Gaming Versus Storytelling: Understanding Children's Interactive Experiences in a Museum Setting

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Abstract. Museum's audiences are increasingly looking for compelling experiences where, besides learning, engagement and enjoyment are key success factors. While gaming and storytelling are considered to be common approaches to engage audiences with a museum's collections, a formal comparison of the two has not been found in literature. In this paper, we present the design and comparative study of two distinct interventions, namely a mobile game and a mobile story that were designed to engage a young audience with the exhibit of the local natural history museum. Focusing on the same scientific content derived from the museum's collection, we compare the effects of both interactive experiences on a group of children. When comparing engagement, enjoyment and learning outcomes, we correlate results with data derived from observations and skin conductance biofeedback. The data collected so far suggest that children are 27% more excited when using the game application compared with the story driven one. Moreover, we find that children's excitement peaks when encountering selected artefacts presented in the museum exhibit. Finally, children's learning nearly doubled (44%) when using the game based experience versus the story. We conclude the paper by discussing the implications of our findings and by proposing potential future improvements.

Keywords: Interactive experiences · Gaming · Storytelling · Skin conductance · Proximity sensing

1 Introduction

Museums are gradually moving from a passive display of artifacts towards more interactive presentations, engaging visitors and augmenting their knowledge in new and compelling ways [17, 19]. Nevertheless, they find themselves competing for attention with the entertainment industry. Museums therefore need to make their "product" more appealing and attractive to a variety of audiences, while combining educational and entertainment aspects [22]. Gamification, storytelling and playful interaction [6, 13, 26, 37, 43] afforded by the ubiquity of mobile personal devices (in museum settings) offer opportunities to attract young visitors [5] enabling a closer relationship with the museum's stories and exhibits, and creating a "new and more powerful way to learn" [41].

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Previous research demonstrates that storytelling and game-based approaches benefits museums by promoting joyful and exciting experiences, which have the potential to support meaningful learning [16, 22]. Moreover, games [33, 48] and storytelling [12, 25] are two of the most used techniques to engage young and adult audiences as museum visitors. Mystery and treasure-hunting [8, 15] as well as problem solving tasks have the potential to engage, entertain and scaffold visitors' learning through museum contexts [3, 10, 34, 37, 44].

While on one hand, the use of mobile devices to enhance and enrich museum visits has a long history [4, 9, 18, 21, 27, 30, 31, 40], the idea that interactive playful mobile experiences can play an equal role alongside the learning mission of most museums is a more recent approach. Stories and games can boost the learning goals of the museum, while enhancing the playful aspects of the visit. The advantages and disadvantages of mobile gaming and storytelling in museum contexts have been extensively investigated, but the two approaches have not been compared at a practical level. What are the most appreciated features from both kinds of interventions? What works best in terms of learning, engagement and enjoyment with the museum and with which audiences? To answer these questions, we designed and compared two mobile interventions, a story driven (Ocean Story, hereafter OS) and game driven one (Ocean Game, hereafter OG). Aware of the long conversation between ludologists and narratologists, in defining driving strategies and building blocks in games versus narratives [1, 2, 7, 23, 24, 28, 32, 39, 49], we did not draw a straight line between the game and the story approach, however we did design two different approaches for the two interventions (OS and OG) that would make predominant use of game mechanics versus dramatic arc and narrative focus to motivate the audience. The two applications make use of the same scientific content and exhibits in the same museum settings. Our study aims at comparing engagement, enjoyment and learning outcomes of both of our applications, in order to better understand and hence design mixed gaming/storytelling interventions for young audiences.

Museums are therefore becoming hubs where children can experience various kind of entertainment while they enrich their knowledge and solve challenges by themselves [17]. Mobile gaming and storytelling experiences in museums have been an active arena of research. We report on several inspiring research projects that helped us design our interventions. Most of these interventions do not make a clear-cut distinction between game elements and story, hence rather fuse the two approaches into a single application. Research by Sánchez et al. [40] presents "Touch & Share", a Near Field Communication (NFC) and Tangible User Interface (TUI) game for children interacting with the taxidermied species of a local zoological museum. Cabrera et al. [8] reports on the design of an interactive museum game which allowed students to play and perform tasks related to certain artifacts. As shortcomings of their approach, the authors alert us about the danger of children losing interest in the interactive guide due to the complexity of the tasks, while others switched the focus from the displayed artifacts to the handheld computers. "Ghost Detector" [33], a story driven museum game for children, makes ghosts of various museums' artifacts appear on the screen of the young visitors' mobile device and challenges children to find the artifacts that the ghosts are representing. The study highlights that level of excitement and engagement within the museum premises that were raised by the ubiquitous story/game. "Intrigue at the museum" [48] is a plot driven mobile game for children structured around exploration and task performance. Its plot invites visitors to search for a thief in the museum among a set of virtual characters. By scanning tags deployed in the building the audience is given clues to help them solve the riddles. Following a constructivist approach, the game allows children to freely explore the museum environment, according to their own interests and agenda. Evaluation of this work shows that story driven mobile games represent a relevant learning resource in a museum setting while promoting engagement and entertainment.

Despite the abundant set of studies and recommendations from researchers, curators and content makers [22, 47], a comparison between a game versus a story approach and the difference between the effects these approaches have on users' enjoyment, engagement and learning outcomes, seems to be missing. This motivated our comparative study between a game and a story driven approach, thus designing the two different applications, conveying the same scientific information, however making the use of different engagement techniques (gaming-driven versus story-driven) as well as aesthetics and interaction mechanics. We aim to understand the best features of both techniques and to share the findings with the community of researchers and developers of mobile stories and games for museums.

1.1 Research Motivation and Questions

Motivated by understanding best practices in gaming versus narrative techniques utilized in museum setting, we were guided by the following questions:

- **[Q1]** - Which interactions, in both approaches, cause more excitement in the users? By collecting children's ratings of the applications as well as field observations, complemented by the physiological data obtained through the use of the bio-sensing wristbands, we highlight the most exciting interactions for both the OG and the OS.
- **[Q2]** - Which of the two mediated experiences best supports learning? This is determined through pre and post tests on the children's knowledge.
- **[Q3]** - Which experience do children rate more motivational, engaging and enjoyable? In this instance, we make use of validated scales measuring enjoyment, engagement and intrinsic motivation.

1.2 Design of Two Interactive Experiences

Setup. In order to investigate which mode (gaming or storytelling) engages, amuses and teaches children the most, we created two interactive mobile experiences, the Ocean Game and the Ocean Story. The two mobile interventions, based on the same scientific information, were expressly tailored for the Museum of Natural History of Funchal, Madeira, Portugal (MNHF). As our main audience, we choose to target 10- to 12-year-old children, as according to the museum statistics, they are the most numerous visitors. With the help of the museum's staff, we selected 13 species that are relevant to the local marine fauna of the island, and paired them with 13 RFID proximity sensors (hereafter, beacons, Fig. 1, left) which acted as transmitters of media content. We opted for this technology as: (i) it is a low-cost solution that is already available on the market; (ii) it can be easily attached to most surfaces (glass, wood, concrete); (iii) it is capable of providing interactive experiences as well as contextually-aware interactions [45]. In addition to OG, we designed image icons that represented each one of the marine species. Such icons were placed on the beacons and appeared on the mobile screen upon encountering the specific marine species. AQ2 Scientific content was presented to the children in form of written text appearing on the mobile screen. In the OS on the other hand, the information was triggered by the beacons, however without any image icon. There, the content was presented to the children through narration and several short and hand-drawn animations. Also, if a child would leave the proximity area of a beacon (while accessing content), all the other beacons were muted to reduce the interference.

Fig. 1. Estimote (http://www.estimote.com/) proximity beacons (left), representation of digital icon detected with phone when nearby the specie (middle) and image icon attached to the beacon on specie glass container (right) designed to attract attention to the selected museums' taxidermied marine species

The Ocean Game (OG). Designed as a point driven treasure-hunt, (Fig. 2, left), where children were prompted to search around the museum for each one of the 13-marine species signaled by visual images and in order to collect the points and digital icons. Children were invited to find and read 3 curious scientific facts about each specie. Once in proximity area of a beacon, a digital icon of the selected specie and a small animation was displayed on the device's screen. Using gestures such as taps and swipes, the children would browse 3 scientific facts related to that specific specie presented as short texts (Fig. 2, left). Each accomplished task would grant them points and several icons to collect on their mobile screen. At the end of the game, once all species are collected, children are asked to answer a quiz, which would give them points and rewards. The goal of the OG was to invite children to collect as many visual images as possible, as well as the points related to the correctness of their answers. A visual image of the species could only be collected once the user had read the three curiosities and photographed him or herself with the species. The collection of these selfie snapshots was, in our understanding, important to bridge the real-life surrounding with the mechanics of the game. At the end of the game, a special ranking was established, paring the children with certain marine species based on their quiz results (Fig. 2, left).

Fig. 2. Ocean Game (OG, on the left) and user Interface for treasure-hunting and marine species collection. Ocean Story (OS, on the right) depicting screenshots of diverse animations (intro, curiosities, outro)

The Ocean Story (OS). The story driven experience (Fig. 2, right) featured the same 13 marine species as short animations (4 image frames per second, in a loop). Hand drawn animations of all marine species were coupled with voiceover narration that described the animal's physical characteristics. The story features Madalena, a young fictional character, fond of the sea, who loses her precious notebook, full of scientific notes, during a storm. As a result, she is now asking our young audience to help her recover some of the notebook pages that are actually scattered around the museum. Madalena's story is conveyed by the voice of a young female actress. In addition to the narrated story, characteristic sounds of some exhibited species are added as background sounds (e.g.: the sound of the sea lion). The aesthetic quality of the animation as well as the aural qualities of the narration were intended to function as engaging mechanisms, payoff for the children's engagement. Once near the beacon, the animated content of the missing notebook page would pop up on the mobile screen. The content would narrate three scientific curiosities regarding a specific specie situated very close to the child. Before proceeding in the quest for more notebook pages, children had to view and listen to the three narrated scientific facts in their entirety. The OS participants were also given a headset for the purpose of immersing themselves in the story. Selfie images were omitted as we wanted to immerse children in the story. story ends upon collection of 13 pages of Madalena's notebook, each one focused on a particular taxidermied species of the museum collection. At the end of the journey Madalena' thanks her young helpers and encourages to visit the museum again.

2 Methodology

We tested the OG and the OS with two distinct groups of children, with the same age and demographics. Our participants were between 9 and 10 years of age, 16 children participated in the gamified experience (OG) while 12 children participated in the story-driven experience (OS). In order to compare and contrast the outcomes generated by the gamified (OG) and the story driven (OS) approach to the museum exhibits, three distinct measurements were performed:

- **[M1]** - In both the OG and the OS, we measured skin conductance (hereafter SC) in order to measure children's physiological arousal during their use of each application. The collected data corresponds to 15 s before, and 15 s after specified key moments of each experience, namely the timestamps when the species or notebook pages have discovered.
- **[M2]** - We used pre and post test quizzes to evaluate what the children had learned from each experience. These tests included 13 short questions regarding each one of the 13 taxidermied marine species that were compiled based on our experience (e.g. "Which species use echolocation?"). For each question, multiple-choice answers with three species as examples were provided. For the OG, post test questions were presented on the mobile screen of the application, whereas for the OS, questions were presented on paper, to coincide with the metaphor of the Madalena's notebook.
- **[M3]** - Finally, we used the post test experience scales for (i) enjoyment (Smileyometer) and (ii) engagement (Again-Again Table) from the User Evaluation Toolkit, and (iii) surveys on intrinsic motivation [14, 38], by asking children to rate their own enjoyment, engagement, and intrinsic motivation. In the case of enjoyment, we asked children whether they were happy to participate. Regarding engagement, we asked children to rate whether they would be willing to undergo the experience a second time. Finally, for motivation we asked them to rate questions such as: 'I liked to explore the museum'; 'This activity was fun'; etc. M1 and M3 were further complemented with qualitative observations, that were collected during the children's experiences for both the OG and the OS.

Our study leverages the potential of unobtrusive sensing technologies to collect data regarding users' interactions in the museum context. Recent research shows an increased interest in unobtrusive sensing of interactive experiences [29, 42]. While research on technology driven experiences and gaming is very well established, physiological analysis and unobtrusive sensing in-the-wild is a growing area of interest in affective computing and interaction design [11, 35, 36]. However, there is still a scarcity of emotional understanding of the usage of interactive applications used by younger audiences in-situ. In order to obtain the emotional insight of the children during interactive experiences inside museums, we used the Empatica E4[1], a comfortable wireless wristband, which collect emotional arousal through skin conductance (SC) which is relevant to depicting stress, excitement and empathy [20, 46]. We collected the SC for each and whole participants' experience.

3 Results

In this section, we report on our obtained measurements, in-situ observations while mapping them to our three main research questions:

- **[R1] - Skin Conductance Responses.** In the case of OG, we analyzed and compared skin conductance responses of participants whilst standing in front of the same marine specie for 30 s (Fig. 3, left).

[1] https://www.empatica.com/e4-wristband.

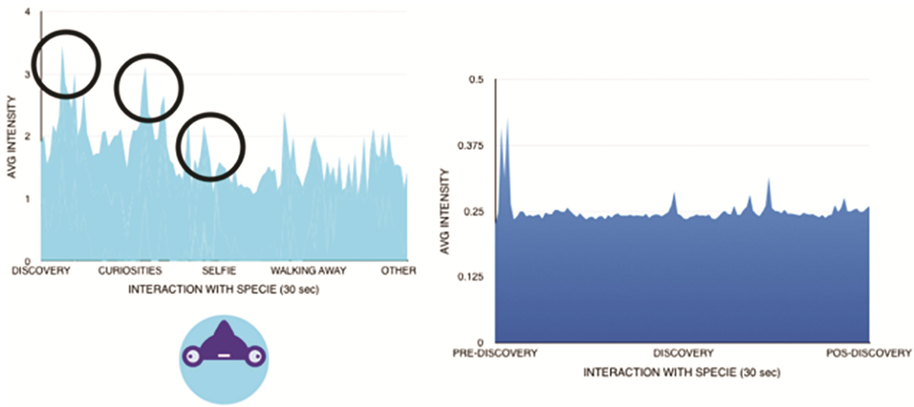

Fig. 3. Ocean Game (OG, left, 30 s × 16 children × 1 marine specie) and Ocean Story (OS, right, 30 s × 12 children × 1 marine specie) - Skin Conductance average during the discovery of a single marine specie (30 s of interactions). **OG Case:** Circles distinguishing the peaks (from left to right): (i) marine species discovered; (ii) curiosities explored; (iii) selfie image taken. **OS Case:** moments include: (i) pre-discovery; (ii) discovery; and (iii) post-discovery.

We have identified three occurring peak patterns (from left to right) and classified them according to the following categories: (i) DISCOVERY (obtained from collected timestamp from the application and synchronized with the wristband) - the moment when marine species and the corresponding beacon has been detected by the phone, and when the visual image of the species performs a subtle animation; (ii) CURIOSITIES (time difference between SELFIE and DISCOVERY) - the moment when participants browse or listen to each one of the three scientific curiosities and explore the characteristics of each marine specie; and (iii) SELFIE (timestamp obtained similarly as in DISCOVERY) - in here, when participants take a selfie snapshot with a single taxidermied marine species. We used these categories to reflect on the diverse moments of arousal paired with the action the child was performing. After analyzing the data, we identified presence of more arousal peaks during the interaction with OG rather than with OS. In fact, in the case of OS, there has been no significant differences between the moments of before, during and after discovering the species (Fig. 3). When analyzing the grand average of SC during the OG, we can observe a declining trend line where the DISCOVERY moment is dominant, followed by the CURIOSITIES and the SELFIE (Fig. 4). In the case of the OS, we did not find any significant differences when comparing the moments before and after discovering each notebook page, and while watching each one of the animations. Children were equally aroused during the animation watching and discovery actions. This suggests that the discovery of the image icon on the beacon (used in OG) or the appearance of it on the screen of the device might cause children to react with excitement to the interaction. Finally, by comparing the grand averages of SC's of all children, for both the OG and the OS (Fig. 5), we find that children are aroused 27% more during the OG.

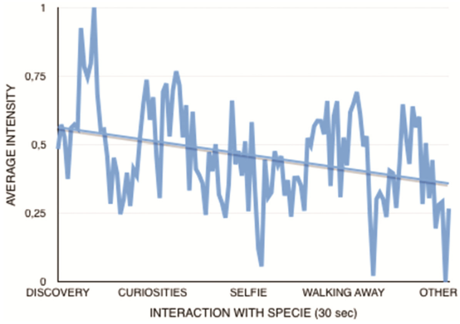

Fig. 4. Ocean Game – Grand average of skin conductance (30 s × 16 children × 13 species)

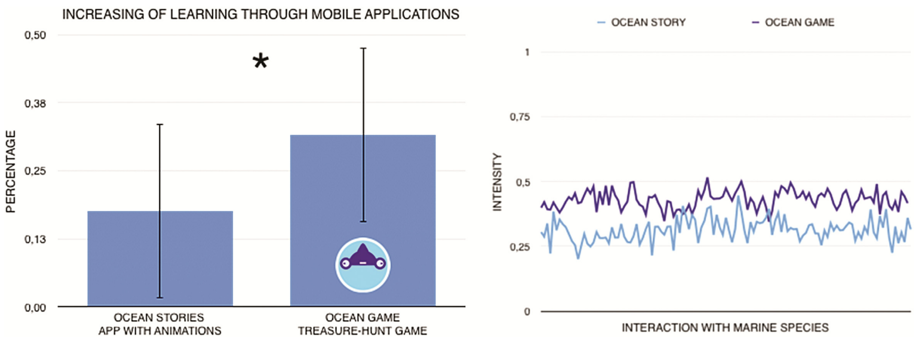

Fig. 5. Comparison of increasing of learning (on the left, with statistical significance) and comparison of grand average of skin conductance (on the right) across the Ocean Story (OS) and the Ocean Game (OG)

- **[R2] - Pre and Post Learning Tests.** Regarding the Q2, we performed the independent Samples T-Test analysis on the pre and post tests from OS ($M = 0.18$, $SD = 0.16$, rated by 12 children) and OG ($M = 0.32$, $SD = 0.16$, rated by 16 children). Percentage score gain showed significant statistical difference ($t = -2.263$, $p = 0.038$) with 95% CI (0.105, 0.175) and large effect size ($d = -0.864$) for OG. In fact, OS group learning was not significant at all ($t = 2.2$, $p = 0.812$) while OG clearly was ($t = 2.13$, $p < 0.00001$) with 95% CI (−925.448, 919.322) and large effect size ($d = -1,769$). Moreover, OS group forgot the knowledge (pre test 91 vs post test 89 correct answers) while OG group increased their ocean literacy knowledge for 44% (from 109 correct answers to 158) as seen in Fig. 5, on the left.
- **[R3] - Experience Scales.** In referring to Q3, at the end of children's exploration of the museum, we asked them to rate their own experiences. Enjoyment and engagement scales in both OG and OS were rated by all 28 children with highest possible scores ($M = 5.00/5.00$ for enjoyment, and $M = 3.00/3.00$ for engagement). Moreover, intrinsic motivation scales in the OG ($M = 4.73/5.00$, $SD = 0.65$, rated by 16 children) and in the OS ($M = 4.69/5.00$, $SD = 0.64$, rated by 12 children) show the data not to

be statistically significant (t = −1.564, p = 0.14). This suggest that both the OG and the OS have the potential of providing similar levels of enjoyment, engagement and intrinsic motivation. Moreover, while observing the children in museum, each group seemed to like both the experiences and the mobile applications.

Timeline Observations. We compared the starting and ending times of all participants for both interactive experiences. Start was identified as a moment when pressing the tag button on Empatica E4 wristband, located on the child's wrist. The end time was identified as a moment when all of the species were collected and quiz responded (OG) or final video watched (OS). In this case, the Ocean Game (OG) timeline showed that all 16 children managed to collect the marine species as well as answer the quiz in an average time of 13 min. For the Ocean Story (OS) the average time of the experiences was 14′22″ (excluding the written test) while the sum of timings of all animations is 13′44″. This shows that children had in average only 38″ to explore the museum and might suggest that children were speeding up the videos. We also observed that in the Ocean Story when children found one notebook page, they would soon move away from the spot where they encountered the content, to explore the rest of museum looking for more pages. When observing the OS participants, children's body language revealed signs of impatience (e.g. constant and rapid movements with one leg) while watching the animations. Moreover, 5 out of 10 children also had a negative time, meaning that they completed the experience before all animations had been completely watched (even below the total time of 13′44″).

In-Situ Observations. During both experiments, we observed children in action and notes were taken in response to our own direct observations. In the end of both experiences, participants were asked for a verbal evaluation of each experience. Regarding the OS, the participants were focused on finding the notebook pages, and rarely stopped to watch the animations. Since the OS content was not signaled by any colored sticker or marker, the children seemed confused or restless and they could not properly identify where to look for it. Our initial choice for not using image stickers was intended to make the task of finding each page more enticing and less obvious. On the other hand, according to our observations, we noted that it did negatively impact the children's exploration of the exhibit. Without visible markers, we often had to help the children find content within the various museum exhibits. Children's verbal feedback about the OS pointed out both positive and negative aspects of the experiences. Regarding the positive ones, the children stated that they liked searching and discovering the pages around the museum, having 7 of them mentioning things like "I like everything! There isn't anything I disliked," but only one of them explicitly reported that he liked to listen to the narrative. Regarding the less positive aspects, 5 of the children reported that they did not like the fact that it was mandatory to listen to all of the narrated scientific curiosities. In fact, we observed that when children would discover a page, they would soon move away to explore the rest of exhibit looking for more. This meant not fully watching some of the animations. Despite the fact that the other beacons were muted while content was running, the children found a way out, and speeded up the animations in order to complete the OS experience without listening to the narrations in full. Moreover, listening to audio in pairs was not something that the children were willing to do, thus when in pairs they always skipped content and moved to the next phase of the experience. Furthermore, it is interesting to notice that none of the children referred to the animations in a positive nor a negative way. In fact, they only talked about the narrated story. On the other hand, we did not ask specific questions regarding the visual qualities of the animations.

In the case of OG, most obvious observation revolved around the fact that most of the children's attention was spent on the task of taking a self-portrait with each one of the 13-marine species (this was also one of the peak arousal patters detected through the SC data). We also noticed that most of the children were concerned with their physical presentation in the self-portraits. Only few of the participants were interested in observing the taxidermied artifacts, and most children spent their time running around the museum in search for the image icons (which coincided with a peak arousal moment according to the SC data). However, the children that were focused on the museum artifacts were often thinking out loud with expressions such as: "I did not know that the seahorses were such small creatures. I thought they were bigger than this". These observations show that the children were connecting the digital visual images of the game with the artifacts that were presented in the museum. We were also able to conclude that most children were highly interested in collecting the image icons and points. Moreover, the children who focused on the museum artifacts were the only ones who actually took self-portraits with the taxidermied species as opposed to the rest of the children who were taking self-portraits with the image icon that was covering the proximity beacon. Also, only a few children spent time reading the scientific information presented in short texts on the screen, after capturing each marine specie's image icon. From the insights from post tests, it was evident that not all of them took the time or read or even understand the information. Overall, most children were reading or looking through the text quite rapidly and rushing through the game with the aim of finishing it on time. Regarding the quiz, at the end of the game, we noted one child worrying about their performance: "Ouch, I might not be able to get it right." Another child went back to the exhibit and as way of verifying their answers. Similarly to OS, all the children when asked reported feeling of excitement and enjoyment regarding the experience.

4 Discussion

In this section, we discuss the obtained results, report our insights, outline several research limitations as well as potential future studies.

Children and Scientific Information Delivery. In both applications, while both interventions were met with high excitement by all children, we detected difficulties in engaging children with the scientific information proposed. Reflecting on the users' timelines we noted that the story-driven experience (OS) was sometimes completed before the total time that it would take to watch all of the animations in a sequence. While observing, we noted signs of impatience in children's body posture while listening to the narrations. We envisage that audio narrations, even if enhanced by special marine and underwater sounds, were not enough to hold the children's attention. We can attribute this to the unfinished qualities of some of the animations. More nuanced plot and character development as well as longer and more detailed animations accompanying the narrations might yield different results. Also, listening to audio in pairs was not an easy task for the children, who would excite each other and want to move on to more action together. For the Ocean Game (OG) similarly, children often just skimmed through the scientific curiosities reported in text, they often would not read but just pretend to, in order to be able to get the points and collect image icons. The results then were evident in the learning evaluation where they were not able to recall the correct answers to the post test questions.

Ocean Game Versus Ocean Story Excitement. Regarding Q1, and according to the collected data, the game experience resulted more exciting than the story experience. Data from biofeedback reveal that children were nearly one third more aroused during the OG rather than the OS (Fig. 5, right). Despite that it is arduous enough to derive exact explanations form the biofeedback alone, we can attempt some reasoning of the why's. Children experiencing the OS lost focus due to the visually repetitive nature of some of the animations and lack of visual signals in the museum to help them look for the content. In fact, the encounters with the marine species' digital icons in OG portrayed the highest arousal moment (overall for both experiences). However, we should take into account that it is entirely possible that the children were just excited to be at the museum, regardless of the technology employed.

Treasure-Hunting and Collecting Mechanisms. Through both studies we detected the highly motivating and exciting results from the treasure hunt (OG and OS) and collecting (OG) mechanisms generated by the applications. From our observations of the OG, we noted that children's excitement would raise when digital icons would appear on their mobile screen, as the children were producing sounds of excitement. On the other hand, in order to give prominence and flow to the story in OS, we did not place any visual cues to help children find content. The treasure hunt feeling in the OS was weakened instead of strengthened. Children were still motivated to look around the museum for content but less excitement was detected in the task. Moreover, we observe that children in OG were willing to find the species incentivized by the task of collecting the digital icons corresponding to each marine specie. As observed by O'Hara et al. [34], collection goals help children motivate their task when using playful mobile learning tools. This was not the case in OS.

Learning Outcomes. The OG reported double learning outcomes compared to the OS, despite the fact that engaging children with the learning content proved challenging in both applications. Regarding Q2, findings showed from the pre and post tests that children learned twice as much when engaged with the gamified experience when compared to the story-driven one. We would assume that, with the OG experience, the learning of the scientific information was reinforced by being presented as a short text and animated icons, compared to the long animations and narrations of the OS. In line with this, we can infer that the story-driven experience was asking for a higher and longer-term concentration. We can summarize that information is best presented as short nuggets of facts instead of longer scientific narrations. Long-term retention seems limited, so strategies for improving it are interesting areas for future work.

Games and Stories in Relation to Engagement and Motivation During Museum Visits. Finally, in relation to Q3, the children expressed themselves positively regarding engagement and intrinsic motivation for both the OG and the OS interactive experiences. Conversely, most of the children showed interest when searching and discovering the exhibition artifacts in novel ways. Nonetheless, we need to be also aware that their feedback could be a consequence of children acquiesce bias, as children are notoriously willing to please the adults and teachers. Therefore, we are aware of the limitations of using these scales as sole measurements of enjoyment and engagement to demonstrate how our young audience genuinely responded to both experiences.

5 Concluding Remarks

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In summary, we learned that children are easy to engage in treasure hunt tasks and enjoy the use of both mobile games and mobile stories. The gamifications aspect of collecting digital icons, points and achievements worked well as a motivation to search around the museum. Nevertheless, this needs to be balanced with a more careful interface design so that the exploration does not take over from the learning objectives. Audio narration is not enough of a channel to involve young children with scientific content, even if coupled with simple animations, while short text seemed more effective. We envisage that with more appealing animations supporting the narrative, these results could be revisited and eventually we want to extend our testing to check the children's emotional connections with the story and its characters, or the digital icons of the marine species collected during the game. Finally, for these analyses we should take into the consideration that the age of children might have played an important role and how easily they engage in gaming practices rather than more reflective story experiences. Also, skin conductance data lack baselines per each child which are omitted with the purpose of avoiding the in-vitru setting and focusing on experience. Conversely, interference of wristbands with the clothes or activities of children might affect the data. Also, recruiting at least 20 participants per treatment would alleviate statistical issues with sample size. The story component was also focused on audio over visuals, however the oral narration could be much more compelling if accompanied by other sounds, which we tend to improve in future versions. Future work will also focus on improving several aspects of both applications, balancing learning with playful aspects of both, and on multimodal analysis of the differences of other collected physiological data (heart-rate variability inferred from blood-volume pulse, temperature, and movement from accelerometer) in comparison with our skin conductance results.

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References

1. Aarseth, E.: Cybertext: Perspectives on Ergodic Literature. The Johns Hopkins University Press, Baltimore and London (1997)
2. Aarseth, E.: Genre trouble: narrativism and the art of simulation. In: Wardrip-Fruin, N., Harrigan, P. (eds.) First Person: New Media as Story, Performance, and Game. The MIT Press, Cambridge (2004)
3. Bakken, S.M., Pierroux, P.: Framing a topic: mobile video tasks in museum learning. Learn. Cult. Soc. Interact. **5**, 54–65 (2015)
4. Barton, J., Kindberg, T.: The Cooltown User Experience. HP Hewlett Packard, Palo Alto (2001)
5. Beale, K.: Museums at Play: Games, Interaction and Learning. Museums Etc, Edinburgh (2011)
6. Bedford, L.: Storytelling: the real work of museums. Curator Mus. J. **44**(1), 27–34 (2001)
7. Bogost, I.: Persuasive Games: The Expressive Power of Videogames. The MIT Press, Cambridge (2007)
8. Cabrera, J.S., Frutos, H.M., Stoica, A.G., et al.: Mystery in the museum: collaborative learning activities using handheld devices. In: Proceedings of the 7th International Conference on Human Computer Interaction with Mobile Devices and Services, pp. 315–318. ACM (2005)
9. Cahill, C., Kuhn, A., Schmoll, S., Lo, W.-T., McNally, B., Quintana, C.: Mobile learning in museums: how mobile supports for learning influence student behavior. In: Proceedings of the 10th International Conference on Interaction Design and Children, pp. 21–28. ACM (2011)
10. Charitonos, K., Blake, C., Scanlon, E., Jones, A.: Museum learning via social and mobile technologies: (how) can online interactions enhance the visitor experience? Br. J. Educ. Technol. **43**(5), 802–819 (2012)
11. Clegg, T., Norooz, L., Kang, S., Byrne, V., Katzen, M., Valez, R., Bonsignore, E.: Live physiological sensing and visualization ecosystems: an activity theory analysis. In: Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems, pp. 2029–2041. ACM (2017)
12. Damala, A., van der Vaart, M., Clarke, L., et al.: Evaluating tangible and multisensory museum visiting experiences: lessons learned from the meSch project. In: Museums and the Web 2016, MW 2016 (2016)
13. Deterding, S., Björk, S.L., Nacke, L.E., Dixon, D., Lawley, E.: Designing gamification: creating gameful and playful experiences. In: CHI 2013 Extended Abstracts on Human Factors in Computing Systems, pp. 3263–3266. ACM (2013)
14. Dijk, E., Lingnau, A., Kockelkorn, H.: Measuring enjoyment of an interactive museum experience. In: Proceedings of the 14th ACM International Conference on Multimodal Interaction (ICMI 2012), pp. 249–256 (2012). https://doi.org/10.1145/2388676.2388728

15. Dini, R., Paternò, F., Santoro, C.: An environment to support multi-user interaction and cooperation for improving museum visits through games. In: Proceedings of the 9th International Conference on Human Computer Interaction with Mobile Devices and Services, pp. 515–521. ACM (2007)
16. Edwards, S., Schaller, D.: The name of the game: museums and digital learning elements. In: Din, H., Hecht, P. (eds.) The Digital Museum: A Think Guide. American Association of Museums, Washington, DC (2007)
17. Falk, J.H., Dierking, L.D.: Learning from Museums: Visitor Experiences and the Making of Meaning. AltaMira Press, Walnut Creek (2000)
18. Fleck, M., Frid, M., Kindberg, T., O'Brien-Strain, E., Rajani, R., Spasojevic, M.: From informing to remembering: ubiquitous systems in interactive museums. IEEE Pervasive Comput. **1**(2), 13–21 (2012)
19. Hawkey, R.: Learning with Digital Technologies in Museums, Science Centres and Galleries. NESTA Futurelab Research (2004)
20. Hernandez, J., McDuff, D., Benavides, X., Amores, J., Maes, P., Picard, R.W.: AutoEmotive: bringing empathy to the driving experience to manage stress. In: Proceedings of the Companion Publication on Designing Interactive Systems, (DIS 2014), Vancouver, BC, Canada, 21–25 June 2014. https://doi.org/10.1145/2598784.2602780
21. Hsi, S., Fait, H.: RFID enhances visitors' museum experience at the exploratorium. Commun. ACM **48**(9), 60–65 (2005)
22. Ioannidis, Y., El Raheb, K., Toli, E., Katifori, A., Boile, M., Mazura, M.: One object many stories: Introducing ICT in museums and collections through digital storytelling. In: Digital Heritage International Congress (DigitalHeritage), vol. 1, pp. 421–424. IEEE (2013)
23. Jenkins, H.: Game design as narrative architecture. In: Wardrip-Fruin, N., Harrigan, P. (eds.) First Person: New Media as Story, Performance, and Game. The MIT Press, Cambridge (2004)
24. Juul, J.: Games telling stories? - a brief note on games and narratives. Game Stud. **1**(1) (2001). http://www.gamestudies.org
25. Katifori, A., et al.: CHESS: personalized storytelling experiences in museums. In: Mitchell, A., Fernández-Vara, C., Thue, D. (eds.) ICIDS 2014. LNCS, vol. 8832, pp. 232–235. Springer, Cham (2014). https://doi.org/10.1007/978-3-319-12337-0_28
26. Kelly, L.: The interrelationships between adult museum visitors' learning and their museum experiences (2007). http://australianmuseum.net.au/uploads/documents/6663/final%20thesis%20for%20graduation_kelly.pdf
27. Koushik, M., Lee, E.J., Pieroni, L., Sun, E., Yeh, C.-W.: Re-envisioning the museum experience: combining new technology with social-networking. In: Yang, H.S., Malaka, R., Hoshino, J., Han, J.H. (eds.) ICEC 2010. LNCS, vol. 6243, pp. 248–253. Springer, Heidelberg (2010). https://doi.org/10.1007/978-3-642-15399-0_24
28. Laurel, B.: Computers as Theatre. Addison-Wesley Longman Publishing Co., Inc., Boston (1991)
29. Liang, F., Nakatani, M., Kunze, K., Minamizawa, K.: Personalized record of the city Wander with a wearable device: a pilot study. In: Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct, pp. 141–144. ACM, New York (2016)
30. Martin, J., Trummer, C.: Personalized multimedia information system for museums and exhibitions. In: Maybury, M., Stock, O., Wahlster, W. (eds.) INTETAIN 2005. LNCS, vol. 3814, pp. 332–335. Springer, Heidelberg (2005). https://doi.org/10.1007/11590323_46
31. Marty, P.F., Mendenhall, A., Douglas, I., et al.: The iterative design of a mobile learning application to support scientific inquiry. J. Learn. Des. **6**(2), 41–66 (2013)

32. Murray, J.: From game-story to cyberdrama. In: Wardrip-Fruin, N., Harrigan, P. (eds.) First Person: New Media as Story, Performance, and Game. The MIT Press, Cambridge (2004)
33. Nilsson, T, Blackwell, A., Hogsden, C., Scruton, D.: Ghosts! a location-based Bluetooth LE mobile game for museum exploration. arXiv:1607.05654 [cs] (2016). http://arxiv.org/abs/1607.05654. Accessed 14 Jan 2017
34. O'Hara, K., Kindberg, T., Glancy, M., Baptista, L., Sukumaran, B., Kahana, G., Rowbotham, J.: Collecting and sharing location-based content on mobile phones in a zoo visitor experience. Comput. Support. Coop. Work (CSCW) **16**(1–2), 11–44 (2007)
35. Onorati, F., Regalia, G., Caborni, C., Picard, R.: Improvement of a convulsive seizure detector relying on accelerometer and electrodermal activity collected continuously by a wristband. Presented at the 2016 Epilepsy Pipeline Conference, San Francisco, California (2016)
36. Picard, R.W.: Measuring affect in the wild. In: D'Mello, S., Graesser, A., Schuller, B., Martin, J.-C. (eds.) ACII 2011. LNCS, vol. 6974, p. 3. Springer, Heidelberg (2011). https://doi.org/10.1007/978-3-642-24600-5_3
37. Pierroux, P., Bannon, L., Walker, K., Hall, T., Kaptelinin, V., Stuedahl, D.: MUSTEL: framing the design of technology-enhanced learning activities for museum visitors. Archives & Museum Informatics (2007)
38. Read, J., Macfarlane, S.: Endurability, engagement and expectations: measuring children's fun. In: Interaction Design and Children, pp. 1–23. Shaker Publishing (2002)
39. Ryan, M.: From narrative games to playable stories: toward a poetics of interactive narrative. Storyworlds J. Narrat. Stud. **1**, 43–59 (2009)
40. Sánchez, I., Cortés, M., Riekki, J., Oja, M.: NFC-based interactive learning environments for children. In: Proceedings of the 10th International Conference on Interaction Design and Children, pp. 205–208. ACM (2011). https://doi.org/10.1145/1999030.1999062
41. Shaffer, D.W., Squire, K.R., Halverson, R., Gee, J.P.: Video games and the future of learning. Phi Delta Kappan **87**(2), 105–111 (2005)
42. Sparrow, L.: Variations in visual exploration and physiological reactions during art perception when children visit the museum with a mobile electronic guide. In: Kapoula, Z., Vernet, M. (eds.) Aesthetics and Neuroscience, pp. 131–137. Springer, Cham (2016). https://doi.org/10.1007/978-3-319-46233-2_9
43. Springer, J., Borst Brazas, J., Kajder, S.: Digital storytelling at the national gallery of art. In: Bearman, D., Trant, J. (eds.) Museums and the Web. Archives & Museums Informatics, Arlington (2004)
44. Sung, Y.-T., Chang, K.-E., Hou, H.-T., Chen, P.-F.: Designing an electronic guidebook for learning engagement in a museum of history. Comput. Hum. Behav. **26**(1), 74–83 (2010)
45. Sykes, E.R., Pentland, S., Nardi, S.: Context-aware mobile apps using iBeacons: towards smarter interactions. In: Proceedings of the 25th Annual International Conference on Computer Science and Software Engineering, pp. 120–129. IBM Corp. (2015)
46. Westerink, J.H., Van Den Broek, E.L., Schut, M.H., Van Herk, J., Tuinenbreijer, K.: Computing emotion awareness through galvanic skin response and facial electromyography. In: Westerink, J.H.D.M., Ouwerkerk, M., Overbeek, T.J.M., Pasveer, W.F., de Ruyter, B. (eds.) Probing Experience, pp. 149–162. Springer, Dordrecht (2008). https://doi.org/10.1007/978-1-4020-6593-4_14
47. Wyman, B., Smith, S., Meyers, D., Godfrey, M.: Digital Storytelling in museums: observations and best practices. Curator Mus. J. **54**(4), 461–468 (2011)

48. Xhembulla, J.R.: Intrigue at the museum: facilitating engagement and learning through a location-based mobile game. International Association for the Development of the Information Society (2014). https://eric.ed.gov/?id=ED557238. Accessed 15 Jan 2017
49. Zimmerman, E.: Narrative, interactivity, play, and games: four naughty concepts in need of discipline. In: Wardrip-Fruin, N., Harrigan, P. (eds.) First Person: New Media as Story, Performance, and Game. The MIT Press, Cambridge (2004)