The design of a smartphone-based AR application to support the experiential quality of life-like in a museum

SANDRA DANG
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ENGLISH – ABSTRACT

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In the perfect scenario, augmented reality (AR) is described to blend the physical world with virtual elements in such way that the user can’t differentiate them, having the potential to make the interactions with virtual objects in an AR experience feel life-like. With the latest advancements in AR for mobile devices, applications that use this technology are increasing. Many cultural heritage sites and museums take advantage of integrating AR in their programs to create enriched environments and increased engagement from their audience. This study investigated how to design for a life-like experience in a museum environment, presenting animated virtual animals that represent the same preserved animals exhibited in the physical environment. The study was grounded in a Research through Design process where a smartphone application prototype was developed and tested to find important elements that create life-like interactions. The functionalities that were developed for the prototype were discussed by their experiential qualities and summarized into points that a designer should consider when designing for a similar life-like experience.

SVENSKA – SAMMANFATTNING

Utformningen av en smartphone-baserad AR-applikationen för att stödja en levande upplevelse och interaktion på ett museum

The design of a smartphone-based AR application to support the experiential quality of life-like in a museum

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ABSTRACT
In the perfect scenario, augmented reality (AR) is described to blend the physical world with virtual elements in such way that the user can’t differentiate them, having the potential to make the interactions with virtual objects in an AR experience feel life-like. With the latest advancements in AR for mobile devices, applications that use this technology are increasing. Many cultural heritage sites and museums take advantage of integrating AR in their programs to create enriched environments and increased engagement from their audience. This study investigated how to design for a life-like experience in a museum environment, presenting animated virtual animals that represent the same preserved animals exhibited in the physical environment. The study was grounded in a Research through Design process where a smartphone application prototype was developed and tested to find important elements that create life-like interactions. The functionalities that were developed for the prototype were discussed by their experiential qualities and summarized into points that a designer should consider when designing for a similar life-like experience.

Author Keywords
Augmented reality; Museum; Experiential qualities; Life-like experience

INTRODUCTION
Augmented reality (AR) is a term used to describe how the physical world is combined with virtual content to create a more enhanced reality. By letting virtual and real objects coexist in a seamless way, where the user in a perfect scenario can’t make a distinction between the both, gives the possibility for creating new experiences in the existing environment [19, 20, 28].

Many mobile phones today support technologies that enable mobile AR (MAR) and applications that use this technology has therefore increased in the last years. Many of the applications target tourism and museums for city tours or discovering cultural heritages and art [e.g. 4, 5, 13, 14, 17, 23]. Publications in the area are wide ranging where some are addressing how the technological aspects makes AR possible [3, 8, 9]. Other studies that are more design-focused, develop a prototype to then evaluate the usability instead of addressing the experience it creates. The majority that does evaluate the AR experience, focus on the learning or engaging experiences that an AR environment can bring to a site [4, 17, 23]. However, few have addressed how to actually design for the experience of a potential perfect scenario where both virtual and physical elements blend together so that the virtual elements feel life-like. This motivates me to investigate what important design qualities that would make an MAR experience feel more life-like. I will investigate this by adding elements of 3D modelled and animated characters to a museum environment that exhibits preserved animals.

Research question
How can a mobile augmented reality application be designed to incorporate experiential qualities that support the feeling of life-like for museum visitors? A study of the Swedish Museum of Natural History1, adding animated virtual representations of the exhibited preserved animals.

BACKGROUND & RELATED WORK
Here, I will briefly review prior work on using AR applications in settings of museums and cultural heritages. I will also give a review on what values that AR brings to these sites followed by a review on using life-like virtual characters to increase the engagement of the user.

AR use and the values it brings to museums
AR has started to become widely used to enhance the experience of tourist attractions and museums, and the implementations are wide ranging [e.g. 4, 5, 13, 14, 17, 23]. There are applications that focuses on enhancing the learning experience by extending the content of the museum exhibits with virtual information [1, 17, 23]. Others have integrated gamification with the technology to investigate how it can influence visitors’ cultural interest [1, 5, 23]. Nofal et al. [23] found the combination of AR and gamification to support collaboration and social interaction among young museum visitors when integrating 3D puzzles and posting cards to share on social media. Hammady et al. [5] evolved their analysis of constraints within AR into

1 http://www.nrm.se/
suggested an app with game elements for the Egyptian museum in Cairo. The app that they suggested first tells a story and ends with a game where users are to defeat the evils in the story. With this, the authors expected that the visitors could learn about the Egyptian culture through a unique experience. Benckendorff et al. [1] suggest using the frameworks of game design (mechanics and aesthetics) to produce informative guiding AR apps. By using the frameworks would outcome in visitors changing attitude and behaviour towards an increased engagement and motivation towards heritage appreciation when using the app.

A third way of implementing AR is through using it as a map system or tour guide for helping visitors and tourists to find their way through a museum or a holiday site. For example, Kourothanassis et al. [13] developed and evaluated a geolocation-based AR tour guide app, CorfuAR, for tourists to find their way to attractions and points of interest on the Greek island of Corfu. By mapping the perceived performance, usability, and experiential effects in accordance to the users’ behavioural responses, the investigation showed that AR with GPS provided a useful and pleasing experience for the visitors. Lim et al., [14] listed other virtual tour guides such as PEACH that is developed for a museum environment. This guide adapts the presentations to what the user has visited before. Gimeno et al. [4] uses Bluetooth technology to retrieve the users’ indoor location in the Casa Battlo museum in Barcelona, so that the AR guide can present information relevant to the room of where the user is present.

There are aspects to consider when designing an AR app for the use of guiding or for use on-the-go. It has been found that it “in terms of scene augmentation, accurate overlaying of graphics is not necessary. What is important is a synchrony between the different sense of enhancements on the real environment. In other words, a presentation has to appear at the right place and at the right time.” [14]. Kourothanassis et al. [13] concluded the same in their study, that keeping the users engaged with the content of an app while on-the-go, the content in the application must be presented relevant-to-the-task as it minimizes the cognitive overload and information noise. Other important usability factors that have been recognised are reliable up-to-date content and consistency. “Providing appropriate feedback, being consistent, and providing error recovery” [18] are guiding principles within HCI when designing for enhanced usability and affordance.

With the wide ranging applications of AR, Dieck & Jung [2] saw the need to analyse if investing in AR gives value for museums. The findings showed that the perceived value that it brings varies depending on the different stakeholders. Internal stakeholders such as CEOs and office managers put high values on the economical perspectives and believe that AR would attract new target groups, increase sales and justify admission fees. Teachers and visitors saw that it would bring more value within categories of learnings and social interaction such as gamification. Common to all stakeholders’ interests was that the most value that AR brings to a museum environment is the engaging interaction that makes the visitors more likely to gain interests in the exhibit and remember the content, because it makes history come to life and enriches the users’ emotional attachment to the story [2]. Richer engagement as a result of using AR was also identified by the earlier mentioned related work [4, 5, 14, 17, 23].

Life-like virtual characters

Although the many successful applications of AR mentioned above, Lim et al., [14] criticise many of the current applications that use virtual guides for not letting the users adapt the applications to their personal preferences and most importantly, that they lack of life-like animated characters. The authors motivate that users become even more engaged in the exhibits, spend more time and are more likely to be perceptive of the information if using life-like virtual characters in the interface to guide the visitors. The engagement would become even more enhanced if visitors could empathize with the life-like animated characters if interacting with them and being told a story from the characters’ own experiences and views. With life-like animated characters they also see the need of “the oddity, the quirk, that gives personality to a character and it is personality that gives life. [...] Both empathy and personality are primary means to create ‘the illusion of life’, permitting user’s suspension of disbelief” [14].

One example of using life-like animated characters in AR is the Pokémon Go, an AR and geolocation-based smartphone game. The game asks players to locate, catch and interact with animal-like virtual creatures in the real environment. Released in 2016, it was the first mobile AR game to top the charts of mobile application [25]. However, the application was not unique to its use of geo-location and AR, the game already existed in another application by the same publisher. But it was not until the adaptation of using animal-like characters that it gained the great success [12] which could prove Lim et al., theories. The great success has been investigated by many researchers [12, 25, 32] and has been found to be grounded in the users’ empathy for the characters as they recognise them from the forerunner of animated TV series, bringing nostalgia to users [12, 32].

METHOD

Here, I will describe the methods that was used and the structure that the design process followed.

Research through design

The method that was used to design the AR experience in
this paper is Research through Design (RtD). The findings in RtD is grounded in the design process where the problem and solutions are explored. During the process of designing and developing a concept or an artefact, new knowledge can be generated and gained. This knowledge can then be articulated through different ways e.g. annotated portfolios, strong concepts, experiential qualities, design methods or design principles [6, 31]. In this study, I have chosen to express the knowledge that was gained from the design process through experiential qualities. Experiential qualities are the key qualities of digital artefacts that suggest usability conditions for design and research [22, 29]. Löwgren describes them as qualities that characterise aspects of using digital products and services “for other designers to appropriate in order to develop their own judgment ability, and to elaborate and modify drawing on their own experience” [11]. There are many experiential qualities that has been identified in the direction towards “how the interaction feels” [11]. This research aims to find experiential qualities in the designed application that could motivate that the AR environment feels life-like for the museum visitors. The degree of which an experience feels life-like is in this study defined as an experience where characters have a personality given by their oddity and quiriness.

**Technology overview**
There are a wide range of technologies that can be used for MAR. The major difference between the technologies is how they track the surrounding physical environment. There are three main tracking technologies used for AR: vision-based, sensor-based and a combination of them both called hybrid tracking [3]. The technology that was chosen for this AR experience was the image-based tracking that lies within the computer vision field of AR and the software used is developed by Apple, ARKit. This software detects pre-assigned images and uses their positions to place virtual content [33]. The software was chosen due to its ability to keep the virtual content stable even when the image target is no longer visible for the mobile camera’s field of view. With this technology, it did not need the addition of Bluetooth technology that many MAR applications use for guiding experiences in museums [e.g. 4], however it came with the drawback on the tracking accuracy. The application was developed in the game engine Unity for the device model iPhone 6s.

**Design process**
The phases that affected the design procedure was mainly observations, design meetings, developing and finally also involving others in evaluating the prototype. Below is a more in-depth description of each phase.

**Observations**
Observations were made to see how the exhibition looked like and how visitors interacted with the current setup. The observations were to understand approximately how long time the visitors spent at each showcase and what they did when looking into it. It was also to get an understanding of how the visitors retained information about the content in showcases.

**Design meeting with the museum advisories**
To understand how to design an AR experience for the museum environment a design meeting was held together with the head of the museum, the program coordinator and the co-designer of the application. The co-designer in the project is an architect and artist that describes his work as bridging nature with virtual environment. The basic idea of this project was founded by the artist and his role is therefore playing an important role in the design process of the autobiographical approach, (explained in the next paragraph). The other involved stakeholders were chosen because of the head of the museum’s knowledge of the museum’s general goals and interests and the program coordinator for her knowledge about planning activities for visitors and what activities are appreciated. The purpose for having the meeting was to gain knowledge about how the museum experts thought an AR environment could be useful in the museum.

The meeting converged from an experimental mobile AR prototype that was designed to show the general concepts of AR and how virtual content could be represented together with the real environment. The virtual content of the prototype contained 3D animated animals that changed their animation behaviour with screen touch interactions. This was to show the basics of how the virtual content could be controlled through smartphone interactions. To also add elements to suggest some quiriness and increased engagement, the animated virtual animals were models of hybrid animals. The hybrid animals used, were for example a mixture of a bat and a horse, which was a bat body with a horse head, or a moose and a tiger, which was a moose body with tiger texture and tail. Ideas on how to extend the prototype and implement it in the current exhibitions were then generated through a brainstorming session and further design meetings.

**Autobiographical design**
Designing the application for the museum included an autobiographical design enquiry. This means that the design process has its starting point from “yourself, your own experiences and desires as key in developing the design” [6]. As motivated in many cases, reported by Neustaedter & Sengers [21], this method is commonly used before other users are invited to test the design so that the invited participants can give valuable insights that doesn’t concern design problems that could have been found through a simple test of the own design, for example software bugs. It
also supports faster iterations than if users would have been invited in every step of the process.

In this study, the ideas and design choices in the prototype were developed through discussions about the experiences and desires between me and the co-designer. As the desires were formulated into concrete design elements and added to the prototype, they were tested both in the development environment and in the museum. The tests generated experiences (new desires and findings of software bugs) that were used to iterate the prototype.

**Involving users to evaluate the design**

When the prototype included all my and the co-designer’s desires and it was good enough to be tested by others, participants were invited to evaluate it in the museum setting. By involving others, knowledge about what designs were good and what needed refinements could be gained. Five of the participants were interaction design students and two were not familiar with the concepts of interaction design. Including other interaction designers in an experience-based design process is motivated by Udsen & Jørgensen and Nielsen et. al., [22, 27] that say it can help articulate experiences in a way that brings value in the process of creating engagement that can’t be expressed by the users themselves. All of the participants had tested smartphone-based AR before. Their ages ranged from 24-27 years. Five of them were female and two were male.

The 7 participants were given a smartphone with the application pre-installed and were told that it would extend the exhibit that is currently represented in the room with an AR environment. A short introduction to what it was supposed to do was presented however, during the actual test, interference with the participant’s use were made as little as possible. Instead, when the participants did not understand, they were informed about what to do in the application while a note about what information were given was written down.

After testing the prototype, a semi-structured interview was held in order to understand what design improvements were necessary and what their felt experiences were. Both improvements and felt experiences were collected through qualitative questions. However, some of the felt experiences were also collected quantitatively through Likert scales [24, 26], a common way to measure attitude. Likert scales let the users rate predefined phrases that are formulated to help describe the participants’ satisfaction and engagement. The phrases in a Likert scale are provided with options for the user to rate the intensity of their attitude, in this case on a scale between 1 equals to ‘Strongly disagree’ and 5 equals to ‘Strongly agree’. The interviews were held in Swedish, and no explanation was given to the word ‘life-like’.

**THE DESIGN CASE**

The results from the design case are presented in the sections of 1) the outcomes from the observation and initial design meeting and 2) different designed functionalities in the prototype that articulated the experiential quality of feeling life-like. Each functionality is first briefly described, followed by a description of how the autobiographical discussion affected the design and finally how the participants’ thoughts were used to further develop the design.

**The overall experience**

**The museum without AR environment**

It was found from the observations that the exhibit is made out of 64 showcases with the majority consisting of preserved animals mounted in scenarios to display their natural habits such as a fox looking for food under the snow, a lynx attacking a bird or playful wolves living in herds. Although the preserved animals gain the most attention from the visitors, the attention is altered between video screens that shows documentary shots of the animals in front of the showcases. Some showcases are designed to be interactive puzzles where the visitors tend to stay longer. Smartphone use is common in conjunction of discovering the exhibit, many of the visitors interact with the preserved animals by taking photos of them, either accompanied with themselves or with the visitors’ friends and family in the photos. This observation motivated the use of AR in the environment. Parents or grandparents often look at the showcases while telling their younger company about their own encounters with the specific animal in the wild. Many children see the exhibit as a playground, running from one showcase to another.

**Adding on with an AR environment**

The idea that came out of the brainstorming session at the design meeting with the museum advisories suggested to use virtual guides that represented animals in the exhibition. The guide could bring the visitors to the real animal showcases through the AR application and encourage visitors that does not have a booked tour guide to enter exhibits with low flow of visitors. In this case, the exhibition of Swedish Nature.

One of the aspects that was important for the museum to include in the application, was a learning experience. How the museum currently implements the learning experience when visitors does not have a personal guide, is to give quiz rounds where the answers of the questions are found when looking into the showcases of the exhibit. There are also interactive screens and showcases in the exhibit. However, the desire of the AR experience would not be to replace the current setup but instead be to explore how to extend it with an AR environment. With the possibilities of smartphone interactions, this allowed us to discuss ideas of a gamified
learning experience in the application. Because the AR prototype that was used in the brainstorming session contained 3D models of hybrid animals (figure 1), the idea of letting the users explore the evolutionary theory in a fictive way was formed, giving the visitors the possibility to mix different preserved animals into new virtual fictive hybrid animals. This would also give a contrast to the life-like experience that would help increase the engagement and not just turn the museum into a virtual zoo. What is important to note however, is that the learning experience was the museum’s desires but was kept outside the scope of the design focus.

![Screenshot of the prototype](image1.png)

**Figure 1. Screenshots of the prototype that was used in the design meeting to show the concepts of AR. It included different virtual hybrid animals (left), for example a bat-horse (right), to give a sense of possibilities in the experience.**

**Virtual guide**

The designed experience started at the entrance to the Swedish Nature exhibition. There the user could find an image target that generated an impersonated virtual guide when the user directed the smartphone camera towards it. During the sessions with invited participants to evaluate the app, the guide was figured as a hybrid of a moose and a tiger. The guide greeted the visitor to the exhibition with information about hybrid animals in the virtual environment. The virtual guide then turned around, walked towards the next task while asking the visitor to follow along to a showcase where the visitor could find another image target. The encounter with the virtual guide can be seen in figure 2.

![Virtual guide](image2.png)

**Figure 2. The virtual guide greeting the visitor, describing the exhibit and asking the visitor to follow along to the next task.**

The decision of having a guide was also to make visitors navigate themselves to the Swedish Nature exhibition. However, even if the content was stable when the camera lost the tracking of the image target (as described in the method section) the technology had small drifting problems that increased when moving too long distances from the image target. Due to this technical challenge to make the figured virtual guide navigate in a stable way from the museum’s main entrance on the first floor to the chosen exhibition on the second floor, it was decided to initialize the guide at the exhibition entrance instead.

**Involving other users, further development and refinements**

All participants that tested the app mentioned that the guide was the part that worked best in the experience because it made the instructions more interesting to follow.

“*What worked best is the moose as guide and that it talked to me instead of just having instruction texts.*” - P1

“*What was intuitive was that you should follow the moose, because it told me to.*” - P6

In the version that was tested by participants, the guide was only present until the next animal was generated. This made the application lack of further instructions after a new virtual animal was found. The desire of having the guide to follow along during the whole experience was mentioned when asking the participants for improvements.

“*For improvements, I would say to add more information for example if the moose continues with us and tells us about how to mix the animals.*” - P6

“*Perhaps a text similar to when it says ‘Follow me’. For example, ‘Look here and this now’ or ‘Now you have found a new animal’. *” - P1

It was mentioned that there was a desire to go backwards in
the text description and that not all information should appear at once in case the user forgets. A solution for refining this function was discussed between me and the co-designer around adding reminders in the app for cases when a reasonable time had passed without the user proceeding to the next step of the experience. This goes in hand with McGrenere & Ho [18] guideline principles of usability factors, mentioned in the background, to present information relevant to the task. Another participant confirmed this:

“It is fine that new texts appear along the way in case you forget.” - P2

Outside the current designed experienced, a participant also mentioned an idea for other use cases of a virtual guide in an AR environment:

“It would be interesting if the guide could give information about closest toilet. It can help me by leading the way there. Or lost children could maybe be guided to find their way back to their school class.” - P6

This could suggest further development of a guiding applications in AR, however this is outside the scope of this study.

**Looking at the showcased animals through AR**

When the user directed the smartphone camera towards an image target attached to a showcase window, the application generated a virtual representation of the preserved animal inside the showcase. It was placed in the AR environment to look as if it was standing in the real environment’s showcase. See figure 3.

![Figure 3. The showcase for of the preserved foxes (left). The virtual fox appears next to the preserved foxes (right) when the user directs the mobile camera towards the image target.](image)

**Autobiographical design choices**

This design choice of having the virtual animals appear inside the showcases became clear when making the initial observations at the museum as the desire was to have both the physical and the virtual environment coexist. With this design, the visitors could both discover the virtual representations at the same time as they saw the physical animal in the showcases but through the camera view on the phone screen.

**Involving other users, further development and refinements**

The aspect in the autobiographical design choice was also grounded in the participants answers when they were invited to test the app:

“That they [the animals] were created inside the showcases made it feel like they came to life rather than if they just appeared on floor.” - P4

“You come closer to the experience, otherwise you might just walk pass the showcases, they are after all stuffed animals. You don’t stay as long without AR.” - P3

“Perhaps something that they hunt, that you continue with the theme that is represented in the showcases. That you continue with how the exhibit look like. What they do in their showcases continues. That would have made it feel more life-like.” - P6

In the later comment, the participant refers to that the first encounter with the virtual animal should continue on what the showcase is displaying. This idea was discussed to be implemented early in the process, making the virtual animals appear at the exact same position as the preserved animals, as if the preserved animal came to life. However, due to the impreciseness of the chosen technology, it was better motivated that the design enabled both the physical and the virtual creatures to coexist with each other with separate lives. Another aspect that motivated the design of the coexistence between the virtual animals and the physical environment was mentioned by another participant:

“The physical animals may give a better understanding of for example textures. But with the content in the app, the experience becomes more relatable than having an impressive and large physical animal just standing still.” - P5

This comment indicates that both environments are valuable for the experience of being life-like.

**Interacting with the virtual animals**

After seeing the virtual animal appear in the showcase, the user could interact with the virtual animal by stroking the screen in circular movements in which the animal showed appreciation through a change of animation and a particle system of hearts. The interaction triggered the animal to follow the user around the exhibition. Stroking the animal
could be done at any stage of the experience after it had appeared in the environment. See figure 4.

![Figure 4. The virtual fox changed animation and showed appreciation through a heart particle system when the user stroked the screen (left). The virtual fox then followed the visitor around the exhibition (right).](image)

**Autobiographical design choices**

To make the interaction more interesting than just having it situated at all time in their showcases made us want to test how it would be to make the virtual animal follow the user. When looking at many popular AR applications that simulates virtual pets that include a stroking interaction to show the pet appreciation made us come to the design choice of first stroking the animals before gaining their trust to follow the user. We considered this interaction to feel intuitive for the user and would make it more life-like.

With the chosen AR tracking technology for the application (described in the method section), a virtual representation of the exhibition room could be created so that it would give the impression that the virtual characters avoided obstacles in the real environment. The virtual 3D model of the room was rendered invisible on the screen so that the real environment was visible instead of the virtual room even if it technically was still present in the virtual environment. The model representation was then mapped with a so-called navigation mesh, a data structure used in artificial intelligence applications to help virtual agents in pathfinding [30]. Simply put, it tells the virtual characters where they can walk and automatically calculates the shortest path to the characters’ assigned destinations. For each image target that was recognised, the 3D model of the room was re-aligned to the new image’s position in case it was previously misaligned with the real world. This decision was to minimise the risks of having the virtual animals look as if they walked through walls or in the air.

**Involving other users, further development and refinements**

The stroking interaction with the virtual animals, was expressed by the participants as one of the key factors for giving a life-like experience. When asking them what made the life-like experience, they replied:

“*That you could do more than just look at them. That you could give them a little love.*” - P6

“*Especially when you could pet them, instead of having them just roaming around.*” - P4

“*When you pet it and it moves a little, I start thinking of when you pet a cat. They became alive. It feels reasonable that you pet them, but some animals may be a bit shy...*” - P5

The participant in the latter case may refer to the matter that some animals will not come forward to you unless you pet the animal. However, it could also mean that this interaction is not done with all kinds of animals. This was explicitly expressed by another participant:

“*What didn’t feel logic was that you would never sit and cuddle with an animal such as a fox or a moose.*” - P7

Also, the designed interaction was not directly intuitive. The majority started to pet the virtual animal by first tapping on the screen. When they saw it reacting some of them started swiping downwards at the screen position where the virtual animal was presented. Two of the users started waving their hand in the air in front of the camera as if the virtual animal was in the physical environment. This was later clarified in the design with clearer instructions on the screen.

That the virtual animal started to follow the user after being stroked was an appreciated function in the application.

“*it was moving and interacting with me, came forward to me like a real animal would have done.*” - P1

“...*it moved, ...it was walking on the floor, ...it followed me!*” - P4
And that the virtual animals were avoiding obstacles in the physical room was described as another reason for making the experience feel life-like.

“Oh was as if the animals followed the layout of the room. Was that really true?” - P4

Although the users expressed that the interaction of the animals following them made it feel more life-like, an interesting design challenge was discovered during the tests. The users needed to look backwards while walking to the next showcase in order to see that the virtual animal was actually following. A discussion about changing the interaction into making the animals guide the user was initiated. However, because the users had expressed that being followed by the virtual animals was the experience that felt most life-like, it was instead solved in the algorithm where the animal followed a position in front of the user, making the animal always visible but still giving the impression that the virtual character followed the user’s path. When the virtual animal wasn’t visible on the screen an off-screen indicator appeared, pointing towards the direction where the user should turn the camera in order to see the animal. See figure 6.

Adding fictive elements of hybrid animals
When the user had successfully gotten two virtual animals to follow and when the two animals walked close to each other, the animals changed their behaviour to interact with each other instead. It was made to look as if they were playing. When the animals had finished playing, a new animal appeared while the initial animals disappeared. The new animal was a hybrid of the both initial animals consisting of their anatomical parts such as legs, head or wings that were randomly put together in the algorithm. This sequence can be seen in figure 5.

Autobiographical design choices
Arriving to this design was not trivial. The major challenge was which algorithm to choose for mixing the animals, as the design was dependent on how the algorithm worked. The first desire was to use a neural network to generate new hybrids of the most popular animals in the exhibition. This would put the design focus on a rating system and the visualisation of it. However this algorithm was not finished on time, so the discussion was furthered into triggering the event as if the animals were buttons. But this did not feel natural in the sense of a creating a life-like interaction. Finally, the design arrived into making the animals play with each other when they came close before a new hybrid animal was created. This decision was based on the museum advisories’ suggestion to not be shy about displaying the animals’ real habits such as them playing or attacking each other. By adding this interaction, also made it possible to keep some of the life-like aspects even if the animals were fictive hybrids.

Involving other users, further development and refinements
While it was expressed by some participants that it was important that the virtual animal representations needed to look realistic, all of the participants rated the interest of having hybrid animals in the AR environment with 5 equals to ‘Strongly agree’ on the Likert scale.

The event of hybrid animals in the tested prototype was however not clear and needed explanation. Three of the participants missed the event where the hybrid animal was created but saw the final result. The reason that they missed the event was that the mobile camera view was pointed somewhere else. One solution for the problem was the screen indicators pointing towards the directions where the users should turn their phone to see the animals that were out of the camera view (figure 6). A second solution was to pause the process so that it didn’t happen until the visitors
had both animals within the camera view. Finally, both a celebration effect of a particle system and a description text was added.

![Image](image1.png)

**Figure 6. Off-screen indicators (circled in red) appeared to point towards the direction where the virtual animal could be seen. 1) The virtual animal was to the right of the user, 2) the animal was behind the user and 3) two animals were off-screen, one to the left and one to the right.**

No refinements were made to the process’s autonomy of creating hybrid animals after the evaluation with participants, although the replies from the participants were ambiguous. When asked if they wanted to be in more control of the content while being explained to that a lot of the content was automated, only one replied ‘Yes’ and referred to the event of pairing the animals. However, when asking the participants more in-depth in other questions, they expressed many ideas that treated the subject of giving the user more control when creating a new hybrid animal for example their food preferences or how they would sound like.

“Let’s say that you can influence which animals would pair, maybe you can let the user choose what they eat. If you create an animal, perhaps you can choose a sound for it.” - P4

**Other comments on the experience**

During the tests, participants were also explicitly asked if the designed AR environment made the exhibition feel more life-like. The rated experience is shown in a more detailed distribution in figure 7.

![Image](image2.png)

**Figure 7. Responses to the statement The exhibition felt life-like with AR.**

They were also asked about if they would have used the AR again in the next visit at the museum. Even though the test was made on a prototype that needed many functionality improvements, all seven participants answered ‘Yes’ to the question. It was even expressed that they would have appreciated to have used the application if they were children. Another participant expressed that she would have brought her younger siblings, thinking that they would appreciate the life-like contrast that it adds to the exhibition.

**DISCUSSION**

With the knowledge gained from the design process, I wish to contribute with some of my reflections in a discussion on how to design interactions for a life-like experience and provide a starting point for future research. I have used pliability and autonomy that are suggested experiential qualities by Löwgren & Stolterman [16] as foundation for the discussion of how the application supported the life-like experience. Pliability is defined as “the degree to which interaction feels involving, malleable, and tightly coupled – and hence to what degree it facilitates exploration and serendipity in use” [15]. Autonomy is defined as “the degree to which digital artifacts act as autonomous agents or actors in an interactive system” [29].

These experiential qualities were not considered in the design process, instead they were later discovered to play important roles in designing for a life-like AR experience as discussed below.

**Compensating elements that reveal the virtuality with other experiential qualities**

The virtual characters representing the animals in the showcases gave away many distinctive factors that revealed that they were virtual characters and not a part of the physical world. Among those elements were for example that it was difficult to capture the real representation of the 3D models’ textures. Many off-the-shelf graphical shaders that can make textures look like fur were not supported by mobile devices due to the high computational power. Another example that revealed the virtuality was the animals’ movements. Their behaviour patterns are functionalities that are important for their believability. Johnson et al., [10] describes how the believability can reduce significantly when the user recognises an agent’s behaviour pattern. Even if the two factors were not possible to be fulfilled in the application, the participants still gave it high ratings concerning the life-like experience. This implies that the design must have instead relied on other experiential qualities, such as the pliability and the immersiveness of the experience that potentially made the user put less emphasis on factors that revealed their virtuality and other elements that affected the AR
environment’s believability. Hence, the interaction still reached a degree of feeling life-like. My reflections lie on that designing for a life-like experience where the user can see obvious elements that don’t belong in the physical world, the design process must identify and include other qualities that can compensate for it.

On the other hand, in the design case described in this study, there were some functions in the tested prototype that were not working properly, so-called software bugs that were known but not fixed due to time limit. These factors could have created irritable moments for the users that decreased the experiential qualities of pliability which in turn couldn’t compensate for the virtuality. It could have even created moments where the virtuality became even more distinctive. This factor should therefore be something to consider when designing for a life-like experience in AR. What is important to note however, is that the discussion above is only considered for AR environment and not environments of solely virtual elements, meaning that the coexistence of both worlds is important for the life-like experience. As grounded in the results, where it showed that the physical environment can capture what can’t be captured in the virtual environment, such as textures, and the virtual environment can capture what can’t be captured in the physical environment, such as movements.

**Reflecting the reality by intuition**

The experiential quality of autonomy was also found important for designing a life-like experience. For this design case, the virtual animals were the agents in the application. Real-life animals’ behaviour in the nature are not controlled, especially not when encountered in the wild which is the scenarios that the museum in this study wish to display them. This makes it vital that the animals give the sense that they can act by themselves. However, in this design case, the designed interactions may have been more influenced by the way humans interact with their pets rather than animals in the wild, where the animals’ autonomy may be expressed differently in real-life situations. This means that the characters’ designed autonomy could have had an effect on whether the participants experienced the interaction as life-like or not. However, from this study it did not seem to matter in the results when asking the participants. The autonomy of for example a wild cat may not be the same as a domestic cat but both would still act autonomous. So, even if the designed autonomy did not reflect reality, I would like to argue that it was more important that the characters actually acted autonomous rather than acting correctly when designing for a life-like interaction. Hoorn et al., [7] argues in their report that when designing for a virtual reality (VR) experience, the focus should be put on designing the situation rather than the realistic features. The design should be relevant and give a personal meaning in the situation so that the user is provided an intuitive way to solve the task. Even though this study concerned an AR experience, we can see this being reflected in the case described about autonomy. Another case where this argument can be reflected is in the findings where each of the participants interpreted the action of how to pet an animal differently. This was the most distinct finding in the study that showed upon that designing an AR experience has potential of integrating life-like interaction, even through a mobile device. In particular, when more than one participant waved their hand in the air as if the animal was in the physical environment. This shows the interplay of affordances in augmented environment and the limitations in smartphone-based interactions through a touchscreen. Although the design confusion was solved with clearer instructions in the application, the interpretation of each user motivates the interests to further investigate the design question about what interactions make the content of AR feel life-like.

**Methodology criticism**

There were several factors that could have affected the findings of this study. The major factor that I would suggest to be done differently is the part where others were invited to test the prototype. Even though it is motivated that other interaction designers give valuable insight in an experience-based design, the designers in this study had backgrounds that were quite similar to each other and also my own, coming from the same education. This could possibly have narrowed the different perspectives that came out of the test sessions. Also, interaction designers’ understanding for the impreciseness in AR is much greater than what a user from the actual target group has and is therefore much more patient when testing the prototype. If the target group of children and families would have been involved in the process, the final design experience might have looked different where emphasis might have been put on other events, possibly more on the content rather than the interaction. On the other hand, the questions in the semi-structured interview can also be designed to capture the desired information about the life-like experience which in this study could have been more in-depth.

**Future research**

For future research in the area, I would suggest a more in-depth qualitative study through involving other interaction designers and in particular the museum target groups to further understand elements that has an impact on the interaction of being life-like. This study only investigated the features in the designed prototype for a smartphone-based AR, however these may not have been articulating all possible perspectives. One of the areas that would be interesting to further investigate for valuable insights is for example how interacting with virtual content beyond using a touchscreen could affect the experiential
qualities of making the interaction feel life-like.

CONCLUSION
In this paper, the design process aimed to create a MAR experience for the Swedish Museum of Natural History for the use of discovering the preserved animals of the exhibition. The animals were showed in combination with animated virtual animals to create a life-like experience.

The evaluation of the application was done with interaction designers for their expertise in articulating experiential qualities. What was found in the study is that an AR experience has great potential of integrating a life-like interaction in museums even through a mobile device where touching on a screen might not reflect on the real-life interaction. The knowledge gained from this research can be summarised in two points to consider when designing for a life-like experience. The first point is that when designing for a life-like experience where the content’s virtuality is obvious, other qualities that can compensate for the decreased feeling of life-like should be identified so that it can be included in the design. Such qualities can for example be pliability which means that the design includes involving interaction that makes the user suspend the disbelief. The second point concerns how the interaction reflects on reality. For example, when designing an animated virtual wild cat’s autonomy, it may be more intuitive for the user if the interaction resembled the real-life interactions with domestic cats. In other words, when designing for a life-like experience, emphasis should be put on making the interaction intuitive for the situation rather than designing for realistic interactions.

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REFERENCES


and mobile computing 18: 71–87.


