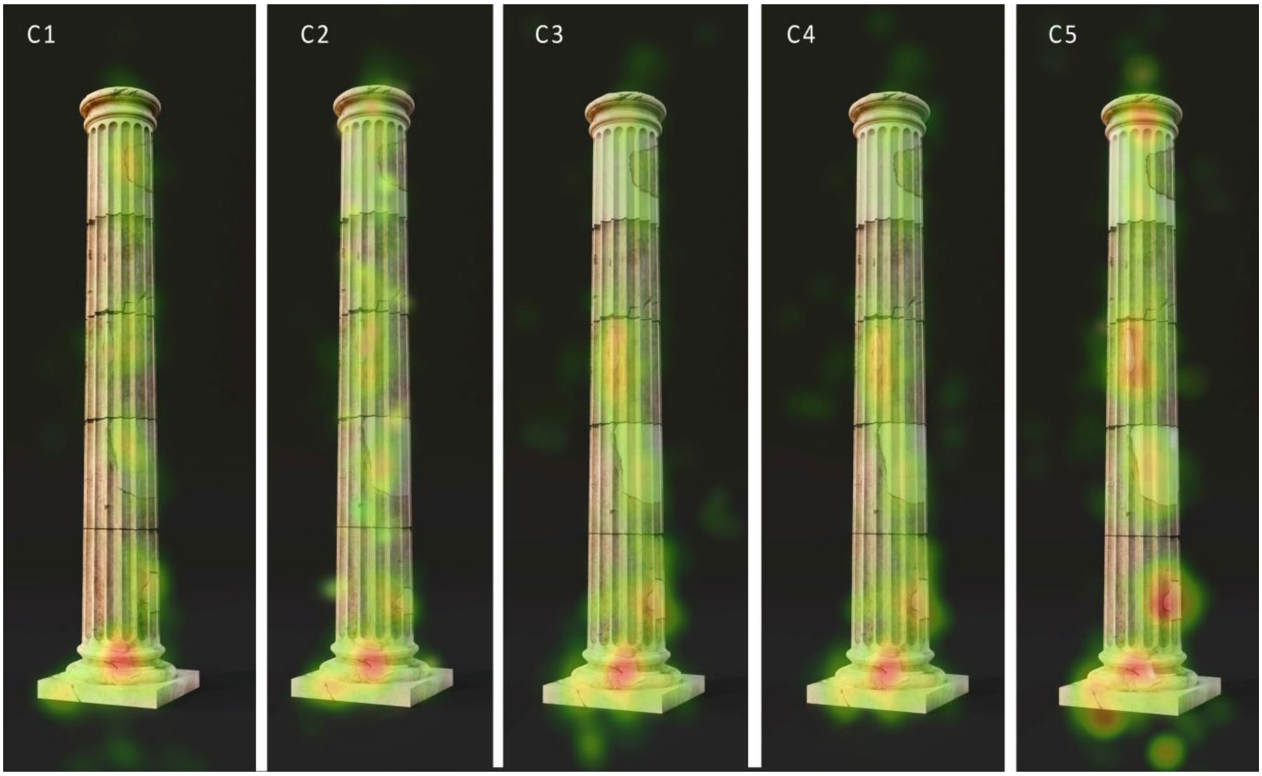

Fig. 7 Comparison of heat maps for examples C1, C2, C3, C4, and C5 (Tobii Pro Lab / author)

an image indicates the efficiency of the search for new fields [76]. However, the fact that two orange spots and one reddish spot clearly go beyond the outline of the presented anastylosis of C5 is of little advantage, and thus the attention map is somehow 'torn'. In this respect, example C4 looks more favourable.

Characteristics of the method of searching for new fields

Involvement in the task–fixation duration.

The most general parameter which can determine the level of the participants' involvement in the process of getting acquainted with the presented stimulus is the average fixation duration. Fixation duration is used to evaluate cognitive workload [39]. In studies of visual searching, learning, problem-solving and reading long-lasting fixations indicate that the object is somehow more engaging or that its comprehension requires more processing [77–80]. In this case, it especially applies to fixations which were performed within the fields which were searched for and were supposed to be counted (ALL AOI NEW), as well as those against which they were distinguished (AOI OLD).The values obtained as a result of the registration are presented in Table 6.

The example the participants looked at with the greatest commitment is stimulus C3. The shortest fixations were recorded for the two extreme examples, i.e. C1 and 5. For some reason, looking at both the old and the new parts was the least engaging for example C5.

Despite the noticed differences, the one-way ANOVA data analysis showed that the observed deviation in the fixation duration should be seen as statistically insignificant ($p > 0.05$). It means that the fixation duration is not a characteristic that could support the interpretation of the experiment.

Task completion time

Another aspect that adds information about the way in which the participants found complements in the presented anastyloses is the data related to the time of performing the task. The time to first fixation on

Table 6 Fixation duration for AOI NEW and AOI OLD (author). Observed deviation in the number of well-performed tasks should be seen as statistically insignificant ($p > 0.05$)

Example / stimulus	C1	C2	C3	C4	C5
Fixation duration on AOI NEW (1–5) [s]	0.197	0.204	0.210	0.206	0.195
Fixation duration on AOI OLD [s]	0.189	0.193	0.192	0.194	0.181

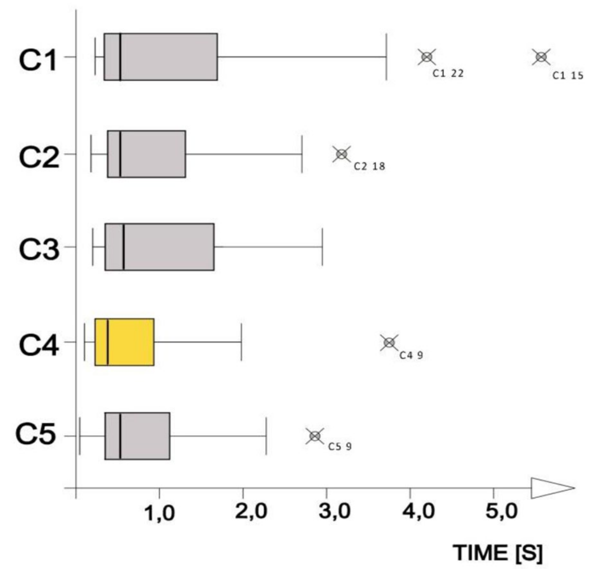

Fig. 8 Time before finding the first added fragment. Box plot including outstanding registrations.(author) Observed deviation should be seen as statistically insignificant (p > .05)

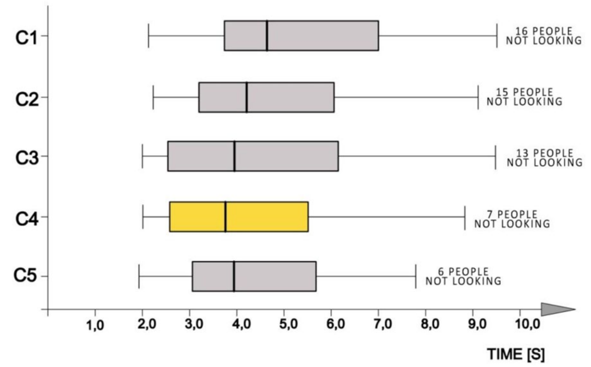

Fig. 9 Time to find the last new fragment of anastylosis. Box plot for all participants of the research.(author) For the reasons mentioned in the paper it was decided not to do an ANOVA test for the data connected with the time that passed before the last AOI was noticed by participants

the target area reflects the moment when the process of searching for new objects could be realised [72]. A shorter time to perform the first fixation on the examined object/field means that it gained properties which make it easier to attract attention. The analysis of the time of performing the first fixation appears a particularly important aspect of recognizing the disposition of visual attention.

Time to finding the first field

Figure 8 presents the comparison of the time to first fixation in one of AOI NEW fields. The results of five participants, i.e. C1 22, C1 15, C2 18, C4 9, C5 9 were marked as points in Fig. 8 because they clearly stood out from other recorded values. In the scale of the entire research, 5 people constitute only 3.1% of the research group size.

It is surprising that the analysis of the (Figs. 8 and 9) shows that finding the first reassembled fragment was not, contrary to the author's original expectations, the fastest for C5. It turns out that observers of C4, considered as a group, achieved the best results. Despite the noticed differences, the one-way ANOVA data analysis showed that the observed deviation in the process of finding the first added fragment is statistically insignificant ($p > 0.05$). Such data indicate that modifications of contrast did not significantly affect how much time it took the participants to find the first AOI NEW.

Time to finding the last field

Time that passed before finding the last field is a parameter much more difficult to analyse than finding the first one. Each participant performed the fixation in at least one of the fields and only one claimed not to have recognized any. However, many participants of the research did not find all five cavity fillings (Fig. 6). For this reason, the analysis covers all participants, but it refers to the issue of 'visually finding' the last AOI NEW field they looked at. The obtained search results took the values presented in the form shown in Fig. 9 (which also shows how many people failed to look at all the fields).

The recorded values show the point after which participants did not recognize any new elements. Again, the results did not show that recognizing new elements was the easiest for those observing the most expressive example. C4 turned out to be the most advantageous once again as the participants who looked at it found all the fields the fastest. A one-way ANOVA test of this aspect was seen as inappropriate. As previously mentioned, the registered times are related to finding a different total number of AOI and therefore any comparison of such sort must be imperfect.

Search efficiency, gazes, and number of fixations 'on target'

The number of gazes within a given field may also indicate a method of finding new fields. A gaze means drawing visual attention to the AOI under study, i.e. performing fixation within it or staying in another zone of the fixation sequence continuously. A large number of returns to viewing the same element, combined with a

Table 7 Average number of gazes (author). Observed deviations should be seen as different but statistically insignificant ($p > 0.05$)

	C1	C2	C3	C4	C5
Average visits in ALL NEW AOI	9.67	10.45	9.52	9.61	10.73

Table 9 Total gaze duration (author)

	C1	C2	C3	C4	C5
AOI ALL NEW [s]	3.041	3.141	1.894	1.672	1.871
AOI old patrs [s]	2.624	4.229	3.723	3.691	3.426
Outside Anastylosis [s]	4.335	2.630	4.383	4.637	4.703

Observed deviations in total gaze duration in relation to new and original fragments should be seen as statistically significant ($p < 0.5$)

Table 8 Number of fixations (author)

		C1	C2	C3	C4	C5
A	On target fixations ALL AOI NEW	15.33	16.79	14.86	15.22	15.51
B	The whole image	27.38	31.55	27.10	28.06	30.15

Observed deviations should be seen as statistically significant (fixations on whole image $p = 0.04$) or significantly different (fixations on new parts $p = 0.056$)

large number of fixations, may indicate some kind of difficulty in reading information [72, 81].

Not only did the participants looking at C4 find the first and the last of the five fields earlier (Figs. 8 and 9), fewer of them also felt the need to recount these areas. This shows that they doubted less their own performance. People looking at C5 returned to the same fields much more often, which is shown in the data in Table 7 regarding the average number of gazes counted for all AOI NEW fields. The number of fixations on target divided by the total number of fixations [76] also shows a reduced search efficiency. Such a comparative analysis can be undoubtedly used for those examples which obtained similar results in the survey. Analysis of the data collected for C4 and C5 shows that this parameter turned out to be the least advantageous for the more expressive element (Table 8).

Time spent looking at the background and beyond the screen

Another element which assesses the engagement of participants in the task is the time they spent looking beyond the presented object, i.e. at the background or completely beyond the screen. The easier the task becomes for the participants, the more it can be boring for the participants who start looking from side to side instead of looking at the presented object. In order to discuss this aspect, a comparison presented in Table 9 was prepared. The values in the second line of this table refer to the average time viewers spent viewing all AOI NEW fields. The third line deals with the time required for getting acquainted with the form of the authentic parts of each of the five presented reconstructions. The last one is about the time spent looking beyond the object, at a black background or even beyond the screen.

Variant C2 turned out to be the most demanding in terms of cognition. The participants exposed to it hardly looked around during the task, devoting most of the time to moving their eyes around the presented object. The data in Table 9 show that stimulus C5 turned out to be the least engaging because its observers spent almost half of the time looking beyond the presented architectural element (Table 9), while at the same time they were not the fastest to perform the task.

Results

The research showed that eye tracking is a method thanks to which it is possible to define conditions that make it easier for non-professionals to recognize what is a new and what is an original element of anastylosis. The course of the experiment proved that interdisciplinary combination of research methods is necessary for achieving scientific precision. The application of an eye tracker made it possible not only to eliminate errors resulting from the nature of survey-based research, but also to study when the participants were the quickest to differentiate between the new and the old parts of the displayed columns.

The tests allowed verification of the research hypotheses.

- The application of higher contrast increased the number of people correctly performing the task but at the same time showed that the highest contrast between the old and the new parts did not result in the most convenient conditions to execute the task quickly and correctly.
- Stimulus C4 turned out to be potentially the best cognitive variant. It means that despite the hypoth-

esis, the stimulus with the strongest contrast turned out to be less advantageous in terms of the recognition of new parts.

- Modifications of contrast proved of little significance when it came to how quickly participants found the first added part, whereas the deviations observed for the time before finding the last added fragment support the hypothesis about shortening the time necessary to complete the task.
- It has to be admitted that the hypothesis that the participants who looked at the examples with most contrast would perform the task faster and then engage in a longer and calmer observation of the historical object was also incorrect.

Discussion

Methodology

After carrying out all the analyses, the author must admit that it was an oversight not to include visualization C6, which presented the core of the column with completely white cavity fillings. This example was eliminated because when displayed on a large monitor it looked completely artificial and bright elements seemed to be simply glaring. However, with the eye-tracking data for this example the interpretation of results would become even more reliable. In the current epidemiological situation, conducting supplementary tests is impossible due to imposed restrictions.

The remaining aspects of the preparation of the research can be considered correct. This applies, for example, to the time that the observers were given to perform the task. On the basis of the data in Fig. 9, it is easy to estimate that approximately 75% of the participants did not find any new fields after 6 s. According to the author's interpretation, this suggests that the time span allocated to the experiment was certainly not too short.

Lack of possibility to conduct an ANOVA analysis for the time until the last AOI was found that could be used in Fig. 9 requires more thought. Such an analysis would make sense in a test where the task would be to point out five new fragments as quickly as possible. Then every recorded time would be connected with finding the fifth area. From the author's perspective, such a modification of methodology may be considered in further research, in which participants would be given unlimited time to complete the task and would have to identify such a new element in a piece of software that would allow marking an area by touching it or pointing at it with a cursor.

The research presented here involved limited time and only one object. As a result, it only offers information about the very first, intuitive reactions of the participants. However, it is impossible to conclude how it affects the aesthetic experience that lasts longer and refers to larger scale anastyloses. Experiments on the perception of anastylosis could be carried out with the application of a mobile eye tracker, making models of various anastyloses.

The places where we display artefacts that have undergone anastylosis are drastically different from the atmosphere of a lab deprived of other stimuli (e.g. background music or conversations of other people). This applies to both traditional museums and archaeological sites that are transformed so that they resemble museums in some aspects. There are eye-tracking techniques that make it possible to register eye movement in such real-life circumstances. A particularly large number of such tests, conducted by means of portable eye trackers, was related to factors influencing safety on the road, for example of cyclists [82], or to diagnose consumer behaviours [32]. This method seems attractive and has been applied in research on perception of space [43], but bearing in mind the aim of the research presented in this paper, it would be virtually impossible to come up with a methodology that would ensure reproducible results in such an environment. While preparing an experiment involving a portable eye tracker, one would have to take into consideration a great number of variables. It would be much more difficult to check whether the participants understand the task they are given and determine the moment when they begin counting. Without a clearly defined moment when the experiment begins, it would be difficult to measure the time that passes before it is completed. Moreover, in a museum exhibition counting new fragments of a historical object surrounded by colourfully-dressed and often noisy tourists would prove a considerable obstacle during the phase of data interpretation. Eye-tracking research in the open air, among relics exposed to changeable lighting would also prove erroneous. The changing direction of the sun's rays, differences in the natural light's intensity and hue would have a crucial impact on perceiving the relations between the old and the new parts of an object. In addition, to use a portable eye tracker, one would have to produce several sculpted copies of the object under consideration that would only differ in the colour of the added elements. Eye-tracking research in a virtual reality environment [36] that would rely on spherical images or video clips would prove less complicated and more reliable since it would be more likely to offer reproducible results. One drawback of such a solution is the need to carefully prepare the methodology of the experiment and to pay a lot of attention to the graphic quality of the presented images. Research that does not comply with such criteria will distort the results and make it less attractive than registrations done on site, by the means of a portable eye tracker. This has been noted and emphasized in the 2017 paper by Brade, Lorenz, Busch, Hammer, Tschieligi and Klimant [83].

Public opinion interest

Conversations with the participants constituted a side element of the research. The impact the unusual test had on the volunteers was noticeable. After the tests, over 70% of the participants wondered what the purpose of the research was, how the eye tracker worked and what such tests were to be used for in the long run. The volunteers discovered aspects that they had never thought about before, which in itself was an impulse for short or longer consideration. Almost 45% of the participants asked to be sent the conclusions of the research. This is consistent with the trends reported in the research on Heritage and Social Value: Public Perspectives on European Archaeology [84] and the declared readiness of almost 50% of laypeople to actively engage in the protection of the region's native heritage. The application of an eye tracker and other devices which in an unusual way engage non-professionals to get to know monuments should be treated as a social advertisement of professionals and topics they deal with. Izabela Parowicz insight fully writes about the need to make such direct contacts [20].

Clarity of the message

By looking in detail at the method which allows viewers to perceive an object designed by a specialist, it is possible to gain valuable knowledge. For example, it is intriguing that even when using very high contrast, as in example C5, it is impossible to be sure that observers will notice new elements. As many as 18.2% of the participants who looked at picture C5 failed to notice at least one of the complements. Another 21.2% of the participants, although they swept the bright element with their eyes, they did not recognize it. This is an important signal for professionals. The participants were focused only on this aspect of reality, which was separated for the needs of the research, but the task still turned out to be too difficult for one third of participants. This shows how important it is to get to know the public's perception of the heritage that archaeologists, architects and museologists take care of. Thanks to such research it is possible to realize that what an expert considers obvious, clear, and unambiguous, does not necessarily have to be so for a large part of the society. Perhaps some messages we would like to convey will never be fully understood by some recipients. This does not mean, however, that we should give up on the efforts to facilitate and deepen the society's relation with monuments. In order to do this, we must observe and listen to ordinary people interacting with the heritage which we manage as experts and, if possible, remove the diagnosed barriers. According to the research, even a small change may cause either an improvement or a significant deterioration of the process of a monument's perception.

Summary and future research perspectives

Despite many studies, we still have a relatively poor understanding of how people actually experience authenticity at heritage sites [85]. The authors of a 2016 eye-tracking research conducted in a Salzburg museum stated that, in order to facilitate the overall heritage experience, greater importance should be attached to the relationship between visitors and museums [55]. Similarly, it may be argued that we would only benefit from highlighting the significance of the relationship between architecture–be it entire neighbourhoods, buildings or little architectural details –and those who look at it. The article presents only one design aspect–luminance modulation–which can distinguish between authentic and newly added elements in the objects from the past that have been reassembled. This is one of the many steps which are necessary to be taken to obtain a complete picture of the perception of designs submerged in a historical context. Further variables are the number and area of complements as well as the use of a different texture of the fragments added. It should not be forgotten that the way a monument is perceived is also influenced by other factors, such as lighting or its surroundings (background). It also seems that further research on the perception of conservation cavity fillings should also apply to monuments which are made from various materials and at various architectural scales [86]. Finally, the visual criteria for assessing anastylosis may change with place, culture, and time [6, 87, 88], so it would be interesting to conduct comparative studies inviting people from different countries and representing different cultures to take part in the tests.

A search for new methods of studying the opinion of the society seems essential as 'future "politics of conservation" must also be accepted and supported by society' [89]. Although some architects and conservators declare more or less openly that 'the idea of public consultation has become fetishized and is simply fashionable,' [67] the author believes that such a community-oriented approach is not so much a fad as an organically progressing evolution, thanks to which the opinions of the society can be studied and taken into consideration on many coexisting levels so that the applicable law and procedures become more and more adequate and effective [44, 90], or in other words, as optimal as possible in a given situation. It is an important step towards a situation in which archaeology and conservation are not 'undertaken by the public' as some experts seem to fear, but rather 'by professionals for the public'[68].

Abbreviations
AOI: Area of Interest; ICOMOS: International Council on Monuments and Sites; VR: Virtual reality.

Supplementary Information
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Additional file 1: Figure S1. Board greeting the participants.

Additional file 2: Figure S2. Board asking the participants to look at a given spot.

Additional file 3: Figure S3. Board thanking the participants.

Additional file 4: Figure S4. Board announcing a simple task.

Additional file 5: Figure S5. Board asking the participants to locate and count new elements.

Additional file 6: Figure S6. Board asking the participants to say out loud how many new elements they have found.

Additional file 7: Figure S7. Board asking the participants to locate and count new elements again.

Additional file 8: Figure S8. Board with thanks for participating in the study Statement 1 List of participants including sex and age.

Additional file 9. List of participants including sex and age.

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Authors' contributions
The author read and approved the final manuscript.

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Availability of data and materials
Data analysed during this study are included in this article and supplementary files.

Declarations

Competing interests
No potential conflict of interest was reported by the author.

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