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Evaluating visitors' experience in museum: Comparing artificial intelligence and multi-partitioned analysis

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ABSTRACT

Analysing visitors' behaviour in a museum or in a cultural site is a crucial element to manage spaces and artworks arrangement as well as improving the visit experience. This paper presents the preliminary results of the ARTEMISIA project, exploiting Artificial Intelligence (AI) techniques to study, design and develop a methodology to interpret visitors' behaviour within a museum context, namely the Museum of Rome in Palazzo Braschi (Rome, Italy). The aim is to combine literature on users' experience (UX) analysis with experimental data coming from the visitor anonymous tracking out of motion sensors (users' stand-still positions, viewpoint direction, movements), merging approaches of different research domains. Through the use of agglomerative hierarchical clustering algorithms, four categories of visitors were identified, then associated to user profiles emerged by UX evaluations. Such analysis may lead to new forms of visitors profiling and to the development of a new generation of customised applications in public and private contexts. Identifying and predicting users' patterns with respect to museum halls arrangement may also be useful to suggest improvement in the museum spaces and exhibitions (new indications, updated storytelling or changes in thematic configuration).

1. Introduction & related works

A museum visit is a complex experience involving different users' features: from psycho-motor skills to cognitive sphere, from sensory-perceptual feedback to emotions, social and technological cultural attitudes (Wang, 2020). This is what connotes the "experiential universes" of people: whenever users face a cultural experience, they behave according to their "universes" involving sensory, mental and motor functions during time and space. The cultural venue is influenced by historical, archaeological and artistic knowledge, or by the contents delivered and presented in the space. The relationship between content and cultural space is what shapes the users' experience, in terms of motor skills, emotion and cognition. Studying and designing this relationship is the goal of Universal Design (Steinfeld and Maisel, 2012). Indeed, users' trajectories inside museum spaces and their visit's styles are affected by several essential factors, relevant to plan exhibitions, visit pathways and, in general, the museum accessibility. Significant literature on the analysis of museum audience flows mainly refers to customer satisfaction and quantitative analysis of the visitor's transit through cultural facilities (Serrell, 1997; Bourdeau and Chebat, 2001; Yalowitz and Bronnenkant, 2009). Analytical and mathematical approaches have been addressed for the analysis of data obtained through both traditional tracking tools and last generation sensors (Centorrino et al., 2021; Casolla et al., 2020). These studies, strongly oriented in a quantitative sense (Balzotti et al., 2020), are mainly aimed at identifying patterns of behaviour, oriented towards the optimization of flows in the museum contexts, for a better functionality of fruition but also for conservative purpose (stabilising and making sustainable the

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parameters of static safety, humidity and temperature, concentration of carbon dioxide, etc.), a goal which is sometimes achieved improving admission policies. Specifically, Orenes-Vera et al. (2021) proposed the RECITE system framework, relying on on Bluetooth Low Energy (BLE) technologies for detecting visitors' locations, it included a set of *fuzzy rule classifiers* (FRCs) able to tag the visit trajectories. In addition, Pierdicca et al. (2019) considered the same BLE technology within a case study based on the ''Rocca di Gradara'' museum. They collected data consisting of tuples, each one consisted of a room name, device-id, entry timestamp, exit timestamp, and a computed visit duration. One of their goals was to perform Principal Component Analysis (PCA) to detect the *most frequent visitor patterns* - a pattern was a sequence of visited museum's rooms. Other quantitative studies not only address the analysis of the visitors behaviours, but they also propose models to *predict* and/or *generate* visit trajectories. This is the case of Centorrino et al. (2021), where a Markov model is described to generate visit trajectories, again, a trajectory is a sequence of museum's rooms. Finally, Rossi et al. (2021) proposed a Deep Learning (DL) model targeted to predict visit trajectories (i.e., given the *first* part of a trajectory, then the DL model is able to predict its *remaining* part) as well as to generate from scratch a set of trajectories similar to the real ones (i.e., the ones on which the DL model was trained). A more qualitative approach deals with visitor behaviour with the explicit aim of drawing ideal paths from the human and emotional point of view, taking into account the optimal individual engagement in terms of storytelling and education (Dim and Kuflik, 2014; Lanir et al., 2017; Palau-Saumell et al., 2016; Alelis et al., 2013; Kuflik et al., 2012; Roussou and Katifori, 2018).

Finally, it is worth mentioning a specific approach centred on the relevance of the architectural design of spaces in determining travel trajectories (Bourdeau and Chebat, 2001; Stoeger, 2011), an orientation that sometimes refers to the more general theory of 'Space Syntax' (Hillier and Hanson, 1984; Hillier, 2007). Studying visitors' interest towards culture contents, the overall satisfaction and perception of cultural experience are key elements for innovative museum research domains such as Audience Development and Audience Engagement (Cuenca-Amigo and Makua, 2017). An essential and pioneering study is the one commissioned by the European Commission in 2017 which brought to the publication of "Audience Development - How to place audiences at the centre of cultural organisations" (Youth et al., 2017) a complete set of documents, born out of 30 case studies, that are meant to be useful to practitioners, policy makers, academics, students and everyone interested in deepening Audience Development in museum contexts.

1.1. Project goals & research questions

The ARTEMISIA project aims at studying a common ground between the aforementioned approaches and techniques, investigating the elements of the cultural experience in museums influencing attention, emotions and visit paths. In this regard, it differs from state-of-the-art techniques by taking its cues in a methodological sense (employment of IoT sensors and AI analytical tools) but the focus on cognitive and emotional aspects. This approach is a widespread practice in the marketing domain, employed to study the arrangement of shop windows and shopping centres. In the corporate sector, the customer journey is usually traced from the beginning (Richardson, 2010), to reach and influence consumers and convey purchase preferences. Moreover, the spread of using new generation sensors in museums to detect users' behaviour, which allows to collect a huge amount of data, will require the development of new protocols and best practices on how to manage this new setting. The present work may contribute in such a direction.

This paper introduces the ARTEMISIA project and its preliminary results (https://www.artemisiaproject.it). The detection of individual behaviour is taken through (a) in-person observation and interviews as well as (b) remote sensor systems and subsequent data processing employing AI techniques. For this purpose stereo cameras, namely Xovis PC2 models equipped with computer vision algorithms, are placed on the museum ceiling. Those cameras can capture users' silhouette from above up to four times per second. The collected data are then processed through AI analytical models to identify behavioural patterns. The final purpose is to obtain standard applications for visitors' monitoring, route planning and cultural marketing approaches for the institutions, starting with the museum that hosted the project's initial stage. Such applications might feed the cultural market with new procedures and methods connecting process innovation and behavioural sensing tools to personalise users' experience in the cultural context. Marketing Automation systems are often related to routine operations, rarely to management tools. Employed with competence and awareness, marketing automation, on the other hand, can produce beneficial effects in developing elementary actions to mitigate maintenance costs and in creating authentic customised user experiences (Colnaghi, 2019).

2. Case study

The project is being tested at the Museum of Rome in Palazzo Braschi (Rome, Italy), chosen for its coherent context in terms of exhibited artworks (paintings), as well as the variability within the exhibition (by subject, era, author, etc.). The palace, in its current aspect, was built between the late 18th and early 19th centuries, designed by the architect Cosimo Morelli (1732–1812) on behalf of Pope Pius VI (1775–1799) according to the noble typical style of that period. The palace was a gift of the Pope to his nephew Luigi Braschi Onesti, representing one of the last examples of papal nepotism before the political and cultural transformations brought by the French Revolution. The construction of the building began in 1792, was interrupted due to the French occupation in 1798 and resumed in 1802. In 1871, the palace was sold to the Italian Government and employed as headquarters of the Ministry of the Internal Affairs and later of various fascist institutions until 1949. After the World War II, the building became the shelter for homeless families and the habitual use of indoor fires caused severe damage to the frescoes and floors (Ricci, 1989). In 1952, the palace became the location of the Museum of Rome, conceived as a repository of artistic and cultural testimony of the Capital's transformation. From 1987 to 2002 the structure was closed to the public and the building underwent complex and extensive renovation and restoration works. Finally, in 2017, the new layout of the museum was inaugurated, organised thematically and no longer chronologically, through the rooms on the second and third floors to narrate the story of Rome between the 17th and 20th centuries. The aim of the actual visiting path is creating a connection between the historical building and the exhibited collection, allowing a cross reading of social and cultural phenomena occurring in the capital city along the centuries expressed by the room's aspect and decorations.

The area identified as most suitable for the project experimentation is the permanent exhibition on the second floor, due to the homogeneity of the type of objects and the static nature of the display over time characterised by a painting section dated up to the 19th century (Pietrangeli, 1971; D'Amelio, 2021). In particular, the visit route starts from Room 1 as point of connection of the themes exhibited in the museum, suggesting two more directions (yellow arrows in Fig. 1a).

- Rooms 2–9 → larger rooms as they were designed for ceremonial purposes of the 18th century noble residence. The exhibition itinerary of these rooms includes the representation of the symbolic places of Rome where civilisation and nature met and overlapped, then narrates the public and collective life aspects (religious and profane), up to the great events of the Renaissance that enabled the transition to the Modern Age.
- Rooms 10–15 → smaller and better exposed rooms because they constituted the residence of Luigi Braschi and his wife. The rooms are characterised with themes of 19th century taste with Napoleonic influences, decorated with a series of portraits (painted and sculpted)

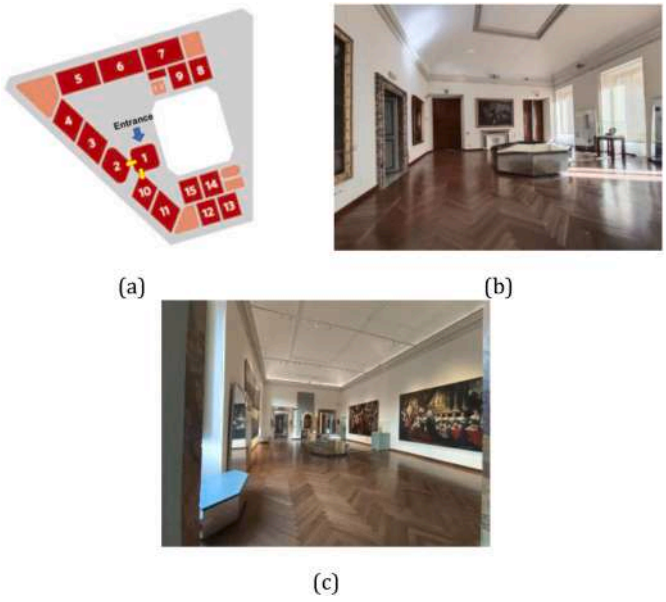


Fig. 1. Museum of Rome Palazzo Braschi (Rome, Italy): (a) second floor map, yellow arrows denote the exhibition routes; the project experimentation is conducted in (b) Room 1 and (c) Room 6.

depicting social conditions, roles and personal characters of the protagonists of the museum.

Two rooms within the exhibition at the second floor were therefore selected: Room 1 at the entrance of the visiting path (Fig. 1b) and Room 6 in the exit area (Fig. 1c).

Such spaces are adequate for this kind of analysis both for their position (entrance and exit areas) and for the dimension and number of art pieces contained. Detailed plans of each room are shown in Fig. 2. Namely, Room 1 (Fig. 2a), with its square shape and dimensions of 10 × 10 m, is accessible from four entrances. Architecturally, it is characterised by natural lighting coming from three large windows all located on one wall, while artificial lighting is focused on the exhibited artworks. The walls are coated with white plaster, and the ceiling, with a variable height from 6.20 to 6.70 m, features a plain vault without particular material decorations. Inside the room, there are four paintings, two display cases, and a central multimedia installation consisting of a mirrored volume with two integrated informational screens providing details about the exhibited works. Additionally, there are two informational panels positioned next to two of the entrances to guide visitors along the exhibition path. Room 6 (Fig. 2b), instead, has a rectangular shape with dimensions of 13.6 × 7.5 m. It is accessible from five entrances and receives natural light from two windows all located on the same wall. As for artificial lighting, it consists of an LED strip running along a valence around the perimeter and two tracks extending along the shorter side of the room, providing focused light on the artworks through a series of spotlights. The walls and ceiling have the same characteristics as Room 1. Inside the room, there are five paintings, a display case, a three-dimensional model, and a central multimedia installation similar to that of the previous room, with a mirrored volume and two integrated informational screens. In addition to the two directional panels, the room also offers several seats for visitors to enjoy the exhibition in a more relaxed way. Due to such constraints, 2 sensors were installed on top of Room 1 and 3 on top of Room 6, to be able to cover the entire space.

3. Methodology

The chosen methodology of ARTEMISIA project relies on a twofold approach: a) it exploits AI models with the purpose of remotely studying visitors' flow while identifying behavioural categories; b) users' experience analysis with *in situ* surveys is employed with the purpose of comparing behaviours, users' attitudes and the visit appreciation. Parallel analysis is required as a comparative model to capture behaviours, attitudes and relations that sensors may not reveal. Indeed, only human operators can detect details in trajectories during museum visits. These two merged investigations are valuable to draft out users' patterns and behavioural models.

A description of the type of every element inside each room is provided in Fig. 3a–b, by presenting the points of interest (POIs), its category, author and year. The passages and the multimedia installations are also indicated.

Authors are aware of the thorny operation of matching methodologies from different domains. The numerical approach that dominates hard sciences, for example, is based on principles of statistical significance, therefore it requires a large number of cases; while the User Experience evaluation inquiry, in the domain of the social science approach, can consider even samples of a few dozen significant events (Patton, 2014; Glaser and Strauss, 2017; Braun and Clarke, 2006; Creswell, 2013). Similarly, behaviours observation by a researcher, widely validated in the field of User Experience analysis (Falk and Dierking, 2000; Kelly, 2014; Anderson and Hetherington, 2019; MacDonald, 2018), may appear highly subjective (and therefore of little significance) to a purely logical-mathematical approach. These are some of the many awkward aspects of attempting a transdisciplinary approach to the analysis. However, stimulating an approach that brings together different disciplines appears important in light of a global vision of heuristic processes, also in harmony with the objectives of the 2030 agenda (Hooper-Greenhill et al., 2019; Paris and Winograd, 2019). Indeed, qualitative approaches in visitor studies play a vital role in advancing the objectives of the Agenda 2030 by promoting education, equality, inclusivity, sustainability, and social cohesion within museum contexts. By listening to and analysing the voices of their visitors, museums and cultural venues can contribute to building a more equitable, resilient, and peaceful world.

3.1. Visitors' trajectory analysis

The project's first stage concerns the detection of visitors' behaviour in Palazzo Braschi, carried out through AI techniques built on data acquired from the latest generation motion sensors. Such system is composed of stereo cameras (Fig. 4 shows two example of images of the selected rooms) recording in a completely anonymous way and storing data in a private server for a customised and limited period of time. The tracking is performed from the ceiling of the room, without recording the face of the visitors or any sensitive data, in order to be compliant with any privacy requirement. Such sensors are equipped with AI and Computer Vision algorithms required to assign and gather basic information regarding visitors (providing an identification number (ID), timestamp of their visit, their position and head orientation on the horizontal plane). Taking advantage of stereo vision, it is possible to reconstruct the 3D space, collect visitors' height and detect visitors' gender. Two approaches describing people tracking and height measurement from stereo cameras can be found in Van Oosterhout et al. (2011), Hsu and Wang (2015). Research papers usually identify museum visitors' behaviours according to animal names (e.g. 'the ant' accurately following a standard path, 'the butterfly' occasionally stopping at a few attractive points, etc.) (Kuflik et al., 2012; Centorrino et al., 2021). Similarly, in order to understand visitors' behaviour in Palazzo Braschi, an unsupervised clustering technique was employed on visitors' trajectories, to separate them in groups. The clustering algorithm does not require the number of groups to be known in advance, using the "agglomerative hierarchical clustering" approach which allows the 'closest' trajectories to be clustered together according to a specific criterion (the 'ward method' is chosen for the experiments). A survey on

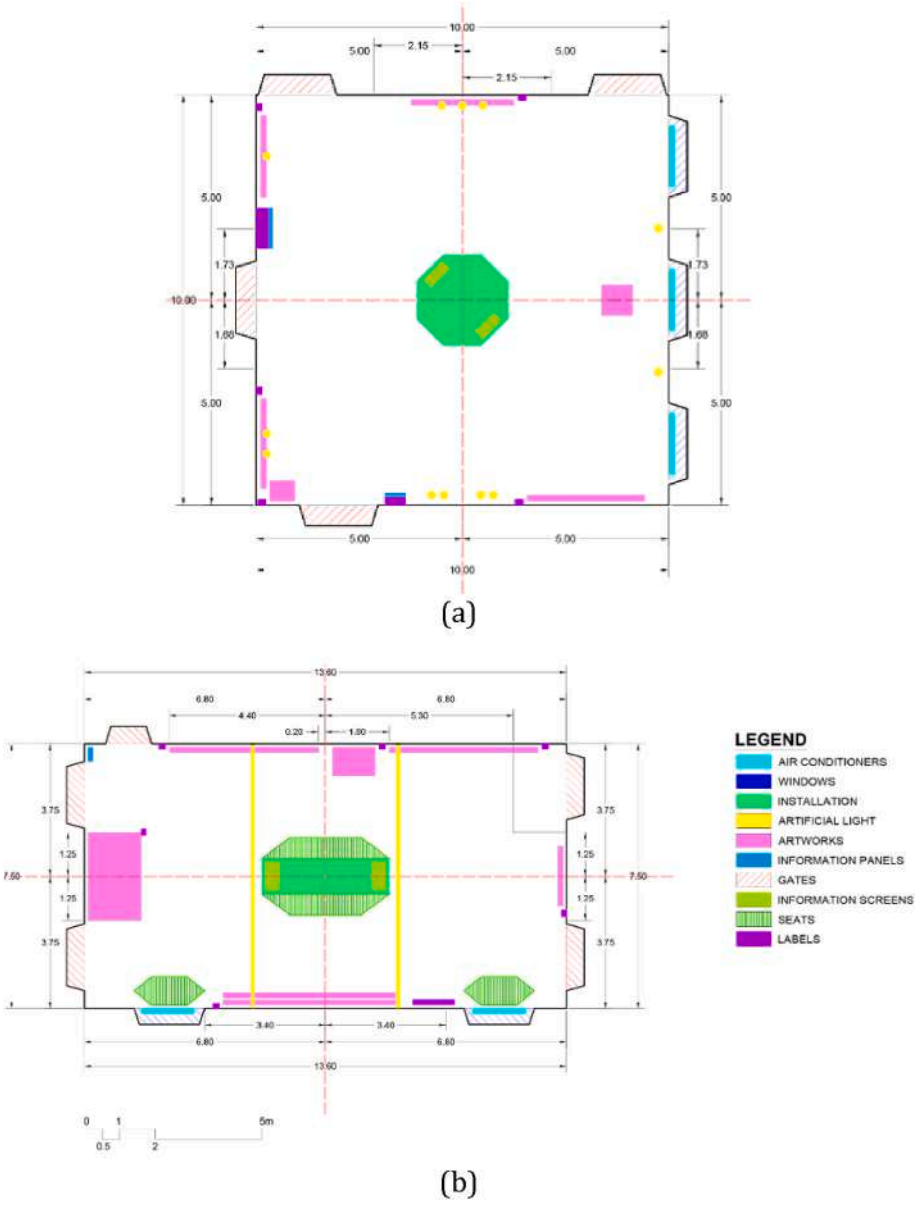


Fig. 2. Plans of (a) Room1 and (b) Room6 with all the elements involved in spaces, explained in the legend.

clustering algorithms can be found in Xu and Wunsch (2005). For each museum's room, trajectories are generated from the collection of the recorded position data. In detail, the ARTEMISIA model displays lines representing visitors' trajectories, black dots representing the rooms' points of interest (POIs), such as artworks (paintings and sculptures), room's furniture, showcases and multimedia installations as shown in Figs. 5 and 8.

3.2. User experience (UX) analysis

3.2.1. Methodological approach to UX studies

UX evaluation follows a methodology named multi-partitioned analysis described in Pietroni et al. (2016). This method is a combination of several evaluation techniques (Sections 4.2.2 and 4.2.3), carried out in different moments of the museum experience by different target users (Section 4.2.4). It takes advantage of the iterative logic of "implementation-detection-modification to a second implementation-detection" phase which generally helps project managers, developers and UX evaluators to assess a product or the experience of a context (the so-called UX evaluation lifecycle) (Pohlmeyer et al., 2009; Kieffer et al., 2017; Chapman and Rodden, 2023).

3.2.2. Nature of the chosen investigation method

The evaluation of UX involves both quantitative and qualitative analyses. In the first case, reflection on the data collected are generally based on closed-ended questions proposed to the user through (a) questionnaires; the percentage calculation of the answers and a cross comparison, through statistical rules, returns a picture of the tendencies related to the investigated topics. In qualitative research, on the other hand, the profoundness and coherence of the data collected are examined; the type of information collected is analysed, the information units cross-referenced, compared and grouped by similarity or divergence. The chosen tools are (b) the guided scenario and (c) the observation, useful for understanding some aspects of the users' interaction, investigating the impressions and comments reported by users regarding their experience. In the guided scenario (Rubin and Chisnell, 2008), visitors usually carry out and solve specific tasks; at the end of the interaction, the operator proposes a questionnaire to understand problems, the logical-decision-making process, their experience evaluation and analysis of the cognitive/emotional impact. Through observation

	n.	Artwork title	Category	Author	Year
Room 6 	1	Exit door to stairs/elevator	Passage		
	2/3	Entrance doors to the room	Passage		
	4	Route passage	Passage		
	5	Multimedia installation	Installation		
	6	Interno della cappella Cybo in S.Maria del Popolo	Painting	L. Garzi, C. Maratta, P. F. Garoli	1687
	7	Innocenzo X Pamphilj conferisce il cappello cardinalizio a Fabio Chigi	Painting	P. L. Ghezzi	1724
	8	Modello della cappella Rospigliosi Pallavicini in S.Francesco a Ripa	3D model	Michetti	1712
	9	Clemente XI Albani conferisce il cappello cardinalizio a Giulio Alberoni	Painting	P. L. Ghezzi	1724
	10	Arrivo al Quirinale dell'ambasciatore veneto Nicolò Duodo	Painting	Unknown	1715
	10	Ingresso a Roma da Porta del Popolo dell'ambasciatore veneto Nicolò Duodo	Painting	Unknown	1715
	11	Santo panneggiato con libro	Pottery	G. L. Bernini	1660
	11	Bozzetto per la statua di S.Longino nella chiesa di S.Pietro	Pottery	G. L. Bernini	1634

(a)

	n.	Artwork title	Category	Author	Year
Room 1 	1	Tazza da puerpera con coperchio, vassoio e cucchiaio	Supply	G. Valadier	1779
	2	Visita di Innocenzo X alla Fontana dei Fiumi a Piazza Navona	Painting	F. Gagliardi	1651
	3	Apollo citaredo	Biscuit	G. Volpato	1789
	3	Fauno danzante	Biscuit	G. Volpato	1789
	3	La musa Melpomene	Biscuit	G. Volpato	1789
	3	Danaide	Biscuit	G. Volpato	1789
	3	Flora Farnese	Biscuit	G. Volpato	1789
	3	Ercole Farnese	Biscuit	G. Volpato	1789
	4	Ritratto equestre di Camillo Rospigliosi	Painting	A. Masucci	1737
	5	Papa Gregorio XVI in visita ai Fori	Painting	P.J. Van Brée	1832
	6	S.Camillo de Lellis salva gli ammalati dell'Ospedale S.Spirito durante l'inondazione del 1598	Painting	P.H. Subleyras	1746
	7	Entrance door to the museum	Passage		
	8	Door (closed)	Passage		
	9	Security station	Work station		
	10	Route passage	Passage		
	11	Multimedia installation	Installation		

(b)

Fig. 3. Description of the chosen points of interest (POIs) for Room 1 and Room 6.

(Kuniavsky, 2003), the operator records the user's behaviour without interfering in his decision-making process and his actions, thus remaining quite "invisible". Eventually, these tools analyse similar aspects and their use is deliberately redundant to verify the users' level of sincerity, awareness and state of mind with which they faced their experience.

3.2.3. *Evaluation tools*

The multi-partitioned analysis consists of three evaluation tools used according to a predetermined timing and a specific pipeline of work. In the ARTEMISIA project, such tools were used to get a deeper but anonymous insight into user profiling and experience, with a slight adaptation to the context of application. The tools of the multi-partitioned analysis are: (i) Observation (OBS): widespread at the beginning of each evaluation activity and during the user experience, as it provides reflections on users and technologies and builds a comparison of the investigative tools. (ii) Semi-structured interview (SSI) replacing the questionnaires at the end of the user experience: essential to probe basic knowledge of each user identifying professional profile and education, establishing needs and expectations, recognizing users' attitude, gestures, movements and comments (Garrett, 2002). (iii) Guided Scenario (SG): this tool has not been employed in the ARTEMISIA project due to the nature of the survey recalling the spontaneity and simplicity of users movements, flow and behaviours inside the Museum of Rome.

3.2.4. *Logistics*

The UX evaluation was performed in three moments. The first one with a non-intrusive operator ; here the operator with an OBS takes note of users' behaviour, psycho-physical and verbal reactions, general condition and times of global use. The second with the operator introducing the survey, its anonymity and the freedom to refuse it. The third one of direct and detailed evaluation. The entire evaluation experience lasts no more than 20 min from the moment of the first meeting with the user until the questionnaire. The operator, throughout the evaluation activity, is impartial.

3.2.5. *Target users*

The UX evaluation was carried out on a sample of 100 users, divided in 51 observed persons and 48 interviewed ones. This number is

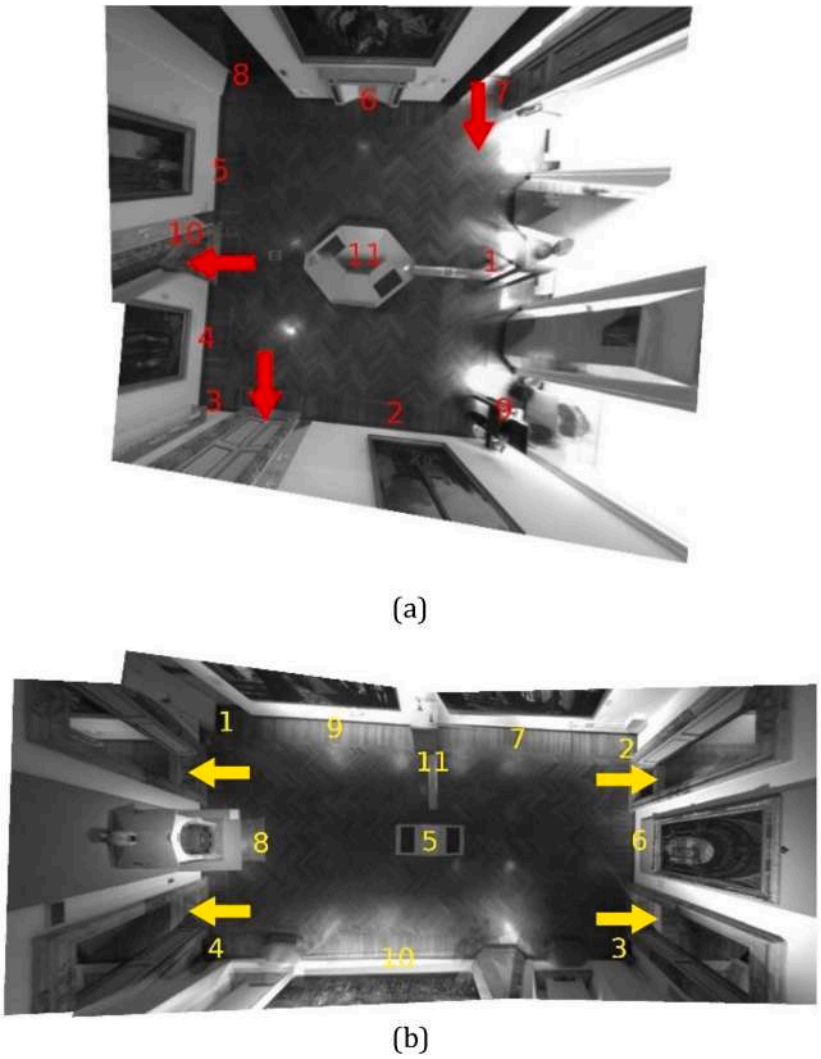


Fig. 4. Sensors points of view in (a) Room 1 and (b) Room 6 where numbers are the points of interest (POIs) and arrows are the passages.

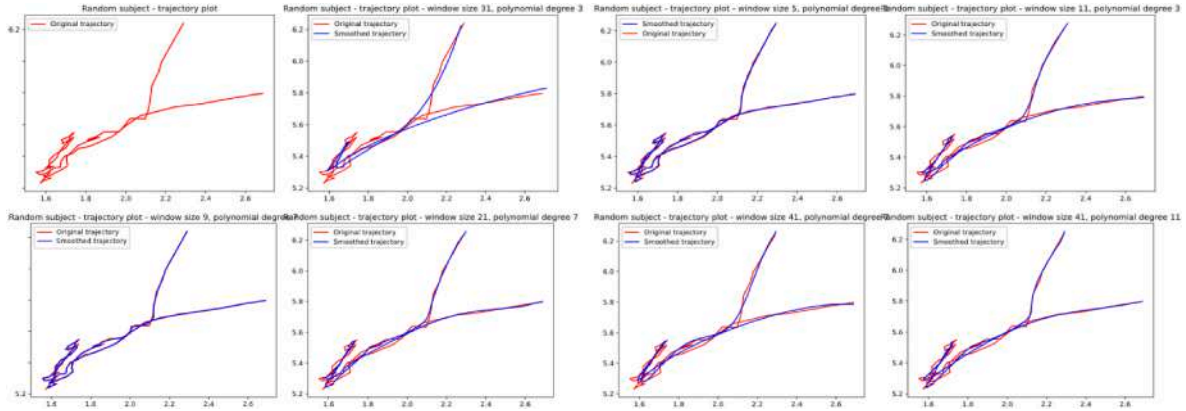


Fig. 5. Example of trajectory smoothing for a random subject. Shown in red are the original trajectories, in blue the smoothed ones. The trajectories are smoothed with Savitzky-Golay filtering technique varying the window size and the polynomial degree as described in Section 5.1.1.

considered more than enough to draw up first behavioural trends and exceeds the qualitative and quantitative standards set by the EU and ISO (which propose test cases with 15–20 participants) (Faulkner, 2003; Sauro and Lewis, 2016).

4. Results

Results of processing sensor data are presented in Section 4.1. In Section 4.2 the outcomes of quali-quantitative analysis of the user experience (UX) together with the surveys taken in the museum are described.

4.1. Data pre-processing

The results of preliminary elaborations included data acquired during the first three months of recording (April–June 2023) at the Museum of Rome. Information acquired by motion sensors consist of text data collecting measurements for each detected visitor: timestamp, anonymous visitor ID, room ID, (x, y) position on the horizontal plane, height, gender and head orientation (x, y) on the horizontal plane as described in Table 1. The purpose of the analysis is to obtain a comprehension of visitors' behaviour in Rooms 1 and 6 of Palazzo Braschi with the aim of comparing it with *in situ* surveys. The data obtained from the sensors contained short trajectories in terms of measurements per visitor. Such trajectories were filtered out.

4.2. Visitors behaviour analysis

4.2.1. Smoothing

As a first step, the trajectories identified through sensors are smoothed in order to disregard redundant data (i.e. imprecise trajectories, anomalies). The chosen technique is the Savitzky–Golay filter, a widespread approach for smoothing data (Savitzky and Golay, 1964). Those filters are based on fitting a polynomial of given degree n to the data in a (usually symmetric) neighbourhood $k–m, \ldots, k + m$ of each data point k (this range contains $2m + 1$ data points and is named window). Each data point is then replaced by the value of the fit polynomial at this point k. Varying those two variables, some examples are shown in Fig. 5, the best trade-off for our data was a polynomial of degree 3 and a window length of size 31. Trajectories shorter than the window size are neglected. In Fig. 6 are the final smoothed trajectories for 4 random subjects.

4.2.2. Clustering

The second step of the analysis concerns visitors' behaviour interpretation and it is carried out separating trajectories in groups. The purpose is to gather similar trajectories according to a specific distance metric. To define the number of clusters suitable for subdividing behaviour, we relied on Centorrino et al. (2021) and on the 'agglomerative hierarchical clustering' (AHC) approach through which a hierarchy of clusters is built, usually presented with a tree structure, using the Manhattan distance metric to compute distances and provide the number of clusters. In Fig. 7 is shown a dendrogram representing the tree structure for the trajectories collected in a single day of recording. The best option for our data was to divide the trajectories into 4 groups. The same "agglomerative hierarchical clustering" approach was then used to collect the trajectories belonging to the four clusters.

The results of behaviour analysis in Rooms 1 and 6 are reported here for four days (see Table 2) (a Thursday, 179 detected trajectories in Room 1 and 208 in Room 6 a Friday, 220 detected trajectories in Room 1 and 157 in Room 6; a Saturday, 263 detected trajectories in Room 1 and 241 in Room 6; and a Sunday, 297 detected trajectories in Room 1 and 239in Room 6). It may be observed the pattern similarity for both days (referring to different rooms), independently from the number of observations. Such pattern features show a similarity, with slight variations, during the entire observation period. It is not obvious to translate such shapes into specific behaviours, nevertheless we labelled them with specific descriptions.

4.2.2.1. Room 1 - museum of Rome. In Fig. 8a and Fig. 8b, a set of clusters is reported, corresponding to 4 different visitors' behaviours retraced within sensors' recording in Room 1: **Behaviour n.1** (red): the majority of users explore the entire room, with the main focus on artwork n.2 "Visita di Innocenzo X alla Fontana dei Fiumi a Piazza Navona" (1651, attributed to Filippo Gagliardi) and on the entry/exit north door. However, the lower right highlighted area corresponds to the museum guardian's seat - which might have influenced the sensors' detection; **Behaviour n.2** (blue): the majority of users focus on artwork n.2 "Visita di Innocenzo X alla Fontana dei Fiumi a Piazza Navona" (1651, attributed to Filippo Gagliardi) and on the entry/exit north door; moreover, the highlighted area is strictly close to the south and west doors; **Behaviour n.3** (green): the majority of users focus on artworks n.4 "Ritratto equestre del Principe Camillo Rospigliosi (1737, Agostino Masucci) and n.5 "Papa Gregorio XVI in visita ai Fori (1832, PhilippeJacques Van Br'ee); moreover, the highlighted areas are related to the entry/exit north door and to the south/west doors, leading to another museum room; **Behaviour n.4** (purple): the majority of users focus on artwork n.4 and on the south/west doors. This angular incidence of users' flow may also be related to the small dimensions of Room 1 and the central multimedia installation which occupies most of the room space.

Beyond the above-mentioned descriptions, we may summarily identify some patterns (1,2), roughly covering the entire room and others (3,4) more focussed on parts of it. The total amount of trajectories of the first two clusters is generally higher than the sum of the others (Table 2).

4.2.2.2. Room 6 - museum of Rome. In Fig. 9a and Fig. 9b a set of clusters is represented, corresponding to 4 different visitors' behaviours in Room 6 of Museum of Rome: **Behaviour n.1** (red): the majority of users examine the room; **Behaviour n.2** (blue): the majority of users focus on the 4 doors in the room; this datum may also be influenced by the multiple passages of users to move from the room to another one; **Behaviour n.3** (green): the majority of users focus on artworks n.9 "Innocenzo X conferisce il cappello cardinalizio a Fabio Chigi" (1724, P. L. Ghezzi), and artwork n.7 "Clemente XI conferisce il cappello cardinalizio a Giulio Alberoni" (1724, P. L. Ghezzi), also considering the passage from the west doors and the exit one; **Behaviour n.4** (purple): the majority of users observe the artwork n.2 "Arrivo al Quirinale dell'ambasciatore veneto Nicola Duodo" and/or n.3 "Ingresso a Roma da Porta del Popolo dell'ambasciatore veneto Nicola Duodo; however, it is relevant to consider the users' shift towards the doors. The linear incidence of users' flow (east or west) may be related to the presence of the central multimedia installation and the seats which both occupy a large part of the available room space. We may summarily identify some

patterns (1,2) roughly covering the entire room and others (3,4) basically focussed on parts of it, and the total percentage of the latter couple of trajectory clusters is significantly lower (see Table 2).

4.3. Multi-partitioned analysis: preliminary results

UX evaluation was conducted between 9th and 25th of June 2023 at

Table 1
An example of data acquired by motion sensors.

Time stamp	ID	Room ID	x	y	height	gender	head x	head y
168473 1797600	6686	1	2.93	0.41	172	MALE	0.14	0.98
168473 2141280	6687	1	2.93	0.41	154	FEMALE	0.78	0.61
168473 2758720	6688	1	2.83	0.41	133	NOT SURE	0.94	0.33

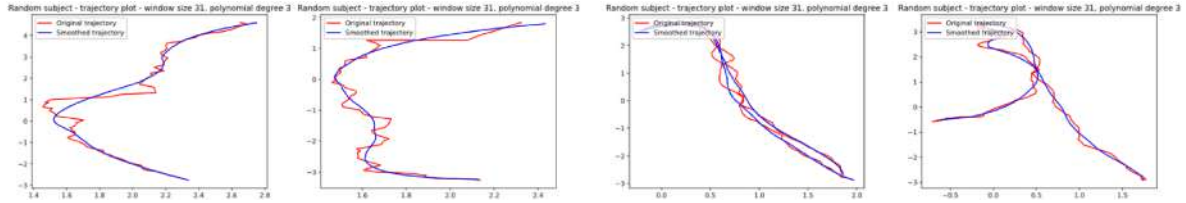


Fig. 6. Examples of trajectory smoothing for 4 random subjects using Savitzky-Golay filtering technique with window size 31 and polynomial degree 3. Shown in red the original trajectories, in blue the smoothed ones.

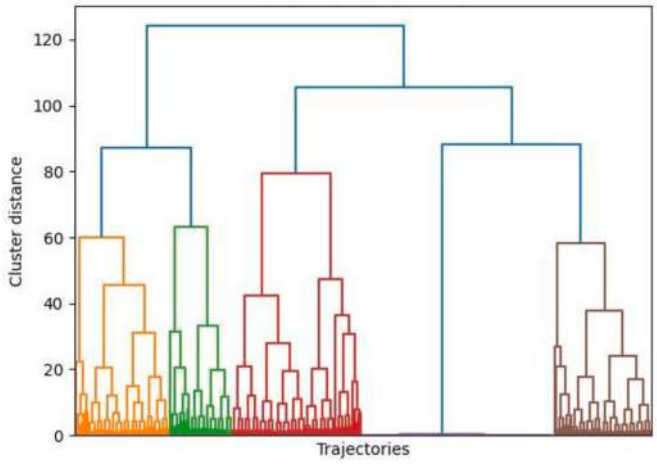


Fig. 7. Dendrogram: hierarchical relationship between 297 trajectories collected in Room1 a single day (June 18, 2023).

the Museum of Rome - 7 days. The multi-partitioned analysis presented in Section 4.2 was applied to Room 1 and Room 6, collecting 99 global feedback divided as Fig. 10 shows.

In Room 1, 18 Observations (OBS) and 23 Semi Structured interviews (SSI) are carried out, while in Room 6, 33 OBS and 25 SSI. Both museum rooms are surveyed with more than 25 people, specifically with 41 vs. 58, providing a reliable overview for UX studies.

The results of the preliminary UX evaluations with *in situ* surveys highlight information comparable with the sensors' outcomes, confirming or simply unveiling users' behaviours, as presented in the following sections.

4.3.1. Target analysis

Of 51 OBS and 48 SSI made in 7 random days, the majority of users were quite balanced in gender (47 male vs. 52 female), with a slight prevalence of female visitors (Fig. 11). The average age was 40–65 (OBS 38,9% vs. SSI 37,5%), followed by 25–40 (OBS 22,2% vs. SSI 31,3%), 0–25 (OBS 22,2% vs. SSI 29,2%) and 65+ (OBS 16,7% vs. SSI 2,1%).

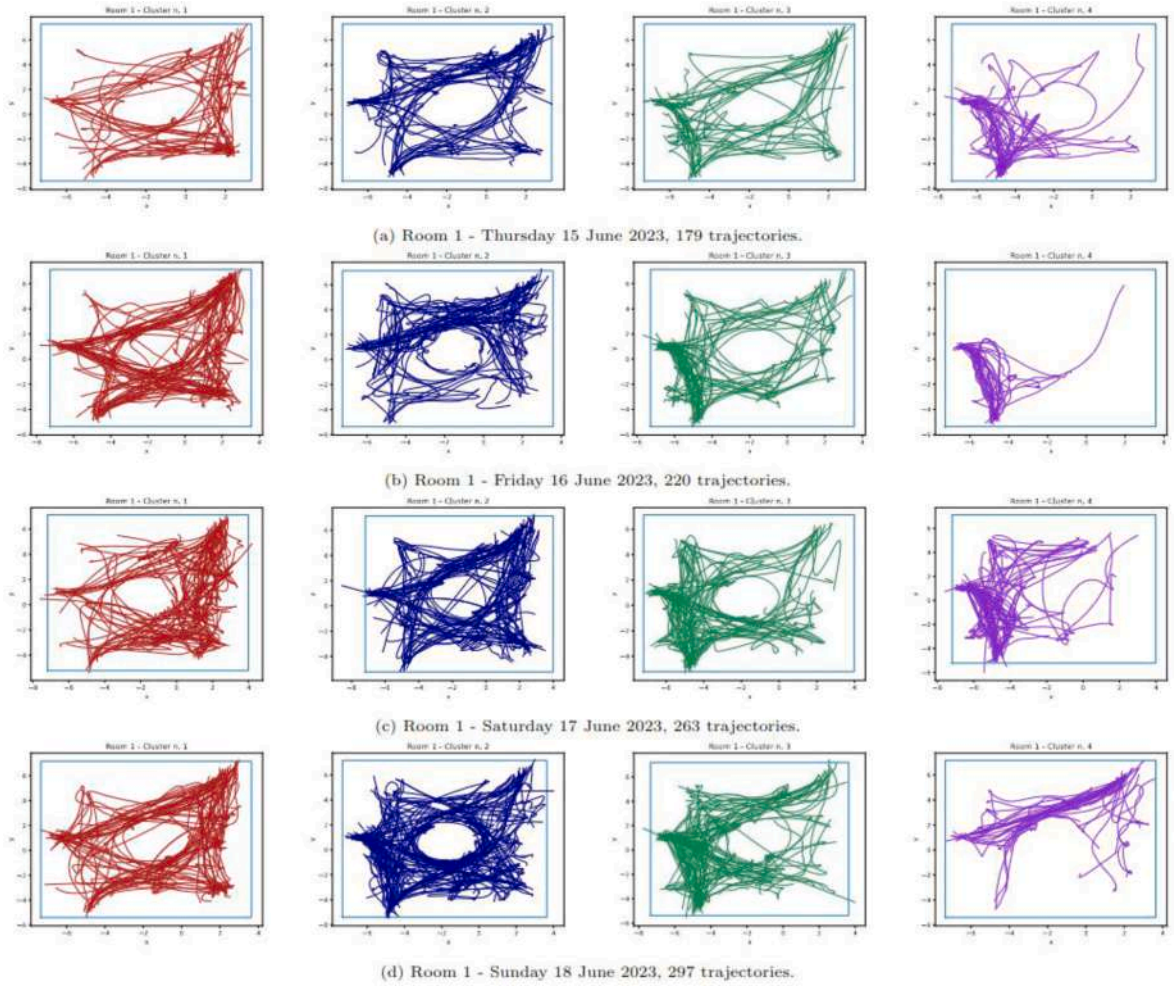
The majority of users (OBS + SSI) were mainly travellers (80% OBS + 50% SSI) from Europe (SSI 48,8%) and USA (SSI 32,6%); European travellers mainly came from Italy (SSI 65%), France, Spain and Cyprus (respectively SSI 10%) and Germany (SSI 5%). 3,9% of users had accessibility issues due to reduced functionalities (OBS wheelchair and crutches). The Museum is equipped with elevators and the doors' gap was enough to let them circulate with no constraints. Relying on SSI data, the users were used to visiting cultural sites more than 5 times per year (SSI 56,3%). Their professions were quite variegated ranging from University attendants (SSI 22,4%), Education (SSI 12,2), Medicine and Public sectors (respectively SSI 14,3%), ICT, Communication and Informatics (respectively SSI 10,2%), Engineering (SSI 6,1%) and Culture and Agriculture (respectively SSI 4,3%). One person was not occupied.

4.3.2. Qualitative analysis

User typology. Taking into account SSI feedback, it was possible to outline the profile of the interviewed visitors: they generally preferred to visit a museum with no indication or guide (SSI 29,7%) or with a physical guide (SSI 23,1%) or audio-guide (SSI 18,7%). 11% of users affirmed to use paper-based guides and/or mobile applications or tablets. Only a bunch of users took into account the chance to know more about the museum contents through totems, digital applications or multimedia installations. Their preference toward autonomy was underlined by the fact that they preferred to get information by reading informative panels (SSI 52,7%) or listening to an audio-guide (SSI 28,4%) rather than using digital installations (SSI 9,5%) or watching a video (SSI 9,5%). Such data confirmed the profile of users as "Avid cultural user" or "Cultural nostalgic", as described in research on audience segmentation (Falk, 2009) conducted by The Audience Agency and Morris Hargraves McIntyre, just to mention two popular companies in the sector. From literature, indeed, the members of the former group "have a marked spontaneity of thoughts because they can see culture as an essential part of their life, the spark that ignites them. Going to the museum could therefore be a choice of independent experience. They also love to visit the museum alone or with friends who are part of their cultural elite. But if visiting with others, they probably are thrilled to share their interests. They wish to satisfy their willingness to know a lot and they enrich themselves acutely […]". Whereas the members of the latter group "appreciate the history and social culture on display. They would pursue the beauty of the environments, the careful display of objects. They would visit exhibitions with well-known subjects and fully enjoy the experience without rushing. They have matured their tastes and appreciation over time. Mostly they are among the adults, but some younger may be fascinated by tradition as well. Cultured by nature, they read all the information unhurriedly and thoroughly. They tend to be nostalgic, and emotional experiences guide them […]".

Kind of visit. Users were mainly visiting the museum in company (OBS 76,5%) while a few were alone (OBS 23,5%). They did not interact or relate with other visitors or museum personnel (OBS 96,1% no vs. OBS 3,9% yes). This datum matches with the user typology presented above.

Behaviour. Relying on OBS data, users watched artworks moving back-and-forth (OBS 28,6% far vs. OBS 35,7% close to artwork). A good number of them observed the general subject (OBS 21,4%) which means the frame and the painting/statue, moving the head around to grab with their eyes the overall scene. Only 2,9% of users paused on details for a long time, while 11,4% of them watched at artworks seated on benches. Observed users seemed not to have a predefined visit path in their mind, walking around the rooms zig-zagging (OBS 66%); only 28,3% of them seemed to follow a precise logic and a sequential observation, reinforced by the 5,7% of users who used a paper-based guide. This datum is quite confirmed by SSI, when 45,8% of interviewed users commented that as far as they understood there is a logic behind exposition and room pathway (even if they were not able to clearly describe it), fighting against 43,8% of users who affirmed instead to not retrace a precise route. This aspect outlined the profile of museum visitors by suggesting an emotive museum experience rather than an organised and academic one. OBS revealed that more than 50% of users were silent and quiet,



(a) Room 1 - Thursday 15 June 2023, 179 trajectories.

(b) Room 1 - Friday 16 June 2023, 220 trajectories.

(c) Room 1 - Saturday 17 June 2023, 263 trajectories.

(d) Room 1 - Sunday 18 June 2023, 297 trajectories.

Fig. 8. Visitors' behaviours in Room 1.

Table 2
Percentages of the identified trajectories in the two room.

Pattern	1		2		3		4	
Room 1	n.	%	n.	%	n.	%	n.	%
15/06	42	23.46	56	31.29	43	24.02	38	21.23
16/06	88	40	48	21.82	57	25.91	27	12.27
17/06	80	30.42	69	26.24	65	24.71	49	18.63
18/06	60	20.20	125	42.09	73	24.58	39	13.13
Room 6	**n.**	**%**	**n.**	**%**	**n.**	**%**	**n.**	**%**
15/06	61	29.33	38	18.27	71	34.13	38	18.27
16/06	47	29.94	43	27.39	23	14.65	44	28.02
17/06	99	41.28	64	26.55	56	23.24	22	9.13
18/06	61	25.52	58	24.27	75	31.38	45	18.83

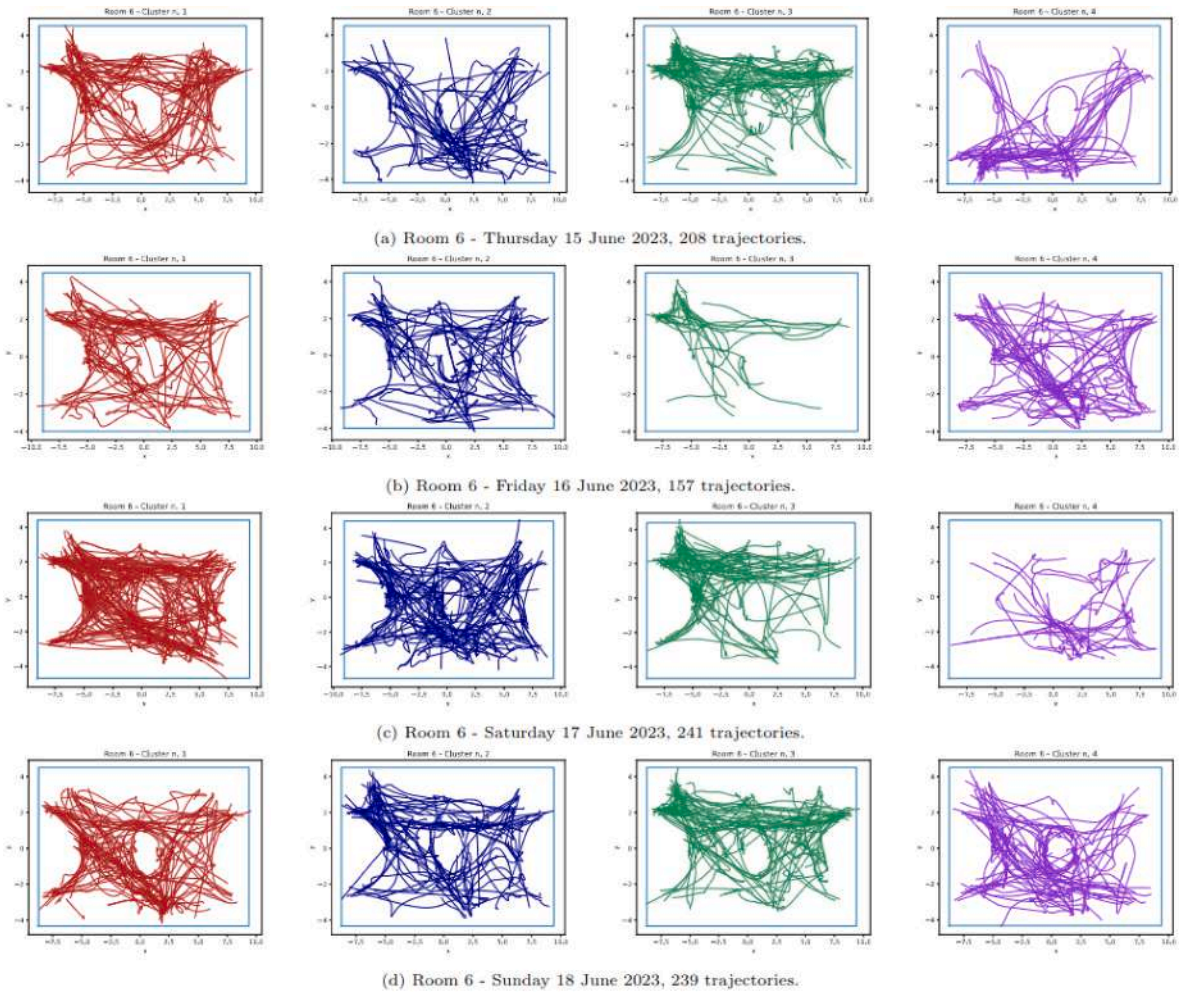
during their visit. They did not listen to any kind of device (OBS 94,1% do not listen vs. OBS 5,9% do listen) and did not use their own mobile phone or tablet - at least the operator did not notice users interacting with them (OBS 80,4% not using personal devices vs. OBS 19,6% use personal devices). Finally, almost all observed and interviewed users did not notice the multimedia totems located in both rooms. Of those who noticed, the majority did not interact with them (OBS 74,5% do not use multimedia vs. OBS 25,5% do use multimedia). This data is in line with the visitor's profile presented above, confirming that museum users were not interested in using any digital installation (SSI 9,5%). Another explanation could be that multimedia were not well highlighted in both rooms: as a matter of fact, their particular design (mirrored covering) and location might confuse visitors.

Emotional Attitude. The majority of users' movements, gestures and facial expression revealed a curious and proactive attitude toward museum contents and spaces (OBS 80,4%). Whereas, 15,7% of them seemed indifferent and uninterested, while only 3,9% seemed passive and quite intimidated, especially visitors who were in couples (Fig. 12a).

Operators attempted to map users' emotions during their visit (Fig. 12b) and what came out was that 55,1% seemed curious toward museum exploration, referring to their head movements and grimaces, and their walk type; 27,5% seemed passive and timid, observing their gaze and hand gestures. 2,9% of them seemed even analytical and 1,4% doubtful. Above all, 1,4% of users seemed happy, and 1,4% amazed, noticing their smiles and signs of wonder on their faces. 10,1% of users seemed, instead, annoyed watching their faces and their flow, moving around the room with no specific target and checking over their mobile phones from time to time.

4.3.3. Quantitative analysis

Room permanence. Studying OBS data, users generally stayed in both rooms less than 3 min (OBS 51%), followed by those who remained for 3 up to 5 min (OBS 25,5%). It is interesting to notice that 21,6% of users, plus 2% of them, stayed in the rooms for more than 6 min (specifically OBS 21,6% between 6 and 10 min, OBS 2% between 11 and 15 min). Moreover, comparing Room 1 with Room 6 (Fig. 13), the majority of users experienced Room 1 for 3 up to 5 min (OBS 44,4%), while Room 6 for less than 3 min (OBS 54,5%). This datum is explicable with the position of such rooms, collocated at the beginning and at the end of the museum visit path, at the second floor: Room 1 can be considered an



(a) Room 6 - Thursday 15 June 2023, 208 trajectories.

(b) Room 6 - Friday 16 June 2023, 157 trajectories.

(c) Room 6 - Saturday 17 June 2023, 241 trajectories.

(d) Room 6 - Sunday 18 June 2023, 239 trajectories.

Fig. 9. Visitors' behaviours in Room 6.

Evaluation tool	Room 1	Room 6	Total per Room
OBS	18 users	33 users	51 users
SSI	23 users	25 users	48 users
Total per Room	41 users	58 users	**99 users** (Room 1 + Room 6)

Fig. 10. Number of collected feedback divided per room and UX tools used.

Evaluation tool	Room 1 ♂	Room 1 ♀	Room 6 ♂	Room 6 ♀	Total per Room
OBS	10 users	8 users	17 users	16 users	51 users
SSI	10 users	13 users	10 users	15 users	48 users
Total per Room	20 users	21 users	27 users	31 users	**99 users** (Room 1 + Room 6)

Fig. 11. Number of collected feedback divided per gender.

entryway, so users might have been curious about objects and painting exposed, spending a bit more time in it; Room 6 is close to toilets and stairs, so users might have accelerated their visit to move to other rooms or floors, spending thus few time in it.

Artworks' observation. Data from OBS showed that users watched at artworks less than a few seconds (OBS 62,7%); 35,3% of them observed them for up to 2 min and only 2% for more than 5 min, on average. Again, comparing both rooms, a slight increase in time spent in watching artefacts is traceable in Room 6. Moreover, detailing what users were observing, operators registered that they spent more time admiring artworks (OBS 50,6%) rather than reading panels (OBS 37%) or the general context of the rooms (OBS 12,3%). Again, comparing both rooms, in Room 1 users spent more time in going through texts and explanations (OBS 45,2% of Room 1 vs. OBS 32% of Room 6). Here the explanation could be the introductory role that Room 1 has, in comparison with Room 6. In the latter, indeed, more information is given to visitors, taking into account also the length of texts and the number of images.

Artworks' preferences. Data from SSI reported that users preferred some artworks in comparison with others, in each room. Room 1 saw preferences for artworks n. 1, 4 and 5. Room 6 revealed preferences for artworks n. 7 and 10 (Fig. 14). All preferences related to religious and

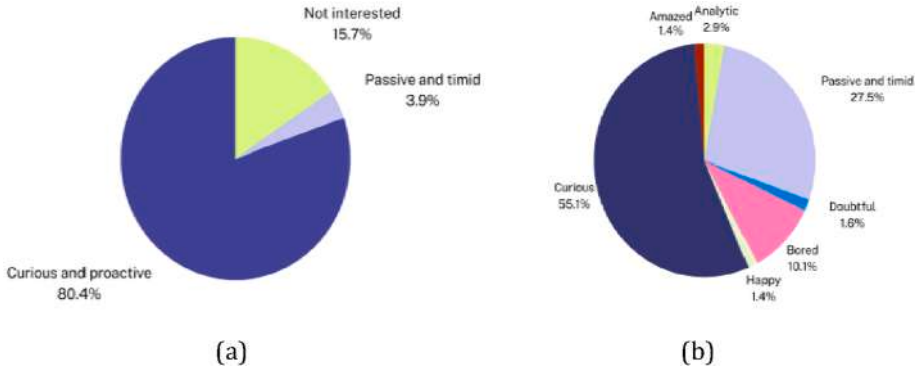


Fig. 12. (a) OBS: Room 1 vs. Room 6 "What kind of behaviour does the user seem to have?". (b) OBS: Room 1 vs. Room 6 "What kind of emotions does the user seem to experience?".

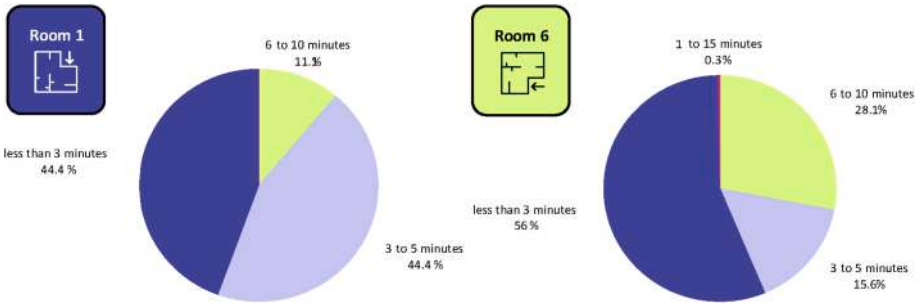


Fig. 13. OBS: Left Room 1 vs. Right Room 6 "Time of user's permanence in museum room".

	n.	Artwork title	N. of preference
Room 1	1	Tazza da puerpera con coperchio, vassoio e cucchiaio	
	2	Visita di Innocenzo X alla Fontana dei Fiumi a Piazza Navona	xxxxxx
	3	Apollo citaredo	xx
	3	Fauno danzante	xx
	3	La musa Melpomene	xx
	3	Danaide	xx
	3	Flora Farnese	xx
	3	Ercole Farnese	xx
	4	Ritratto equestre di Camillo Rospigliosi	xxxxx
	5	Papa Gregorio XVI in visita ai Fori	xxxxx
	6	S.Camillo de Lellis salva gli ammalati dell'Ospedale S.Spirito durante l'inondazione del 1598	xxx
Room 6	6	Interno della cappella Cybo in S.Maria del Popolo	x
	7	Innocenzo X Pamphilj conferisce il cappello cardinalizio a Fabio Chigi	xxxxx
	8	Modello della cappella Rospigliosi Pallavicini in S.Francesco a Ripa	xxx
	9	Clemente XI Albani conferisce il cappello cardinalizio a Giulio Alberoni	xxx
	10	Arrivo al Quirinale dell'ambasciatore veneto Nicolò Duodo	xxxxxx
	10	Ingresso a Roma da Porta del Popolo dell'ambasciatore veneto Nicolò Duodo	xxxxxxxx
	11	Santo panneggiato con libro	x
	11	Bozzetto per la statua di S.Longino nella chiesa di S.Pietro	x

Fig. 14. Artworks' preferences, divided per room.

laic subjects, with a slight preference for panoramas and views. When directly asked, users affirmed in SSI that their preferences related mainly to the subject represented in artworks (SSI 39,6%), then to the (big) dimension of certain paintings/statues as well as colours (respectively SSI 20,8%), which captured the eyes of visitors (Fig. 15). In some cases (SSI 10,4%) also the way artworks were exposed was well evaluated, followed by the pictorial technique (SSI 6,3%) and the relevance of the author/artist (SSI 2,1%). Comparing Room 1 with Room 6, some differences in percentage are highlightable: in the former case, subjects of artworks catched the attention of users at the most (SSI 70%); whereas, in the latter case, the dimension of paintings (SSI 31,1%) plus the colours (SSI 25%) won over the other features. This is in line with OBS feedback and the notes of operators, for both rooms.

Visitors' satisfaction. SSI feedback showed that users were relatively satisfied by both rooms' experience, valuing them as 4 on a scale of 5 points, where 1 means "nothing" and 5 "a lot". Specifically, they were asked to assign a value to aspects like rooms' viability, artworks' exposition, their furniture and services, informative panels and general time of fruition (Fig. 16). Users then replied by evaluating as very satisfying" a) the way artworks were exposed in both rooms, as much as b) the time at their disposal to visit the space, going through their information and admire artworks. Also, c) the visit pathway was evaluated very well. About d) contents, users evaluated them as "quite satisfying" and to improve in terms of length, position and language used; the same goes for e) viability indicators that need to be enhanced in visibility and position.

Regarding point e), users also added that generally viability information is essential in museums evaluating them as "very relevant", on a scale from 1 to 5, where 1 is "not relevant" and 5 "very relevant". Visitors also commented on SSI that the experience of both rooms could be improved in terms of lighting, supplementary services (i.e. benches or chairs) and climate.

4.4. *Comparative analysis: AI vs. UX*

Trying to find a common ground between the two evaluative approaches used for the ARTEMISIA project, authors tried to analyse both results: at first, for confirming or rejecting certain assumptions and/or outcomes; secondly, to probe the effectiveness of sensors in a museum environment; finally, to start drafting (new) models of fruition with target segmentation.

4.4.1. *User typology*

Taking for granted the two user profiles emerged by UX evaluation (Section 5.3.2), it was possible to retrace similarities in trajectories grouped in section 5.2.2., as the majority of the sample belonging to the "Avid cultural user" profile, instead of "Cultural nostalgic", seem to match the higher percentage of trajectories of the pattern 1 and 2

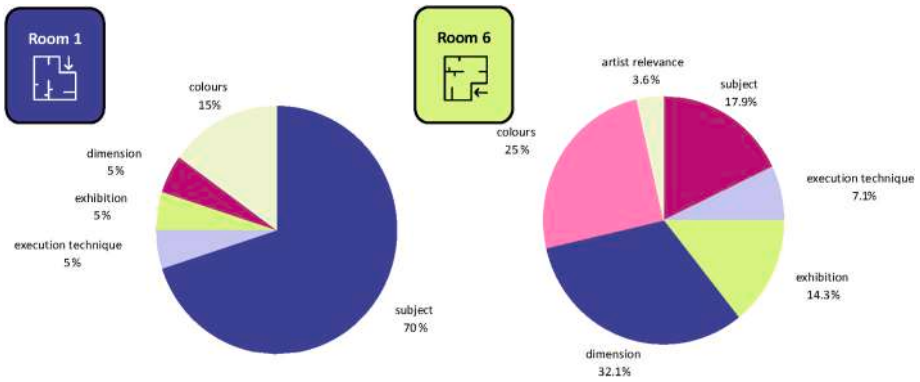


Fig. 15. SSI: Left Room 1 vs. Right Room 6 "Time of user's permanence in museum room".

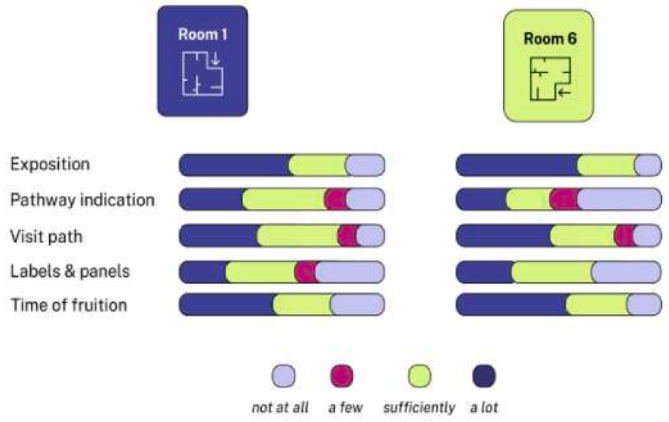


Fig. 16. SSI: Room 1 vs. Room 6 "How much are you satisfied with the following aspects?".

("roughly covering the entire room") reported in Table 2.

First of all, going through the 4 behaviours highlighted by AI sensors in both rooms, these are confirmed by multi-partitioned analysis made by the operator. Secondly, such behaviours, in some cases, were repeated in both rooms. Here, we propose a preliminary list of Artemisia eXperiential Profiles (AXP) inside the Museum of Rome:

Profile A. "Want to see everything" approach (ideally linkable to trajectory behaviour n.1, reported in Table 2). This user is typically interested in admiring all artworks and museum objects, not developing a precise preference for a specific topic or masterpieces. This user is eager to see everything, visiting all museum rooms, following indications as well as moving back and forth around the rooms with curiosity. This user reads almost all labels and panels and often takes advantage of a guide (paper-based or digital or in person). This user usually visits the museum alone or with selected and interested people (colleagues or friends) who share the same curiosity and cultural alphabetization. That was the case of some ARTEMISIA project's users.

Profile B. (ideally linkable to trajectory behaviours n. 3 and 4, reported in Table 2, as focussed on specific targets). "Limited field of view" approach. This user moves guided by contextual impulses, going around in museum rooms by focusing on what comes in front of him/her but also observing what captures his/her attention (alternatively the artwork's colours or dimensions or the represented subjects). Obviously, the field of view of this user is influenced by museum visit path and museum exposition. This user is not interested in the entire museum collection, nor has a precise stylistic preference or cultural vocation. Whereas he/she gets inspired by the moment and the space. This user usually visits the museum in company (family or friends). That was the majority of the cases of ARTEMISIA project's users.

Profile C. (ideally linkable to trajectory behaviours n. 3 and 4, reported in Table 2, as focussed on specific targets). "Focus on masterpiece/s" approach - religious or panoramic views subjects. This user does not have a profound artistic culture; nevertheless he/she keeps up with trends and contemporaneity, being updated with the most relevant artworks of museums and the general history. This user is generally interested in sharing experiences on social media as well as visiting city's landmarks like museums alone or in big groups. Masterpieces are his/her main target, so this choice influences his/her visit path and movements: this user goes strictly to such artworks or to biggest ones or the most impressive ones in terms of colours, moving fast in certain rooms' area, while standing still for seconds (or minutes) in front of them. Usually, this user does not use guides nor reads much of panels and labels; nevertheless, he/she gets curious in case of in-person guide leading other visitors, coming close to them. That was the case of ARTEMISIA project's users, who were in some cases attracted by religious subjects or paintings representing Rome's panoramic views.

Profile D. (ideally linkable to trajectory behaviour n. 2, reported in Table 2, as focussed on doors and pathways) "Follow museum indications" approach. This user is typically open to Culture, enthusiastic of learning, putting himself/herself in the condition of being guided or suggested. For such a reason, this user follows museum indications and pathways. His/her visit path is generally regular, not zigzagging around museum rooms, exploring what labels and panels indicate at first. This user's gaze goes on artworks which are exposed on his/her trajectory so, often, he/she focuses the attention on close and lateral objects, limiting his/her view of artworks from the opposite site, from far away. That was the case of ARTEMISIA project's users, who were in some cases watching at certain artworks located on side walls, only because the room walkway brought in that direction.

5. Conclusions

The museum inquiry developed in the ARTEMISIA project has the purposes of studying and identifying users' biases influencing the cultural context flow, appreciation, usability, interaction and overall experience, in order to map experiential profiles and propose new tools to predict and direct visitors' pathways and exhibitions' planning. Many statements emerged from the work, tracing promising research paths to be deepened: the validation of the validity of the UX sample (even if limited), to obtain information which are confirmed by an AI more extended approach; the relevance of "curiosity" as major emotional factor, which may lead to different behaviours (mainly referring to profiles A,C,D); the "high intensity" emotion-referred status ('astonished', 'happy', 'amazed') characterising the longer permanence in the museum's rooms. The commercial sector debates (Caruso et al., 2024) the use of automation systems in marketing, particularly concerning message customization and meeting targeted user needs. In the cultural domain, artificial intelligence (AI) systems enhance experiences and show potential for managing and promoting cultural offerings. Studying

audience behaviour offers new investigative avenues for cultural venue managers. AI tools track visitor flows indoors and outdoors, providing valuable data for cultural management stakeholders. This data help to reach optimization and crafting predictive models for subsequent promotional and managerial actions related to cultural requests. Through marketing automation tools, criteria and indexes highlighted in the project could open up museum management to new ways of audience segmentation and visitor engagement, while boosting new forms of entrepreneurship by connecting the technological expertise of a growing sector such as marketing automation tools and cultural heritage. The first 4 Artemisia eXperiential Profiles (AXP), emerged by cognitive analysis out of AI sensors and multi-partitioned analysis, suggested recurring behaviours among visitors at the Museum of Rome - Palazzo Braschi and represent a starting point to set up deeper analysis on users' approach to museum visits, in order to refine and focus effective museum practices and cultural marketing strategies.

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CRediT authorship contribution statement

Sofia Ceccarelli: Data curation, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Amedeo Cesta:** Conceptualization, Formal analysis, Funding acquisition, Methodology, Project administration, Resources, Supervision. **Gabriella Cortellessa:** Conceptualization, Formal analysis, Investigation, Methodology. **Riccardo De Benedictis:** Conceptualization, Data curation, Formal analysis, Methodology, Software, Validation. **Francesca Fracasso:** Conceptualization, Data curation, Investigation, Methodology, Validation. **Laura Leopardi:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Project administration, Validation, Writing – original draft, Writing – review & editing. **Luca Ligios:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Software, Writing – original draft. **Ernesto Lombardi:** Data curation, Funding acquisition, Methodology, Project administration, Supervision. **Saverio Giulio Malatesta:** Conceptualization, Formal analysis, Funding acquisition, Methodology, Supervision, Writing – review & editing. **Angelo Oddi:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Resources, Software, Writing – original draft, Writing – review & editing. **Alfonsina Pagano:** Data curation, Formal analysis, Funding acquisition, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing. **Augusto Palombini:** Conceptualization, Data curation, Funding acquisition, Methodology, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing. **Gianmauro Romagna:** Data curation, Formal analysis, Software, Writing – original draft. **Marta Sanzari:** Conceptualization, Data curation, Formal analysis, Methodology, Software, Writing – original draft, Writing – review & editing. **Marco Schaerf:** Conceptualization, Formal analysis, Funding acquisition, Methodology, Supervision.

Declaration of competing interest

The authors have no conflict of interest to declare.

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