Museum ExplorAR: Exploring Affect and Electrodermal Activity in a Museum Augmented Reality Application

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Abstract

Augmented Reality (AR) applications for museum environments are rapidly reaching a new stage of maturity in their development and design. This study seeks to demonstrate the affective potential of AR visitor experiences, and considers methods for understanding forms of embodied affective response. Through an interdisciplinary approach to affective computing, and understanding affect in the fields of heritage studies and psychology, the study investigates visitors' experiences during an AR tour developed at Amgueddfa Cymru – National Museums Wales, UK. The study reveals tensions between the claims of affective computing, the seductive nature of neat visitor response metrics, and the physiological and psychological evidence. The analysis of electrodermal activity (EDA) indicates key caveats in the use of this form of data, and its suitability for use in a museum context: namely, problems with data loss during ambulatory monitoring, as well as data processing protocols that, as this study shows, lead to the exclusion of whole demographic groups. This study finds that while affective embodied experience has a physiological resonance, this does not represent a complete picture, but merely an echo of an affective experience – one that is potentially larger, messier, and more complex than EDA data can attend to. The paper also reveals the affective potential of AR and presents key questions for its development in the cultural sector.

Keywords: Augmented Reality (AR), affective computing, emotion, visitor experience, embodied affective response, electrodermal activity (EDA), physiological data, affective technology, biometric data, museum technology, cultural sector innovation.

Introduction

Augmented reality (AR) is commonly understood as a three-dimensional, real-time, interactive overlay of virtual graphics upon physical space (Azuma 1997), and has emerged as one of the most exciting forms of computing within the category of extended reality (XR) (Liao and Iliadis 2021; Liao 2019; Drakopoulou 2013; Graham et al. 2013). A lively and ever-expanding body of work on AR exists within the heritage and cultural sector, ranging from research on the development and design of AR applications, both at case study level (Fazio and Turner 2020; Cisternino et al. 2021; Krzywinska et al. 2020; Koo et al. 2019; Lewis and Taylor-Poleskey 2021; Lehto et al. 2020; O'Dwyer et al. 2021; Hammady et al. 2020; Díaz et al. 2018; Yi and Kim 2021), and at review level (Bekele et al. 2018). In recent years, scholarship has also sought to unpack the motivations and needs of museum professionals (Damala and Stojanovic 2012) and stakeholder perceptions of the value and role of AR technologies in museums (Dieck and Jung 2017). It has also attempted to understand the visitor experience of AR (Trunfio and Campana 2019; Pallud Monod 2010; tom Dieck 2016; Jung et al. 2016; Han et al. 2013; Yi and Kim 2021). Researchers have also paid attention to the potential of digital tools for capturing attention, stimulating the imagination, and provoking emotional responses in visitors (Kidd 2015, 2017; Poole 2018; Perry 2019; Vrettakis et al. 2019). However, there are no studies

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that have empirically evaluated adult visitors' emotional and affective experience of AR in tandem with an evaluation of their physiological activity. This paper makes that intervention, and investigates AR as a novel form of visitor interaction with attention to its role in affective experience. The paper responds via an empirical study of visitor experience within an AR gallery tour launched at Amgueddfa Cymru's National Museum in Cardiff. Through the use of a case study, it draws attention to emerging critical implications of AR within museum experiences; it demonstrates that AR devices can mediate and affect personal experience, and draws on an interdisciplinary body of research to argue that AR, as a form of spatial computing, not only impacts but creates spatial and social relations. The paper also explores AR as a legitimate means of affective digital storytelling – one which has profound implications for the future of visitor experiences. From this position, it makes a claim for the need for further engagement with AR as an emerging form of affective, cultural expression. The methodology proposed to undertake this study draws on approaches to affect in heritage studies, as well as debates within the disciplines of psychology and cultural studies on this issue. The result is a mixed methods approach that incorporates monitoring via wearable sensors, as well as qualitative data gathered via post-visit surveys. The resultant data sets are held in conversation to explore both the value of the tools employed in this approach, as well as to determine the affective potential of AR. The paper firstly outlines its theoretical approach, and the precedents it draws upon, before presenting the study's method and results. It then closes with a discussion about emotional response and the experience of AR, as well as the caveats around the use of physiological monitoring, before positing that AR, as a new cultural form, is poised to change how we think about interpretation and space in museum displays.

Affect: Navigating Computing and Museum Approaches

Over the last twenty years there has been considerable research into affective forms of experience across multiple disciplines (Ahmed 2004; Blackman 2012; Blackman et al. 2008; Blackman and Venn 2010; Blackman and Cromby 2007; Gregg and Seigworth 2010; Hemmings 2005; Leys 2011; Thrift 2008; Wetherell 2012, 2013, 2014; Walkerdine 2016; Springgay and Truman 2017). As a result, there is a growing body of scholarship responding to the emotional experiences of museum and heritage site visitors (Savenije and de Bruijn 2017; Falk and Dierking 2000; Falk and Gillespie 2009; Schorch 2014; Hubard 2015; Palau-Saumell et al. 2016; Tröndle et al. 2012; Smith et al. 2018). Many of these debates are rooted in museum education (Dierking 2005; Falk and Dierking 2000; Falk and Gillespie 2009; Hooper-Greenhill 1999; Hein 1998), although the concept of visitor experience has increasingly expanded to include a broad range of emotional and affective relationships, and this has stimulated debates on terms such as affect, empathy, and enchantment (Perry 2019; Savenije and de Bruijn 2017; Kidd and Sayner 2019). While a full discussion of the development of this practice and its motivations would far outstrip the remit of this article, these shifts provide a context to the study's approach to affect and emotion. This paper draws on Smith, Campbell, and Wetherell's definition of affect as embodied meaning-making, which views affect, feeling, and emotion processes, not as neat, easily packageable progressions, but as dynamic and flowing configurations in which emotion is action-orientated. Here the terms embodiment and meaning-making are understood via a conception of emotions as "commentaries on things that are important to us… [as] forms of evaluative judgement, inextricably linked to cognition" (Smith et al. 2018: 1). Crucially, this view marks a departure from approaches to understanding visitors' experiences that are driven by assumptions that the museum is primarily an educational space. Instead, I propose an understanding predicated on heritage as a process of meaning making in which meanings are brought to the encounter and reinforced during the visit (Smith 2020). However, this study also distinguishes itself by choosing not dismiss embodied forms of affect and emotion entirely; instead it approaches the potential physical resonances of emotion in the body with a degree of curiosity and caution. This paper consists of an exploratory investigation concerned with what, if anything, physiological data can offer this understanding of affect. Within the field of affective computing, multiple definitions of affect – and multiple approaches to its analysis – have proliferated, both of which are riven with tensions present between different disciplines and epistemological approaches. As founder and director of the Affective Computing Research Group at the Massachusetts Institute of Technology (MIT) Media Lab,7 Picard laments the "generalised references to constructivist theorists" (Picard et al., 2004) found in many theories of affect, and calls for "tools and technologies that elicit, sense, communicate, measure, and respond appropriately to affective factors" (Picard et al. 2004: 254). She believes that new technologies "play a particularly important role in these efforts, helping us to measure, model, study, and support" the collection of affect data, and suggests this is possible because their work goes beyond "classical armchair observations and thought experiments" in the pursuit of understanding affect (Picard et al. 2004: 255). Having said this, Boehner et al. argue that approaches like the one put forth by Picard, largely treat 'affect-as-information' and operate under the assumption that this information can be algorithmically interpreted and sorted into discrete emotional categories (Boehner et al. 2007). However, such data has been described as "precise yet ambiguous" by BioSENSE, the socio-physiological computing research centre at UC Berkeley. As the authors continue:

> Biosensors are increasingly able to produce readings with many significant figures, yet the high-level inferences drawn from these raw signals will be context dependent and highly ambiguous. For instance, a single emotion may have different associations or spectrums for one individual compared to others. (Howell et al. 2018)

Howell et al. argue that as biosensing technology is increasingly used in emotion research, such tools are increasingly seen to "promise authoritative insight by presenting users' emotions as discrete categories" (Howell et al. 2018). Howell et al. extend this argument by exploring how biosensing devices propagate forms of biopower and normalize biometric surveillance via their assertions of truth and their offer of 'actionable insights', the consequences of which are that they "shape our cultural imagination about what data is and what it can do" (Howell et al. 2018: 1). In response to Howell et al. and Boehner et al., the approach taken in this study is informed by interdisciplinary literature on affect, emotion, and physiology, and therefore represents a departure from Picard's perspective. As a result, this paper draws on an understanding of emotion and affect as indicative of embodied and social constructions of personal and collective meaning. It marries this with a keen awareness of the critiques of these devices. Physiological measurement is achieved by real-time monitoring via a wearable device tracking EDA, blood volume pulse (BVP), acceleration, heart rate (HR), and temperature. However, rather than looking for neat, packaged emotions, this study first sought to understand the self-reported affective work done during a visit, second, determine the validity of the physiological data, and third, explore the value of holding these two data sets in conversation with each other.

Precedents in Wearables and Physiology

While there is an abundance of lab-specific methodological approaches and experimental procedures, no well-established methodological protocols exist for ambulatory monitoring in real-world environments (Dawson et al. 2001; Boucsein et al. 2012). Unsurprisingly, there is little agreement on the validity of physiological measures, and this means there are still serious methodological issues to be considered in any research design seeking to include data from ambulatory participants in real-world settings (Fairclough 2009; Levenson 2014; Mauss et al. 2005; Mauss and Robinson 2009; Kreibig 2010; Friedman and Kreibig 2010). Here it is important to understand the evidence that exists for viewing physiological measurements as a form of affective metrics. Mauss and Robinson found little evidence for direct relationships between physiological response and specific emotions, and agree with two further meta-analyses, both of which found links between physiological response and specific emotion labelling to be empirically inconsistent (Cacioppo et al. 2000; Lindquist et al. 2012; Mauss and Robinson 2009). Kreibig's meta-analysis provides evidence not for exacting specificity, but for general modal relationships between reported experience and certain physiological responses (Kreibig 2010).

Despite the wealth of robust, qualitative research on affective visitor experience, it has been argued that visitors' experiences in museums cannot be investigated reliably via questionnaires or surveys alone, as questionnaires are deployed at a temporal distance from the experience itself, and therefore only attend to the cognitive and linguistically processed echoes of a previous experience (Tröndle et al. 2012; Tschacher et al. 2012). This perspective has led some researchers to investigate wearable technology and physiological response data within the museum environment. Tröndle et al. (2012) conducted a five-year study examining the physiological, social, psychological, and aesthetic relationships involved in museum visitation. Results showed that some physiological measures were significantly related to self-reported aesthetic-emotional assessments. For example, artworks described by participants as 'beautiful' or 'surprising/humorous' were associated with raised HRV (heart rate variability), but electrodermal activity was not significantly linked to forms of aesthetic appreciation. The study's focus on correlations between physiological response and aesthetic qualities provides a tighter framing of relationships between emotional experiences and any associated physiological response. In contrast, this study takes a broader view of the process of visiting and the affective work that is undertaken. Furthermore, this article explores the methodological challenges that arise in ambulatory physiological monitoring through a mixed-methods approach to understanding visitors' affective experience as it is reported by participants and potentially reflected in physiological responses.

Background and Method

National Museum Cardiff, situated in the capital of Wales, UK, is home to national collections of botany, fine art and applied art, geology, and zoology. In 2019 museum staff commissioned an AR tour to offer new perspectives on the permanent collections without the cost and disruption of large-scale gallery redevelopment. The result was *Museum ExplorAR*, a self-led mobile experience that brings the museum's artefacts to life through animated augmentations of key areas of the collections. This form of 'exhibition enhancement' (Bekele et al. 2018), was delivered via a handheld tablet, through which visitors to National Museum Cardiff could explore marine life, impressionist art, and prehistoric displays galleries with AR overlays.

An evaluative single case study was developed in collaboration with museum staff to explore the impact of AR on the visitor experience. The study collected physiological data via a wearable device, an Empatica E4, fitted to visitors' wrists. Recruitment was supported via university newsletters, flyers in research centres and student social areas, as well as via social media. The £10 rental fee was waived for research participants; due to the limited number of devices, participation in the study needed to be pre-booked. A total of 13 adult visitors were recruited. All participants were between 25 and 54 years old, with seven between the ages of 35 and 44. Gender was weighted towards male visitors (n=10). Of the sample, 12 had visited the museum before, with eight visiting one to two times per year. In terms of ethnicity, 12 identified as 'white British', with one person choosing to identify as 'other'. Participants were informed that the researcher was working with the museum to understand AR and their feelings during the visit. Ethics and consent procedures were conducted. In line with Levenson, the study rejected the notion of the 'rest' period in which the subject is asked to do 'nothing' (Levenson, 1988). Instead, it opted for a baseline activity that produces a moderate level of physiological activation – a short walk between the recruitment area and the galleries.

A visitor using Museum ExplorAR in the Prehistoric gallery.

Museum ExplorAR followed a set route with three set periods of AR activity. All participants experienced the same three galleries in the same order. AR elements were signposted in the galleries and participants were observed to determine average dwell times in each area. The Empatica E4 device was only used for one visitor per day, as a pilot study had shown that using a device for multiple data capture sessions across multiple visitors increased data errors and loss (Hoare 2020). Post-visit surveys were provided to participants on tablets at the end of their visit. Survey data was collected via closed and open questions, which allowed for the collection of both qualitative and quantitative data within the survey.

Survey Analysis: AR and relationship to space

It was expected that visitors would reflect on the role of AR in creating a novel experience. Unsurprisingly, 10 visitors commented on the AR and its contribution to their experience. Survey comments highlighted new forms of relationship to the collections. Participant 11 wrote that they felt “absorbed in a different way. More focused on the information and less distracted”, and that “delving into the experiences was thought-provoking, and I felt quite focused and away from the rest of the day” (A11). Comments from participants about both the access to information and the enhancement of focus enabled by AR also appear in other *Museum ExplorAR* accounts. Participant A10 wrote:

> I felt more engaged with the things I could see and interact with via the AR device, which meant I paid a bit more attention to the information. However, I was also aware I wasn’t paying as much attention to the things that weren’t on the AR device.

Participant A6 described how *Museum ExplorAR* offered them new perspectives on familiar collections, but that the experience of the museum through AR felt somewhat removed from the displays:

> During past visits, I’ve loved looking at the exhibitions, particularly the dinosaur exhibition and the content of the art galleries. The details and the textures. What felt different this time is that although I was given another perspective, I felt that I looked less at things and skimmed over the detail. And somehow ‘looked’ less and [was] more detached.

Other visitors described the museum experience as being shaped by the AR technology.

For example, the use of AR directed and focused their attention in a new way, as Participant A5 explains:

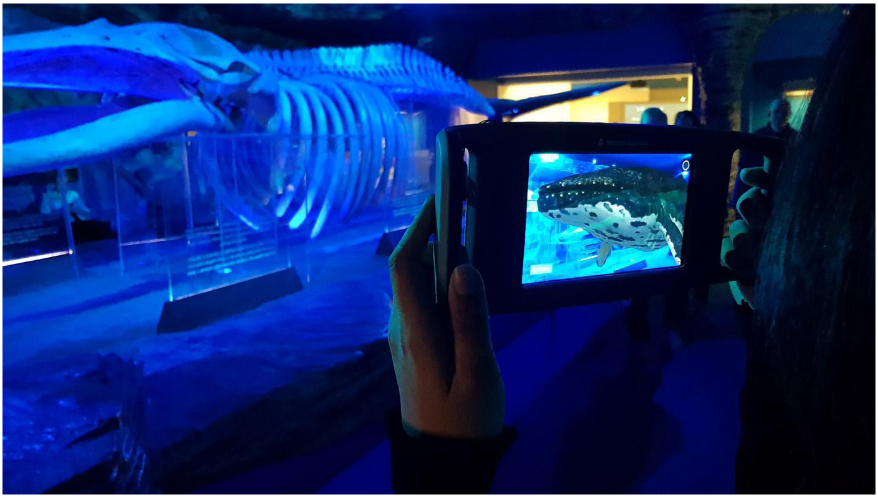
> I enjoyed being followed by a shark, even if the image itself wasn't the best of the bunch. The AR encouraged me to navigate the spaces in a different way. It meant I didn't engage fully with the static exhibitions though and went more for thrill seeking.

Visitors A5 and A6 describe perceiving a change in their behaviour as a result of the technology. Indeed, there is a tension between visitors reporting that they feel more focused on aspects of the collection highlighted by the tour, and visitors saying they feel more detached from those not included. This seemingly contradicts an understanding of AR as a form of 'layering', whereby the technology provides a means for museum spaces to become a "stage for endless extra layers of information" (Ding 2017). Instead, this study suggests that instead of mere 'layering', AR offers potentially more interesting spatial relationships in which objects and contexts can be dynamically foregrounded (and receded) in order to impact visitor attention and focus.

A total of eight visitors recall moments when the animal and marine collections were brought to life. Here the distinction between real objects and computer-generated objects can become unclear in some cases; one visitor, for example, identifies being drawn in by the "waterlilies in the impressionists room and the talk by the Davis sisters and Monet" (Participant A5). The talk described is delivered by AR, but the waterlilies could reference computer-generated waterlilies transposed across the gallery floor or the Monet painting present in the room. As an emerging form of interaction, it is interesting to note the potential for AR to confuse and collapse 'object' and 'interactive'. This has methodological implications for research focused upon AR, and speaks to the potential for spatial 'collapse' where distinctions between AR objects and the physical collection become less clear. This calls for ways of thinking about AR in museums that see it not as an overlay or form of layering, but as potentially creating new parts of the collection.

Survey analysis: affective experience

When asked to name a feeling they associated with the visit, six common states were commonly reported by visitors (engaged, excited, enjoyment, calm, curious, and connected). Visitors connected with real-world issues and recalled specific aspects of the collection's provenance. For example, participant A5 wrote they had learned "information about the whale and how parts had been destroyed by fire", and Participant A11 used another narrative related to the history of the collection, "learning that the sea creatures, such as the whale and turtle, were washed up in Wales". Another visitor wrote: "in the underwater section, I felt a connection to the whale which was excitement and sadness especially within the current environmental position". (Participant A7). In these examples, visitors describe a connection to place or relationships to nature, and these descriptions speak to forms of affective experiences. The experience of the whale skeleton and taxidermy turtle brought to life by AR appears to animate not just these objects, but also issues relating to marine conservation, helping to support meaning-making on the topic. Notably, the climate crisis was not referenced within the interpretation in the gallery. This demonstrates, as Smith has argued, how visitor experience can contain elements of affective work that are unrelated to the intentions of museum staff, and are instead driven by pre-existing experiences and beliefs (Smith 2020).



View of the augmented whale and the original whale skeleton in the Marine gallery.

Physiological Data Analysis

In order to undertake analysis, the duration and end time of each individual's physiological data recording were matched with their tour start time and the timestamps on the survey. Data were checked for signal noise, including any unwanted modifications or interruptions to the sensor signal that occurred during transmission, capture, storage, or processing of the data. Heart rate signal was found to periodically stop in over half of the group and had to be discounted. This left only electrodermal activity (EDA) for analysis. EDAExplorer, an online tool for the analysis of EDA data, was used to identify EDA datasets with excessive signal noise (Taylor et al. 2015). Any EDA data set with over 25 per cent noise was excluded from the study in line with recommendations for the exclusion of potentially invalid datasets (de Looff et al. 2019). Worryingly, this procedure led to the exclusion of all female participants, and highlights issues concerning the proclivity of noise protocols to exclude the EDA data of female participants, who have been found elsewhere to have higher EDA fluctuation overall (Román et al. 1989). Three participants appeared to have low response levels, which could mean they are classified as non-responders. It has been estimated that between 10 and 25 per cent of the general population can be classified as having hypo-responsive electrodermal activity (Braithwaite and Watson 2015). The sample used in the study was restricted both by data loss and the demographics of size, gender, and age range. The investigation progressed in line with the study's exploratory nature. As a result, demographic analysis was not performed, although differences in the visit frequency are considered.

Table 2: Breakdown of EDA data loss

	Museum ExplorAR Visitors
Total participants	13
Data lost to noise	5
Data corrupted	1
Non-responders	1
Total loss	7
Remaining for analysis	6

The remaining data were subjected to two methods commonly used to examine individual electrodermal data: peak counts and a visual inspection of the data. Visual inspection and peak counts are used extensively in affective computing and psychophysiology (Benedek and Kaernbach 2010; Boucsein et al. 2012; Taylor et al. 2015). EDAExplorer was used to detect peaks within the data dependent on user-defined parameters to define peaks (Taylor et al. 2015). Using publication standard protocols for peak identification (Boucsein et al. 2012), any rise of at least 0.05 uS, which subsequently began to fall within a four second window, was detected and flagged by the software, which then parsed this peak against temperature and accelerometer data. The software automatically excluded peaks occurring in line with sustained rises in temperature. Detected peaks were grouped and plotted in five minute intervals. The resultant graphs were compared with visitors' self-report data to determine whether relationships between EDA and self-reported emotion could be established.

Participant EDA data

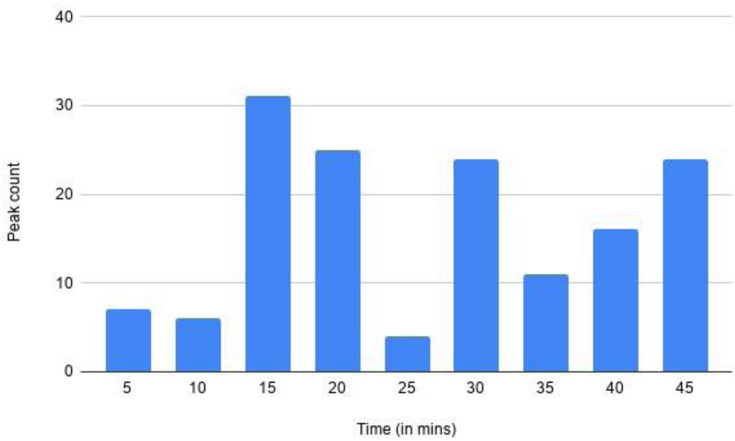


Figure 1: Participant A3's EDA peak graph

Visitor A3's EDA, shown as peaks per five minutes period in figure 1, contains three periods of higher levels of EDA. These three periods, with the increases in EDA peaks at around 15, 30, and 45 minutes, map onto the three AR periods. The highest rise occurs in the Prehistoric Gallery, where the visitor first experiences AR. However, descriptions given by visitors do not reference this initial experience. Instead, they cite the final AR segment in the Impressionist Gallery as the most memorable. A rise in EDA can be observed, although it is not the highest period of EDA, during the final period of the tour when the visitor would have been in the Impressionist Gallery. Given the rudimentary tracking, it may also have been the case that the end of the tour and the anticipation of the survey caused a rise in EDA. Visitor A3 described feeling connected to the past and linked this feeling to "detail" and "type of information" encountered on the visit. Visitor A3 recalls being interested in the collection's provenance; they report that the Impressionist Gallery made them "more appreciative of our history". Arguably, the visitor's use of 'our' conveys a sense of connection arising from the visit, and may represent a form of affective meaning-making premised on connection and identification with the collection.

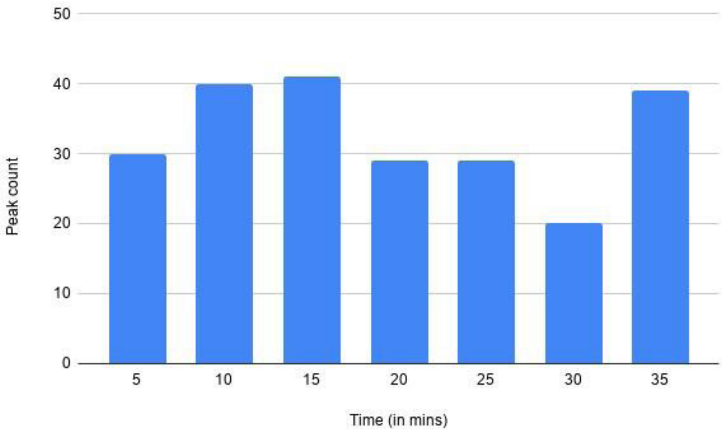


Figure 2: Participant A5's EDA Peak Graph

In figure 2, the EDA peak graph shows a rise in visitor A5's EDA during the 10 to 15 minute range, which occurs during the first AR segment. This suggests that the first encounter with AR may cause the highest EDA peak count in this visitor. However, this was the visitor's first time at the museum, and the unfamiliar environment may have increased EDA. Another rise in the number of EDA peaks occurs at the end, after approximately 35 minutes, when the participant would have been in the Impressionist Gallery. Again, as with visitor A3, the rise at the end of the tour may be related to survey anticipation. Such ambiguity is indicative of the challenges of EDA interpretation in an open, ambulatory setting. Factors contributing to EDA response cannot be wholly known and controlled. However, links do appear between high EDA and visitor A5's recollection of the most memorable and interesting part of the experience. This visitor reported finding the final encounter in the Impressionist Gallery most memorable, and said they were most interested in the provenance of impressionist artworks from the collection. During this final AR segment, higher (but not the highest) levels of EDA can be observed.

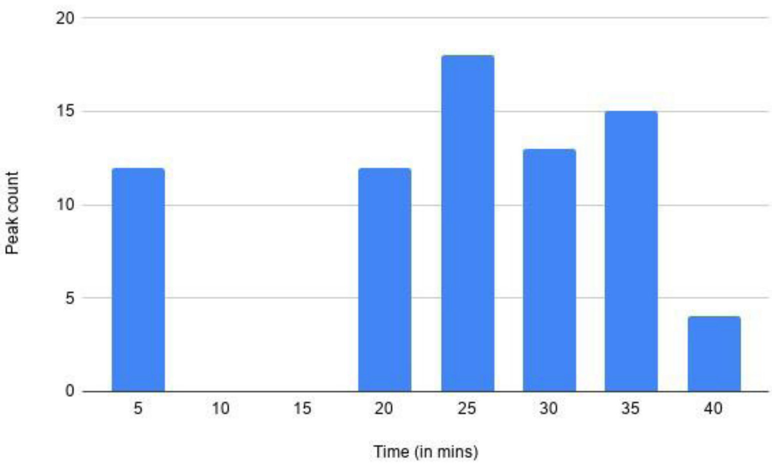


Figure 3: Participant A15's EDA Peak Graph

Figure 3 shows visitor A15's levels of EDA rose at the very start of the experience, after approximately five minutes. This was quickly followed by no activity, before a sustained period of EDA at 20 minutes onwards, with a drop in the final five minutes. The visitor cites the "moving AR images of dinosaurs and Marine life" in the first two galleries as the most memorable part of the experience. This can be linked to figure 3, which shows peaks at the points where the visitor would have been in the Prehistoric and Marine Galleries, both at the start after approximately 20 to 25 minutes. The visitor recalls feeling "curious" about the "decisions about the use of AR around paintings and the history of the collection" in the Impressionist Gallery. In the case of visitor A15, a potential rise in EDA can be seen while they are in the Impressionist gallery, given that EDA rises again after 35 minutes, at the end of the experience. In this visitor, there are three clear periods of EDA that might be seen to correspond to the three AR experiences. Links are also present between aspects of the experience reported by visitors and higher periods of EDA. This indicates that a relationship exists between periods of peak activity and experience described by the visitor, but conclusions here are limited by the rudimentary nature of the tracking used in the study.

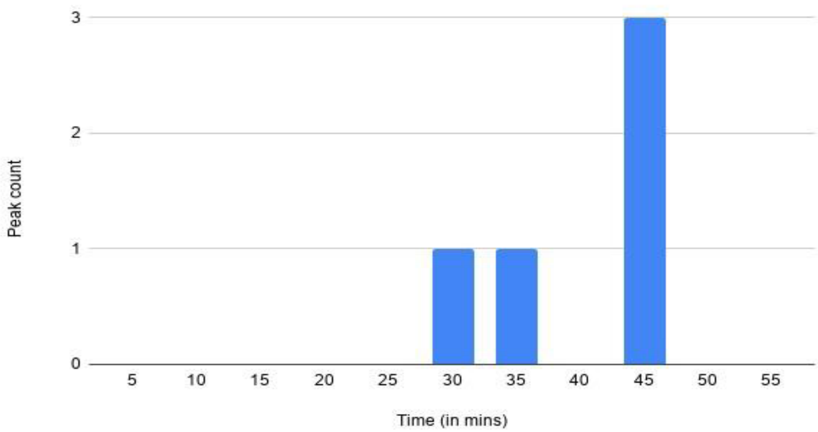


Figure 4: Participant A11's EDA Peak Graph

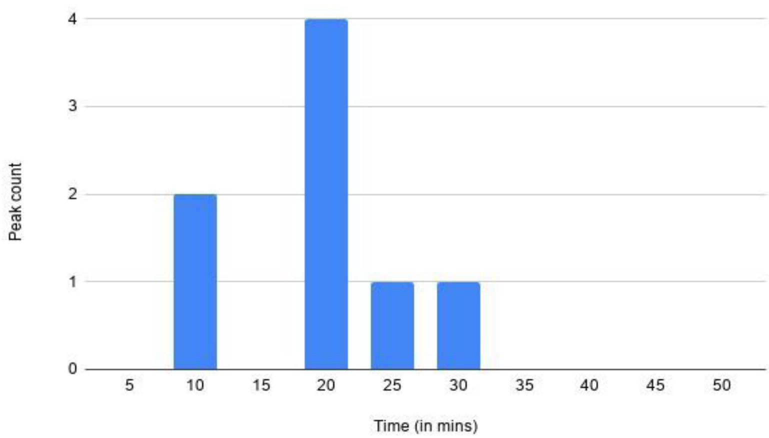


Figure 5: Participant A6's EDA Peak Extraction

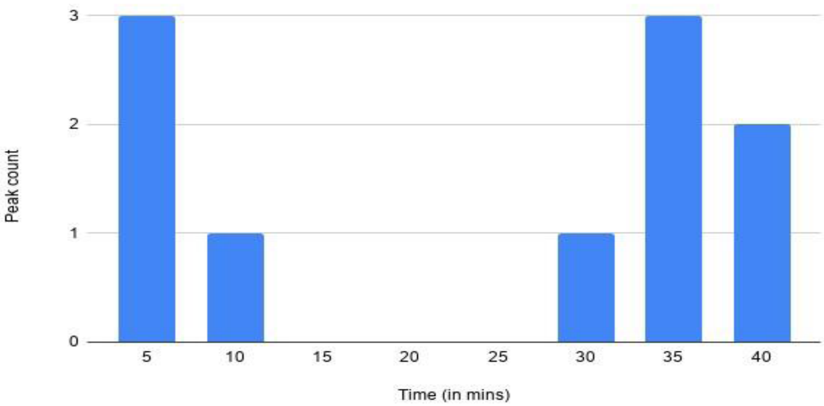


Figure 6: Participant A12's EDA Peaks

Figures 4, 5, and 6 show very little EDA in Visitors A11, A6 and A12. The data collected on these visitors brings to the surface some key issues relating to EDA monitoring. In terms of peak extraction parameters, current publication standards for peak detection do not adequately encompass the whole range of electrodermal response across the general population. This has caused some physiological researchers to argue for a review of these standards (Braithwaite and Watson 2015).[1] Support for these claims is found in figures 7, 8 and 9, in which EDA data presented by Empatica's GUI shows EDA with clear peaks, which are nonetheless at very low levels for visitors A6, A11, and A12. Given the appearance of clear, peaked EDA response at low levels, it may be that published standards for peak parameters are likely not suitable for these individuals, and lower rises of EDA might constitute 'peaks' in these participants.

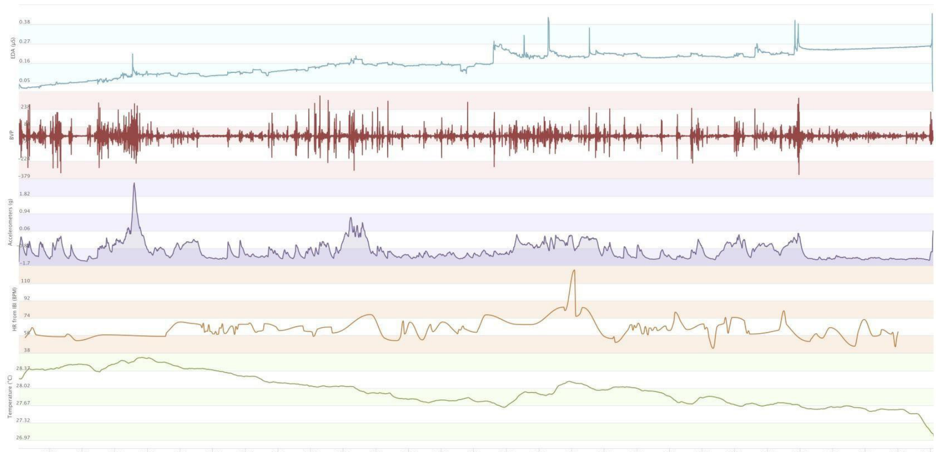


Figure 7: E4 GUI Data in Museum ExplorAR Participant A11

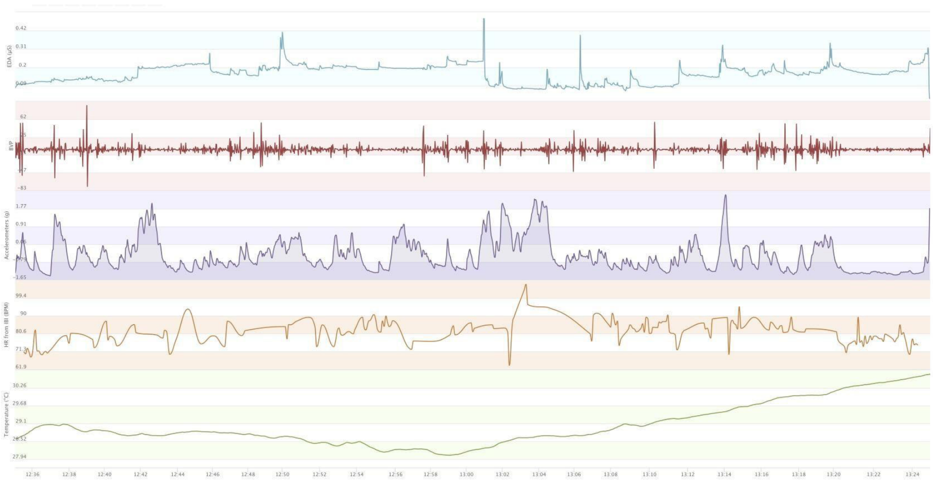


Figure 8: E4 GUI Data in Museum ExplorAR Participant A6

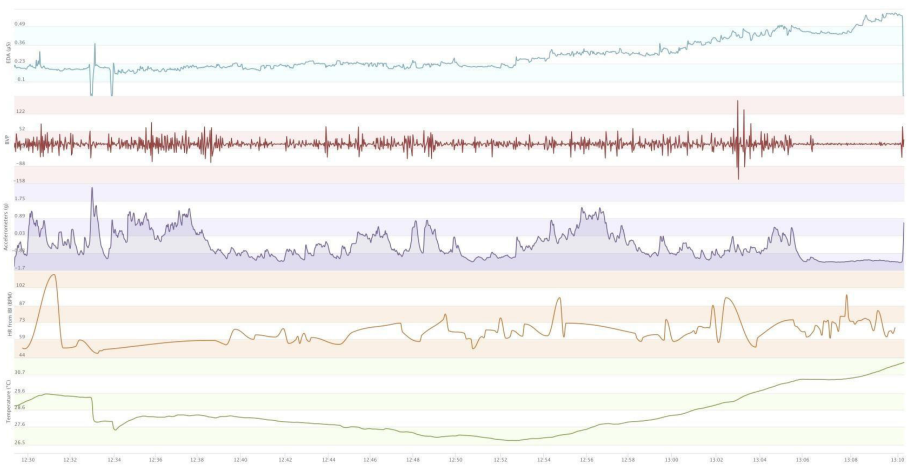


Figure 9: E4 GUI Data in Museum ExplorAR Participant A12

There are further conditions that contribute to a lower EDA level. First of all, familiarity with the stimuli may impact EDA. Previous research has suggested that familiarity reduces EDA and novelty increases EDA (Boucsein 2012). Therefore, a visitor's visit frequency is a factor to consider. Figure 8 shows EDA peaks in visitor A12, who attends more than four times a year. Secondly, the EDAExplorer programme compares EDA, accelerometer, and temperature data. The temperature data rises by over two degrees centigrade over the last 20 minutes of the visit. This temperature rise would cause EDAExplorer's algorithm to discount peaks in this period.

With regards to the issue of low levels of electrodermal response in participants, crucially EDA must not be understood as a 'catch-all' indicator of emotional response. Previous research cites EDA as a useful marker of concentrated, attentive forms of arousal, but one that offers less insight when exploring subtle or more introspective experiences (Conati 2003; Howell 2018). Overall, this confirms that in some visitors EDA may increase during the periods in which they find something interesting, whereas visitors who describe a calm or relaxing experience may have a lower EDA response overall. Moments of calm or reflection do not create EDA peaks as understood by the parameters in this study, but low levels of EDA are not an indicator of no affective response. Participant A6, for example, recalls feeling “uplifted” during this final phase of the tour, and attributes this feeling to the art collection. Participant A12 described feeling “relaxed” and “calm” during their visit, and linked this feeling to the museum environment. In these cases, visitors identified emotional processes, but these experiences did not coincide with increases in peak counts in the EDA data. Only in participants A3 and A15 did higher EDA appear as three periods of activity that could be crudely mapped onto the three AR experiences. Participants A3 and A5 both demonstrated the highest EDA response during the first section of AR in the prehistoric gallery. Participants A3, A5, A12, and A15 were found to have higher EDA during the periods they described as most memorable. Participants A5, A12, and A15 also demonstrated higher EDA during the parts of the tour that they identified as interesting in their survey response This demonstrates that EDA may have some cognitive and affective relationship but that this relationship is highly individuated.

Discussion and conclusion

Caveats of ambulatory, museum EDA monitoring

This study has demonstrated issues relating to signal noise, data loss, and data cleaning protocols, as well as highlighting how physiological monitoring reproduces societal inequalities. While the study illustrates some relationships between EDA and the data contained in visitor descriptions of experience, it ultimately concludes that an individualized calculation for EDA peak parameters may improve any future analysis. These conclusions fit with the suggestion of a limited “general alignment” between increased EDA and certain kinds of stimuli (Barrett 2006: 40). Future research may wish to reflect any revision of EDA peak standards or seek to collect EDA data from participants over a sustained period and calculate individual parameters. In particular, the study raises questions regarding the validity of noise protocols, given their propensity to exclude female participants, which raises significant concerns regarding the ethical implications of physiological monitoring.

This study also demonstrates that introspective emotions might escape physiological monitoring, which aligns with the observations of Conati et al., who concluded that it is “not clear how effectively the sensors can detect emotions that may be expressed more subtly” (2003: 1). The study therefore speaks to a need to intervene in understandings of physiological monitoring that take the view that total and fixed forms of knowledge about affective experience can be realized through their use. The current study is not alone in this regard; issues relating to signal noise, emotional valence, and the value of physiological activation, have all been reported elsewhere (Resch et al. 2015; Conati et al. 2003).

Deterministic relationships between EDA and emotion are beyond the reach of what data captured in an ambulatory, real-world setting such as a museum can provide. However, monitoring technologies such as the Empatica E4 used in this study, and the quantifiable data it produces, are tied to a politics of aggregation and the reduction of human experience to metrics – acts that appear to promise a sense of certainty but more readily contribute to the “production of uncertainty” (Beer 2017: 189). The impact physiological monitoring may have on the types of values that are ascribed to museum visits reaches far beyond this study, and taps into debates about the role of museums, and the wider heritage sector, in supporting health and wellbeing. In exposing issues inherent within physiological monitoring, this paper responds to Beer’s claims that before determining whether a particular set of metrics provides useful social insights, we need a “more conceptual, contextual, and politically sensitive appreciation of metrics and data” (Beer 2017: 8).

Qualitative qualities of affect

By way of contrast, qualitative data generated by the study provides descriptive feedback, recalls information and narrative, and gives examples of visitors assimilating personal contexts and existing knowledge to create meaning. That our emotive selves can feel an emotion in response to an experience or have our imagination captured by a momentary interaction, was evidenced by the affective texture of participants' sense of wonder at the natural world, or during a moment of subtle calm in front of a Monet painting, for example. As Perry writes, such encounters have the power to "stand as seedbeds for human generosity, ethical mindfulness, and care for the world at large…and this affective response can motivate us to act back on the world in constructive, ethically-minded ways" (Perry 2019: 354). As recent museum practice has shown (Harris 2020; McGreevy 2020), the benefits of making space for affect and emotion in visitor research includes the potential of such work to explore the ways museums might create and sustain affective, social relations that are urgent and relevant in current times.

Experiencing AR

As a rapidly developing technology, AR is increasingly moving beyond layers of visual and audio content clunkily applied on top of real-world environments. Through artificial intelligence, object relations, and the computational physics needed to create convincing interactions between AR and the real world, objects are becoming increasingly simplified, and will likely progress further through the use of artificial intelligence in programming. Future heritage and cultural experiences will enchant, connect, and challenge audiences in ways previous forms of interpretation could not. It is also likely to offer ways to carry out surveillance of visitors through technologies such as eye tracking, physiological monitoring, and facial capture. This represents an influx of new forms of audience data that come with new social, ethical, and political considerations that the cultural sector will need to grapple with.

AR can turn bone into flesh, ruins into regal interiors, or empty agricultural landscapes into battlefield scenes, and as experiential and enchanting AR applications emerge, attention must be paid to the impact on spatial and social relations. This findings of this study point to future methodological considerations, namely ensuring clarity and attending to the act of collapse and perhaps understanding this as a key tenant of an AR environment. Conceptual questions also arise. For example, as such technologies become increasingly naturalised and sophisticated and their novelty fades, what forms of interaction and objecthood emerge? How do these developments meet with the affective experience and what impact does this have on visitors?

By exploring the emotional responses described by visitors during the AR tour experience, the study uncovers pressing questions that speak to the way that AR as a cultural form shapes a museum visit and may impact museums and their visitors in ways we cannot yet anticipate. It draws attention to the relationship between the emotive, the social, and the spatial within an augmented intervention. The first wave of museum-based AR experimentation has brought with it several tropes, such as animating extinct animals, and introducing us to time-travelling narrators. The next wave of AR experiences might accommodate more careful considerations about how extended reality tools, such as AR, might offer interpretation of collections from new, perhaps non-human-centric perspectives, and meet a wider range of access needs by reshaping traditional relationships between interpretive content, display, and delivery. As this study has shown, AR can provide a powerful means of capturing and holding visitors' attention, but how to engage with and how to honour that attention in an inclusive and dynamic way remains an evolving question.

Notes

1 The issue of publication standards is complicated by the fact they are based on what could be read by the human eye on analogue equipment, and do not reflect the degree to which EDA fluctuation can now be tracked (Braithwaite and Watson 2015).

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