

# **Spectatorship of Medieval Nubian Paintings: A Cross-cultural Eye Movement Study at the Archaeological Site of Old Dongola, Sudan**

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## **Abstract**

Our understanding of how visitors' cultural backgrounds shape their visual engagement with archaeological heritage remains relatively limited. The present study explores the effect of visitors' cultural backgrounds on visual inspection. Forty-eight Sudanese and 19 Western visitors of the Monastery on Kom H at the Old Dongola archaeological site (Sudan) were asked to view 17 mediaeval Nubian wall paintings while their eye movements were being recorded. Sudanese participants maintained a broader focus of attention than Western participants when viewing paintings, which marked a greater likelihood of looking at the painting context. In contrast, Western participants focused more on the human figures and their attributes. Taken together, these findings support the hypothesis that cultural background shapes viewing. The results are discussed in terms of development of inclusive strategies that facilitate visitors' engagement with artefacts present at archaeological sites.

**Keywords:** eye-tracking; mediaeval Nubian wall paintings; cross-cultural studies; community archaeology; Sudan; Old Dongola

## Introduction

With important exceptions, archaeological practices in Africa are still influenced by Western narratives (Kleinitz 2013; Pikirayi & Schmidt 2016; Humphris, Bradshaw & Emberling 2021; Dores Cruz 2023). Recent archaeological programs have started to address this issue and involve local communities in shaping narratives about their cultural heritage. For example, Humphris and Bradshaw (2017) used questionnaires at the Meroe archaeological site to measure attitudes toward archaeology in the local community, as an initial step in developing successful engagement programs. Tully and Näser (2016) used interviews to gain insight into the educational needs of the local community at Morgat Island to add them to an information booklet about the archaeology of the island (see also Tully 2014, 2015; Näser & Tully 2019). Moreover, Fushiya and Radziwiłko (2019) applied autophotography to understand the perception of the Old Dongola archaeological site by children from local schools. While such attempts are important efforts in decolonizing archaeological practice and engaging local communities, little attention has been given to potential group differences between visitors in looking at or visually engaging with artefacts at archaeological sites.

One way to measure visual engagement is to record and analyse where, when, and for how long visitors look at objects present at an archaeological site. Recording visitors' eye movements and fixations provides a useful tool to estimate where attention is distributed when interacting with cultural artefacts (e.g. Rusnak 2021; Mandolesi et al. 2022; de Winter, Dodou, & Tabone 2022; Rusnak et al. 2024). For instance, Walker et al. (2017) showed the differences in eye movements between children and adults who looked at van Gogh's paintings. Compared to adults, children focused more on areas of the paintings characterised by higher brightness, greater colour intensity, and stronger orientation. Another example is the eye-tracking study conducted by Rainoldi, Yu, and Neuhofer (2020),

which demonstrated that in a museum context adults spend more time engaging with information devices, especially information boards, compared to younger participants. In addition, Palumbo et al. (2023) provided evidence that visitors' personal characteristics, such as high openness to experience, is associated with longer viewing times of contemporary artworks in a museum.

In the present study, we successfully extended the eye-tracking paradigm used in these museum studies to understand visitors' engagement at an archaeological site. Specifically, we aimed to explore how members of a local community and Western visitors looked at Christian mediaeval Nubian paintings at the Old Dongola archaeological site in Sudan (Fig. 1). We used a mobile eye tracker to record visitors' eye movements and patterns of fixations to see what people looked at, and therefore what they found most interesting, while viewing Christian medieval Nubian paintings. Our goal was to explore to what extent differences in visual exploration between visitors are driven by their cultural backgrounds. We understand individuals from different backgrounds as originating from either collectivist or individualist cultures (Pelham et al. 2022). At the heart of these cultural orientations are the ways individuals form their identities, either through personal characteristics or via relationships with others (Nisbett & Masuda 2003).

The visual-cognitive psychological literature suggests that cultural background may influence scene processing. Cross-cultural studies show that people from collectivist cultures are more sensitive to contextual information when looking at visual scenes, whereas people from individualist cultures focus more on focal objects (Masuda & Nisbett 2001; Nisbett & Masuda 2003; Kitayama et al. 2003; Boland et al. 2008). Nisbett & Masuda (2003) proposed that collectivist cultures promote sensitivity to relations and holistic thinking ('me as part of a larger whole') while individualist cultures support more object-oriented thinking ('me as individual').

The difference between participants from collectivist and individualist cultures has also been observed in eye tracking studies. Chua, Boland & Nisbett (2005) found that Americans (individualist culture) fixated more on focal objects presented in photographs and tended to look at objects more quickly than Chinese study participants (collectivist culture). Goh, Tan, and Park (2009) observed that when presented with a changing series of photographs of objects against backgrounds, Americans compared with Singaporeans. Moreover, Singaporeans alternate between focal objects and backgrounds to a greater

degree than Americans do. Goh et al.'s finding suggests that differences between collectivist and individualist cultures not only influence the ways in which people are visually engaged with images, but that they also affect how visual information is sampled (see also Duan, Wang, & Hong 2016; Šašinková et al. 2023).

Cross-cultural differences can also be observed in fixation patterns made to paintings. In a study on the perception of traditional Chinese ink-wash paintings, Liu et al. (2013) found that Chinese participants fixate longer on white spaces as compared to Western participants. White spaces are an important element of ink-wash paintings, and according to Chinese tradition they are a place for imagination. Thus, visual exploration may strongly depend on cultural knowledge and familiarity with this type of art. As a result, white backgrounds serve as spaces for exploration for Chinese but not Western viewers.

The importance of artwork origin was also explored by Trawinski et al. (2024). They asked Chinese and British participants to remember a set of East Asian and Western paintings for later memory test sessions. The results showed that a cultural match between painting tradition and viewers' cultural background led to a greater focus on faces in the paintings, at the expense of viewing other parts of the paintings. The cultural effect observed with respect to fixations on faces was especially pronounced at later stages of viewings, suggesting that cultural differences did not have immediate influence on viewing behaviours (Trawinski et al. 2023).

While Trawinski et al. (2023, 2024) conducted these studies in laboratory settings with images of paintings, we did not know to what extent this effect would be generalised to paintings present at the archaeological sites. Moreover, it should be noted that some studies only partially confirm the existence of cultural differences in cognitive styles and visual processing (Rayner et al. 2007; Kuwabara & Smith 2012; Alotaibi, Underwood, & Smith 2017), while others do not support their presence at all (e.g. Evans et al. 2009; Rusnak et al. 2024; Trawiński et al. 2024). This suggests that differences in the distribution of attention may emerge in relation to specific tasks, stimuli, or personal characteristics, rather than culture alone. Therefore, the aim of our study was to examine whether, and then to what extent, cultural differences influence the allocation of visual attention to wall paintings.

Specifically, in the present study, we tested whether there were any differences between Sudanese and Western visitors in the visual exploration of Christian mediaeval

Nubian paintings (dating from the second half of the 11th century to the second half of the 12th/beginning of the 13th century), which depict biblical characters, scenes, and local rulers. Comparing the distribution of eye movements across different paintings requires defining areas of interest (AOI). As suggested by the visual-cognitive literature, cultural differences in visual exploration may be more pronounced at specific elements of paintings (Trawiński et al. 2023, 2024). Here, we distinguished four AOIs: faces, bodies (hands, clothes, feet/shoes), attributes (e.g. wings, halos, keys, scrolls, holy books, crowns), and contexts (monochromatic backgrounds, inscriptions, scenery of biblical events) (Fig. 2). We distinguished these elements as the crucial components of the figures and scenes of the paintings needed to understand the paintings' narratives.

Human faces are known for attracting a majority of the fixations when viewing paintings (e.g. Harland et al. 2014; Savazzi et al. 2014; Trawinski et al. 2021). Faces are a special type of stimulus as they communicate evolutionarily relevant information regarding people's emotional states and identities. However, the visual processing of faces is susceptible to cultural modulation. An observer's cultural background may influence accuracy of facial recognition (Meissner & Brigham 2001) and the speed of their detection (Masuda et al. 2008). Trawinski et al. (2021) reported that when a participant's culture matches the artistic tradition, faces receive more attention as compared to situations where there is a mismatch (see also Goldinger, He, & Papesh 2009 for face perception studies). Considering that Western visitors, as compared to Sudanese visitors, typically have greater cultural familiarity with Christian art, we expected that Westerners would look more at the faces in the paintings at Old Dongola than would Sudanese visitors.

Beyond face AOI, we also recognized bodies and attributes as elements of paintings sensitive to cultural modulation. In Nubian Christian mediaeval art, these elements hold significant symbolic meaning. For instance, a halo adorned with a cross is closely associated with Christ, while keys symbolise Apostle Peter and various clothing elements, such as vestments, signify church dignitaries. However, due to cultural differences, different aspects of paintings may hold varying degrees of significance for different groups. One manifestation of this is the allocation of attention to aspects of a visual scene considered informative (Henderson & Hollingworth 1999; Henderson & Hayes 2018). Assuming that Western visitors have greater familiarity with Christian symbolism, we hypothesised that

Western visitors would look proportionally more at bodies and attributes than Sudanese visitors.

Finally, considering that Sudanese people are considered to be members of a collectivist culture in contrast to representatives of individualist Western cultures (see Pelham et al. 2022) we identified context as an important element for investigation. Although context in mediaeval Nubian paintings, similarly to Byzantine Christian art, is mostly limited to monochromatic backgrounds, we expected that Sudanese visitors would spend more time looking at context than Western visitors.

To summarise, in our study we explored two issues. First, we tested the extent to which cultural background influences the visual exploration of faces, attributes, bodies, and context AOIs. We hypothesised that Western visitors would spend more time looking at faces, attributes and bodies, whereas Sudanese visitors would focus more on contexts. Second, we explored whether the potential influence of cultural background on visual exploration is manifested from first fixations or starts to emerge in later viewings. We hypothesised that, despite the absence of differences in the location of a first fixation, cross-cultural differences in visual exploration between Westerners and Sudanese individuals would begin to emerge later in the viewing process.

## **Methods**

### ***Participants***

Forty-eight Sudanese (34 males and 14 females; age range: 18-62;  $M_{age} = 34$ ,  $SD = 12.7$ ) and 19 representatives of Western cultures (nine males and ten females; age range: 24-68;  $M_{age} = 42$ ,  $SD = 13.4$ ) participated in this study. The Sudanese participants were recruited among the local community at the Old Dongola archaeological site and included Sudanese collaborators of the archaeological mission. All originated from the towns of el-Ghaddar and Bukibol. The sample of Western participants in this study were from Poland, Germany, the UK, Spain, Italy, and the US. Western participants were recruited from among tourists visiting the archaeological site and also included collaborators of the archaeological mission. This research group was selected with the aim of broadening our understanding of how both the local community and foreign visitors engage with the paintings.

Statistical analysis showed no difference between groups regarding the number of participants who had seen the paintings more than once. Consequently, we did not exclude participants based on previous visits to the site. All participants reported normal or corrected-to-normal vision. Sudanese participants were classified as representatives of a collectivist culture while Western participants were considered as representatives of an individualist culture (Pelham et al. 2022).

Among the Sudanese participants, ten declared primary education, 21 had completed middle school, seven were students, and ten held higher education degrees. In the group of Western participants, 17 held higher education degrees and two were students. Most of the participants reported having a little to moderate knowledge of Christian Nubian art. There was no statistically significant difference between the Western and Sudanese groups in terms of declared knowledge about the paintings, ranked on 5-point Likert scale (where 1 means “very limited knowledge” and 5 means “very extensive knowledge”) (Western:  $M_{knowledge} = 2,37$  range = 1-5  $SD = 1.09$ ; Sudanese:  $M_{knowledge} = 1,79$  range = 1-5;  $SD = 1.16$ ;  $t(65) = -1.91$ ,  $p = .06$ ). Moreover, there was a higher level of subject art-related expertise in the Western sample compared to the Sudanese sample, as more of the Western participants worked as archaeologists or art specialists ( $N_{Western} = 8$ ;  $N_{Sudanese} = 3$ ;  $\chi^2 (1, N = 67) = 10.27$ ;  $p = .001$ ).

For the majority of participants, their involvement in the study marked their first exposure to the researched Nubian paintings ( $N_{Western} = 10$ ;  $N_{Sudanese} = 32$ ). Analysis of the responses to the question regarding prior visits to the research site (yes/no) showed no significant difference between the Western and Sudanese groups in terms of their previous exposure to paintings ( $N_{Western} = 9$ ;  $N_{Sudanese} = 16$ ;  $\chi^2 (1, N = 67) = 2.13$ ,  $p = .143$ ).

The study was approved by the Committee for the Ethics of Research Involving Human Participants University of Warsaw (Identification code: 112/2021). All participants gave written consent prior to the study.

### ***Stimulus***

The study was conducted in the Monastery on Kom H at the Old Dongola archaeological site. In the mediaeval period, Old Dongola was capital of the Kingdom of Makuria, functioning between the 5th/6th -14th centuries CE in contemporary northern Sudan. Shortly after its foundation the kingdom was Christianized under the influence of the

Byzantine Empire (Godlewski 2013). Several religious and residential buildings have been discovered from mediaeval Makuria, including the Monastery on Kom H, which was founded probably in the 6th century and remained active until the 14th century (Dzierzbicka & de Lellis-Danys 2021). The monastery walls (up to 4 m in height) have survived until this day, giving visitors a unique opportunity to see an authentic place associated with the mediaeval history of Old Dongola.

For the purpose of this study, four rooms located in the Northwest Annex of the monastery were selected (nos. 12, 13, 18, 29; Martens-Czarnecka 2011: 54). The selection of rooms was determined by their accessibility and their state of preservation, in order to minimise health and safety risks to our participants. Rooms 13 and 29 were most likely used as small chapels and the functions of rooms 12 and 18 are unknown. In total, participants were asked to view 17 paintings (nos. 18, 24, 38, 46-48, 56, 65, 66, 68-71, 73-76; for detailed information about the paintings see catalogue compiled by Martens-Czarnecka 2011). The main topics of selected paintings are holy figures (nos. 46, 47, 56, 65, 66, 68, 70, 71, 73, 74, 75, 76), biblical scenes (nos. 24, 69, 48), mediaeval rulers (no. 18) as well as church dignitaries (nos. 38, 65, 71). The majority of human figures are depicted in static, frontal pose (Fig. 3). Some of the paintings are accompanied by inscriptions in the Greek language.

### ***Apparatus***

Eye movements were recorded using Tobii Pro Glasses 3 eye-tracking glasses, calibrated before viewing using a one-point manual calibration method. Gaze was collected with the sampling device at 100 Hz. Viewing was binocular and movement of both eyes was recorded. The eye-tracker recorded first-person video through a scene camera. The coordinate system for eye-gaze localization related the pupil-centre corneal-reflection-vector to positions from the scene camera (Holmqvist et al. 2011).

Data processing was carried out in Tobii Pro Lab (version 1.194.41215). Fixations were classified using the I-VT Attention algorithm and subsequently mapped onto the scene using the Tobii Analyzer Pro Real-World Mapping tool. All mapped gaze data were manually inspected and corrected when required. In rare cases of ambiguous fixations (e.g. those falling between areas of interest), such fixations were excluded from the analysis.

### ***Procedure***

The study was conducted between November and December 2022. Data were collected during fixed morning and afternoon sessions to ensure consistent natural lighting conditions provided by a skylight. The weather remained steadily sunny and cloud-free throughout the study. At the onset of the study, participants were requested to complete a sociodemographic questionnaire, which asked about their age, sex, education level, occupation, nationality, as well as their familiarity with paintings in the monastery and their history of visiting this site. During the screening interviews, participants were also asked about visual impairments and the need for vision correction. Next, participants were asked to visit two sets of rooms in the monastery (set 1: 12, 13, 18; set 2: 29, see Fig. 4).

All participants began the study from the same place (near painting no. 18, room 12) and visited set 1 first, followed by set 2. Prior to the visit of each set of rooms, a calibration procedure was conducted in order to mitigate potential data distortion. During calibration, participants were presented with a card positioned on the wall and were asked to fixate on a black dot in the centre of the card. In cases requiring vision correction, participants used corrective lenses provided with the eye-tracker (ranging from  $-5$  to  $+3.5$  dioptres). Participants received the following instruction, which was presented before the study:

‘In this research we invite you to view mediaeval paintings. Your task will be to go to the rooms indicated by us and look at the paintings there. The mode of viewing these paintings is up to you. After completing the task, we will ask you about your impressions of watching the paintings. If you have any questions while viewing the paintings, we will be nearby and we will be happy to answer them.’

After the completion of the eye-tracking session, a semi-structured interview was conducted. Participants re-visited each room with the researcher and were asked to describe their experience of participating in this study. By interviewing participants, we aimed to gain a deeper understanding of their experience at the archaeological site. Detailed analyses of the semi-structured interviews fall outside the scope of the current manuscript and are not reported here.

## **Results**

The first goal of these analyses was to examine whether there was evidence of a difference across cultures in the distribution of fixations to the four AOIs in the paintings. We did this to explore whether there is an overriding cultural influence on the spatial distribution of fixations across face, body, attributes, and context. We tested three specific hypotheses. First, we hypothesised that if cross-cultural theory in scene perception can be applied to spectatorship of paintings in cultural heritage settings, then Sudanese participants would look more at context AOIs in the paintings. In contrast, Western participants would present a greater focus on face, body, and attribute AOIs.

Second, we hypothesised that if potential cultural differences in eye movements between Sudanese and Western participants are due to a lack of familiarity with these types of pictorial representations, then we would observe reduced engagement in visual exploration of the paintings by Sudanese participants. If this were the case, then the difference between Sudanese and Western participants would be pronounced, with Sudanese visitors making fewer fixations on faces, attributes, and bodies, as their meanings would not provide enough visual information to support the spectatorship process.

Finally, we hypothesised that potential cross-cultural differences would manifest in strategies for visual exploration of paintings. In particular, we investigated whether differences start to emerge after the initial fixations made on paintings, visible by examining time-course probabilities for when different groups of participants look at AOIs. Following the findings of Trawiński et al. (2023), we anticipated that the probability that Sudanese participants would look at context in paintings later in viewings would be higher than the probability that Western participants would look at context in paintings later in viewings. This could result from the adoption of a broad attentional focus, emerging after an initial exposure to a painting, as a way to compensate for a more limited amount of information obtained when viewing other parts of paintings. In contrast, Western visitors would demonstrate a higher probability of looking at faces, artefacts, and bodies as viewings progress.

To test our hypotheses, eye movement data were analysed in two steps. First, we considered four measures: total number of fixations, mean fixation duration, total fixation duration, and proportion of viewing time spent looking at each AOI. The total number of fixations indicated the sum of all fixations made on each AOI. Mean fixation duration indicated the average duration of all fixations on each AOI. Total fixation duration indicated

the sum of all fixation durations on each AOI. The proportion of viewing time was calculated by dividing the total fixation duration made on each AOI by the sum of all fixation durations. A  $4 \times 2$  ANOVA statistical test (AOI type  $\times$  cultural background) was conducted on each of these measures with within-participants factor AOI (4: body vs. face vs. context vs. attributes) and between-participants factor Culture (2: Western vs. Sudanese). All pairwise comparisons were corrected using the Tukey statistical method to avoid inflation of Type I error.

Second, we explored fixation patterns across the first 20 seconds of participants' viewing of paintings, as this was the average time spent viewing each painting. The time course of the influence of culture on fixations to specific AOIs was explored using growth curve analysis (Dink & Ferguson 2015). Within time-course analysis, a series of t-tests was performed at each 260 ms time bin to identify significant differences between the groups in the likelihood of fixating on different elements of the paintings.

Total number of fixations: There was a main effect of Culture,  $F_{1,65} = 5.44$ ,  $p = 0.023$ ,  $\eta_p^2 = 0.077$ , with more frequent fixations made by Western than Sudanese participants (see Fig. 3). Moreover, there was a main effect of AOI,  $F_{3,195} = 150.74$ ,  $p < 0.001$ ,  $\eta_p^2 = 0.699$ . Specifically, participants were more likely to fixate on the body than on other AOIs ( $p$ 's  $< 0.001$ ) and attributes received more fixations than faces or context ( $p$ 's  $< 0.001$ ). There was no difference in the number of fixations made on faces and context ( $p = 0.650$ ). The two-way interaction between Culture  $\times$  AOI was not significant,  $F_{3,195} = 1.48$ ,  $p = 0.222$ ,  $\eta_p^2 = 0.022$ .

Mean fixation duration: There was a main effect of AOI,  $F_{3,195} = 82.64$ ,  $p < 0.001$ ,  $\eta_p^2 = 0.560$ . Participants made the longest fixations on faces rather than on attribute, body, or context AOIs ( $p$ 's  $< 0.005$ ). The main effect of Culture and interaction between Culture  $\times$  AOI were not significant ( $F_{1,65} = 0.70$ ,  $p = 0.405$ ,  $\eta_p^2 = 0.011$ ;  $F_{3,195} = 1.68$ ,  $p = 0.174$ ,  $\eta_p^2 = 0.025$ , respectively).

Total fixation duration: Similar to analyses performed on the total number of fixations, there was a main effect of Culture,  $F_{1,65} = 4.17$ ,  $p = 0.045$ ,  $\eta_p^2 = 0.060$ . Western participants spent more time viewing the paintings ( $M_{total\ fixation\ duration} = 4\ min\ 59\ sec$ ,  $SD = 1.43$ ) than Sudanese participants ( $M_{total\ fixation\ duration} = 3\ min\ 56\ sec$ ,  $SD = 1.57$ ). This corresponded to the average duration of each visit. Sudanese participants spent an average of six minutes and 36 seconds in the monastery ( $SD = 1.32$ ), whereas Western participants

spent an average of eight minutes and 44 seconds ( $SD = 1.53$ ). There was also a main effect of AOI,  $F_{3,195} = 78.44$ ,  $p < 0.001$ ,  $\eta_p^2 = 0.547$ . Again, participants were more likely to look at bodies than at other AOIs ( $p$ 's  $< 0.001$ ). In addition, attributes and faces were looked at longer than contexts ( $p$ 's  $< 0.001$ ). There was no difference in total fixation duration made to faces and attributes ( $p = 0.926$ ). The interaction between Culture  $\times$  AOI was not significant,  $F_{3,195} = 0.08$ ,  $p = 0.972$ ,  $\eta_p^2 = 0.001$ .

Proportion of viewing time: There was also a main effect of AOI,  $F_{3,195} = 119.68$ ,  $p < 0.001$ ,  $\eta_p^2 = 0.648$ . Analyses of proportion of viewing time for each AOI revealed the same results as for total fixation duration. Specifically, both Sudanese and Western participants spent proportionally longer times looking at bodies than at other AOIs ( $p$ 's  $< 0.001$ ). In addition, attributes and faces were looked at for proportionally longer times than context ( $p$ 's  $< 0.001$ ), while the difference between faces and attributes were not significant ( $p = 0.653$ ). The main effect of Culture and interaction between Culture  $\times$  AOI were not significant ( $F_{1,65} = 0.14$ ,  $p = 0.709$ ,  $\eta_p^2 = 0.002$ ;  $F_{3,195} = 0.68$ ,  $p = 0.563$ ,  $\eta_p^2 = 0.010$ , respectively) (Fig. 5).

Analyses of the influence of culture on fixations to specific AOIs showed that Westerners looked at the paintings for longer periods than the Sudanese participants did. Contrary to our hypothesis, the effect of culture on eye movements did not involve any interaction with AOIs. Interestingly, when the proportion of viewing time was considered, the difference between Sudanese and Western participants was no longer significant. Taken together, these results suggest that when proportions of overall viewing time are considered, the magnitude of the effect of culture on fixation patterns across AOIs is diminished.

We now explore the probability of making fixations on each AOI (face, body, attributes and context) over the first twenty seconds of each viewing. Eye movement data were aggregated across all participants to calculate the probability of fixating on the face in each 260 ms time bin, which corresponds to the median fixation duration in this study.

Time-course analyses showed that cross-cultural differences start to emerge during the first fixations. Western participants tended to start their viewings by looking at the body of the depicted person whereas Sudanese participants were more likely to make their first fixation on attributes. Next, relative to Sudanese participants, Western participants showed an increased probability of fixating on faces, which followed a shift in fixation from bodies to

attributes. In contrast, relative to Westerners, Sudanese participants were more likely to look at faces later in viewings, followed by a greater focus on context at the final stage (Fig. 6).

## **Discussion**

In this study, we aimed to investigate whether the visual exploration of paintings in the Monastery on Kom H at the Old Dongola archaeological site was influenced by viewers' cultural backgrounds. We hypothesised that Sudanese people, as representatives of a collectivist culture, would fixate more on context compared to Western visitors, who represent a more individualist culture. We also expected that due to a greater cultural familiarity with Christian art, Western visitors would pay more attention to faces, bodies, and attributes. Finally, we predicted that after an initial similarity in the visual exploration of paintings, Sudanese visitors would be more likely to look at context, whereas Western visitors would be more likely to look at depicted characters and their attributes.

Our results suggest that visual exploration is markedly affected by a viewer's cultural background. While participants from both groups spent the same proportion of time viewing each AOI, they did differ in how they engaged with various parts of the paintings. Major cross-cultural differences were observed during the first fixation, and then started to emerge again around eight seconds after the onset of viewing. Specifically, Western participants focused more on faces, bodies, and attributes, and less on context, whereas Sudanese participants, after fixating at first on attributes and faces, demonstrated an increased focus on context.

It has been suggested that where on each painting people initially fixate would be affected both by viewing strategies acquired through previous experience as well as by salient elements of the stimulus (Wu et al. 2014; Henderson & Hayes 2018). Our results suggest that due to different cultural experience, Western and Sudanese visitors used different viewing strategies from the very beginnings of their viewing experiences. The greater focus by Western visitors on bodies, indicated by the location of the first fixation, may be explained both by a tendency to consider human characters as important semantic elements of paintings (Villani et al. 2015) as well as by a tendency to start a viewing from the centre of a painting, which generally corresponds with the position of a body AOI (e.g.,

Tatler 2007; Bindemann 2010). In contrast, Sudanese visitors were initially more likely to fixate on attributes. It could be that where on a painting people first fixated may have resulted from assigning a particularly informative role to attributes in understanding the meanings of the paintings. This hypothesis is supported by the Sudanese participants' comments reported after the eye tracking sessions. For example, crowns were interpreted as symbols of powerful individuals, scrolls as symbols of royal messengers, and shields and swords as symbols of warriors. Some of the attributes were also interpreted as items used today; for instance halos as turbans, or scrolls as wooden boards (*lohn*) for writing the Quran. This suggests that attributes play a special role in interpreting narratives of depicted scenes.

The increasing difference between Sudanese and Western participants' spatial distribution of fixations over time may have resulted from the attempt of Western participants to use faces as important sources of information about the meanings of depicted scenes as well as a possible identification cue for character identity and emotional states. Using faces as a source of information requires viewers to be familiar with this specific form of face representation (see Valentine, Lewis, & Hills 2016). We suggest that the act of looking at faces in these paintings is linked to a viewer's general knowledge about biblical characters. Consequently, Western participants' tendencies to fixate on faces, which was followed by a focus on the body and then attributes, was driven by an attempt to understand the meanings of biblical scenes. In comparison, Sudanese participants tended to advance their visual inspection of the paintings by attending more to the contextual elements, as the meaning of the scene did not guide their attention in the same manner (Fig. 7). Together, the distribution of fixation data is consistent with an interpretation holding that Sudanese visitors maintain a broader focus of attention than do Western viewers over a time-course. It seems plausible to us that the adoption of this broad focus is an attempt to compensate for a relatively limited amount of information acquired when looking at faces. This suggestion is consistent with the claim put forward by Trawiński et al. (2023, 2024).

We think that these results may have significant implications for the development of inclusive strategies for presenting paintings, and by extension the sets of tools used in evaluation of the delivery of community-oriented programs. In the case of Sudanese visitors, their increased visual engagement with attributes suggests that providing

information about attributes could serve as a good starting point for expanding knowledge about the depicted characters. Additionally, informing viewers about the identities of depicted persons, and stylistic conventions used to portray them, would increase focus on faces and support ways of processing paintings. Notably, mediaeval artists from Old Dongola often depicted faces in schematic ways, without differentiating individual characters (Martens-Czarnecka 2011: 255). Explaining this artistic form of expression may therefore respond to the needs of the local community. Western viewers' attention could also be guided towards contextual elements. In subsequent stages, guiding narratives may shift to the meaning of gestures, clothing, and attributes, as these aspects also tend to attract the attention of Western participants. Notably, in the case of Western participants, an explanation of artistic form regarding facial expressions could be important, as faces were significant attractors for this group.

In terms of potential limitations, we acknowledge that contrary to our hypothesis, the cross-cultural effect in time-course analysis was not supported when analysing average time spent looking at each AOI. One could argue that the lack of an effect by culture on average scores results from the preservation state of the paintings. In the case of several paintings, elements of facial expressions (eyes, noses, lips) or attributes (e.g., halo) were not well preserved. As reported by Fontoura et al. (2023), visitors are more engaged in visual exploration of paintings after their restoration than before, which suggests that more visible parts of paintings attract more attention than less visible or incomplete ones. Therefore, visual information that is more challenging to process requires prolonged viewing time (Fundel et al. 2008). Even though Sudanese participants looked at paintings for a shorter time, they attended to the same elements in the paintings as did the Western visitors. This finding suggests that the extent to which the participants' attention is attracted and held for a prolonged period of time may be predicted by level of knowledge about the paintings. Harland et al. (2014) have reported similar findings in museum studies, where both art experts and novices attended to similar objects in paintings; however, art experts spend more time looking at them.

Some may argue that the results presented here are not driven by cross-cultural differences but by level of familiarity with the semantics and styles of the depicted scenes. To address this issue, participants should have had a similar level of knowledge about Nubian art. If our predictions regarding the influence of cross-cultural differences on visual

processing of paintings were to be confirmed, then both groups of participants (both ill-informed about the subject of Nubian art) should then still demonstrate differences in visual inspection. In contrast, expertise in Nubian art by one group could counter cross-cultural effects. Since some Western participants were archaeologists, it is important to consider that their prior knowledge and related expertise may have shaped their viewing behaviour. However, all Western participants generally demonstrated a higher level of familiarity with the subject matter of the paintings, as these depicted Christian motifs. Consequently, Western participants showed a greater familiarity with Christian iconography compared to the Sudanese participants. This highlights an important consideration in cross-cultural studies regarding variability within participant groups, which can be addressed by designing balanced laboratory experiments where such individual factors are measured (e.g. Trawiński et al. 2024). However, comparing groups in this way would make the study less realistic and less relevant to real-life situations. Here, we demonstrated how basic differences in visual exploration may influence perception of depicted scenes. In order to facilitate knowledge transfer about cultural heritage, and to make Christian medieval Nubian wall paintings more accessible to diverse visitors, it is essential to develop evidence-based guidance materials that accommodate differences in perceptual frameworks. However, before such materials can be produced, it is first necessary to identify and understand these perceptual differences between viewers. More specifically, we should understand how individuals from different cultural backgrounds perceive, interpret, and engage with artwork and other artefacts. Developing this understanding provides a foundation for creating inclusive interpretative resources that resonate with a wide audience and promote meaningful, culturally sensitive engagement with archaeological sites.

Our results may be also affected by viewers' aesthetic evaluations of the paintings. Trawinski et al. (2021) showed that a higher appreciation of 19th century paintings was associated with a greater tendency to look at the faces of the people portrayed in those paintings. Moreover, paintings subjectively rated by participants as beautiful are viewed by participants in a more structured manner, which manifests as a greater number of refixations, and repeated sequences of fixations, than when viewing a painting subjectively rated as non-beautiful (Jankowski et al. 2020). It could be that reported cross-cultural effects would be different in the case of artwork that is subjectively highly appreciated by

visitors. It is for further studies to determine if the findings we report in the present study generalise to these types of paintings presented at archaeological sites.

There is also a methodological issue that is worth considering: Nubian art mostly depicts Christian scenes. It could be that the religious backgrounds of visitors influence patterns of visual exploration. Comparing representatives from the same cultures, such as members of the Christian diaspora in Sudan or neighbouring countries, would enable us to measure the extent to which religious background influences the visual processing of paintings. It is possible that religious beliefs shape the manner of engagement with art, as depicted scenes also have transcendental meaning (Lang, Stamatopoulou, & Cupchik 2020). Exploration of this question is beyond the scope of the present study but stating it provides a clear direction for future experiments investigating the influence of religious beliefs on visual inspection.

Finally, it should be noted that the AOIs were defined by the researchers following standard procedures established in the literature (e.g. Trawiński et al., 2021, 2023, 2024). This seemed appropriate given the basic socio-semantic categories of interest. Nonetheless, it may be beneficial in the future if definitions of the AOIs are provided by both participants and researchers to identify commonalities and differences between the two groups, and to conduct further analyses in case of discrepancies.

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### Data availability statement

The data that support the findings of this study are available on: <https://osf.io/u8qzv/>, DOI: 10.17605/OSF.IO/U8QZV

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## Figures and captions

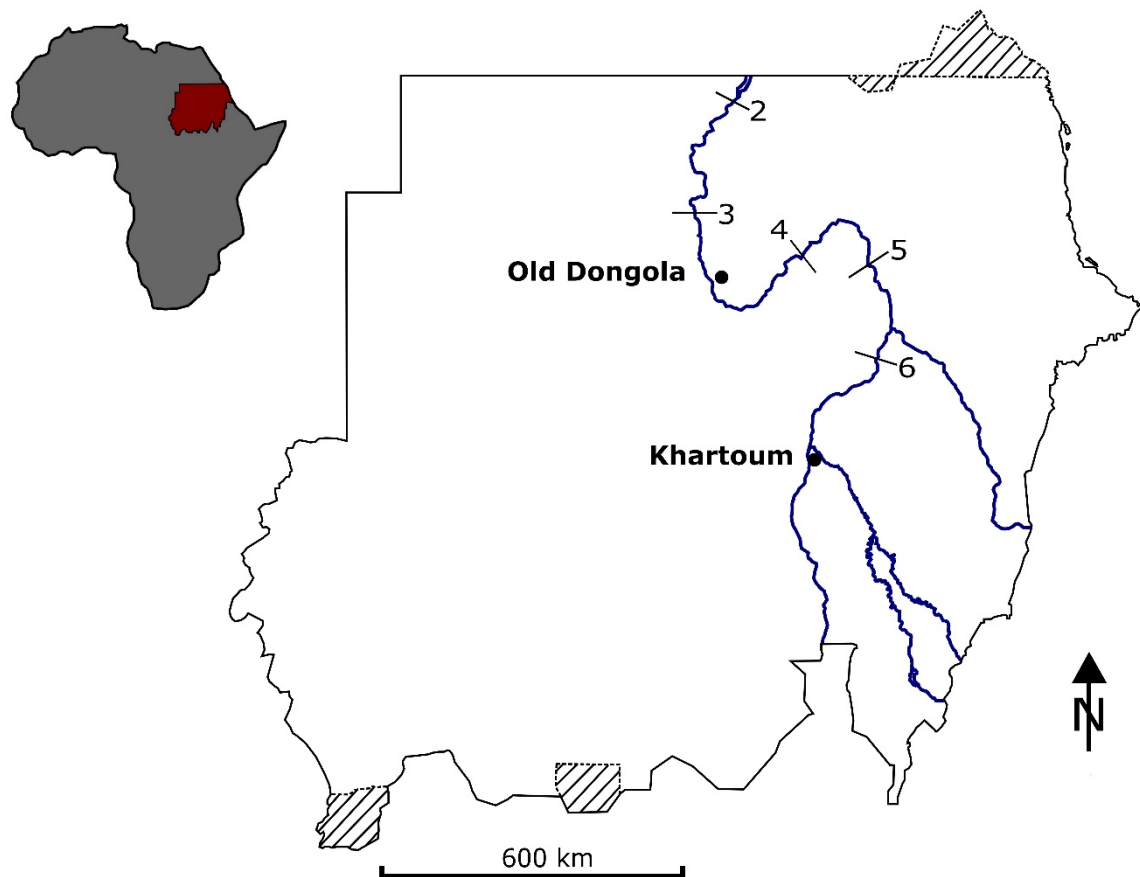


Figure 1. Location of the Old Dongola archaeological site in Sudan – schematic map. The site is lies on the eastern bank of the Nile, halfway between the Third and Fourth Cataracts (marked with numbers on the map).



A



B

Figure 2. Painting 'Archangel Michael and Holy Trinity' (A) divided into AOIs (B): long dashed line/orange area - context, solid line/blue area - attributes, short dashed line/pink area - body, dots/yellow area – faces.



A



B



C

Figure 3. Examples of paintings used in the study. Note varying preservation states. A: Archangel Michael; B: Healing of a blind man at the Pool of Siloam; C: Christ and College of Apostles.

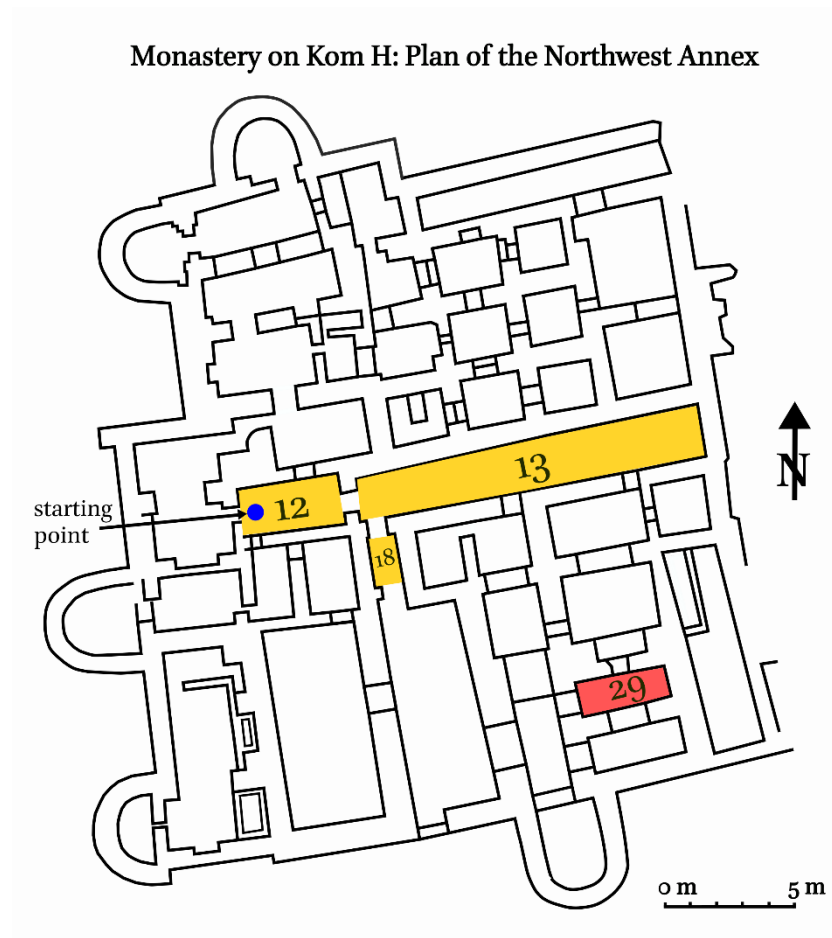


Figure 4. Schematic plan of the Northwest Annex of the Monastery on Kom H in Old Dongola. The orange area indicates the first set of rooms (12, 13, 18), the red colour indicates the second set of rooms (29), and the dot marks the starting point of the experiment (painting 18 in room 12).

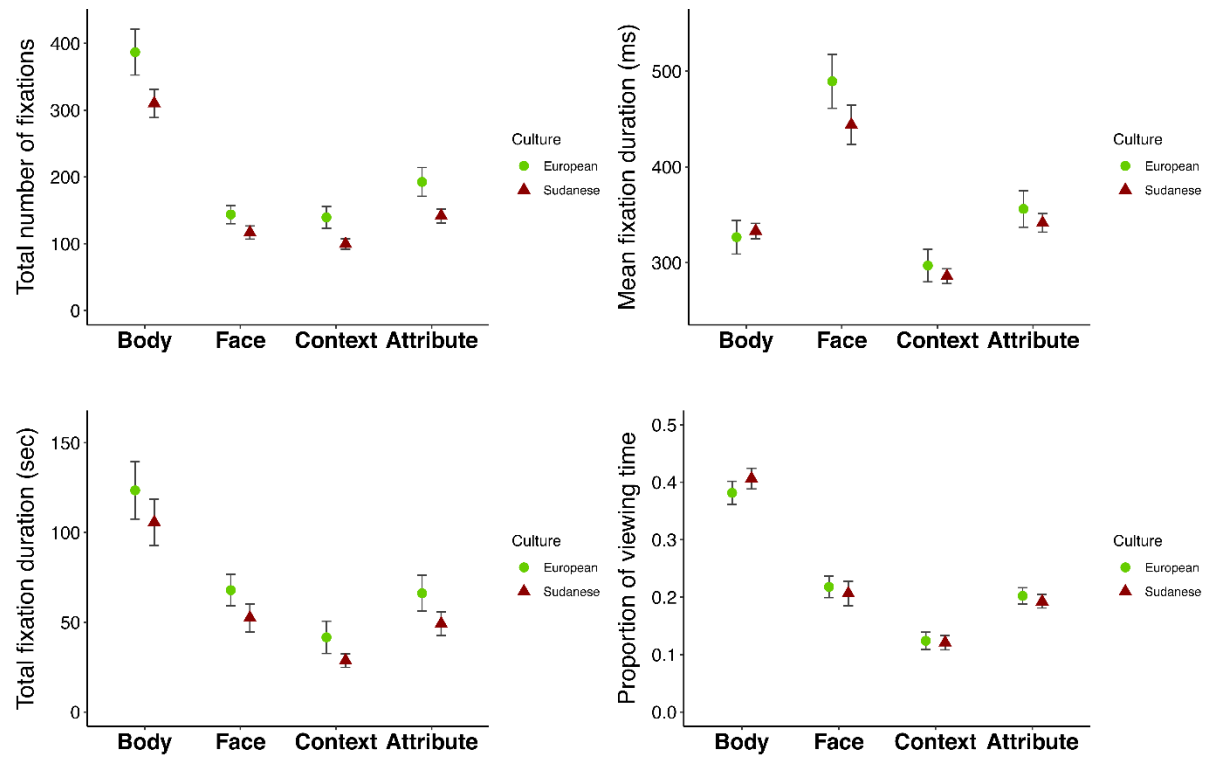


Figure 5. Total number of fixations, mean fixation duration, total fixation duration, and proportion of viewing time as a function of AOI and Culture. Error bars represent standard errors.

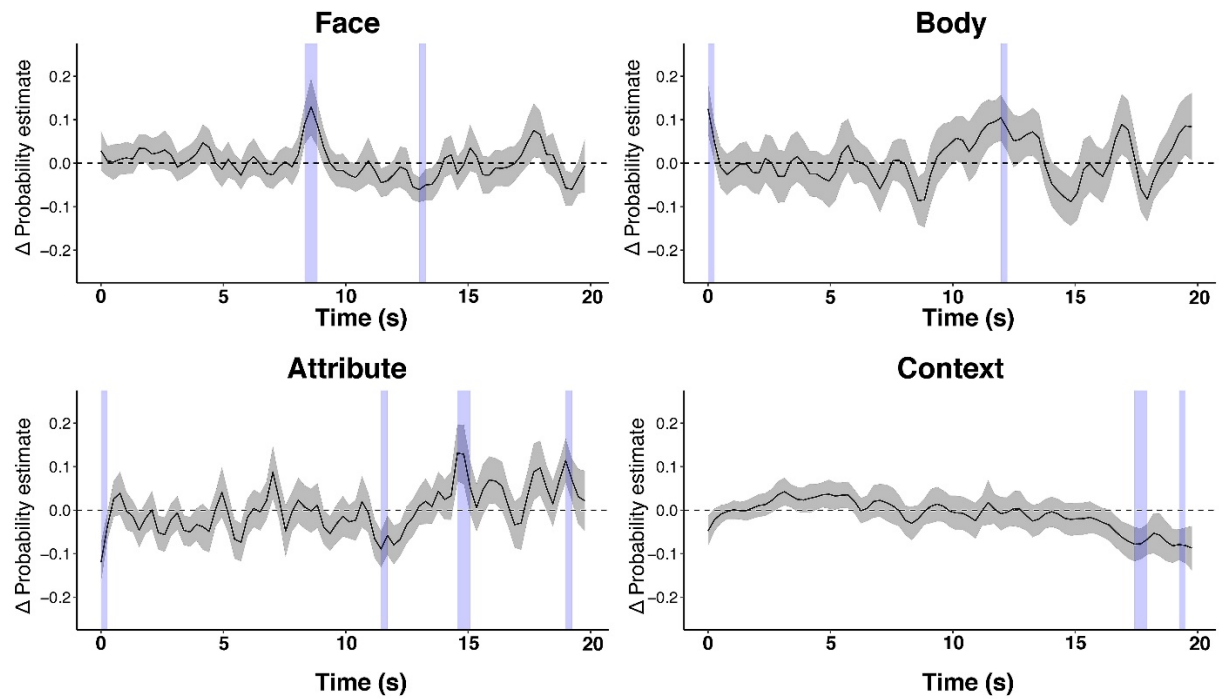


Figure 6.  $\Delta$  Probability estimate functions (SE) for fixating on paintings' faces, bodies, attributes, and context during twenty seconds of viewing. The  $\Delta$  probability estimate was indexed by the difference between Western and Sudanese participants in fixating on each AOI. Positive scores indicate a higher probability of looking at the specific AOIs by Western relative to Sudanese participants, while negative scores indicate a higher probability of looking by Sudanese relative to Western participants. Note: The grey area around the probability line represents the confidence intervals. The blue vertical bands indicate time periods during which a statistically significant difference in the probability of looking at the designated AOIs was observed between Western and Sudanese visitors.

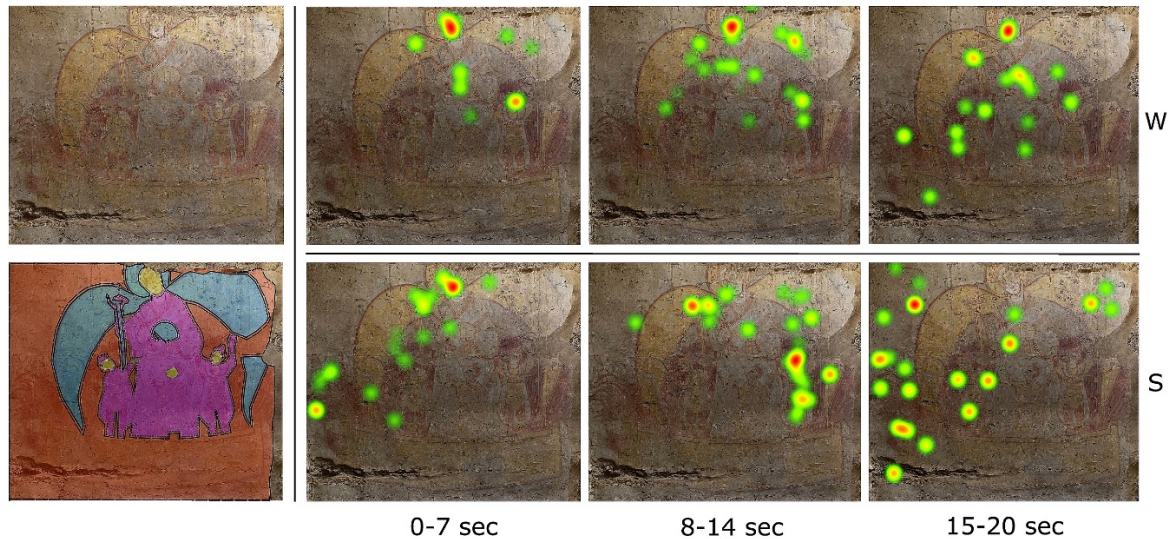


Figure 7. Example of heat maps of the painting 'Three Youths in a Fiery Furnace' during the initial 20 seconds of viewing by a Western visitor (right part: upper row) and a Sudanese visitor (right part: bottom row). Areas coloured in red represent regions with the longest dwell time, while areas coloured in green indicate regions with shorter dwell time (radius: 50 pixels). Left bottom picture depicts division of the painting into AOIs: long dashed line/orange area - context, solid line/blue area - attributes, short dashed line/pink area - body, dots/yellow area – faces. During the initial seven seconds of viewing, the Western visitor primarily focused on the faces and hands (body) of depicted characters, while the Sudanese visitor paid attention to faces as well as to attributes (wings and swords) and context. During the later stage (8-14 seconds), the Western visitor continued to focus on faces (Archangels and two Youths) while also exploring attributes (sword, wings). At the same time, the Sudanese visitor mainly focused on the face and body of one of the Youths and continued exploring attributes. During the last stage (15-20 seconds), the Western visitor continued to explore faces and attributes, and slightly explored context. In contrast, the Sudanese visitor focused mostly on context (fire).