The Museum Learning Experience Through the Visitors' Eyes: An Eye Tracking Exploration of the Physical Context

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Abstract Experiences always need to be designed with the visitor in mind. In our society, museums hold a prominent place for human learning and experiences. Museum experiences have become a sophisticated blend of spatial design, exhibit curation, and multimedia selection, shaping the overall physical context of the visitor's experience. Driven by the question of how we can create effective visitor learning experiences in contemporary museums, a large-scale mobile eye tracking was conducted. Mobile eye tracking has recently entered tourism research as a novel method to study visitor behaviour in real-life environments and in a non-intrusive manner. The findings reveal that the physical context greatly influences the museum learning experience, and show significant differences in attention and engagement levels across the exhibition's elements. The study adds insights into the relationship between visitors' museum learning processes and the physical context and contributes to the model of contextual learning. Practical implications for museum experience design are offered with regards to spatial experience design and different visitor age segments.

Keywords Museum · Learning experience · Mobile eye tracking

1 Introduction

Museums offer liminal spaces that invite visitors to have engaging learning experiences. While experiences unfold, it has been common knowledge that maintaining visitors' attention in art galleries, exhibitions, and museums is not an easy task due to museum fatigue and satiation (Antón et al. 2018; Germak and Khan 2017). The former refers to a predictable tiredness that leads to the decrease of interests during the visit (Davey 2005). The latter suggests a lack of attention resulting from the

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repeated exposure to similar stimuli (Antón et al. 2018). Since visitors often spend the same amount of time centred on exhibits during the visit (Rainoldi et al. 2018), one central question for the design of these spaces (Hein 1998) is how to effectively facilitate learning experiences. With the advancement in information and communication technologies (ICTs), institutions and organizations have attempted to transform learning activities from traditional printed materials to technology-enabled formats (Pachman et al. 2016). This is supported by a number of studies showcasing that digital materials are valuable to learning and teaching (McGuinness and Fulton 2019; Henderson et al. 2017; Zwart et al. 2017). As opposed to traditional media that are static in nature, technology-driven elements attract higher levels of interest and attention (Venkatraman et al. 2018) and have been used as an effective tool to serve educational purposes (Henderson et al. 2017).

In the same vein, physical gallery spaces and museums have incorporated digital technology to aid visitor experiences by facilitating the learning process (Pallud 2017) and improving visitor engagement levels (Kounaves et al. 2016). Well-known examples can be seen from the application of interactive technologies in the Louvre Museum, Brooklyn Museum, and British Museum, among others. To effectively combine the old and the new, it is necessary to investigate the interaction between visitors and the physical context of an exhibition (Falk and Dierking 2013). While doing so, one also needs to bear in mind various visitor profiles, such as age differences and technology preferences. Younger consumers are often characteristics as tech-savvy, whereas older consumers might be reluctant to using technology-related objects (Douglas et al. 2018). Therefore, museum experience designers have to strategically create a diversified, interactive, and engaging platform for visitors (Falk and Dierking 2013).

If achieved, a positive museum experience could not only enhance the visitor satisfaction and revisit intentions (Kang et al. 2018) but also improve the extent of learning capability (Pallud 2017). Notably, earlier research has applied the Contextual Model of Learning (Falk and Storksdieck 2005; Lundgren and Crippen 2019; Hsu and Liang 2017; Rainoldi et al. 2018) as a suitable framework to study the complexities of the museum experience at a socio-cultural, personal, and physical level (Falk and Dierking 2013). This study has an interest in the physical context that is inextricably related to the design of museum learning experiences.

To investigate visitors' attention during the visit, the application of mobile eye tracking glasses has gained increasing popularity in tourism research (Scott et al. 2019) as it allows natural movement in real-world situations. For instance, Mokatren et al. (2016) explore the role of mobile eye trackers in enhancing the museum visitor experience. More recently, the study of Krogh-Jespersen et al. (2020) investigates visitors' visual attention in a science museum and discovers that the position of signage is related to the feeling of connectedness within an exhibition space. Nonetheless, given the potential benefits of mobile eye tracking, research on visitor real-life experiences is still in its infancy, not to mention the generational differences between visitors in the museum context.

Therefore, the current study aims to tackle the research gap by investigating the museum experience of visitors in different age groups. Specifically, this research seeks to uncover the effectiveness of space design by examining different elements of an exhibition (e.g. textual information boards, traditional exhibits, and digital materials). By bridging the interdisciplinary fields of visual attention, contextual learning theory, experience design, and museum management, this research provides additional knowledge to the body of mobile eye tracking research in the context of tourism. Practically, it highlights the importance of effective object and space design for museums to provide a flow experience for visitors.

2 Literature Review

2.1 The Importance of Visual Attention

Attracting visual attention has been a key topic in the domain of tourism research (Wang and Sparks 2016; Scott et al. 2019). Specifically, visual attention refers to one's cognitive processing in filtering out the irrelevant information from all the visual elements (Kastner and Pinsk 2004). Notably, humans' eye movements are largely influenced by the nature of objects. For instance, pictures are more visually appealing than text (Lin et al. 2017), whereas digital contents are more attractive than traditional static materials (Venkatraman et al. 2018). In the age of the Internet, the application of technological-driven materials gains its popularity not only in marketing and advertising (Venkatraman et al. 2018; Beck et al. 2019) but also in education (McGuinness and Fulton 2019) and experience design (Neuhofer et al. 2014; Rainoldi et al. 2018). Specific to the tourism field, visual attention plays a crucial role in information retention (Goulding 2000) sightseeing, and interpretation (Scott et al. 2019). Additionally, the overall tourism experiences can be largely affected by attracting and holding one's attention (Ooi 2003). Similarly, other scholars highlighted the need for managing distractions within an environment to allow a more pleasant experience (Ooi 2003; Ellis and Rossman 2008; Wagler and Hanus 2018). Since eye movements often occur at an unconscious level (Kastner and Pinsk 2004), it is nearly impossible to study visitors' gaze attention with traditional research techniques, such as surveys or interviews (Scott et al. 2019). Recent research has therefore opened more experiential methods, and adopted eye tracking tools as an emerging technology in this particular context (Eghbal-Azar and Widlok 2012; Schwan et al. 2020; Filippini-Fantoni et al. 2013).

While the study of visual attention is not new in other disciplinary areas such as psychology or neuroscience, it is only recently that tourism research is embracing the benefits of the eye tracking technique (Scott et al. 2019). Apart from a more conventional practice to study tourists' eye movement in laboratory settings (Pachman et al. 2016), a wearable eye tracker is designed to capture natural gaze cues in real-life situations, such as in retail shops (Huddleston et al. 2015), urban environments (Kiefer et al. 2014), cultural heritage locations (Mokatren et al. 2018), and museums (Mokatren et al. 2016; Rainoldi et al. 2018). In response to numerous product and object presentations nowadays, designers have to be aware of the selective attention resulting from the mental fatigue and satiation (Antón et al. 2018; Germak and Khan 2017). Earlier research underpinned that insights from visual attention could improve mobile learning (Mayr et al. 2009), and enhance visitor experiences (Mokatren et al. 2016). A typical example where tourism spaces have been designed with an educational purpose in mind are museums (Trofanenko 2010). Greater importance should, therefore, be attached to the learning–museum relationship in order to facilitate the overall visitor experience (Rainoldi et al. 2018).

2.2 Visitors' Gazes in the Museum Context

Museums are vital public spaces collecting and preserving historical and cultural objects (Falk and Dierking 2013), and improving social cohesion. By connecting past and contemporary events, museums also play a key role in learning and educational purposes (Trofanenko 2010). As one can imagine, arranging the collection of artefacts in different rooms and exhibitions has been a crucial task for the designers. What is equally important is to facilitate the individual learning experiences through an effective visitor flow (Hein 1998; Falk and Dierking 2013). Experiences by nature are however highly subjective at the time of their occurrence, and when evaluated (Neuhofer et al. 2014). This means that in human-centred design, it is critical to take individual differences into consideration. Individual visitor interests and preferences are far from being the same. For instance, Holdgaard (2012) revealed that older visitors are more interested in cultural heritage while younger visitors show a higher interest in natural history. Strohmaier et al. (2015) suggest that visitor paths visualization can be an effective way to help museum professionals improve the design of experiences. Similarly, a plethora of studies discussed the relationship between visitor movements and visitor experiences (Yoshimura et al. 2014, 2019; Tsiropoulou et al. 2017). The artefacts that attract visitors' attention thus become the fundamental elements in influencing one's learning and the overall experience (Bitgood 2006), which subsequently affects the satisfaction, revisit intentions (Kang et al. 2018), and the recommendation intention of the museum (Zanibellato et al. 2018).

With the gaining popularity of eye tracking research, this technique offers real-time information on an individual's perceptions and behaviours (Scott et al. 2019). In particular, wearable eye trackers have been applied in various real-life situations (Huddleston et al. 2015; Mokatren et al. 2018; Rainoldi et al. 2018). Although its application in the museum context could be traced back to the 1980s (Buquet et al. 1988), the complexity and sophistication of eye tracking technology in place today provides more valuable insights into visual attention and attentional processes (Knight et al. 2014). For instance, Mayr et al. (2009) discovered a pattern where visitors tend to scan across the exhibition walls before exploring a single artefact according to their interests. When focusing on an individual level, Filippini-Fantoni et al. (2013) found out that physical objects, photographic substitutes, attract more attention from younger visitors. Other than that, while intuition may suggest that textual information is generally undesirable, a recent study claims that adults around 40 years old tend to perform deep reading once they notice the description presented around the artefacts (Schwan et al. 2020). However, it must be noted that most museum studies focus on very homogenous age group samples (Bartneck et al. 2007), which limits the understanding of how people in different age groups undergo their learning experiences. After all, mobile eye tracking technology has the potential to uncover visitors' unconscious mind, which can barely be described by themselves (Eghbal-Azar and Widlok 2012). Echoing the relation between visual behaviours and learning experiences (Mayr et al. 2009), it is thus necessary to deepen the understanding regarding which specific elements can facilitate the learning process in museums.

2.3 Contextual Model of Learning

In a free-choice setting condition, individuals' attention spans can be influenced by a wider socio-cultural and personal level (Dunlop et al. 2019). To investigate learning behaviours in the museum context, Falk and Dierking (2004) developed the Contextual Model of Learning. The framework covers three interrelated factors that influence visitor learning; namely, the socio-cultural context, the personal context, and the physical context. Specifically, socio-cultural dimensions refer to the interactions between one another, whereas personal contexts imply individuals' interests, backgrounds, and motivations towards the exhibition (Falk and Storksdieck 2005). Lastly, physical contexts relate to the orientation of the space and the design of exhibits (Falk and Storksdieck 2005). With a particular interest in the present study, it is the physical elements of an exhibition that are the most influential towards a visitor's overall experience (Falk and Dierking 2013). Nevertheless, one needs to bear in mind that none of the contexts remain constant throughout time and that there is an on-going interaction between all three elements (Falk and Storksdieck 2005).

Earlier literature has underpinned the Contextual Model of Learning as a theoretical framework in analyzing museum learning experiences. For instance, Hsu et al. (2018) applied the model to examine children's learning behaviours in a museum embedded in a virtual game. Moreover, Hsu and Liang (2017) discovered that physical sources and social interactions positively influence visitor satisfaction and motivation for continuous learning. With regards to the physical environments that can be controlled by museum professionals, it is worth noting that elements that are large in size and create multisensory experiences are the most memorable ones (Anderson and Lucas 1997). Other scholars pointed out that learning experiences are strongly influenced by the orientation of the physical environment, including the large-scale objects and the detailed information contained within it (Falk and Storksdieck 2005). Another study highlights the fact that the distance between the artefacts and the visitors should be carefully planned to allow a positive outcome (Bartneck et al. 2006). To facilitate the learning process through digital products, the study of Bartneck et al. (2007) reveals a surprising result where visitors' age difference did not affect their usage. Yet, it appears that the elderly demonstrate a sense of difficulty when using the digital technology in the museum context (Bartneck et al. 2007). Nevertheless, given that the interaction between visitors and artefacts in a museum environment is critical, it is the purpose of this research to address the existing gap and understand the relationship between the physical context and the learning experience, and how age differences could affect visitors' experiences in a museum context.

3 Methodology

Since the museum learning experience appears to be influenced from the physical context and that the way individuals interact with the museum textual information, physical and digital elements seem to be shaped by one's age, this study aim was to unlock an in-depth understanding of learning processes on-site through an analysis of visual attention.

3.1 Sampling and Data Collection

For this study, participants were recruited in the entrance hall of Salzburg Museum over a 3-month period, between June and August 2016. A purposive sampling strategy was adopted for the recruitment of museum visitors. Visitors selected to take part in the study were required to (a) have knowledge of the German language, (b) have no visual impairment, and (c) being first-time visitors of the exhibition 'Bischof. Kaiser. Jedermann.' The exhibition focused on Salzburg's history and development from Roman times to today from the perspective of the local population.

Suitable participants were asked to take a screening survey to assess their motivation for the visit. Based on the Falk and Dierking's (2013) seven typologies of museum visitors the aim of such survey was to identify those 'explorers' visitors whose visit was motivated by an interest in the content of the exhibition and desire for learning. Following the selection processes, 41 visitors volunteered to take part in the study.

Participants equipped with Tobii Pro Glasses 2 were instructed—after the calibration of the eye tracking glasses—to independently walk through the exhibition at their own natural pace and according to their own personal interests and learning objectives. To guarantee a natural learning experience, participants were allowed to enjoy their museum visit together with eventual accompanying people. Tobii Pro Glasses 2 was chosen as the data collection tool because of its wearability enables participants to move freely and experience the museum in an unrestricted manner and in a natural environment. As a result, it enabled to attain an ecologically valid (Bojko 2013) dynamic snapshot of the museum learning experience by capturing the participants' gaze as they move through the context in which they are immersed through the combination of a scene camera and infrared sensors.

Finally, a post-survey was used to collect demographic data as well as data regarding participants' overall museum experience. Eye tracking recordings were screened to ensure completeness and accuracy before been processed and analyzed in the Tobii Glasses Analyzer. Seven recordings needed to be excluded from the final analysis, due to incompleteness of the recordings or calibration inaccuracies.

3.2 Data Analysis

As museums are environments extremely rich in written information, objects, engaging media, and interactives (Falk and Dierking 2013), the process of data analysis focused on what attracts visual attention thorough an investigation of visitors' fixations. A fixation is thereby defined as a short pause between eye movements in which the attention is focused on a specific area of the visual field (Duchowski 2007). Fixation times are of particular interest for assessing learning processes because the length of a fixation is indicative of the brain information processing and cognitive activity that occurs at a particular moment in time (Bojko 2013).

Thus, for the purpose of this study, the fixations of 34 participants were analyzed in the four following steps. First, the 214,263 recorded fixations (Ø 6.301) extracted from over 25 h of data (Ø 45′23″) where mapped against the museum floor plan of the six analyzed rooms on which each element of the exhibition was previously categorized in following AOIs (Areas of Interest): (a) exhibition's information board, (b) room's information board, (c) exhibits case' information board, (d) exhibits, (e) video screens, and (f) touchscreens. Figure 1 demonstrates the example of Room 1 the categorization of the exhibition's elements into thematical AOIs.

Second, (a) time to first fixation (TFF), (b) total fixation duration (TFD), and (c) average fixation duration (AFD) eye tracking metrics were generated to explore by means of descriptive statistics to appreciate differences in visual attention across exhibitions elements (see Table 1). Third, based on these initial statistical results, a correlation matrix was computed to graphically present the different typologies of exhibitions' elements and their related eye tracking metrics as well as to visualize correlations between exhibition's elements (see Fig. 2). Finally, to discern any significant differences existing between visual attention on the different exhibition's elements and participant's age (based on percentile), a series of one-way analysis of variance (ANOVA) was conducted.

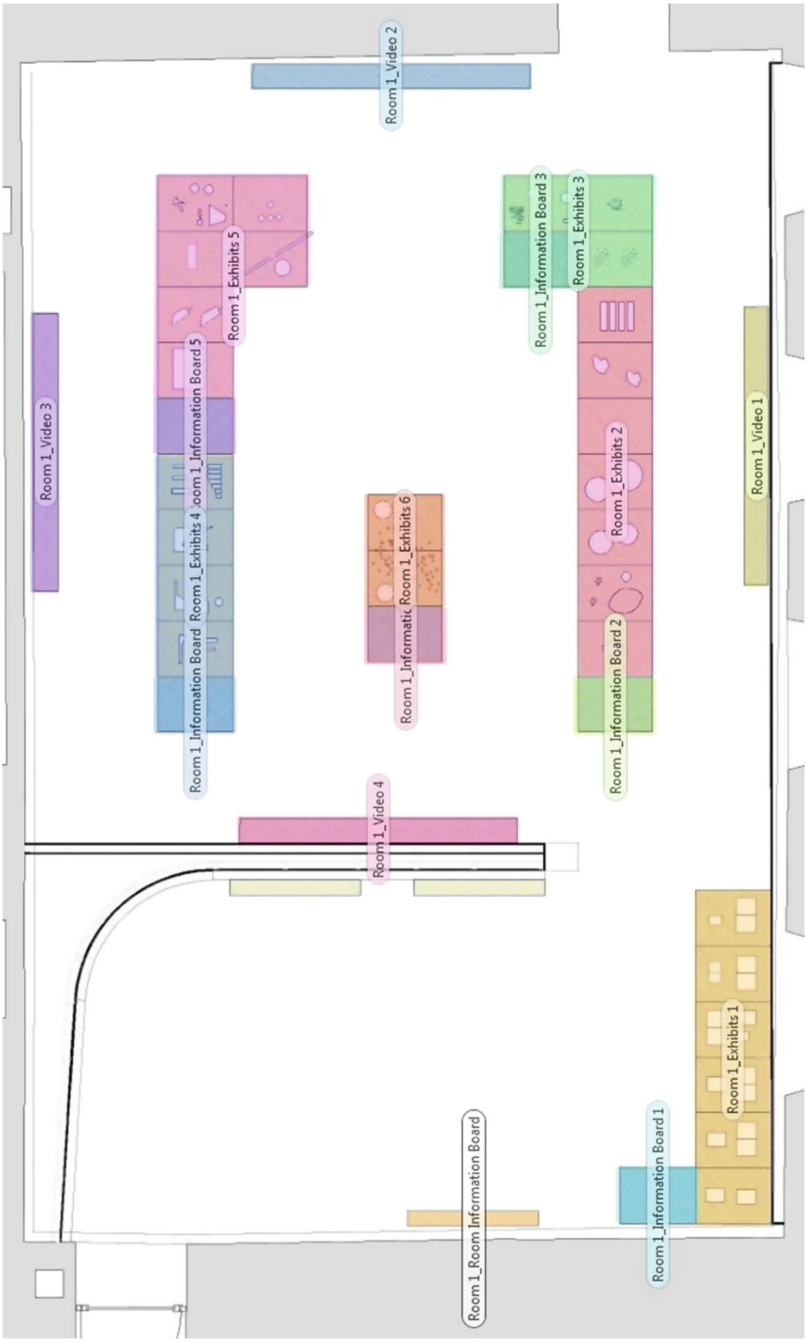

Fig. 1 AOIs Room 1

Table 1 Descriptive statistics of eye tracking metrics

	TFF		TFD	AFD
	[Min, Max]	*M* (SD)	*M* (SD)	*M* (SD)
Exhibits	[38.08, 349.45]	139.99 (69.81)	35.50 (21.47)	0.23 (0.05)
Exhibition's information board	[0, 4.10]	0.22 (0.76)	24.76 (15.20)	0.22 (0.05)
Exhibits case's information board	[20.03, 333.39]	160.06 (88.18)	13.60 (6.74)	0.20 (0.05)
Room's information board	[2.13, 182.50]	39.08 (36.06)	22.01 (10.38)	0.22 (0.05)
Video screens	[26.33, 222.40]	111.95 (55.70)	45.58 (33.33)	0.29 (0.06)
Touchscreens	[18.84, 598.90]	195.52 (123.09)	33.25 (26.54)	0.20 (0.05)

TFF time to first fixation, *TFD* total fixation duration, *AFD* average fixation duration; time in millisecond

4 Results

4.1 Descriptive Statistics

The analyzed data were collected from 34 museum learning 'explores' (14 males and 20 females), ranging from an age of 17 to 80. Participants were categorized into three different age groups based on percentiles, including 13 younger adults, 10 adults, and 11 older adults. The age range of younger adults was 17–29, whereas adults was 30–49. Older adults were ranged between 50 and 80 years old. The overall descriptive statistics of different eye tracking measures on the designated AOIs are presented in Table 1. The results show that most participants first look at the exhibition's information board with an average of 0.22 ms, which is placed at the entrance of Room 1. Next, the data reveal that participants tend to look into the general description first when they enter the rooms with differences between features. When comparing digital materials and exhibits, it appears that touchscreens had the shortest TFF from stimulus onset, followed by video screens and exhibits. Given that, touchscreens had the highest average TFF (195.52 ms). This implies that there might be only a group of museum learners that notice the touchscreens at the very beginning. With regards to the TFD, the results suggest that participants spent the longest time with video screens, exhibits, and touchscreens. However, the information board of different exhibits appears to be the least attractive. Lastly, the results imply that the AFD is similar across the AOIs, with video screens having the highest AFD. Interestingly, the AFD of touchscreens, as digital materials, was the same as the textual description (e.g. exhibits case' information board).

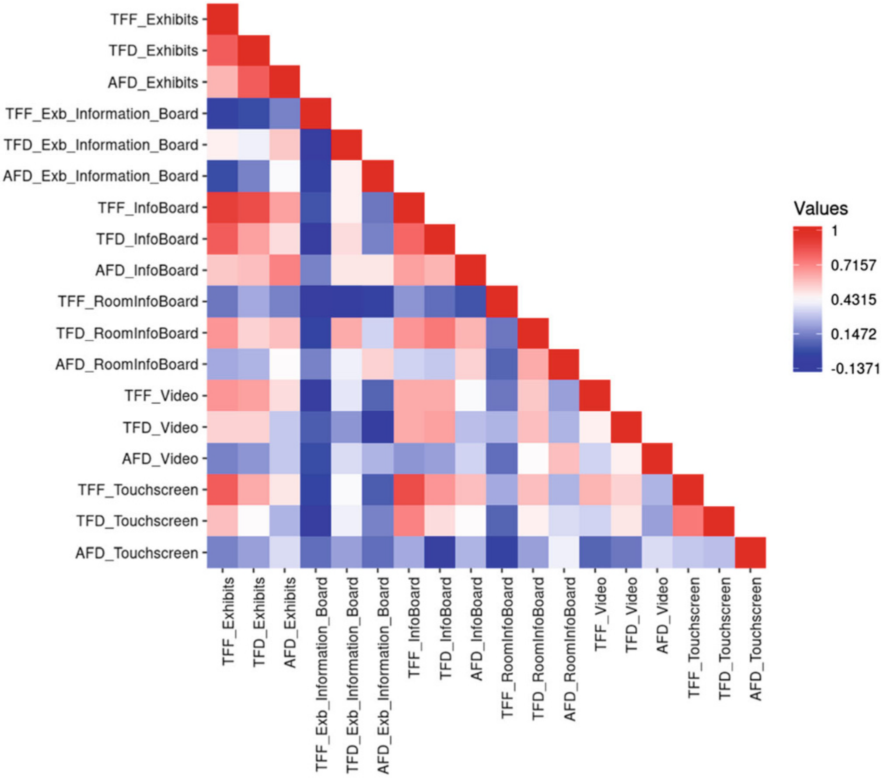

Fig. 2 Visual representation of correlation between different AOIs. *TFF* time to first fixation, *TFD* total fixation duration, *AFD* average fixation duration; time in millisecond; *Exb_Information_Board* exhibition's information board, *InfoBoard* exhibits case' information board, *RoomInfoBoard* room's information board; video= video screens

4.2 Main Analysis

Overall, the relationship between the eye tracking metrics of the designated AOIs are presented in Fig. 2. Colour transparency suggests the strength and direction of the correlation between two variables. Higher transparency implies a weaker relationship. A negative correlation is presented by blue; a positive correlation is presented by red; a correlation closed to zero is indicated by white. The results demonstrate that three eye tracking measures of the exhibits were (strongly) positively correlated with the eye tracking measures of the exhibits case' information board. However, it appears that the eye tracking metrics of video screens and touchscreens were (slightly) negatively correlated with the eye tracking metrics of the general exhibition's information board. Yet, since it is unclear if the museum learners' eye attention would be different when taking the age into account, further analysis was carried out.

To investigate the effectiveness of various types of materials in the museum based on the museum learners' age difference, this study performed several one-way ANOVAs. First, with regards to the exhibits, the results suggest that there was no significant difference on the TFF, $F(2, 31) = 0.841$, $p = 0.441$, TDF, $F(2, 31) = 0.820$, $p = 0.450$ and ADF, $F(2, 31) = 0.263$, $p = 0.771$. Likewise, there was no significant difference for the exhibits case' information boards on the TFF, $F(2, 31) = 1.376$, $p = 0.268$, TDF, $F(2, 31) = 2.430$, $p = 0.105$ and ADF, $F(2, 31) = 0.881$, $p = 0.424$. Nonetheless, a significant result existed on the AFD of the general information boards of the exhibit, $F(2, 31) = 5.749$, $p = 0.008$; yet, not on the TFF, $F(2, 31) = 1.268$, $p = 0.296$ and TDF, $F(2, 31) = 0.694$, $p = 0.507$. Specifically, Tukey post hoc analysis revealed that the AFD was statistically significant between younger adults and older adults ($p = 0.008$) as well as between adults and older adults ($p = 0.043$), where older adults had the highest AFD, followed by adults and younger adults. Nevertheless, for the room's information boards, there was no statistically significant difference on the TFF, $F(2, 31) = 1.570$, $p = 0.224$, TDF, $F(2, 31) = 1.465$, $p = 0.247$ and ADF, $F(2, 31) = 2.523$, $p = 0.097$.

The analysis proceeded further to examine digital objects. In the case of digital materials, the results showed that there was a significant difference for the TFD of video screens, $F(2, 31) = 4.561$, $p = 0.018$ and the TFD of touchscreens, $F(2, 31) = 6.459$, $p = 0.005$. In particular, the TFD of video screens was statistically significant between younger adults and adults ($p = 0.030$), but no other group differences were significantly different. Overall, adults had the longest TFD on video screens, followed by older adults and younger adults. On the other hand, the TFD of touchscreens was statistically significant between younger adults and adults ($p = 0.005$) and between younger adults and older adults ($p = 0.049$). Similarly, adults had the longest TFD on touchscreen, followed by older adults and younger adults. Finally, there were no significant differences existed on the TTF, $F(2, 31) = 0.544$, $p = 0.586$ and ADF, $F(2, 31) = 0.950$, $p = 0.398$ of video screens, nor on the TTF $F(2, 31) = 1.707$, $p = 0.198$ and ADF $F(2, 31) = 0.516$, $p = 0.602$ of touchscreen.

5 Discussion

This study zoomed in on the physical context of a museum as a key element of the museum visitors' learning experience (Falk and Dierking 2004). The analysis first examined various museum elements, and compared visitor's engagement with the room's information boards, exhibition's information boards, exhibits case' information boards, exhibits, video screens, and touchscreens. The analysis of several AOIs and the exhibition's elements revealed that most visitors first notice and look at the exhibition's information boards. It is interesting that touchscreens had the shortest TFF (time to first fixation) and having the highest average TFF (total fixation time), which highlights the great visual attention attraction power of such digital elements within a museum exhibition. This suggests a critical difference in the exhibition's elements being noticed and lure the attention of visitors when entering an exhibition space.

The analysis of the exhibition elements TFD (total fixation duration) revealed that visitors spent most time engaging with video screens, followed by exhibits and touchscreens, while information boards of different exhibits seem to have attracted the least attention. These findings confirm the central importance of integrating digital media in exhibition spaces. This is in line with previous studies arguing that digital materials can lead to higher interest and attention levels (Venkatraman et al. 2018). While digital media per se may not be the motivating factor for people to visit a museum, they are indeed the elements that receive the most attention during a visit (Falk and Dierking 2013).

A deeper comparison of the AFD (average fixation duration) of the exhibition's elements revealed that touchscreens and textual description (e.g. exhibits case' information boards) had the same AFD. This might imply that touchscreens do not attract additional attention but are rather perceived as a mere substitute to traditional media and reading materials offered. The correlation analysis of eye tracking measures further revealed insights into the relations of fixation times and the exhibition's elements. The findings show that a strong positive correlation exists between exhibits and exhibits case' information boards, sharing a high TFF and TFD. This means that when an exhibit catch the visitor's attention, the information board close by is likely to become of interest. Moreover, the relationship between exhibits and touchscreens has been analyzed, and a positive correlation of the TFF has been found. It can, therefore, be concluded that visitors who viewed the exhibits first are also likely to engage with the exhibits case' information boards and touchscreens, and also likely longer with the exhibits case' information boards (TFD). In addition, visitors who saw the exhibits case' information boards are also more likely to also notice the touchscreens and engage with it.

Furthermore, the findings have revealed several interesting negative correlations between the physical exhibition's elements (see Fig. 1). There is a negative correlation between the time spent on the exhibition's information boards to the first-time view on the room's information boards. This implies that visitors who engage right away at the entrance with the general room information board may think they have sufficient information, which causes them to engage less time with the exhibition's information boards. Moreover, those participants who spend a longer average fixation time on the exhibition's information boards seem to spend less total time engaging with video screens. This suggests that the more time visitors spend on average engaging with a physical information medium, the less likely they are to spend time watching a video. Finally, the study could reveal that visitors who notice the exhibition's information board first spent less time engaging with touchscreens. Overall, these insights show the importance of TFF, the time to first fixation, as an indicator of what medium is used subsequently for knowledge acquisition and learning (e.g. information board vs. video screens vs. touchscreen). From the total fixation duration, a key learning is that visitors are highly subjective in their behaviours, and show a preference of a type of medium throughout their visit, e.g. visitors spending time on exhibition's information boards spend less time engaging with digital media, i.e. videos.

Finally, the study was interested in understanding museum visitor behaviours by age group. When it comes to the visitors' time spent on general information boards, the analysis could demonstrate statistically significant differences between the three compared age groups. It was found that the average fixation duration on the exhibition's information boards was highest within the group older adults, followed by adults and younger adults. This suggests that information boards are particularly valuable to older age groups, while younger visitors may spend less time interacting with this particular medium, or may have a preference for information acquisition through other displayed media relating to an artefact (e.g. touchscreens, video screens). In fact, the analysis of digital media, namely video screens and touchscreens, found a significant difference between the age groups. Adults had the longest total fixation duration on both video screens and touchscreens, followed by older adults and younger adults. This may suggest that adults and older adults generally spend longer time engaging with objects, compared to younger people. Overall, the comparison of visitors' age groups revealed that for many forms of exhibition elements engagement, no significant differences could be found, suggesting similar behaviours. At the same time, a few interesting nuances relating to TFD could be found, which suggests a difference in attention spans between age groups. This finally highlights the importance of carefully designed exhibitions by keeping in mind in what form, where, and for how long information is presented.

6 Conclusion

Physical contexts, space design, and the exhibition's elements play an important role in museum learning experiences (Falk and Dierking 2013). As the landscape of museum experiences is diversifying through the integration of digital technologies, it is of particular interest to design artefacts in a way that they blend physical and digital media for an optimal visitor flow and learning experience (Venkatraman et al. 2018; Rainoldi et al. 2018). This study used a mobile eye tracking research design with 34 participants to capture the visitors' experience in a real-life museum context. The findings suggest that the museum experience is a complex construct happening at the intersection of the visitor's personal context (e.g. age) and the physical design put into place by the museum (Falk and Dierking 2013). The data analysis of the visitors' eye fixations, from time to first fixation, average fixation, and total fixation duration, revealed which exhibition's elements particularly capture visitor attention and lead them to engage and spend time. A comparison of three age groups highlighted varying overall fixation times, e.g. with older people spending more time on information boards than younger people. Fixation time is a primary indicator for visual attention and cognitive processes, and thus a marker of learning taking place (Rainoldi et al. 2018). Therefore, a nuanced understanding of how much time visitors generally, and at different ages, spend on observing the exhibition's elements offers valuable insights into designing effective museum learning experiences.

6.1 Theoretical and Practical Implications

By conducting a mobile eye tracking research, this study adds to the scarce body of literature using mobile eye trackers in real-life situations (Krogh-Jespersen et al. 2020; Mokatren et al. 2016; Rainoldi et al. 2018; Scott et al. 2019). Mobile eye tracking was critical to gather insights into real-life visitor behaviour and gaze movement (Filippini-Fantoni et al. 2013) that could not have been revealed otherwise. This study builds on recent studies, e.g. Rainoldi et al. (2018), in that it analyzed museums as experiential environments of interest to study visitor behaviour.

This study expanded our understanding of the relationship between the exhibition's elements and visitor interaction and put the analysis of the physical elements found in a museum design at the centre stage. One of the core tasks of museums is to design experiences in a way that they are engaging, invite visitors to interact with the artefacts, and foster learning (Falk and Dierking 2013; Rainoldi et al. 2018). For the practice of museum design, our study shows not only which exhibition's elements visitors interact with or not, but also highlight that there exists a relationship among exhibition elements, and the way (order, sequence, duration) visitors engage with them (e.g. exhibits, information boards, and videos). The closer analysis of physical versus digital media elements brought to light the insight that digital media could attract the highest attention and engagement levels.

On a more general level, the study emphasizes for experience design that there is no such thing as one experience for all. Instead, museum experience designers need to design with their target audience in mind. This means in a first step (1) getting to know the visitor target group and age structure, and (2) design the experience of exhibition rooms, visitor flows, and information presentation with different age groups in mind that maximizes the possibility of individual experiences that visitors can have. For example, one visitor type may want to get a fast general overview at the room entrance, and then quickly look at exhibits to get a feeling of the room, while a second visitor type may only want to learn about exhibits through digital media, and a third visitor type may want to spend extensive time on each exhibit and the surrounding descriptions and information boards.

6.2 Directions for Future Research

Mobile eye tracking research in tourism research is a method that has just started to gain traction. In line with recent studies (Krogh-Jespersen et al. 2020; Scott et al. 2019), we recommend further application of mobile eye tracking as a method that is particularly suited to understand real-time visitor behaviours without intrusion in natural environments. Market research could use mobile eye tracking to offer answers to specific problem situations, e.g. design or redesign of retail stores, visitor attractions, public spaces of interest, where the goal is to (a) design new experience concepts, or (b) enhance existing experiences, flows, and customer journeys. Moreover, for scholars in the research field of tourism experiences, mobile eye tracking could be a particularly beneficial method to uncover cognitive and behavioural insights that often remain hidden in traditionally used methods that ask for the articulation of the lived experience in retrospect.

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