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Original article

Exploring the impact of cultural context on eye-tracking studies of architectural monuments in selected European cities: Sustainable heritage management

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ABSTRACT

Sustainable management of architectural heritage requires conducting an inclusive diagnosis of users' opinions, considering both residents and tourists as the recipients of urban space. Given the cultural diversity within these groups, proposing the use of eye-trackers (ET) as an alternative to traditional public consultation prompts the need to assess the method's advantages and disadvantages. It remains uncertain whether individuals from different countries look at historical architecture and its transformations similarly. The uniqueness of this subject matter prevents drawing parallels from experiences in other domains. Moreover, prior research provides conflicting conclusions and may include methodological errors. This uncertainty impedes the adoption of ET as an administrative and legal tool. To address this gap, 320 volunteers, encompassing both Poles and foreigners, were invited. Qualification involved optometric tests and questionnaires. Subsequently, a portion of the participants underwent the experiment using ET while viewing visual stimuli on a monitor. The experiment featured twelve monuments, with six originating from Wrocław and six from another major European city (Paris, Rome, London, Berlin, Dresden, Dortmund). The study focused on the nature and pattern of fixations made on original photographs and their modified versions. Analyzing the collected ET data for 24 stimuli, two primary aspects were explored. First, whether both groups, irrespective of their familiarity with the object or the city of residence, looked at the original photographs in the same manner. Second, it was investigated whether participants cultural background significantly influenced observers' reactions to visual changes in the buildings. Only 8 out of 160 comparisons demonstrated statistically significant deviations. Other results, including visitor numbers, fixation counts, average fixation duration, total visit duration, and time to first fixation, exhibited similarity across the board.

1. Introduction

The challenge of sustainability of the cities makes it necessary to take into consideration multiple aspects concerning the technologies and materials applied, respecting the resources, getting familiar with specific climate conditions, including the economic and social context. Basing on the classification by Angelidou [1] while planning a smart city it is necessary to consider 'hard' and 'soft' development factors. It is clearly stated in documents of international significance [2,3] that set both specific goals described with the use of numbers, as well as general ideas characterized exclusively by words. In order to join both worlds: sub-

Abbreviations: EU, European Union; WUST, Wrocław University of Technology; GUS, Główny Urząd Statystyczny (Central Statistical Office); AVG, average; M, median; SD, standard deviation; AFD, average fixation duration; AOI, Area of Interest; D, diopter; ET, eye-tracker / eye-tracking; FN, fixation number; TTFF, time to first fixation; TVD, total visit duration; VN, visitors number; H1 / H2 / H3, hypothesis 1 / 2 / 3; PL, Poles; FO, foreigners; ORG, original picture; MOD, modified picture; COL, Colosseum, Rome; RST, Reistag, Berlin; TATE, Tate Modern, London; DU, Durtmunder "U", Dortmund; CAT, Cathedral, Wrocław; POD, tenement house at Podwale Street, Wrocław; MM, Młyn Maria, Wrocław; KAZ, Kazimierza Wielkiego Strett, Wrocław.

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stantial/mathematical and humanistic/emotional, it is necessary to adopt a flexible approach towards smart city management [4].

Smart city should constitute a pleasant place for both residents as well as tourists [5], and this requires culture-oriented Smart governance [6]. Touristic traffic has a huge impact on the life of residents and this in turn influences the way in which experts manage urbanized spaces [7]. Both monuments as well as entire historical urban arrangements are adjusted in a way to make them possible to be visited by many people who appreciate their beauty but may also destroy them [8]. The needs of tourists may stand in opposition to the needs expressed by residents [9,10]. The differences refer to numerous aspects, a lot of them concerning aesthetics. "The interdependence between identity as perceived by tourists (external observer) and the identity of the residents rooted in the relationship with the place (in-group) are key to addressing the identity of historic urban areas." [11].

The interface between architectural heritage and tourism is extremely complex [12]. The dynamics and multi-faceted character of changes require the improvement of existing strategies, but also the search for new tools enabling objective and fast diagnosis. It refers in particular to legal and administrative procedures in force, enabling inclusive collection, efficient processing and fast sharing of updated information concerning built spaces [13–15]. The researchers are looking for the methods of holistic combination of co-governance with co-design [9,16]. Eye-tracking (ET) as the method enabling the description and interpretation of visual reactions coming from numerous observers in various scales and environments [17,18] may constitute one of the ways to achieve transparency in urban end environmental planning [19]. Appropriate use of these tools may constitute a solution to the problems that make it necessary to establish the dialogue between experts and the society. This method makes it possible to get non-professionals involved in making joint decisions within the areas that have so far been publicly discussed mainly by experts. Aesthetics constitutes one of them. In the future, devices tracking physiological reactions may enable a clear description of the aesthetic experiences of different users. Procedures involving neurocognitive tools can support the delineation of intervention boundaries and resolution of legal disputes related to the protection of architectural and urban heritage. [20]. To achieve this, many gaps need to be filled. To begin with, it would be essential to understand, for example, to what extent diverse cultural backgrounds influence the process of eye movement when observing monuments.

1.1. Eye-tracking and heritage

People build their knowledge concerning monuments mainly basing on the sense of sight. Mutual relationships between shapes, colours and contrasts create observers' feelings. Eye-tracking techniques make it possible to measure how a given cognitive situation influences the receivers. Eye-trackers enable the recording of the gaze path [21]. By registering the position of eye pupil and recording the image of the reflection of infrared light sources on the cornea, the software is capable of determining the direction in which the research participant is looking. Subsequent locations of observation points are recorded in time. The analysis of the collected data makes it possible to determine the scan path. The process can be divided into two sub-groups of behaviours: fixations and saccades. Fixation is a short moment of maintaining the visual gaze within a narrow observation area (point). Fixation usually lasts from 100 to 500 ms [17,18,22]. Eye movements between subsequent fixations are called saccades. It is possible to connect recorded gaze path with the appearance of studied objects shown on a screen or recorded by ET camera. Data describing all fixations and saccades can be divided and analyzed. To do so, it is usually necessary to assign them to Areas of Interest (AOI) determined by researchers. The data obtained in this way makes it possible to establish various parameters determining for example Visitors Number (VN) per given AOI; Fixation Count (FC) per AOI; Average Fixation Duration (AFD) on a given AOI; Time to First Fixation (TTFF) referring to the time before a given AOI was visually examined for the first time; as well as Total Visit Duration (TVD) referring to the overall amount of time spent on observation of a given AOI.

Although ET is used for research in area of tourism [23], urban planning [24–29], landscape studies [30,31], architecture [32–35], monument care [36–39], as well as broadly understood design [40–42], the conducted studies are multi-faceted and interdisciplinary [43,44]. Tracking the way in which observers look at Built Environment has so far contributed mainly to the description of case studies [45–48]. The authors have not found the information that it is actively used for conducting public consultations, as a tool for resolving legal disputes, as a component of administrative procedures in force. By employing eye trackers, scholars have previously scrutinized tangible heritage from diverse perspectives, as observed through the gaze of non-experts. However, this knowledge is not yet utilized for implementing pro-social changes within the smart city context. Understanding what enhances or diminishes visual attention without using words can be an effective means of understanding current needs and testing alternative design solutions. Apart from the lack of awareness of the existence of such method, among the reasons for this situation, one can enumerate economic aspects (high device cost) and social factors (generally low level of citizens' involvement). The potential of this method is also reduced by the lack of definitions of the applied architectural notions (dominant, disharmonious component) described by means of visual reactions. What is more, architects, archaeologists and conservators conducting pioneering ET research with relation to material heritage would copy and combine the fragments of methodology used by the experts in other fields. As a result, some of the results published can be discredited, in particular due to procedural deficiencies. The studies concerning built environment appear highly specific and their methodology requires individual consideration. A vast number of experiments presented in the articles cannot be repeated due to missing description fragments [49]. The authors, motivated by the intention to strengthen the position of ET research in relation to architecture and urban planning, aim at developing research methodology. In the present paper we are presenting our considerations and the related experiment concerning the cultural context of conducting eye-tracking research with relation to architectural heritage.

1.2. Cultural context of monuments and their observers

While analysing the reports relating to tourism in EU member states [50], important diversification concerning the activity of subsequent countries can be noticed. In 2021, Dutch citizens were the most active in this aspect. As many as 81% of individuals aged over 15 left their place of residence at least once for touristic purposes. The citizens of Bulgaria were the least active in this area (22,7%). The statistics prove important diversification of the cultural context of individuals using holiday accommodation (GUS). For example, in Croatia 89.6% of accommodation services were provided to foreigners, while in Romania, Poland, Germany and Finland the percentage of foreign tourists reached ca. 10% (8,9%-11,9%). For this reason, should the individuals responsible for monument care in Croatia attach greater importance to the opinion of foreign tourists than to what they learn from the residents and citizens of their own country? And thus, in Poland and Germany, should the manner of monument transformation depend exclusively on the results of local consultations? These two questions, asked in a provocative way, became the basis for our further scientific investigation.

Diversified character of touristic traffic on a national scale constitutes a complicating factor here. Some of the monuments are important for the international community, constituting the attractions visited by tourists from different corners of the world: the Forbidden City, the Colosseum, Taj-Mahal, the Palace in Versailles, the Great Wall of China, the Statue of Liberty etc.. Other sites of historical significance can also be considered as icons that shape national identity [51]. As far as Poles are concerned, these are the Wawel Castle in Cracow, the Palace in Wilanów, the Crane in Gdańsk or the Warsaw Old Town. However, the biggest group of monuments is constituted by those that the inhabitants of the region, enthusiasts and history lovers feel most attached to. Very few individuals come to see them, and even when they are noticed, hardly any attempts at interpreting them are made [52,53]. The monuments, even less popular ones, play important social and economic roles [54]. For example, they enable the development of cultural tourism that has a positive influence on stopping migration and suburbanization [55,56].

The paragraphs above point out to the topic to which refer at least two interdependent variables. The first aspect concerns monument context connected with its rank. Some monuments are watched more often while others, even though they are precious, might be hardly ever noticed. This aspect will thus be connected with how popular the image of a given object is within a given community and with the number of tourists visiting this site. The second component refers to the origin of its observers. There exist multiple psychological studies, also those supported by ET, that refer to the influence of culture on observers' behaviours [57]. In some of them the researchers pointed to significant deviations concerning the recognition of faces and emotions [58,59] as well as the method of text analysis [60]. Significantly different visual behaviours were observed among the teachers from different countries [61], as well as among application users representing different cultures [62]. The recorded differences refer to fixation count, fixation duration and even to the amplitude of saccades performed between the objects and their background [63–65]. The biggest number of studies refer to the differences between the western way (e.g., Europeans, Americans) and east Asian visual perception scheme [66–68]. Culture may also influence attention [65]. However, according to other studies the way of perceiving objects and phenomena seems to be conditioned mainly by biological aspects and in most of the tasks it does not depend on culture [69]. Some researchers are even taking a step further by making a strong claim that there is no evidence that proves the diversification of visual reactions resulting from cultural or ethnic background [70]. It is hard not to agree with many arguments presented in the Journal of Vision, all the more so that the results of some of the studies quoted above have already been the source of concern for researchers [69]. Some of the quoted studies have certain methodological weaknesses. For example, the recorded deviations may result from using different ETs or screens, performing the tests with or without using the chin holder [64] and not from cultural diversity. Comparing the data collected at laboratories with so diversified equipment does influence research results. In other cases, the authors do not mention whether study participants had had the quality of their vision checked (visual acuity, lack of stereovision, normal contrast sensitivity), excluding those suffering from significant defects [71]. In many cases it is hard to determine how the results can be influenced by significant subject matter diversification, hierarchy of the composition of presented stimuli as well as varying educational experience among the participants [64,71]. Research results can also be influenced by the procedure itself as within it the observers, during a single experiment, would look at a few changing illustrations [63]. It was not alternatively studied whether the invited individuals use their short-term memory in a similar way as well as to what extent they were surprised by atypical modifications and guessed the hidden purpose of the research. Another interesting aspect is constituted by the influence of the fact that the age of study group participants was limited to 18-21 [67], while cultural identity applies to people of different ages.

Doubts expressed above can constitute the source of confusion. Despite the implementation of comprehensive research, the methodology for pro-social heritage management using the eye-tracker remains undisclosed. The occurrence of the described alterations in visual behaviours among the observer groups remains uncertain. In the presence of cultural context-induced diversity in visual behaviours, determining which group's behaviours should be accorded greater significance poses a challenge. Should greater significance be attributed to the reactions of observers associated with this heritage through their identity (native residents), or to those who, at times, form the largest recipient group due to tourist activities? The studies show how diversified their needs may be [5]. In connection with prior research experience, arose regarding the acceptance of changes (for example placing the informative sign on the façade [72] or the extension) is more limited in the case of greater "attachment" to a given object? While considering illumination options for a given site, should the experts concentrate on building a local or universal night attraction? While postulating the introduction of ET into monument management process [73] methodology of such research should be reliable architectural monuments serve various roles in subsequent communities, and thus their perception and modifications concerning them may differ. The lack of knowledge on the scale and scope of these deviations makes it impossible to use eye-tracking data for developing reliable reports, basing on which it will be possible to modify the existing conservation doctrines, developing regulations unambiguously protecting characteristic urban views. What is more, due to the noticed gap there is no possibility to determine the rules that will enable the scientists to refer to architectural and conservation tests conducted by researchers active in other parts of the world. It is possible that the number of eye-tracking studies concerning monument management and representing international significance will for this reason become very limited. As the researchers present so big deviations, will it be justified to quote the results of studies conducted in Taiwan or China by those involved in studying European culture and the architecture that forms its part?

2. Research aim

There is a strong need to verify if "there is clear evidence that cultural values and experiences shape neurocognitive process." [57] Having studied the subject matter, we would like to answer the questions formulated in the introduction. **It seems crucial whether and on what conditions it is possible to connect the data from persons representing different national groups looking at architectural objects.** It is necessary to answer this question in order to be able to use ET in the research from the area of tourism, urban planning, architecture, management and conservation. Determining the rules for future utilization of ETs in setting intervention boundaries in existing cultural landscapes is necessary. Laws need to be made based on facts.

2.1. Research hypotheses

Three hypotheses were formulated for structuring the search and achieving study objectives.

(H1) Cultural immersion, object location, and observers' nationality have no influence on the way of looking at unfamiliar architectural objects. This implies that there will be no differences in the area of perception for the parameters Total Visit Duration (TVD), Fixation Number (FN), and

Visitors Number (VN) concerning unrecognized monuments from Wrocław and Europe. Additionally, there will be no differences in the area of perception (TVD, FN, VN) concerning changes made to poorly recognized monuments from Wrocław and Europe.

The verification of H1 is crucial to identify potential deviations caused by the research methodology.

(H2) Cultural context influences the way of looking at known objects and introduced architectural changes. This implies that individuals culturally connected to a specific object will perceive the changes faster and more frequently (Visitors Number (VN), Time to First Fixation (TTFF) for known objects from Wrocław). Conversely, people without cultural connections to the monument will have shorter gaze duration and lower cognitive involvement (for example shorter visit duration (TVD)) for known objects from Wrocław.

(H3) Group of observers, regardless of nationality, have the same preferred model of acquainting themselves with important cultural monuments. This implies that iconic objects and the introduced changes will not significantly affect the way they are observed.

3. Materials and methods

In order to study both aspects described in the Introduction it was necessary to select the research group appropriately as well as to choose proper monuments. **Six key decisions (A-F)** were made, influencing the entire methodology:

A. Studied changes were reality-based and they refer exclusively to architectural objects considered monuments. The selected objects had to be already subjected to modifications or undergoing the reconstruction and their final structure was known (*result: narrow research scope, reducing the surprise effect concerning intervention type*).
B. Studied monuments should represent different regional and international context. The objects originated from Wrocław, Poland or from other EU member states. Due to the concerns resulting from different cultural relationship with natural landscape [74] all of the presented objects should possess typical architectural and urban planning context.
C. Each sub-group has to include three monument types:
    a. those probably known to the observers (architectural icons, often watched in books and films);
    b. those that are sometimes watched and whose names won't probably be provided by the participants (not main attractions near well-known streets / squares);
    c. those that the participants have probably never seen before (not exposed in urban space or hidden).
D. Research group consisted of the Poles **(PO)** residing in Wrocław for a long time and of Foreigners **(FO)** who have come to the capital of Lower Silesia region recently or are tourists *(result: respondent group consisted of persons that could be the observers of the studied monuments, moved around the city of European scale, they know the architectural and urban context).*
E. It is necessary to eliminate all variables that could have a negative influence on the effect of comparison: visual and acoustic distractors; equipment-related and technical aspects, psychological aspects (short-term memory, cognitive intention), as well as optical, medical, psycho- or physiological ones; the aspect of expert education etc.
F. It is necessary to concentrate on the analysis of those aspects and parameters that could support decision-making in the area of projects as well as legal and administrative aspects referring to architecture and urban planning *(result: Visitors Number (VN), Fixation Count (FC), Average Fixation Duration (AFD), Total Visit Duration (TVD), Time to First Fixation (TTFF)* will be analysed, pupil diameter and saccade characteristic are not to be analysed).

These decisions influenced the course of research:

- monument selection (A, B, C);
- selection of photographs and preparing photomontages - the look of stimuli (A, E, F);
- research group selection and participant qualification (B, D, E);
- research procedure and composition of the scientific team (A, B, C, D, E, F);
- as well as verification and data analysis method (C, D, E, F).

Such attitude shall allow the verification of all three hypotheses.

3.1. Monument selection and preparing visual stimuli

First of all, basing on the authors' findings and verification whether they meet assumptions A, B, and C; 12 objects from Wrocław and Europe were selected. Each of them was assigned with 2-4 letter code. The selection of famous European facilities, initially subjective, included: the Colosseum **(COL)**, the Arc de Triomphe **(ARC)**, Reichstag **(RST)**, while in Wrocław the Cathedral **(CAT)** and Sky Tower skyscraper **(ST)**. Among the objects less known to the observers there were Dortmunder U **(DU)**, Bundeswehr Museum in Dresden **(DR)** as well as the outbuilding in the courtyard at Kazimierza Wielkiego Street **(KAZ)**. What is more, it was decided to include the photographs of other modified buildings: Tate Modern **(TATE)**, Maria Mill **(MM)**, Tenement House at Podwale Street **(POD)** as well as the military shelter at Legnicka Street **(MS)**.

With the use of Photoshop CC 2015, 3DMax and Blender software, photographs of selected monuments were modified to form pairs (Fig. 1). Original photographs are marked with the letters **ORG**, while photomontages as those requiring the performance of modifications with **MOD**. Full resolution illustrations are available in the open repository **(RepOD)**.

3.2. Research procedure

The research consisted of five stages.

(I) Preliminary qualification of research participants (on-line)
(II) Questionnaire part 1
(III) Examination by an optometrist
(IV) Eye-tracking recording
(V) Questionnaire part 2

3.3. Stage I. preliminary qualification of research participants

Volunteers were recruited through leaflets, posters, Facebook posts, Wrocław University of Science and Technology website, and local radio broadcasts. Google Forms were used for registration. It was assumed that the participants would know that the subject matter of the study was architecture and monuments, but as late as within stage V, after ET recording, they could discover detailed research objective and immediately utilize visual long-term memory [75] for detecting modifications in the illustrations. By avoiding explicit suggestions, the study aimed to enable unbiased observations. The form content was influenced by this approach. Volunteers were contacted via phone or email through applications, and those unable to participate were notified accordingly.

Participants aged 18-60 were recruited in two modes: **PL** (Poles living in Wrocław for at least three years) and **FO** (foreigners residing in Wrocław for up to two years). The FO group included individuals from various countries, including Germany, France, Italy,

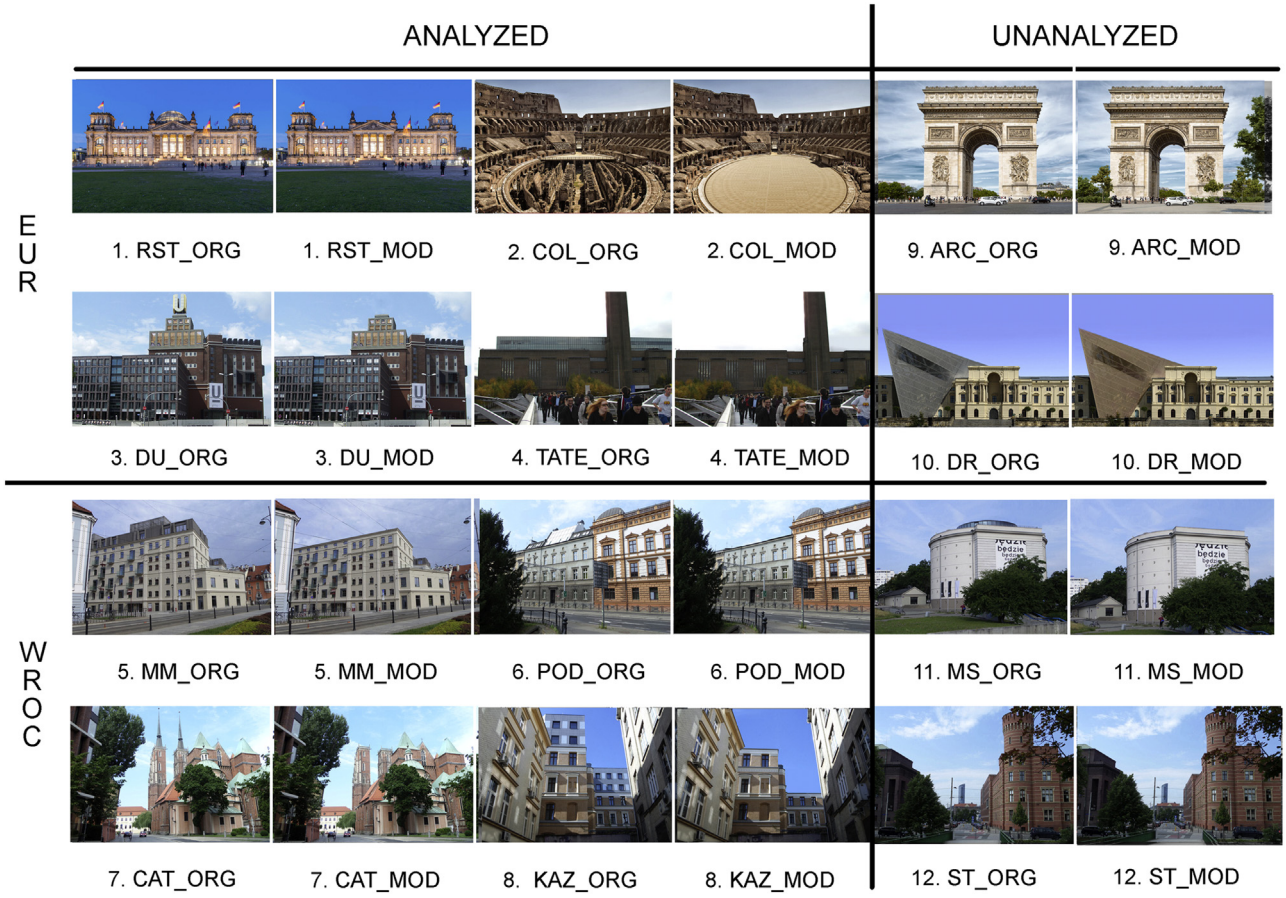

Fig. 1. 24 visual stimuli performed basing on 12 monuments in the original (ORG) and modified (MOD) form. RST, Reichstag; COL, Colosseum, DU, Dortmunder U; TATE, Tate Modern; MM, Maria Mill; POD, Tenement House at Podwale Street; CAT, Cathedral; KAZ, courtyard at Kazimierza Wielkiego Street; ARC, Arc The Triomphe DR, Bundeswehr Museum; MS, military shelter; ST- Sky Tower;.

Spain, Portugal, England, Ireland, Slovakia, Taiwan, Japan, Turkey, Ukraine, Belarus, Russia, South Africa, Cameroun, Zimbabwe, Nigeria, Brazil, and Argentina. The idea consisted in forming a group of people who naturally reflect the diversity of observers of Wrocław urban spaces.

The PL Group was assumed to have a stronger connection with Wrocław due to their longer stay, facilitating intuitive visual long term memory use. In contrast, the FO Group, comprising individuals from diverse cultural backgrounds and affected by the Sars Cov2 pandemic, had limited opportunities to explore the city deeply. Thus, their emotional attachment to Wrocław's architectural heritage and urban landscapes might have been less developed.

The volunteers were not experts in the field of architecture, conservation, urban research, planning, art history, or students in these domains (expert perception [76,77]). The questionnaire excluded individuals with significant vision defects, such as strabismus or vision defects above +4.0D or below -3.0D who did not wear contact lenses.

3.4. Stage II. Questionnaire Part I

320 individuals were invited to take part in the test. They had the opportunity to read research procedure (agreed with the Ethics Commission of WUST) and expressed their written consent. First questionnaire section verified nationality, gender, age and profession. Additionally data was excluded from subsequent calculations if participants reported less than 6 hours of sleep, as adequate rest was a requirement.

3.5. Stage III. Examination by an optometrist

The optometrist examination excluded individuals with reduced visual acuity, suppression, strabismus, or impaired contrast sensitivity. All participants underwent an optometric examination, including visual acuity, subject refraction measurement, contrast sensitivity test, and binocular vision. Those with visual acuity below 0.6 (decimal) for 60 cm were excluded, unless they agreed to correct visual acuity to at least 0.6 with contact lenses.

3.6. Stage IV. Et recording

Tests were conducted in laboratory conditions. The fundamental constraint within the context of reality is the inability to modify or eliminate existing architectural extensions or incorporate additional details or elements. As it is known that context influences the level of involvement of those observing works of art [78,79] the number of variables occurring in a natural cognitive situation (whether; pedestrians, sounds etc.) would not allow the performance of comparative analysis of exclusively the planned variable factor. Recording occurred in a quiet, controlled environment, with consistent conditions for all participants. Only the test participant and their supervisor remained in the examination room. The intention was to eliminate visual and acoustic distractors [80]. The test participant's setup included an adjustable swivel chair with a chin holder and a calibrated 24'' DELL Ultra Sharp U2415b screen placed horizontally at a distance of 60 cm from their eyes. After adjusting the chair, screen height, and chin rest to individual needs, participants wore the Tobii Pro Glasses 2 eye-tracker. The test conductor

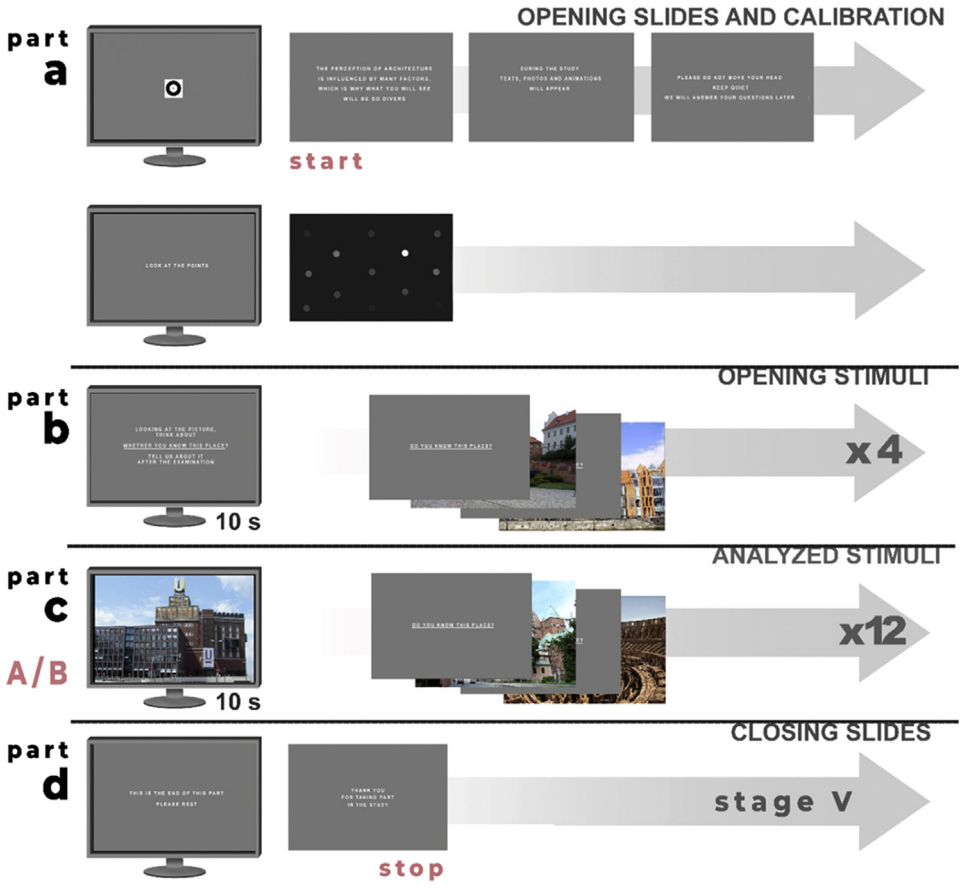

Fig. 2. Screening scheme for stimuli within stage IV. The stage consisted of four parts a-d. Part c included one of the two illustration sets A or B.

silently supervised the process and took notes out of the participants' sight.

The experiment was supervised with the use of Tobii-Pro-Lab software and mp4 player. Calibration started with a single-point procedure following the manufacturer's recommendation. Acceptable precision and accuracy were achieved if the maximum error was below 0.50° and the average error was within 0.30° [81]. When ET recording was launched, the video including introductory boards explaining test rules was shown (Fig. 2). The recording continued for 6.5 minutes **(RepOD)**. The aim of four illustrations presented at the beginning was to familiarize the participants with the procedure (Fig. 2). It was important for the observers not to use any kind of their visual short-term memory [82]. For this reason, two versions, A and B, were prepared, with each of them including only one of the two variants of each of the twelve studied illustration, ORG or MOD (Fig. 2), while in each of the sets A and B, some of the photographs would appear only in MOD version, and some only in ORG version. The illustrations representing the ORG and MOD conditions were deliberately and randomly intermixed. Each stimulus appeared on the screen for 10 seconds. Cognitive intention of observers was supposed to be known [83,84], the same for all participants. Participants were shown a board with the question "Do you know this place?" for 3 seconds before each illustration to activate their visual long-term memory (Fig. 2).

3.7. Stage V. Questionnaire part 2

Immediately after removing the eye-tracker and moving to another room, participants received black-and-white miniatures (4 × 5cm) of the original photos shown during the presentation. They indicated whether they saw the objects for the first time during the experiment, had seen them somewhere before, or knew them personally. In case of familiarity, they provided additional details, such as the monument's name, city, or country where it is located. This knowledge is essential to exclude from the analysis objects that are known to varying degrees by different groups.

4. Results

The analysis began with preliminary analysis of ET data. Incomplete or lower quality recordings (less than 89% of ET data collection time calculated for the entire recording) were excluded from the collection of data. Having research methodology and data quality in mind, only 201 recordings were considered compliant with basic research criteria.

4.1. Verification of strategic decision C

In this part, basing on the answers provided in the second part of the questionnaire, the correctness of decision C was verified, within which in each sub-group, three monument types had to be included: well-known to the participants, known by some of the participants and not known to the participants. Appendix 1 and Appendix 2 include the summary of the conducted analysis and determine how many percent of participants (PL or FO) stated that they had known the presented objects before. When participants indicated their familiarity with an object but failed to provide either its name or location, their responses were not included in the subsequent calculations. This decision was made to ensure that the data could not be unambiguously interpreted. As a result, a total of 11 recordings were excluded from the analysis.

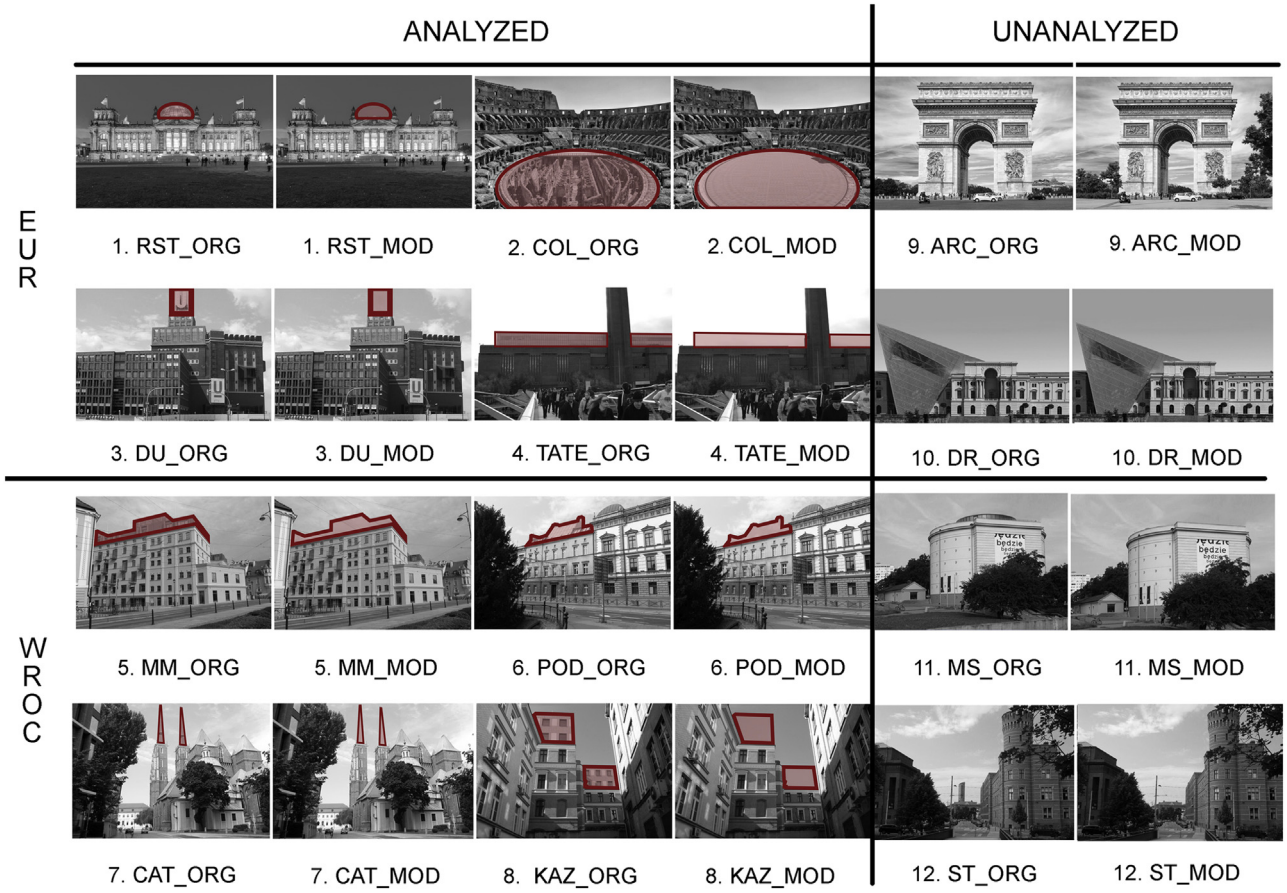

Fig. 3. The method for determining **AOI CHANGE** on all illustrations subject to analysis. Stimuli 9-12 were not subject to comparative analysis, which is justified by the analyses presented in Appendix 1 and Appendix 2. ORG, original; MOD, modified; RST, Reichstag; COL, Colosseum, DU, Dortmunder U; TATE, Tate Modern; MM, Maria Mill; POD, Tenement House at Podwale Street; CAT, Cathedral; KAZ, courtyard at Kazimierza Wielkiego Street; ARC, Arc The Triomphe; DR, Bundeswehr Museum; MS, military shelter; ST, Sky Tower.

Table 1
Visitors number (VN) looking at the AOI_CHANGE field on each of the 8 illustrations (in the versions _ORG and _MOD), for PL and FO separately.

	VN_AOI CHANGE			
	PL_ORG	PL_MOD	FO_ORG	FO_MOD
COL	62 of 62 (100%)	58 of 63 (92%)	32 of 32 (100%)	29 of 33 (89%)
RST	23 of 62 (37%)	**2 of 63 (3%)** *	11 of 32 (34%)	**6 of 33 (18%)**
TATE	45 of 63 (71%)	**18 of 62 (29%)** *	23 of 33 (70%)	**5 of 32 (16%)***
DU	14 of 62 (25%)	**3 of 63 (5%)** *	8 of 32 (25%)	**4 of 33 (12%)***
CAT	29 of 63 (45%)	**4 of 62 (6%)**	14 of 33 (42%)	3 of 32 (9%)
POD	28 of 63 (44%)	1 of 62 (2%)*	15 of 33 (45%)	**5 of 32 (16%)***
MM	30 of 63 (48%)	**3 of 62 (5%)***	16 of 33 (48%)	**6 of 32 (19%)***
KAZ	57 of 62 (92%)	**29 of 63 (46%)***	30 of 33 (91%)	**17 of 32 (53%)***

*Significantly different values $\Delta > 5\%$.
PL, Poles, FO, foreigners; ORG, orginal; MOD, modified; RST, Reichstag; COL, Colosseum, DU, Dortmunder U; TATE, Tate Modern; MM, Maria Mill; POD, Tenement House at Podwale Street; CAT, Cathedral; KAZ, courtyard at Kazimierza Wielkiego Street.

As a result of analyzing responses provided in the second part of the questionnaire (Stage V) four monuments were finally excluded from the group subject to analysis. Two of them were located in Wrocław (MS, ST) and two in other EU countries (ARC, DR) (Fig. 1). The reason for this elimination was constituted by significantly different knowledge of monuments by both groups, and subgroups amounting to more than 5% (app 1; app2). We can apprehend both familiar and unfamiliar objects in distinct manners, owing to the deliberate exclusion, wherein the sole studied variable was intentionally maintained as a diverse cultural relation. Complete analysis will thus refer to 8 sites: RST, COL, DU, TATE, MM, POD, CAT, KAZ.

In this study, Areas of Interest (AOI) for analysis were defined, including **AOI ENTIRE IMAGE** covering full illustrations and **AOI CHANGE** highlighting elements subject to change. Fixation points from 190 recordings were automatically mapped onto an analytical medium using Tobii Pro Lab and video data for analysis. The process was inspected and potential errors in fixation localization were manually corrected (it is estimated that fixation errors did not constitute more than 2% of the number of all fixations identified in total within 190 measurement fixations on the analysed images). From processed data, four color-coded collections were generated: PL_ORG (brown), PL_FO (red), FO_ORG (green), and FO_MOD (blue).). The data referred to parameters Visitors

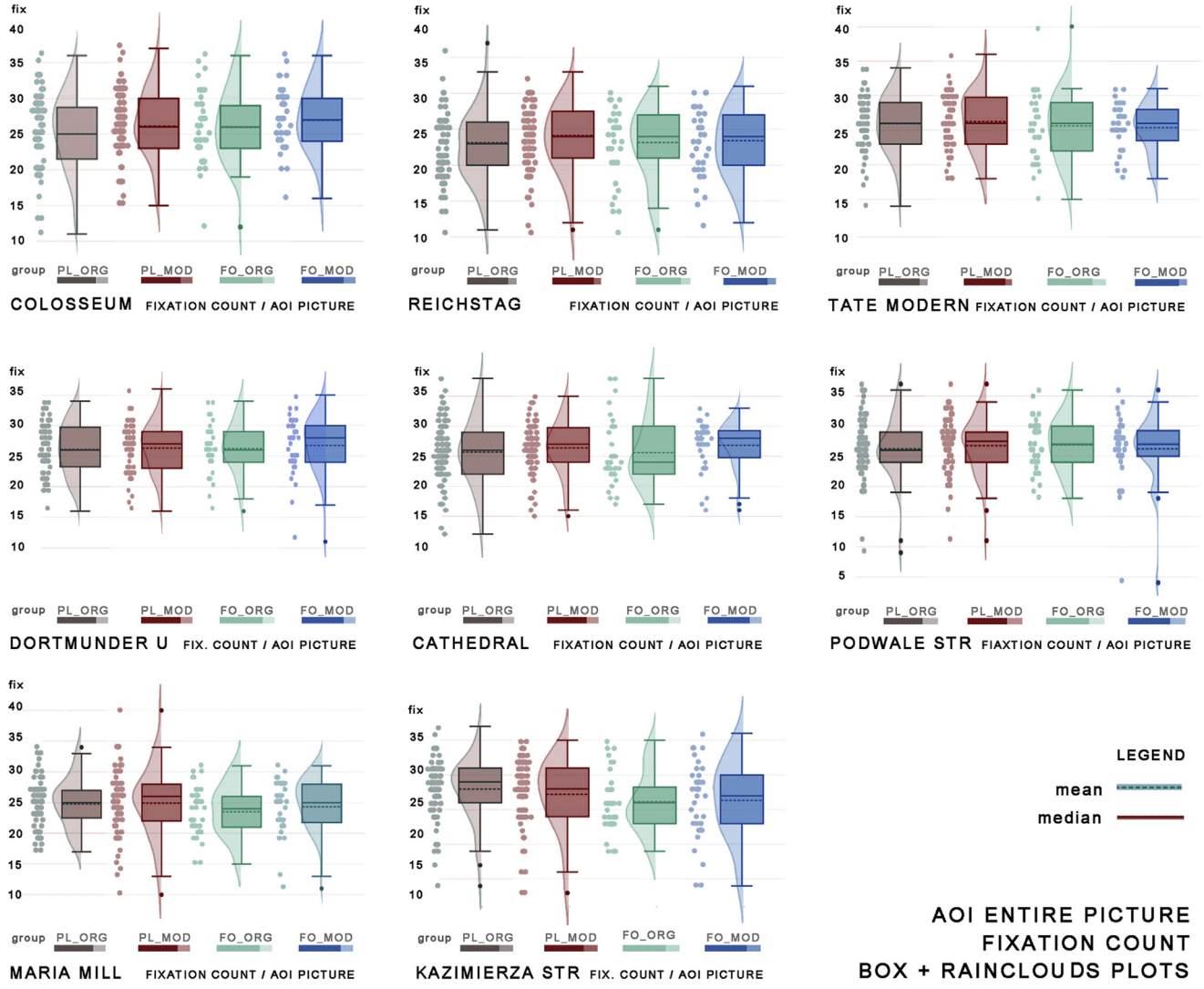

Fig. 4. Box plots and raincloud plots of the Number of Fixations (FC) on the entire illustration for 8 analysed stimuli.
PL, Poles, FO, foreigners; ORG, orginal; MOD, modified.

number, Total Visit Duration, Fixation Count, Time to First fixation, Average Fixation presented separately for each visual stimulus. These are the parameters that, according to prior research conducted by the authors in the field of architectural modifications [72] presented significant variations. Summary under the form of the table as well as full-resolution illustrations are available in appendixes and the repository **(RepOD).** Comparative analyses were conducted based on the data to determine if groups PL and FO observed ORG illustrations similarly and perceived the changed MOD variants identically.

4.2. Participants

Final data collection included a set of 190 participants recordings. 125 Poles (57 men / 68 women; age: AVG=30, M = 28, SD=10.7) and 65 participants of non-Polish origin (26 men / 37 women; age: AVG=28, M = 26, SD=8.7). According to research methodology, the participants would look at the presentations containing one of the two sets of illustrations. Characteristics of the four sub-groups are provided in additional materials (app. 3). There were no significant differences in gender and age among the groups, allowing for further analysis.

4.3. Results concerning AOI entire picture

All ORG as well as MOD illustrations were interesting for PL and FO observers. Total Visit Duration (TVD) for 16 analysed illustrations was on average from 9.75s to 9.92s (app.4). Kruskal-Wallis tests were performed on the collected data, checking p value for multiple comparisons between PL_ORG and FO_ORG as well as PL_MOD and FO_MOD. Two pairs were found for which $p < 0.05$. For COL_PL_ORG and COL_FO_ORG $p = 0.0226$, while the average time of looking at these illustrations was 9.87s and 9.82s respectively. For CAT_PL_MOD and CAT_FO_MOD $p = 0.00$. For the remaining analyses $p > 0.05$, which means that the there are no significant differences between the analysed collections (Fig. 3).

Average Fixation Duration (AFD) established for the observation of entire picture was on average from 0.29s to 0.37s (app.5). The biggest difference between the values concerning subsequent stimuli between the column PL_ORG and FO_ORG amounts to 0.04s (one way ANOVA $p < 0.05$). The difference between the columns PL_MOD and FO_MOD was 0.04s (one way ANOVA $p > 0.1$).

Fig. 4 presents box plots complemented with data distribution points and curve concerning Fixation Count (FC) for all illustrations, divided into four sub-groups. Kruskal-Wallis tests were performed, analysing p value for multiple comparisons between PL_ORG and FO_ORG as well as PL_MOD and FO_MOD. No signif-

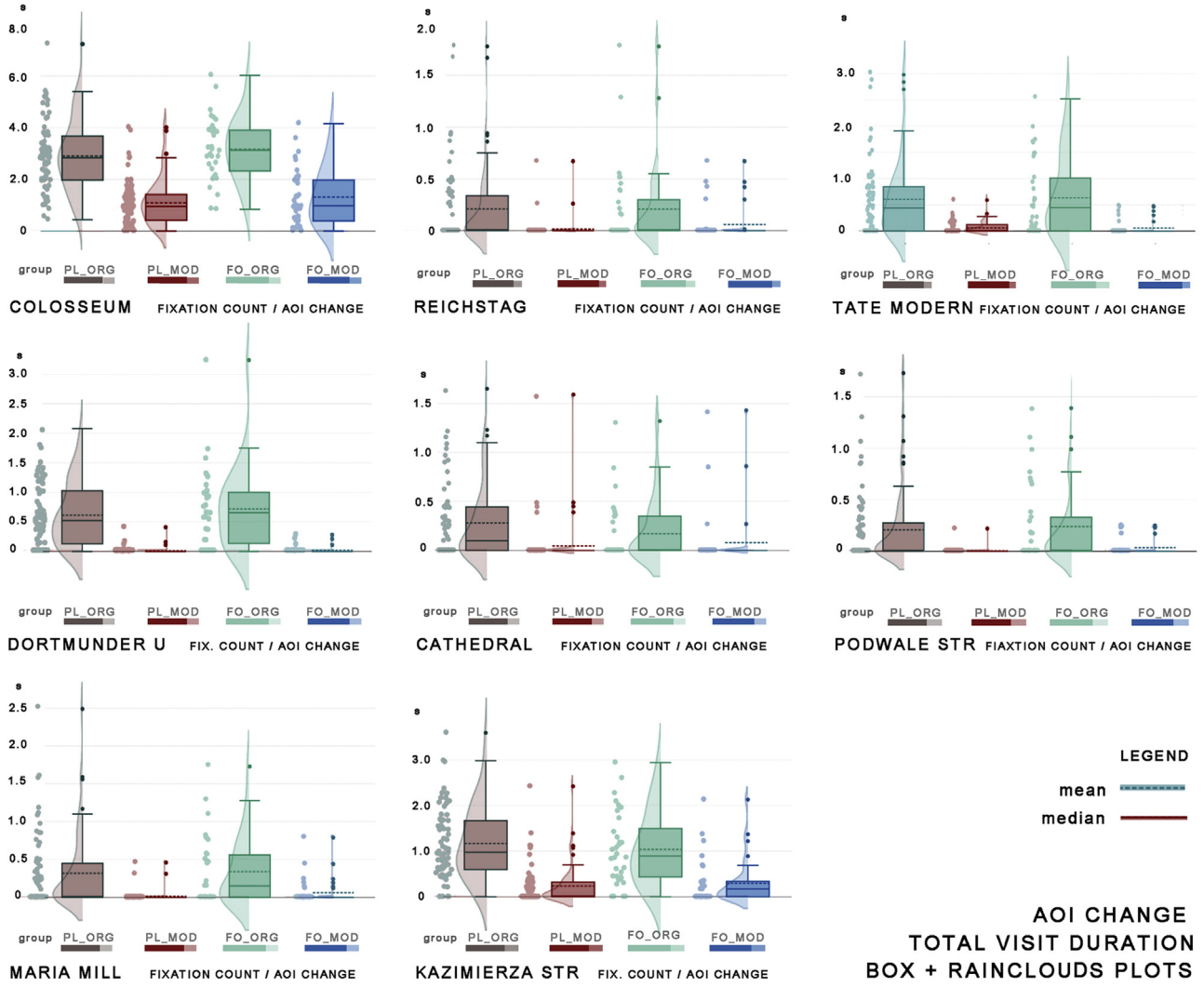

Fig. 5. Box plots and raincloud plots of Total Visit Duration (TVD) for a AOI CHANGE part of the illustration for 8 analysed stimuli for the versions _ORG and _MOD for PL and FO participants.
PL, Poles, FO, foreigners; ORG, original; MOD, modified; RST, Reichstag; COL, Colosseum, DU, Dortmunder U; TATE, Tate Modern; MM, Maria Mill; POD, Tenement House at Podwale Street; CAT, Cathedral; KAZ, courtyard at Kazimierza Wielkiego Street.

icant differences were stated (p >0.05) (app. 6) basing on all sixteen comparisons.

4.4. Results concerning AOI change

The first compared value was the number of people looking at the area of AOI CHANGE with its original look (ORG) and modified look (MOD). Data were presented in Table 1. There are no big deviations (0-3%) between the values concerning PL_ORG and FO_ORG. Significantly bigger variations can be noticed while comparing PL_MOD and FO_MOD. Six out of eight comparisons represent the difference bigger than 5%. The biggest difference of 15% concerns illustration RST_MOD. A similar percentage of test participants looked at COL_MOD and CAT_MOD, so at the monuments forming part of the group of well-known sites.

As a result of data distribution analysis based on Total Visit Duration (TVD) box plots (Fig. 5), no significant deviations between the pairs PL_ORG and FO_ORG as well as PL_MOD and FO_MOD were stated. Graphic analysis was supported with the performance of Kruskal-Wallis test. Multiple comparisons showed that $p > 0.05$ for all of the 16 pairs compared (app. 7).

Fig. 6 presents box plots complemented with data distribution points and curve concerning Fixation Count (FC) for all AOI CHANGEs, divided into four sub-groups. Kruskal-Wallis tests were performed, analysing p value for multiple comparisons between PL_ORG and FO_ORG as well as PL_MOD and FO_MOD. As a result of all sixteen comparisons, $p > 0.05$ was stated (app.8).

Fig. 7 presents box plots complemented with data distribution points and curve concerning Time to First Fixation (TTFF) for all AOI CHANGEs, divided into four sub-groups. Kruskal-Wallis Tests were performed, analysing p value for multiple comparisons between PL_ORG and FO_ORG as well as PL_MOD and FO_MOD. For nine comparisons, $p = 1.00$ was obtained in statistical test, for the remaining comparisons $p > 0.05$ (app.9).

5. Discussion

Verification of the H1 - *Cultural immersion, object location as well as observers' nationality do not have the influence on the perception of objects not known to the observers.*

According to the results of the questionnaire, unknown objects intended for ET analysis should be TATE, DU as well as the courtyard of tenement house at KAZ. The analysis of data from appendix 1,3, Fig. 4 makes it possible to state that for the three enumerated examples TATE_ORG, DU_ORG as well as KAZ_ORG there is no statistically significant deviation concerning the way of looking

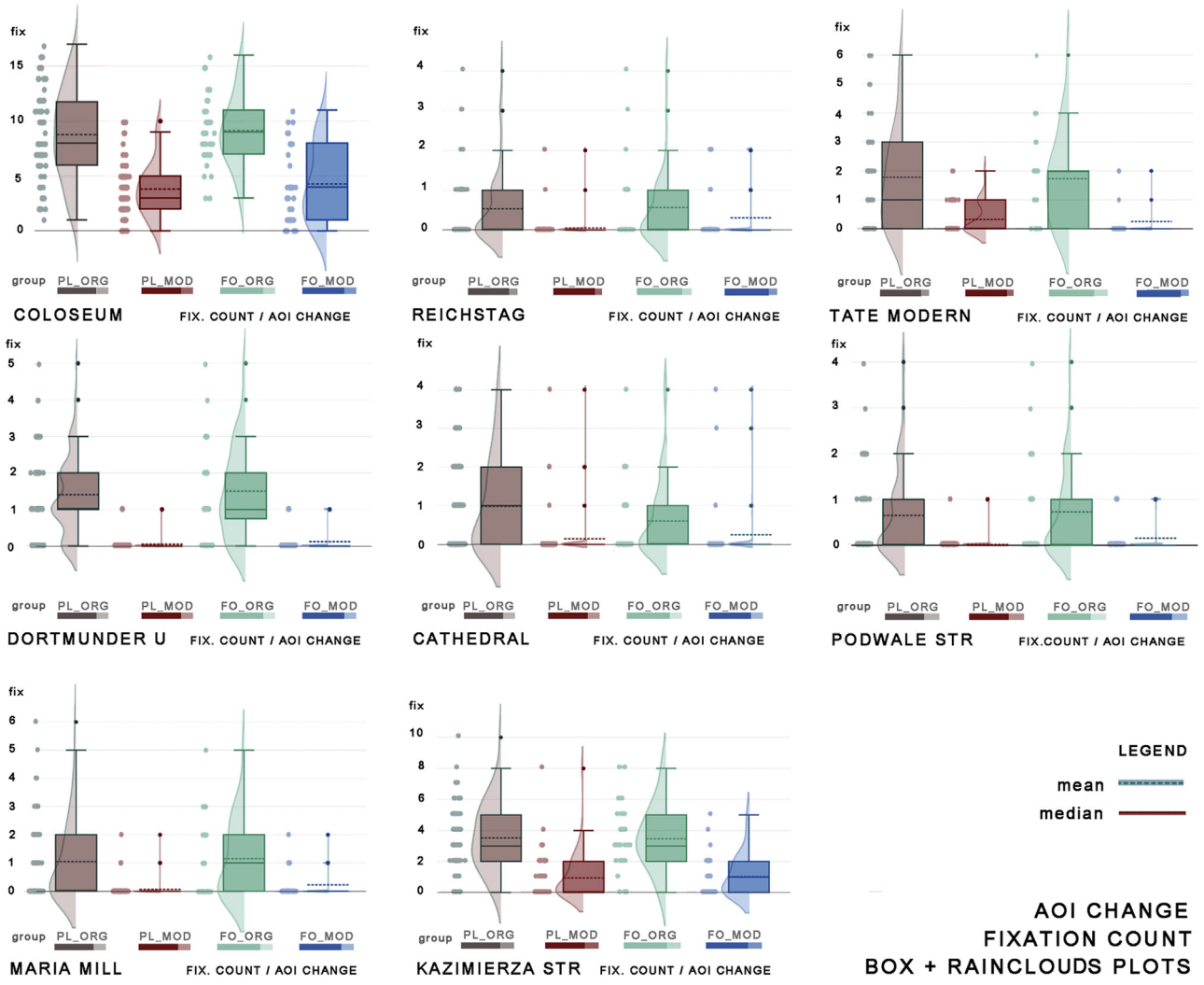

Fig. 6. Box plots and raincloud plots of Fixation Count (FC) for a AOI CHANGE part of the illustration for a AOI CHANGE part of the illustration for 8 analysed stimuli for the versions _ORG and _MOD for PL and FO participants.
PL, Poles, FO, foreigners; ORG, original; MOD, modified; RST, Reichstag; COL, Colosseum, DU, Dortmunder U; TATE, Tate Modern; MM, Maria Mill; POD, Tenement House at Podwale Street; CAT, Cathedral; KAZ, courtyard at Kazimierza Wielkiego Street.

at AOI ENTIRE PICTURE for PL and FO. All of the tested parameter's Total Visit Duration and Average Fixation Time present no statistically significant differences. Similarly, no significant differences were recorded for Fixation Count (FC), Total Visit Duration (TVD) as well Time to First Fixation (TTFF) with reference to AOI CHANGE fields. Due to a small number of persons looking at AOI MOD in the examples TATE and DU (Table 1) it was stated that studying Time to First Fixation would be unreliable. Time to First Fixation (TTFF) analysis for KAZ_MOD shows that the time after which the first fixation was performed on the AOI field does not differ significantly (K-W test: $p > 0.05$) and is 6.76 s (0-9.1s) for Polish observers and 7.10s (0-9.56s) for foreign observers (app.9).

The only difference to be quoted refers to how many people looked at AOI CHANGE when it was subject to modification (Table1). The scale of change was from 7 to 14%. In 2 out of 3 cases Polish observers, contrary to original assumptions, would perform the fixations within AOI CHANGE fields less often than foreigners (FO).

Apart from slight interruption connected with Visitors Number (VN), all considerations seem to confirm hypothesis **H1.** All the more so that in all 3 examples analysed within this stage, there were no eye-catching details within the AOI CHANGE field. Test participants performed fixations on the sky. Fixations performed within this field should be treated as random. The presence of such deviation in one aspect together with no deviations in other aspects subject to analysis proves the experiment to be correctly prepared from the methodological point of view.

Verification of the H2 – *Cultural context influences the perception of objects and architectural changes introduced in them that are known to the participants.*

For the verification of this hypothesis, two examples from Wrocław were used: KAT and POD (app.3). Contrary to the assumptions, persons with no cultural connections with the monument would not look at the modified area for a shorter time (Total Visit Duration - TVD). Poles culturally connected with the monuments situated in Wrocław would not look at the areas subject to modification more often. On the contrary: 6% PL and 9% FO looked at AOI CHANGE on the illustration CAT_MOD, while for POD_MOD it was 2% PL and 16% FO (Table1). This is contradictory to the assumption presented at the beginning of the article. While analysing how fast the fixation was performed within AOI CHANGE it is necessary to notice that the analysis for POD_MOD is unnecessary as only one citizen of Wrocław looked at the area from which tenement house extension was removed. People who are expected to have a stronger cultural connection with the observed monument did not seem to notice more frequently or quickly when cer-

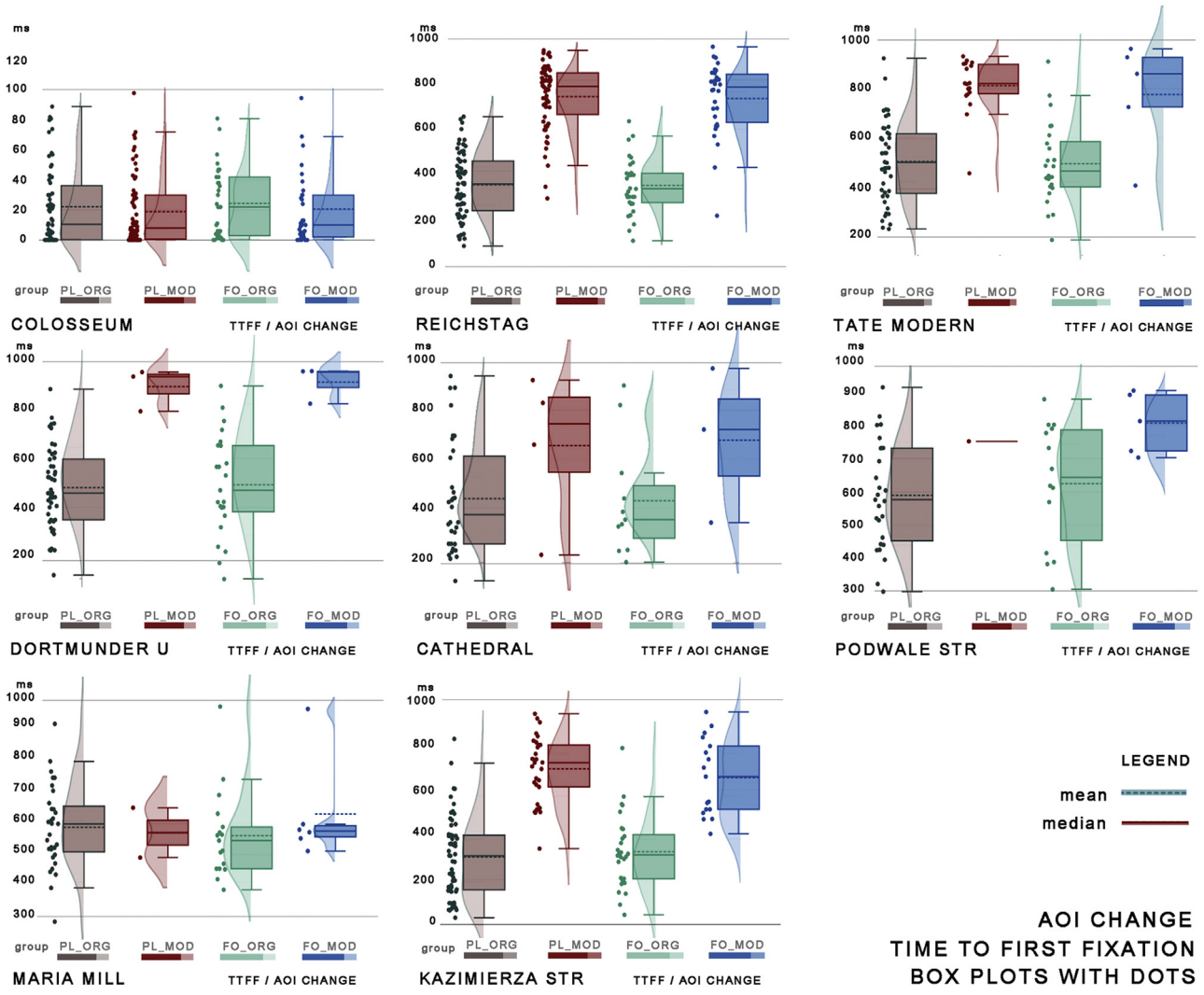

Fig. 7. Box plots and raincloud plots of Time to First Fixation (TTFF) for a AOI CHANGE part of the illustration 8 analysed stimuli for the versions _for ORG and _MOD for PL and FO participants.
PL, Poles, FO, foreigners; ORG, original; MOD, modified; RST, Reichstag; COL, Colosseum, DU, Dortmunder U; TATE, Tate Modern; MM, Maria Mill; POD, Tenement House at Podwale Street; CAT, Cathedral; KAZ, courtyard at Kazimierza Wielkiego Street.

tain additional architectural elements disappeared or were added. It is visible in particular in the case of illustration CAT_MOD. Box plots concerning PL and FO observers do not present diversification, which was confirmed by Kruskal-Wallis test; $p = 0.2870$ (app.9).

Verification of the H3 – *The observers, irrespective of their nationality, should look in the same way at the monuments that they know, but which represent universal cultural expression and are important for the international culture. The observers should react to the suggested modifications in a similar way.*

Two examples from Europe: COL and RST, will be used for the verification of this hypothesis. The results concerning nearly all of the analysed parameters do not show diversification. The Poles living in Wrocław as well as persons not born in Poland (FO) looked at entire illustrations in the ORG and MOD variants with on average a similar number of fixations, what was presented on Fig. 4. Deviations were observed with reference to eye-tracking time for COL_ORG. PL group looked at the illustrations for 9.87s on average, while FO group for 9.82s. The difference concerning data distribution is surprising, especially if we analyse minimum and maximum Total Visit Duration (TVD). The results are very similar both for PL and FO groups (from 9.29 to 10.00s) **(RepOD).** The analysis of the way of looking at AOI CHANGE with respect to COL and RST shows that the PL and FO looked at this area in the same way when it was in the original and modified form. Interestingly, the Poles and foreigners looked in the same way at the vast even arena of the Colosseum or its underground and at the small AOI CHANGE field analysed basing on the look of Reichstag in Berlin.

It is important to note that the presented images were displayed in a 2D format on a screen, rather than in 3D form. Examining the impact of non-existent objects and their variations on the perception of real-life monuments is not feasible within the scope of this research. Using VR goggles or augmented reality would be an opportunity for conducting field research. The combination of AR technology, specifically the HoloLens and eye tracking in outdoor settings has certain drawbacks. One such disadvantage is the inability to gather reliable ET data in connection with different light conditions. Intense sunlight disrupts both the eye-tracking process and the display of the hologram. Another technological limitation of the technology is lack of complete sense of immersion and clear difference of holograms and real elements. Moreover, the utilization of 3D stimuli and virtual reality goggles also entails certain drawbacks that may deviate from the natural cognitive context. These drawbacks include issues such as motion sickness, neck fatigue, changes in distance assessment, and problems with scale perception. These concerns have been documented

in many previous studies [85–88]. Considering these factors, the conscious decision was made to utilize flat stimuli in this research. This choice aligned with the objective of comparing four datasets of Poles and foreigners looking at pictures of original and modified buildings (PL_ORG, PL_MOD, FO_ORG, FO_MOD). collected under the same conditions in laboratory. The limitations and constraints of the technology available were taken into account, and the 2D format was deemed suitable for achieving the study's specific goals. The focus of our study was directed towards identifying differences and similarities rather than aiming for precise numerical values that correspond to the real situation, which is unattainable. The authors have investigated the effects of different research environments [89,90]. In unrealistic laboratory conditions certainty can be established that other variables (acoustic and visual distractors) do not inadvertently impact research results. To conduct studies in urban space, it is necessary to further verify the extent to which familiarity with the object affects the way eyes move. With the results of these two laboratory studies, they can be compared with research conducted in urban space.

A weak point of the studies conducted in this way consists in the fact that as many as 39% of data could not be used due to the participants' significant vision defect, failure to adjust to test procedure by the volunteers, as well as technical or procedural issues. The advantage is that some of the obstacles were detected within the questionnaire stage and preliminary tests. We estimate that new experiments would make possible to reduce the quantity of data lost to the level of ca. 25-30%. Such loss should also be taken into consideration while planning future studies. If virtual reality was used for conducting the tests, it is anticipated that there would be an increase in the number of participants who choose to withdraw from the study [85,89]. What is more, some doubts can arise in connection with the use of different languages during the entire research process. Using a foreign language can be more stressful and / or tiring, and fatigue influences visual behaviours [91]. The attempts were made to reduce such tension by familiarizing the participants with the task. The same instructions preceding four stimuli were presented, which served training purposes and were aimed at teaching the procedure.

In spite of above-mentioned doubts, the verification of Hypothesis **H1** shows that the methodology applied was correct, which is very important. The course of the study as well as its results clearly show that ET can be used in the studies concerning architectural and urban-planning research in smart city's. The group of 32-33 individuals with positive results of the optometric test proved to be sufficient to obtain the data consistent with those based on a nearly twice as large group (62-63 people).

The confirmation of **H1** makes it possible to state with confidence that hypothesis **H2** was not confirmed, and hypothesis **H3** was confirmed. What does it imply in total? Invited non-professional observers reacted in a similar way to the architecture presented to them on a screen. It is not a simple set of features that makes a stimulus memorable or forgettable [75,92]. The presented monuments were diverse and subject to modification. However, it appears that, for the invited participants, cultural connections did not influence the way observers looked at the object during experiment. Probably in case of architecture perception, nationality and culture do not effect differences both in visual long term memory and in visual attractiveness of details.

It is very important to remember that the presented examples originated from the same cultural environment – EU states. In further research, studies based on the monuments from Asia, Africa and Latin America could be performed. It is necessary to consider the verification of studies by establishing the cooperation with a scientific centre China or Japan. However, within this research stage it is highly probable that the studies concerning architecture can be conducted basing on the groups including the participants with diversified cultural background. Nevertheless, it is necessary to bear in mind the context of presented stimuli, which was related to the urban space and not landscape. Another important aspect may consist in the fact that the suggested modifications were realistic and for this reason both the original photographs as well as photomontages were not the source of astonishment for the participants.

5. Conclusion

The significant objective of the study was to ascertain whether "there is clear evidence that cultural values and experiences shape neurocognitive process." [57] The results show that this assumption may not always refer to build environment and monuments located within it. Further research is needed to investigate changes in galvanic skin resistance and brain activity induced by observing architecture.

The study was based on 12 pairs of illustrations concerning modified stimuli. 8 pairs of illustrations, ORG and MOD, which participants, both from Poland and abroad, paid attention to things equally often were eventually analyzed. During the interpretation of results, 5 visual parameters were used for two AOIs of different sizes. The results including a dozen questions asked in the questionnaire were taken into consideration. 320 participants were questioned, with 190 recordings considered reliable. The uniformity in so many variables is surprising. Only 8 out of 160 comparisons showed any statistically significant deviations and, as described in the text. What is important their actual scale is small and pertaining to random examples.

The research aimed to explore the potential use of ET as administrative and legal tools to support and supervise processes related to heritage care. The objective was to answer whether and how ET could be utilized in diverse cultural contexts involving observers and presented locations. From the point of view of using ET for pro-social shaping of changes introduced within the area of historical city the result is very favourable. Researchers involved in studying the relationships between touristic traffic as well as architecture and heritage are gaining the certainty that by giving the observers a cognitively neutral task, they will look at the monuments presented to them in the same way.

To sum up, such surprising results should be confirmed on another research groups, but if the presented considerations are true, then ET constitutes a more versatile method for conducting public consultations in the area of architecture and urban planning as well as such related topics as tourism than assumed. The results also suggest that comparing architectural and urban studies conducted with the use of ET in different countries with the use of uniform methodology is justified.

Statements

This research received founding from National Science Center Poland (NCN) 2021/05/X/ST8/00595.

The research was approved by the Research Ethics Committee of the Wrocław University of Science and Technology, and the Committee assessed the following: the procedure of informing and conducting the research, research documentation, selection of research methods and means (Research Ethics Committee of the Wrocław University of Science and Technology No. O-22-11 of March 31, 22).

Data: (RepOD) Rusnak, Marta; Marta Szmigiel; Malwina Geniusz; Zofia Koszewicz; Monika Magdziak- Tokłowicz, 2023, "Eye tracker jako narzędzie wspierające prospołeczne zarządzanie zabytkami w przestrzeniach miejskich. Badania metodologiczne dotyczące problematyki różnorodności kulturowej zabytków i odmiennej tożsamości obserwatorów.," https://doi.org/10.18150/0Y7W4M, RepOD, V2.

AI generative tools

Not used.

CRediT authorship contribution statement

Marta Rusnak: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Marta Szmigiel:** Data curation, Formal analysis, Supervision, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Malwina Geniusz:** Data curation, Supervision, Formal analysis. **Zofia Koszewicz:** Data curation, Visualization, Writing – review & editing. **Monika Magdziak-Tokłowicz:** Resources, Software, Writing – review & editing.

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Appendix 1. Level of knowledge of objects from Europe based on the questionnaire 2. The list includes the responses of participants whose ET recordings were considered to be properly acquired

Level of knowledge of objects from Europe			
PICTURES (ORG/MOD)	POLES PL	FOREIGNERS FO	Δ PL_FO
COL sub group deviation	**78**% ORG vs MOD +/- 4%	**76**% ORG vs MOD +/- 5%	**2**% < **5**%
RST sub group deviation	**58**% ORG vs MOD +/- 3%	**55**% ORG vs MOD +/- 4%	**3**% < **5**%
ARC sub group deviation	**90**%* ORG vs MOD +/- 4%	**52**%* ORG vs MOD +/- 11%	**38**% > **5**%
TATE sub group deviation	**14**% ORG vs MOD +/- 5%	**12**% ORG vs MOD +/- 3%	**2**% < **5**%
DU sub group deviation	**3**%* ORG vs MOD 0%	**11**%* ORG vs MOD +/- 5%	**8**% > **5**%
DU sub group deviation	**2**% ORG vs MOD +/- 1%	**5**% ORG vs MOD +/- 0%	**3**% <**5**%

*Significant differences in the level of knowledge between the groups PL and FO.

PL, Poles; FO, foreigners; ORG, original; MOD, modified; RST, Reichstag; COL, Colosseum; DU, Dortmunder U; TATE, Tate Modern.

Appendix 2. Level of knowledge of objects from Wrocław based on the questionnaire 2. The list includes the responses of participants whose ET recordings were considered to be properly acquired

Level of knowledge of objects from Wrocław			
PICTURES (ORG/MOD)	POLES PL	FOREIGNERS FO	Δ PL_FO
CAT sub group deviation	**88**% ORG vs MOD +/- 2%	**88**% ORG vs MOD +/- 4%	**0**% < **5**%
ST sub group deviation	**60**%* ORG vs MOD +/- 7%	**72**%* ORG vs MOD +/- 2%	**12**% >**5**%
POD sub group deviation	**62**% ORG vs MOD +/- 3%	**59**%% ORG vs MOD +/- 5%	**3**% < **5**%
MS sub group deviation	**83**%* ORG vs MOD +/- 11%	**51**%* ORG vs MOD +/- 14%	**32**% >**5**%
MM sub group deviation	**44**% ORG vs MOD +/- 5%	**42**% ORG vs MOD +/- 5%	**2**% < **5**%
KAZ sub group deviation	**10**% ORG vs MOD +/- 1%	**9**% ORG vs MOD +/- 5%	**1**% < **5**%

* significant differences in the level of knowledge between the groups PL and FO.

PL, Poles; FO, foreigners; ORG, original; MOD, modified; MM, Maria Mill; POD, Tenement House at Podwale Street; CAT, Cathedral; KAZ, courtyard at Kazimierza Wielkiego Street.

Appendix 3. Age and gender of participants of four sub-groups

(M-man; W-woman)	Stimuli set A	Stimuli set B
Polish – PL	PL_A 63 (26M / 37W; av. Age 31 years)	PL_B 62 (31M / 31W; av. Age 28 years)
Foreigners – FO	FO_A 33 (18M / 15KW; av. Age 27 years)	FO_B 32 (15M / 17W, av. Age 28 years)

Appendix 4. Average Total Visit Duration for each of the 8 illustrations (in the _ORG and _MOD versions), for PL and FO separately

	TVD_AOI ENTIRE PICTURE			
	PL_ORG	PL_MOD	FO_ORG	FO_MOD
COL	**9.87 s** *	9.88s	**9.82s** *	9.84s
RST	9.92s	9.88s	9.86s	9.84s
TATE	9.80s	9.80s	9.79s	9.75s
DU	9.83s	9.80s	9.81s	9.83s
CAT	9.83s	**9.85s** *	9.83s	**9.81s** *
POD	9.86s	9.86s	9.89s	9.83s
MM	9.83s	9.86s	9.81s	9.80s
KAZ	9.81s	9.90s	9.84s	9.91s

*Significantly different values $p < 0.05$.

TVD, Total Visit Duration; AOI, Area of Interest; PL, Poles, FO, foreigners; ORG, original; MOD, modified; RST, Reichstag; COL, Colosseum; DU, Dortmunder U; TATE, Tate Modern; MM, Maria Mill; POD, Tenement House at Podwale Street; CAT, Cathedral; KAZ, courtyard at Kazimierza Wielkiego Street.

Results of Kruskal-Wallis (K-W) test for parameter **Total Visit Duration** based on observation of **AOI ENTIRE PICTURE.** Full data in open repository (RepOD)

Columns V and VI contain comparisons of PL_ORG and FO_ORG and PL_MOD and FO_MOD when $p < 0.005$.

I	II	III	IV	V	VI
general analysis comparisons within all groups PL_ORG / PL_MOD / FO_ORG / FO_MOD			detailed analysis parallel comparisons for pairs ORG i MOD		
K-W	H (3, N = 190)	p-value		FO_ORG	FO_MOD
COLOSEUM (COL)	15.20384	**0.0017**	PL_ORG	**0.022558**	–
			PL_MOD	–	0.058215
REICHSTAG (RST)	10.95409	0.0120	$p > 0.05$		
TATE MODERN (TATE)	9.463327	**0.0237**	PL_ORG	0.146360	–
			PL_MOD	–	0.218406
DORTMUNDER U (DU)	5.652353	0.1298	$p > 0.05$		
CATHEDRAL (CAT)	9.463327	**0.0237**	PL_ORG	0.755205	–
			PL_MOD	–	0.218406
PODWALE STR (POD)	8.197000	**0.0421**	PL_ORG	1.000000	–
			PL_MOD	–	0.063587
MARIA MALL (MM)	10.38934	**0.0155**	PL_ORG	0.291592	
			PL_MOD	–	0.065607
KAZIMIERZA STR (KAZ)	23.04115	**0.0000**	PL_ORG	1.000000	–
			PL_MOD	–	1.000000

PL, Poles; FO, foreigners; ORG, orginal; MOD, modified.

Appendix 5. Average fixation duration (AFD) for each of the 8 illustrations (in the _ORG and _MOD versions), for PL and FO separately

	AFD_AOI ENTIRE PICTURE av (min;max)			
	PL_ORG	PL_MOD	FO_ORG	FO_MOD
COL	0.36s (0.17;0.74)	0.33s (0.16;0.64)	0.35s (0.24;0.78)	0.31s (0.19;0.59)
RST	0.37s (0.21;0.57)	0.35s (0.18;0.68)	0.36s (0.20;0.82)	0.38s (0.23;0.76)
TATE	0.31s (0.15;0.50)	0.39s (0.22;0.67)	0.32s (0.19;0.61)	0.30s (0.18;0.53)
DU	0.32s (0.20;0.51)	0.32s (0.20;0.47)	0.30s (0.17;0.43)	0.31s (0.18;0.82)
CAT	0.33s (0.19;0.66)	0.33s (0.16;0.61)	0.32s (0.17;0.53)	0.29s (0.15;0.52)
POD	0.33s (0.17;0.78)	0.33s (0.18;0.76)	0.31s (0.20;0.51)	0.32s (0.21;0.51)
MM	0.33s (0.17;0.52)	0.34s (0.14;0.85)	0.35s (0.19;0.75)	0.33s (0.21;0.74)
KAZ	0.30s (0.20;0.61)	0.30s (0.15;0.60)	0.34s (0.18;0.75)	0.32s (0.18;0.80)

*Significantly different values $p < 0.05$.

AFD, Average fixation duration; AOI, Area of Interest; PL, Poles; FO, foreigners; ORG, original; MOD, modified; RST, Reichstag; COL, Colosseum; DU, Dortmunder U; TATE, Tate Modern; MM, Maria Mill; POD, Tenement House at Podwale Street; CAT, Cathedral; KAZ, courtyard at Kazimierza Wielkiego Street.

Appendix 6. Results of Kruskal-Wallis test (K-W) parameter Fixation Count (FC) based on observation of AOI ENTIRE PICTURE. Full data in open repository (RepOD)

I	II	III	IV	V	VI
general analysis comparisons within all groups PL_ORG / PL_MOD / FO_ORG / FO_MOD			detailed analysis parallel comparisons for pairs ORG i MOD		
K-W	H (3, N = 190)	p-value			
COLOSSEUM (COL)	2.211475	**0.5297**	all $p > 0.05$		
TATE MODERN (TATE)	1.182048	**0.7573**			
DORTMUNDER (DU)	0.9752759	**0.8072**			
CATHEDRAL (CAT)	3.977750	**0.2639**			
PODWALE STR (POD)	0.9641728	**0.8099**			
MARIA MALL (MM)	2.364256	**0.5003**			
KAZIMIERZA STR (KAZ)	5.504507	**0.1384**			

PL, Poles; FO, foreigners; ORG, original; MOD-modified.

Appendix 7. Results of Kruskal-Wallis test (K-W) for parameter Total Visit Duration (TVD) based on observation of AOI CHANGE. Full data in open repository (RepOD)

Columns V and VI contain comparisons of PL_ORG and FO_ORG and PL_MOD and FO_MOD when $p < 0.005$.

I	II	III	IV	V	VI
General analysis comparisons within all groups PL_ORG/PL_MOD/FO_ORG/FO_MOD			Detailed analysis parallel comparisons for pairs ORG i MOD		
K-W	H (3, N = 190)	p-value		FO ORG	FO MOD
COLOSSEUM (COL)	80.15552	0.0000	PL ORG	1.000000	–
			PL MOD	–	1.000000
REICHSTAG (RST)	80.15552	0.0000	PL ORG	1.000000	–
			PL MOD	–	1.000000
TATE MODERN (TATE)	55.61378	0.0000	PL ORG	1.000000	–
			PL MOD	–	1.000000
DORTMUNDER U (DU)	98.89008	0.0000	PL ORG	1.000000	–
			PL MOD	–	1.000000
CATHEDRAL (CAT)	34.40183	0.0000	PL ORG	0.973136	–
			PL MOD	–	1.000000
PODWALE STR (POD)	36.57218	0.0000	PL ORG	1.000000	–
			PL MOD	–	1.000000
MARIA MALL (MM)	43.05561	0.0000	PL ORG	1.000000	–
			PL MOD	–	1.000000
KAZIMIERZA STR (KAZ)	74.03652	0.0000	PL ORG	1.000000	–
			PL MOD	–	1.000000

PL, Poles; FO, foreigners; ORG, original; MOD, modified; RST, Reichstag; COL, Colosseum; DU, Dortmunder U; TATE, Tate Modern; MM, Maria Mill; POD, Tenement House at Podwale Street; CAT, Cathedral; KAZ, courtyard at Kazimierza Wielkiego Street.

Appendix 8. Results of Kruskal-Wallis test (K-W) for parameter Fixation Count (FC) based on observation of AOI CHANGE.

Columns V and VI contain comparisons of PL_ORG and FO_ORG and PL_MOD and FO_MOD when $p < 0.005$.

I	II	III	IV	V	VI
general analysis comparisons within all groups PL_ORG / PL_MOD / FO_ORG / FO_MOD			detailed analysis parallel comparisons for pairs ORG i MOD		
K-W	H (3, N = 190)	p-value		FO ORG	FO MOD
COLOSSEUM (COL)	66.25836	0.0000	PL ORG	1.000000	–
			PL MOD	–	1.000000
REICHSTAG (RST)	24.34937	0.0000	PL ORG	1.000000	–
			PL MOD	–	1.000000
TATE MODERN (TATE)	53.97852	0.0000	PL ORG	1.000000	–
			PL MOD	–	1.000000
DORTMUNDER U (DU)	94.20366	0.0000	PL ORG	1.000000	–
			PL MOD	–	1.000000
CATHEDRAL(CAT)	36.28898	0.0000	PL ORG	1.000000	–
			PL MOD	–	1.000000
PODWALE STR (POD)	36.81141	0.0000	PL ORG	1.000000	–
			PL MOD	–	1.000000
MARIA MALL (MM)	41.36684	0.0000	PL ORG	1.000000	–
			PL MOD	–	1.000000
KAZIMIERZA STR (KAZ)	73.01564	0.0000	PL ORG	1.000000	–
			PL MOD	–	1.000000

PL, Poles; FO, foreigners; ORG, original; MOD, modified; RST, Reichstag; COL, Colosseum; DU, Dortmunder U; TATE, Tate Modern; MM, Maria Mill; POD, Tenement House at Podwale Street; CAT, Cathedral; KAZ, courtyard at Kazimierza Wielkiego Street.

Appendix 9. Results of Kruskal–Wallis test (K-W) for parameter Time to First Fixation (TTFF) based on observation of AOI CHANGE.

Columns V and VI contain comparisons of PL_ORG and FO_ORG and PL_MOD and FO_MOD when $p < 0.005$.

I	II	III	IV	V	VI
general analysis comparisons within all groups PL_ORG / PL_MOD / FO_ORG / FO_MOD			detailed analysis parallel comparisons for pairs ORG i MOD		
K-W	H (3, N = 190)	p-value		FO ORG	FO MOD
COLOSSEUM (COL)	1.75594	**0.6245**	$p > 0.05$		
REICHSTAG (RST)	113.6133	0.0000	PL ORG	1.000	–
			PL MOD	–	1.000
TATE MODERN (TATE)	34.45445	0.0000	PL ORG	1.000	–
			PL MOD	–	1.000
DORTMUNDER U (DU)	15.67522	0.0013	PL ORG	1.000	–
			PL MOD	–	1.000
CATHEDRAL (CAT)	3.770801	**0.2870**	$p > 0.05$		
MARIA MALL (MM)	1.897562	**0.5939**	$p > 0.05$		
KAZIMIERZA STR (KAZ)	68.31816	0.0000	PL ORG	1.000	–
			PL MOD	–	1.000
	H (2, N = 46)	p-value			
PODWALE (POD)	6.9745	0.0411	PL ORG	1.0000	–
				–	–

PL, Poles; FO, foreigners; ORG, original; MOD, modified; RST, Reichstag; COL, Colosseum; DU, Dortmund U; TATE, Tate Modern; MM, Maria Mill; POD, Tenement House at Podwale Street; CAT, Cathedral; KAZ, courtyard at Kazimierza Wielkiego Street.

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