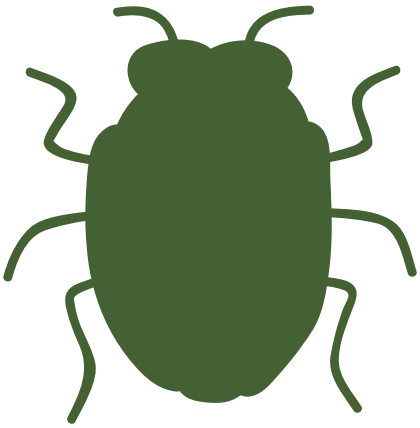
SCENTSORY

OLFACTION AND THE SENSES IN
MUSEUM EXPERIENCE DESIGN



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ABSTRACT

This bachelor thesis examines the potential of multisensory learning and experiencing in museum exhibition design. We specifically focus on the use of scents and the olfactory sense within this context. Substantially the aim of this thesis is to utilize multisensory experience design to provide innovative ideas for the development of museum exhibition design and mediation. The use of such multisensory and embodied learning approaches is motivated by the indication of the significant benefits of such experiences in comparison to traditional ways of learning. We look at the current circumstances around the visitor experience of museum exhibitions and discuss visitor expectations and the responsibility of museums in this manner. The notion of multisensory design was specifically approached in the context of an exhibition focusing on insects. This thematic context arises from a collaboration with the Natural History Museum of the University of Zurich, who was our partner in this project. In the following pages the research, concept, design and development process of the project „Scentsory" is described, which is an interactive game table designed to unclose the world of insects' olfactory behavior to museum visitors in a playful and explorative way. There is a specific emphasis on the implementation of olfaction in the experience in an interactive manner. Furthermore, the thesis is concerned with the responsible and careful use of technology within this context. More precisely we embark on the possibilities and impact of the implementation of technology in museums.

KEYWORDS

Museums experience design, sensory learning, social interactions, olfactory experience

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Museums are a space for learning, experiencing and exchanging. In all these aspects they represent a space of significant cultural relevance. Thus the preservation but especially also the innovation and development of these spaces is a task of great importance for society. As described by Calvi and Vermeeren (Calvi & Vermeeren, 2023) some see a future where museums will be replaced by digital services that can be accessed from anywhere. While such services can be an enrichment to museums and their accessibility they are still not able to replace many of the unique experiences museums offer. Especially aspects like the possibility for social exchange and learning with the body and space can only be recreated to a certain extent by digital remote experiences. In this bachelor thesis we investigated into these unique experiences museums have to offer and the potential to develop and innovate them. Specifically we experimented with multisensory and bodily learning and eventually set a focus on olfaction. As we have discovered through our research we believe that the implementation of multisensory learning and experiencing in museums has a lot of potential. It that has already been explored to some extent but can still be developed much further.

In collaboration with the Natural History Museum of the University of Zurich we developed a concept and prototype for a multisensory interactive installation. This project is limited by a few baundary conditions provided by our collaboration partner. The Natural History Museum proposed insects as a thematic content for the project in the framework of an exhibition planned in Museum für Gestatung Zürich in 2025 labeled Museum of the Future. In this framework this thesis relates the just described design notions to the context of insects specifically.
First and foremost, the goal of our project is to spark curiosity and enthusiasm for learning and the learned content in museum visitors. We see the responsibility of the museum and thus also of our thesis project in providing pithy learning experiences. This enables creative forms of learning that would not be viable in other contexts like schools or the comfort of the home.

5.2 CONTEXT AND POTENTIAL

Museums, like many other fields, are facing a time of rapid change. If they want to ensure their future relevance, they will have to adapt consequently to the changing expectations and needs of their visitors, if they want to ensure their future relevance, for their customers and society in general. For sure, there have been some notable changes and advancements in museum experience design in the past. But there is still a general demand for innovation in the field of museum experience design. We thus state that it is not only important to investigate the trends in technology and media use, that surely have a distinct place in all of this, but also to take a strong look at the expectations and needs of contemporary and future museum visitors. In addition we ask ourselves the question what benefits and special characteristics does and will the physical museum have to keep its visitors engaged.

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RESEARCH

ABOUT THE PROJECT 6.1

What are the benefits of a physical museum visit? Why and how will museum exhibitions stay relevant to the people? How can we design to expand or enrich a museum experience for the visitors? These were the questions that concerned us when we first joined the Natural History Museum of University of Zurich in this project to create an exhibition experience concerning the whimsical world of insects. Since both of us are fascinated by the field of museum exhibition and experience design, we were inclined to approach this project with a generalist mindset. To understand the methods and process around this field and explore and experiment with its possibilities. Thus, the design and research questions leading us through our process come from a rather holistic approach. in this regard and become more context specific as our designs start to take form. Therefore, this thesis is concerned with the question of the exhibition experience in the more specific framework of the magnificent Insect realm.
Before we could find answers to the questions above, we first needed to understand the responsibilities, purpose and value of the museum with respect to their visitors.

ABOUT THE MUSEUM AND ITS VISITORS 6.2

As Vermeeren, Calvi and Sabiescu explain (Vermeeren et al., 2018) museums need to deal with new technology and adapt to the changing needs of their visitors. Like many other fields they are constantly changing. But they are also a creative realm of mediation and entertainment experiences and as the authors make clear the visitors and society in general expect them to provide extraordinary experiences in the museums. Otherwise, why bother going to a museum, when there is nothing new, exciting or peculiar to see or experience there? Especially nowadays, where we can access so much knowledge and information on the tip of our fingers and might just inform ourselves online, we might ask ourselves what has a museum still to offer? And that's where we really get to

the bottom of the responsibilities of and expectations for contemporary museums. As described in an article about museums responsibilities by scientist and museum administrator George Brown Goode in 1895 there was a time when society used to rely on museums much more solely to archive, lecture and exhibit (The Relationships and Responsibilities of Museums, 2024). These aspects are still important in museums nowadays but speaking in regards to the expectations and wishes of their visitors museums should do much more than this now (Levent & Pascual-Leone, 2014). From Vermeeren, Calvi and Sabiescus' arguments we draw the conclusion that museums are places that provide a fusion of learning and entertainment experiences that go beyond what classrooms, or your comfortable living room can provide. They have the special condition and responsibility of a space for the public to learn, engage in a topic, meet and discuss, and not least important spend entertaining leisure time (Allen, 2004). For this reason, museums and the people designing for them are consecutively working on new exciting ways to design museum exhibitions and visits.

6.3 HOW TO DESIGN FOR MUSEUM EXHIBITIONS

Now that we understand more about the expectations and motivations of the visitors the Question arises: How does one design for those wants and needs? Of course, there is not one right way to design a museum exhibition. No cookbook with precise recipes and instructions to work by that will turn out in a delicious exhibition that everyone enjoys every time without fail. But there are certain frameworks, methods and media that we can rely on and work within the design process, that have shown potential and proven positive impact in the context of museums responsibilities and purpose (Calvi & Vermeeren, 2023). All museums are different, but most follow the overall goal to exhibit their content, make their visitors excited about it, make them care about and engage in it. Thus to teach them and finally to see them off with a good memory of their visit. So there are some specific design approaches that have proven to, generally speaking, enhance these experiences in the field of museum exhibition design, like gamification (Çetin & Erbay, 2021), augmented reality (Calvi & Vermeeren, 2023), ambient learning spaces (Winkler et al., 2014), multisensory experiences (Levent & Pascual-Leone, 2014) and more. In this thesis we focus specifically on the potential and unique challenges and characteristic of multisensory experiences.

Before we take a deeper dive into this design approach it is important to mention, as it is our hypothesis, that with all these design media it is very crucial that the design decisions always lean on the content and topic of the exhibition to be designed and the specific context of the project. Sophia Prince, researcher in the DIZH confirmed this assumption as she stated the use of digital media is only relevant, if

the content changes accordingly. Also as Calvi and Vermeeren (Calvi & Vermeeren, 2023) make clear with all the mediums, methods and technologies we use to design an exhibition we should always ask ourselves: Is this relevant for this topic and to our audience? Does this make the content more meaningful? Will it help to make our visitors excited, engaged or care more about what we are presenting? We also believe that for example even in these general design methods we can already make distinctions regarding the thematic categorization of the museum. Therefore, a history museum might find methods like storytelling and ambient learning spaces more suitable for their exhibitions, as they usually are a more natural fit to the content. While a science museum may find multisensory experiences and gamification more suitable, as they try to engage their audiences more into complex scientific processes rather than historic personas and cultural relations.

6.4 WHY MULTISENSORY EXPERIENCE

Most of us have experienced the extent of the connection between our senses and our memory. Like the taste of the dish your grandmother used to cook or the song we mumble under our breath when we recall the alphabet. Like with these examples there is many ways in which our senses are tied to our memory formation.

All our experiences are inherently multisensory. But designers have been investigating and creating opportunities to design multisensory experiences carefully and intentionally (Velasco & Obrist, 2020).We believe that a multisensory design approach can benefit not only the memorability of exhibitions but also help us to engage our visitors and make them curious for what we have to show and tell. Multisensory experiences have the potential to add meaning and context to information (Levent & Pascual-Leone, 2014). They can form a more tangible connection to the contents and engage us in active participation and exploration. Though the general concept of multisensory experiences is more and more discovered and experimented with, there is still much more potential there to draw from and they can be used more intentionally to guide user experiences. We see much undiscovered potential to explore the use of multisensory experiences also in regard to participation and interaction.

Multisensory experiences are rather cumbersome to include in classroom learning. The development of multisensory learning in classrooms is desirable. Museums so far have greater possibilities to put this design approach to use due to less constraints. This is one reason this concept is so intriguing and conducive in museum exhibition design. As already mentioned: If a museum doesn't offer anything new, exciting or peculiar, why bother visiting? This is definitely something to keep in mind in the design process in terms of user expectations. We furthermore believe that with this approach we can also bridge the challenge between very diverse user groups that museums face regularly.

6.4.1 Smell

One of the lesser-used senses in museums is the smell receptors of the human. Nevertheless, odors are already used in museums today, often in connection with fragrances themselves, such as the Perfume Museum in Paris (Musée du Parfum) or a wine museum in Bordeaux (Cité du Vin). These exhibits use odors to make the craft itself understandable. For example, which ingredient makes a perfume last longer and how does it smell, which compounds are used to create a scent story over time?

But using smells, where it doesn't necessarily fit with the content is often overlooked. Using smells to create an impression of something that cannot be experienced per se is rarely done. If ever, they are used for an immersive experience like in the Stapferhaus exhibition "Nature and Us?". They used odors in the section about human garbage. It smelled like garbage. It was not really pleasant, but we also didn't have to leave the area immediately. This part of the exhibition left a memorable experience. Smells or the smell of people have great properties that designers or curators can work with.

The human sense of smell consists of receptors located in the nose at the level of the nasal bridge. We humans have on average 300 receptors. The different odors often consist of mixtures of molecules that represent a particular smell for us. We can distinguish an extremely large number of odors, but if we are exposed to an odor for a long time, we become accustomed to it so that we can better perceive changes in smell. People differ in how and how much they can perceive. This is exactly the same with smells, just as the perception of smell changes with age, some people can smell more or less (Stevenson, 2013). How we perceive odors is influenced by the smells that we are familiar with. For example, the different spices from the food cultures have an influence. The more familiar the scent is the easier it is to identify. Therefore, the smell is very subjective. Keeping this in mind, when creating a scent-based exhibit, will improve its usability.

The sense of smell is well connected to personal memories in the brain. Compared to the other senses, smells are best at triggering memories. Additionally, emotional memories are also closely connected with the olfactory system (White, 2009). This could be used for a memorable experience and storytelling, where the emotions of the human are used to get them hooked. By using smells, the visitor is likely to smell again, and the memory of the exhibition is likely to surface again. Another effect that the olfactory system has is that it makes us feel like we are in close contact with the scent. It also triggers direct responses in our body, like feeling ill or disgusted(Levent & Pascual-Leone, 2014). In the museum, this could be used to make you feel closer to the subject matter.

In general, smells could be used more often in museums, as they have the ability to make an experience more memorable, emotional, immersive and, make you feel close to the matter. It's important to keep in mind how people perceive scent and if they even do. The experience should still work without scent.

Use of smell in museum exhibition design 6.4.2.

In their book the multisensory museum Levent and Pascual-Leone give a summarized, well-arranged insight into designing with smell in museums (Levent & Pascual-Leone, 2014). The authors explain that the implementation of sensory sensations in museums exceeding visual designs is a newly emerging notion in museum exhibition design. The implementation of the olfactory sense has some unique challenges and characteristics. Although they are continuously more explored, the potential of this sense in the museum has still much more to offer. Levent and Pascual-Leone describe five ways of implementing scents into a museum in their book. Briefly summarized the five use cases they propose are: A) scents to make the visitors feel more present. B) scents to evoke a feeling of childhood nostalgia. C) scents to evoke negative feelings. D) scents to evoke positive feelings. E) scents as a navigation indicator. Some of these use cases described in the book are provided with more specific ideas for implementation and others remain rather general. Most of them seem to represent a rather passive presence of the scent for the visitors. Levent and Pascual-Leone don't see these five use cases as a completed or final manuscript of the use of olfaction in museums. Rather they suggest that there can be many more ways to implement smell in a museum visit experience and we agree here.

It is our hypothesis that olfactory experience design could benefit from design methods more specifically focused on an interactive approach, prompting users to smell more actively rather than passively. This could make the users engage with their olfactory sense in a more attentive manner rather than using smells solely as a subconsciously noticeable side character. This notion of consciously motivated smelling could possibly also result in stronger memory formation and connection to the content experienced in the exhibition. Most of the implementations of olfac-

tion in museums proposed by Levent and Pascual-Leone could also be explored in such a manner. In our research we've found little work or projects that embrace this notion. The project olfactory labyrinth 2013, which is further described in the related projects section, was one interesting example of an interactive olfactory installation. It closely relates to the fifth possible use of scents in experience design proposed by Levent and Pascual-Leone. The authors explicitly mention this approach to be suiting for visually impaired people. However, the project olfactory labyrinth was also suitable for visually abled people.

6.4.3 Touch

In museums, the significance of touch is often underestimated. The ability to engage with an object through touch or interacting with a surface can enhance one's connection and memory of the item (Levent & Pascual-Leone, 2014). However, some exhibits are off-limits to touch, as they need to be preserved from wear and decay. It's crucial to avoid touching them to ensure their protection. Fortunately, with the advancement of technology, there are now several viable solutions available. Creating replicas or material samples can be useful. Even 3D printing objects can allow for closer inspection and resizing, making it easier to understand things on another scale. This can also be an excellent opportunity for visually impaired individuals to explore a vast site like the Tower of Pisa (Rossetti et al., 2018).

6.4.4 Sound

Sound is one of the elements that is used quite frequently in museums. Most common in the form of Audio Guides and stationary headphones. But often these museums give the user only more information on the artefacts that they already can see. Other museums want to create a reflective and calm environment for the visitor. Those are all valid usage of sound but does not incorporate the potential of sound for storytelling. One way sound can be used is to create an immersive environment by playing the sounds of crickets chirping and the wind blowing. Where the visitor can dive into the context even more through sound. We humans can perceive so much over our ears we otherwise would not notice. Additionally, sounds are a great way to convey emotions and therefore stories as well.

LEARNING IN THE MUSEUM 6.5

One of the museum's main goals is to educate the visitors. Therefore, knowing how the human learning process works helps to design better exhibits. In the next paragraphs, we will go into the process of learning and mapping of knowledge and then look into additional factor that support the learning experience besides multisensory learning.

The process of learning 6.5.1

According to K Patricia Cross's paper "Learning Is About Making Connections" (Cross, 1999) our brain is wired with connections of neurons that spin around their axis to form new connections. These connections carry electrical impulses to create our memory, knowledge and thoughts. Sensory stimulation strengthens these connections. On the other hand, if the connections are only occasionally used or never these connections get dissolved to enhance the efficiency of the brain. The brain is one of the smaller organs that accounts for only two percent of our body mass and uses 20% of oxygen and nutrients the body consumes on a daily basis (Steiner 2020). Research suggests that if you keep your brain active through enough stimuli people are less likely to develop Alzheimer's (Wilson et al., 2021). Therefore, to maintain the pathways in the neural network, individuals must engage in regular use and practice, thereby reinforcing their neural pathways and enhancing their cognitive capabilities. Extending this theory to the field of museums, introducing stimulating exhibits with different methods such as multisensory experiences can help provide multiple pathways for regular use.

6.5.2 Mapping of Knowledge

Cognitive scientists have discovered that the brain does not make random connections. Instead, it structures knowledge into meaningful systems called schema (or plural, schemata). The brain forms not just one, but multiple schemata, which create relations and organize facts in a useful way. These schemata are used to create our understanding of the world. This explains why people often have different understandings of the same object or word, since their understanding of it is built based on neuron connections that look different from person to person, depending on their existing schemata and experiences (Cross, 1999). For example, in ancient Egyptian culture, the scarab beetle is a symbol of resurrection and immortality whereas in Western cultures it is often perceived as pests.

Using analogies and comparison helps people use existing knowledge to remember and comprehend a new subject or information (Baumann, 2020). On the other hand, using multisensory learning mechanisms has been proven to be beneficial for learning (Shams & Seitz, 2008). So combining those benefits is an efficient way to enhance learnability as shown in this paper about multisensory substitution (Lloyd-Esenkaya et al., 2020).

Another way to use knowledge mapping is the use of context. Often objects get removed from their original context in museums. Reintroducing the context again with different methods helps the visitor to place the new information in maybe already existing schemata. For example, showing the honeybee in their significant role in the agriculture, where we can connect them to our food consumption can foster a deeper understanding how important their role the bee play in the ecosystem.

6.5.3 New experiences

Visiting museums allows people to have new experiences that have a variety of positive effects on the brain. These experiences can increase motivation by stimulating inner curiosity, improve the ability to pay attention over longer periods of time and promote deeper understanding (Kong, 2021).

Furthermore, new experiences in museums enable the brain to develop new neural circuits. These are essential for adapting to new tasks and areas of knowledge. In some cases, this can even lead to the reconfiguration of existing neural networks, which is particularly useful when learning complex topics (Mikulak, 2021).

For museum designers, this knowledge is crucial. It emphasizes the need to design exhibitions in a way that not only informs visitors, but also actively engages and challenges them. By designing interactive and immersive exhibitions that raise curiosity and stimulate thought, museum designers can enhance cognitive processes, creating a deeper and more lasting learning experience.

TANGIBLE USER INTERFACE 6.6

Interactive table surfaces or Tangible User Interface (TUI) is an interface that allows users to interact through physical objects with a digital information layer. The groundwork for TUI's was introduced more than two decades ago in 1997 by Hiroshi Ishii and Brygg Ullmer (Ishii & Ullmer, 1997). Since then, the topic has been remaining mostly in academia as it is costly to develop because it requires special hardware like infrared cameras and custom-designed objects. Additionally, you have the development of the content and the program which can introduce complexity into the setup (Krestanova et al., 2021).

Tangible user interfaces present their own unique set of challenges, but these challenges are less severe for museums. They have ample physical space to accommodate TUIs, generally a big enough budget and the resources to develop specific content.

In the last years there has been rapid advancement in technologies such as augmented reality (AR) and virtual reality (VR), which requires minimal physical space. This directly competes with TUIs, as they rely on physical space for interaction. Additionally, VR and AR are primarily focused on single-user experiences, lacking the benefits of social interaction and social learning that are central to TUIs. TUIs are designed to facilitate interaction among multiple users, fostering dialogue and collaboration (Ma et al., 2015).

Tangible interfaces offer the added benefit of physical interaction, providing a hands-on learning experience. When people engage with these interfaces in a physical context, they are better able to find unique and effective solutions to specific problems. For instance, an abacus (hand operated counting tool) allows for visual and spatial understanding when manipulating numbers, thereby enhancing one's ability to perform arithmetic tasks (Hatano et al., 1987). Another benefit of the physical aspect is the enhancement of accessibility for visually impaired individuals (Vaz

et al., 2016). For example, 3D printing insects and using them as tangible objects that visitors can explore which allows them to feel the body of the insect.

Tangible User Interfaces seamlessly blend physical and digital interactions, enabling users to interact with digital information through physical manipulation. This has the potential to improve spatial cognition for designers, which allowed them spend more time to research their design problem and come up with improved results (Kim & Maher, 2008). Tangible objects also have the ability to represent digital information in a contextual manner for schools, adding understanding between theoretical and practical work (Do-Lenh et al., 2010).

In summary, TUI's offer museums an innovative and interactive way to engage visitors with digital content. By providing a hands-on approach to accessing information, TUIs enhance problem-solving and creative thinking among visitors. In the museum context, TUIs can be used to create interactive exhibits where visitors can manipulate physical models to explore concepts in real-time. This interactive element makes learning more engaging and memorable. By integrating TUIs, museums can offer dynamic and interactive learning environments that captivate and educate visitors of all ages.

6.7 INTERACTION DESIGN IN MUSEUMS

Research about the impact of interactive design approaches on visitors' experiences in museum exhibition design is scarce. One possible reason for this might be that this notion is not easy to evaluate in a scientific manner. Though there is not much scientific evidence around the exact impact of interactivity on museum visitors Haywood and Cairns (Haywood & Cairns, 2006) observe the attention this concept has been granted with. The authors explain that with interactive exhibits museums aim to live up to the expectations of their visitors to be entertained and educated. Despite the lack of empirical studies on the matter we can gain an understanding of these relations. Calvi and Vermeeren (Calvi & Vermeeren, 2023) have addressed the topic in their paper digitally enriched museum experiences. They have gathered valuable insights through interviewing designers from renowned design agencies who

shared their experiences. Various of these experts have stressed the importance of interaction and engagement for a playful and memorable experience. Haywood and Cairns also mention similar enthusiasm around the practical implementation of interactions by museums. They also highlight their assumption that high engagement might be threatening to the attention of the users to the scientific content. This is an important insight that will become relevant later in our process when we need to carefully consider how to design for the desired focus and motivation of our users and critically evaluate the implementation of competition in the playful experience.

6.8 SOCIAL CHALLENGES AND OPPORTUNITIES

Since museum visits are more often than not a social undertaking and the social exchange happening around the visit is an essential part of it (Falk & Dierking, 2013), the notion of social interaction in the museum context comprises an important topic in this thesis and the resulting project. The sociality of museum visits is not only to be seen simply as an attribute of the experience but rather to be identified as another expectation of the visitors. Since most visitors visit in groups, social interactions are a core aspect of the museum experience (Falk & Dierking, 2013) and thus should also be included and considered in the design of such experiences. In Learning Conversations in Museums, Leinhardt, Crowley and Knutson outline the relevance and potential of conversations in museums and the impact they can have on the learning experience (Leinhardt et al., 2002). In another paper Schroyen et al. explore the potential of collaborative and social learning for teenagers in museums with mobile games (Schroyen et al., 2008). They also highlight the risk of neglect of social interplay in technology enabled by learning environments that has occurred in museums in the past, possibly due to a lack of carefully considered implementation of the technology. Blud talks about the under explored effects of social interaction in the learning process (Blud, n.d.). It becomes clear how this notion could facilitate more informed museum experience design.

Though the specific effects of social interactions and their impact on the learning experience in museums is certainly still under explored we see that this notion is definitely of reasonable relevance in museum experience design and shows a lot of potential to influence the museum visitors experience in positive ways. From the above mentioned references we also set up the hypothesis that such social interactions can take form and be implemented in museums experiences in different ways. So, such interactions might manifest as conversations, observations, collaboration, sharing, rivalry, explaining or even just the notion of having a shared experience that adds a layer of emotional connection to the experience. All these insights make clear the importance of social interaction in museums experience design and thus informed the design decisions around this project later on.

6.8.1 The User Group

In regard to social aspects, museums additionally grapple with another tricky challenge. Since they are a space for everyone, they deal with an extremely diverse user group, comprising almost all ages from 5 to 85. And so arises the problem of speaking to and intriguing the 5 year old without boring the 85 year old and vice versa. We believe that a multisensory approach also has the potential to bridge this challenge. They can offer a layer of physicality which is more intuitive and constructive for the users among different ages in this context (Vermeeren et al., 2018).

6.9 IMPLEMENTATION AND USE OF TECHNOLOGY

The use of technology in museum experience design uncloses great possibilities. Which is why it's so easy to overlook also the forfeits and challenges that can arise with the implementation of novel technology in museums as we've already touched upon in the previous section. In the field research we did in various museums like the natural history museums of London and University of Zurich, the science museum of London and national museum in Zurich, we made a few insightful observations concerning the use of technology, which helped us immensely in the design process. We believe that it is very important to implement technology with caution and intention in museums and be aware of the various effects it can have on the visitors experience, positive and negative. A believe we share with and in which we are reassured by the investigations of Calvi and Vermeeren (2023) around the use of technology in museums.

Many of these insights and findings from our research regarding the use of technology informed a lot of our design decisions later on in the process. Through the observation made we formed the assumption that the combination of physical objects or installations with technological elements are quite engaging. This assumption is supported by Blud (1990) and Calvi and Vermeeren (2023). We've seen the importance of physicality in museum mediation, as it adds meaning and tangibility to the content, whereas entirely technological solutions can distance us from the topic shown, especially when they appear solely on a screen. Of course, we have seen exceptions to this, where also only screen-based designs were really intriguing and informative. Through our field research we were able to grasp the extent of the benefit of physical components in museums firsthand and just how much more life they can bring to an exhibition.

We've seen many instances where physical models and components helped to invite people to interact with the exhibit or installation. Technology could then function in many ways to enhance and add value to the experience. Like with projections to add information or another layer of interaction, with screens to show more complex and in-depth content, with vibration motors for playful interaction and learning or with soundscapes to immerse users in a subject. More detail information about our field research can be found in the chapter Field research.

We've also gained some invaluable information about the use of technology in our interview with Sophia Prinz. Where she emphasized the use of technology as a tool for mediation and how its effectiveness in that regard depends a lot on if curators and designers are sensitive to put it in relation and design it alongside to the content. Which coincides with Calvi & Vermeerens research and the statements they gathered from various design studios (Calvi & Vermeeren, 2023). We conclude from these two sources, that the use of technology in museum experience design should always serve a greater purpose in the context of the exhibition to enhance the visitors experience, e.g. to tell a story, to add meaning, to immerse the visitors or to improve learning or memorability. So, technology always has to be designed in regard to the specific context.

6.10 GAMIFICATION IN MUSEUMS

There are discussions around entertainment in the museum realm. These approaches aim to enrich the visitor experience and promote learning by integrating elements from the world of games and entertainment. Gamification is a term used to describe the addition of game-like mechanisms to boost engagement and motivation.

The arguments in favor of gamification are that museums with gamification attract more visitors, especially in the younger generation. Using game elements like rewards, levels, and challenges can improve the interest rate of the visitor(Çetin & Erbay, 2021). Another aspect of gamification is that it enhances learnability through game mechanisms and interactive methods(Ćosović & Brkić, 2020). Games can also enhance engagement with the matter and the social exchange between visitors (Nofal et al., 2020).

While there are advocates for incorporating gamification into museums to enhance visitors' experience, there is a counterargument that it may detract from the primary educational goals of the exhibits. Critics expressed concerns that the use of game elements could potentially shift the focus away from the intended educational objectives, leading to a loss of educational value (Madsen, 2018). The use of gamification elements could also be seen as an attempt to commercialize cultural institutions, which could compromise their educational and cultural mission. The effectiveness of gamification in education is still the subject of research and debate. Not all studies show clear benefits and there are concerns about the long-term impact on learning (Madsen, 2018).

These discussions are important to keep the main goal of the museum institution intact. Namely to educate and entertain the general public. They have to carefully evaluate which technologies and methods are compatible with their message and exhibition context to support the target visitors during their visit. We believe if gamification is used intentionally it can generate added values. For this project, gamification could be used to achieve certain steps in the process.

A more physical example of this could be escape rooms. Even though the main purpose of an escape room is entertainment, the museum could learn from them in the aspect of gamification, fun, and immersion.

DIGITAL TRANSFORMATION OF MUSEUMS 6.11

Digital transformation broadly refers to the process of integrating digital technologies and tools into various aspects of an organization's operations, with the goal of enhancing its overall performance and effectiveness. In the context of museums, digital transformation refers to the adoption of digital technologies and strategies to improve the visitor experience, enhance accessibility, and streamline internal operations. This may include the use of digital exhibits, virtual tours, interactive displays, online collections, and social media platforms, among other tools. The ultimate aim of digital transformation in museums is to create a more engaging and immersive experience for visitors and stakeholders, while also improving the overall efficiency and effectiveness of museum operations. In addition, visitor numbers are falling at many museums in Switzerland. According to the Federal Statistical Office, the figures have not yet recovered since Covid-19 (Bundesamt für Statistik, 2024). Over the past few years, there has been a growing trend in employing technology and digital applications to facilitate knowledge transfer in museums. These innovative methods encompass a wide range of tools such as digital immersive technologies, social networks, apps, and guides that are being increasingly adopted worldwide. To create an optimal learning experience for museum visitors, designers, curators, and scenographers must pay attention to the interplay between virtual and real-world elements. While some digital applications strive to enhance the physical museum visit, others provide a complete alternative to the need for a physical visit altogether.

Historical background 6.11.1

Museums have been around for quite some time. It started with private collections of items that only a couple of people had access to because they were rich and powerful people who could afford collecting and only their circles had ever the chance to see them exhibited.

Around the late 1700 museums like the Louvre and the British Museum opened their doors to the public. These museums started through the Enlightenment ideals. They wanted liberties, to democratize and educate society. Museums had the intention to preserve and archive for the public good.

By the 1900s a lot of countries had national museums. The collection was sorted by date and ecologies. They set the context of the exhibition on the development of cultures and compared cultural goods with other societies. Over the years other di-

sciplines like biology, anthropology and industrialization joined the museum realm. Displaying the science of our world was sometimes a double-edged sword because presenting the advancement of societies was a form of power demonstration and glorification of the presented progress. But not all inventions are purely good because of the destruction they caused (Roppola, 2013).

They have also been utilizing technology for educational purposes. As early as the year 2000, exhibitions in Switzerland were equipped with screens and audio. It was quickly realized that information could be presented in an interlaced manner. The additional layers of content could be discovered at will.

6.12 IDENTIFICATION OF ASSUMPTIONS

The following assumptions must be scrutinized in the context of this work. Museum visitors go to museums to learn something in a physical and spatial context. These are the main advantages of a museum, in contrast to digital data which can be accessed quickly and in huge quantities. If the focus is placed too strongly on digitalization, the content of the exhibit is not conveyed. What often happens is that you use the latest technologies or find an interesting way to interact. But these aspects can distract from the actual content if visitors want to find out how the exhibit was developed.

Another assumption is that visitors like sensory experiences and help with mediation. We humans have many senses that were vital to our survival when we were hunter-gatherers. We assume that social interaction enriches the exhibit and builds a stronger bond with the subject through exchange.

6.13 PEOPLE AND MOTIVATION BEHIND THE PROJECT

Carina

What do I see in the future of museums? Why is there still potential? I believe that many museums are already in the process of transitioning towards the future of museums. This shift involves the use of digital technology within the museum space, such as screens, audio guides, and interactive installations. Museums have a unique opportunity to use technology in ways that other educational institutions cannot. Their main strength is their physicality, which can be leveraged to create powerful

sensory experiences through design. I believe that sensory experiences are essential, especially in our modern world where we spend most of our time indoors working in front of screens. Our senses are often underutilized, and museums have the potential to help us reconnect with them.

However, this potential is not new. What I see as particularly exciting is the combination of sensory design and social experiences. A museum's physical space can have a significant impact on the overall exhibit, and the visitors themselves are an integral part of the experience. By incorporating social interaction into the museum experience, museums can create a more memorable and enjoyable visit. Ultimately, the key to the next generation of museums is to combine multiple aspects and work with the benefits of the museum itself.

Lea

The future of museums in the face of the digital era is indistinct. Digital learning applications that can be accessed easily from home or in classrooms pose a possible threat to the existence and relevance of physical museums. While such alternatives can make museums more accessible and be an enriching addition to the physical museum, I believe that museums constitute a physical space of enormous social and societal relevance and that there is a need to continue to foster and develop museums and the experience of museum visits. Possible alternatives and additions in this regard are still not able to replace the social experience of spending time with family, friends and classmates in a museum nor do they achieve to recreate the extraordinary installations and creative experiences one can find in museums, which often bring an additional layer of meaning and memorability to the visitors by their interactive, physical and sensory nature. The rise of digital and technological learning applications should not be seen as a threat to museums. Rather we can find ways to implement technology in museum exhibitions to promote the benefits of physical museums. Furthermore, museums have usually a much higher possibility to include the body into the learning and exploration experience. All this outlines the exciting potential to innovate and develop exhibition design. Going into this project I was driven by a curiosity and desire to explore the possibilities of physical museum experiences. Especially the notion of the body in the design of learning experiences was one of the main inspirations for me. I've always been more the type to learn from doing and exploring rather than just listening or reading. Throughout my school years I felt a strong need for more embodied and explorative learning approaches, a need which I later heard a lot of friends express too. I see a strong potential in museums to satisfy this need and make such embodied learning experience possible and more accessible and provide the space for people to explore them. Thus, I saw a chance to investigate into the possibilities for embodied and sensory learning and experiencing in our bachelor thesis.

CHAPTER OVERVIEW

6.14

The following chapters include the concept, project development, and conclusion. The concept includes desk research, field research, and then how the concept for the project emerged from that. The project development includes the planning and development of the project and a final prototype. The conclusion contains the contribution, the reflection, and the next steps.

Research

Scentsory

7

CONCEPT DEVELOPMENT

RESEARCH QUESTION 7.1

How might we use multisensory and social experiences to make an insect's olfactory behavior perceptible to museum visitors playfully and excitingly?

METHODOLOGICAL APPROACH 7.2

Our methodology began with a thorough and comprehensive analysis of the museum's design landscapes. We delved deeply into the world of museums and exhibitions, with a firm goal of understanding their workings and offerings. Alongside our observations, we sought the advice of experts from the museum and insect domains to acquire valuable insights. Drawing on this wealth of information, we conducted experiments, brainstormed ideas, and assessed prototypes to refine our design. Our commitment to this iterative approach ensures that our final product will be of outstanding caliber and crafted to exact specifications. These steps and insights are described in the following chapters.

These new insights will then flow into various prototypes. The prototypes will be used to work out the various options. The use of "Wizard of Oz" testing was crucial in our process. As we had technical dependencies that were not met at the time and point, we needed to test the functionality. Based on those prototypes we continued to develop with further iterations. Because of time constraints, we will test the prototype as a whole in the exhibition of the bachelor thesis and will rework it until the presentation and present then the new findings.

As a designer, creativity is not something that comes in isolation. We all get inspired by the world and transform our ideas into our own creations. We talk to people, colleagues, friends, and family to learn and grow. To gain more knowledge and insights, we actively engage with different communities. For instance, we talked to museum experts to understand their perspectives and gain more knowledge. We also spoke to a person from the committee of DIZH (Digitization Initiative Zurich), which is part of the „History(s) for the global present. Digital co-creation in schools and museums" team. Additionally, we consulted two insect experts to understand the complex world of biology and find our way into the project's content.

RELATED PROJECTS

7.3

We have selected related projects to position our work among others. Additionally, this should inspire us to incorporate additional and new aspects that will help us venture into different areas of the project.

7.3.1 Shelly

By Nadine Cocina & Clio Wolfensberger (2018) Switzerland

In collaboration with the „Zoological Museum of the University of Zurich“ and interdisciplinary collaboration between the fields of Interaction Design and Scientific Visualization this project tells the story of a sea turtle. Shelly is a 3D projection mapping storytelling exhibit that uses the interplay of scientific, didactic visualization to tell her life cycle as an interactive experience.

In this project we find it intriguing how the creators employed interactive storytelling techniques, utilizing projections to narrate the life cycle of a sea turtle. Storytelling serves as an excellent didactic tool, enabling visitors to better comprehend the information being conveyed. Furthermore, the interactive nature of the storytelling allows users to explore and proceed at their own pace, rather than being forced through like in a video, transforming them into active participants.

7.3.2 EcoTile floor

by Yon Visell, Karmen Franinovic, and Moritz Kemper (2012)

A floor-tile platform for audio-haptic simulation of different types of grounds. The floor is composed of tiles that provide vibrational and sonic feedback in order to generate audio-haptic sensations of walking across different ground surfaces.

This project is a remarkable demonstration of how two sensory inputs can be utilized to alter the human mind's perception of reality. It highlights the delicate nature of our perceived surroundings and the potential to manipulate them through simulated sensory experiences. It is a powerful example of how even with just two sensations, a truly immersive experience can be created.

7.3.3 insects: models for design

by taku satoh, takeshi yoro (2019) Japan

This exhibition is a collaboration between graphic design specialist Taku Satoh and insect lover Takeshi Yoro. The goal is to inspire visitors with the complex diversity and brilliance of nature as a template for design (designboom, 2019).

This exhibit of insects is a remarkable example of showcasing their diversity and the wonders of the natural world. Many insects are magnified and presented from new perspectives. Often, we fail to appreciate insects as they inhabit a much smaller world, yet they are vital to our planet, to the animal diversity and coexist with us.

7.3.4 Olfactory Labyrinth ver.1

A labyrinth with no walls and only scent to guide you on the olfactory journey. The project is implemented by small bottles of essential oils hanging from the ceiling. The essential oils travel through the securing thread into the room in a 20cm radius. The bottles are hung up in a grid with a distance of 40cm so one can travel through spatial smells.

The task of incorporating scents in design poses a distinctive obstacle, given that scent molecules are air-borne and can intermingle with various other odors. Furthermore, the evaporation of scents over time poses a challenge for museums striving to uphold a constant aroma. The project showcases the utilization of oil-based scents that are released through a thread and a bottle opening to decelerate the evaporation process. Additionally, it highlights the potency of the human scent in a spatial context. Furthermore it is an interesting case where users actively engage with scents in an installation and interact in the sense that they explicitly smell the bottles to navigate through space.

7.4 FIELD RESEARCH

In the following section, we summarize the findings from the field research, which enabled us to further narrow down the scope of our project concept.

7.4.1 Natural History Museum Zurich

We began our field research journey at the Natural History Museum of the University of Zurich to gain a better understanding of the foundation we were working with. We visited the museum, which is free of charge and open to everyone on a Wednesday afternoon, along with several other visitors, mostly families. The museum was neither too crowded nor too empty. Before the museum closed for the setup of a new dinosaur exhibition, we observed the layout and what the museum had to offer, using the „fly on the wall“ method to gain some insights into how visitors perceive the museum.

Several key findings emerged from our observations: Interactive elements, such as touch screens and lighting proved highly engaging for visitors. However, the initial appeal quickly diminished if the exhibit lacked functionality or usability. Social groups, particularly parents and children, demonstrated a collaborative and supportive approach during their visit. Further details on our specific observations are outlined in the following paragraphs.

Upon entering the museum, an information desk can be found on the right-hand side where visitors can book guided tours at a certain cost based on their length or ask for information. Free guided tours are offered on Sundays. On the other side, visitors can enter the exhibitions. We started our tour on the left side with the Swiss birds, which were presented in glass display cabinets.

The birds were labeled on the wall, and a turned-off LED was placed next to the label. Visitors could press a button on the device next to the cabinets to hear the bird singing if they held up the earpiece. At the same time, the LED would light up in the cabinet next to the corresponding bird. This device was popular with children, and parents would help them to find the matching bird. If the bird was high up, they would lift their children in their arms. Children were much more interested in the sounds than adults and would often play every sound on the device.

In some parts of the exhibition, touch tables were placed, allowing visitors to gain greater insight into different species. The information was well-structured, but many options were not clickable. We could not figure out if it was the screen or the application itself that was preventing visitors from exploring topics in-depth. The touch table was a visitor magnet, but visitors would quickly give up when they realized its shortcomings.
At one exhibit, visitors could touch the fur of different animals, which was also popular with children. They often ran to this exhibit.

Concept Development

Scentsory

Figure 3 Device to play bird sounds

Figure 2 Bird display at museum

Figure 1 Visiting Natural History Museum Zurich

7.4.2 Natural History Museum London

We visited London and made a few stops at the museums to expose ourselves to different exhibits. The idea was to compare them against exhibitions at Swiss museums. Our first stop was at the Natural History Museum, which had free entry except for a few additional exhibits requiring a small entrance fee. Fortunately, the insect exhibit was free and it was amazing to witness the creativity of the curators and designers. We observed visitors interact with the displays. This section of the museum was called „Creepy Crawlies“ and showcased insects and spiders, catering to both children and adults, which was evident from the diverse audience present.

What stood out was the interactivity in the exhibits. The whole exhibition was separated into different sections of types of animals and then into different topics per exhibit. For every topic, you had information and some interactive elements. This could range from a turning mechanism to a game with a big physical model that changes depending on the game. Not every exhibit had something interactive. Some displayed different stages of the shell of an insect. Some interactions were simple, like having a magnifying glass to examine certain details on different insects. Others were more physically engaging, allowing visitors to move around parts to get different contexts. For example, the night and day state of plankton in the sea. We noticed a young girl playing with one of the mechanisms while her older sister explained what was happening, as the younger one could not yet read. Kids loved to play with moving parts and the older kids helped them figure out what is happening.

Another exhibit that had a queue of people waiting was the spider game. When you first approached it you could see a big mechanical spider that had moving parts. The body of the spider could be assembled or disassembled based on the screen interaction one could make. The screen interaction was a quiz about spiders. For example, it would ask you “How many legs has a spider?” and you had three choices to pick. If you answered correctly the legs of the spider would be added to the model in front of you. If you answered incorrectly nothing would happen to the model and the screen would prompt you to try again. Here the learning was gamified with a quiz. The motivation to play the game is to assemble the big mechanical spider.

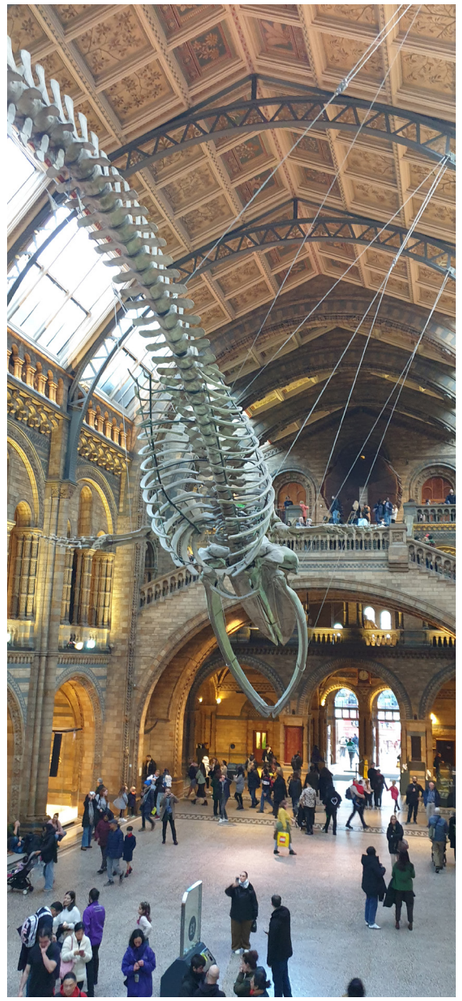

Figure 4 Entry Natural History Museum London

Figure 5 Feeling spider web vibrations

Figure 6 Comparison insect jaw

Figure 7 Mechanical spider game

Concept Development

Scentsory

7.4.3 Science Museum of London

To improve creativity and inspiration we wanted to look also into other museums as well. The Science Museum of London has some similarities but is still different enough to take away some learnings. The museum is enormous. They have 6 floors full of exhibitions. All of them were free. They mostly contained huge models of rockets, steam engines, and airplanes. On the other hand, you had cool exhibits that asked the question “Who are we” and went into topics like identity, brain, and cognition. In all those exhibits they placed some interactive elements. I would say around 30% was interactive and 70% was more static and involved looking and reading.

One exhibit was particularly interesting. It was in the section on medicine. It was a separate room that had the atmosphere of an old pharmacy around the turn of the 20th century. When you enter the room an audio narrative is started. There are three interactive touch interfaces. They incorporated physical objects with projection mapping and animations. We observed multiple times that queues were building up because everybody wanted to try out the experience. The interaction with the content of the interface was fluent because you only had one place where you could touch something during the whole interaction. Here we have the input through three senses vision, hearing, and touch (of actual objects).

Figure 8 old pharmacy ehxibit

Figure 9 Interactive projection 1

Figure 10 Interactiveprojections 2

7.4.4 Landesmuseum in Zurich

For user and curator interviews we wanted to check out another local museum. We chose the Landesmuseum because it has a good reputation in the design community. We wanted to know what the buzz was all about. The Landesmuseum is exhibiting topics about Switzerland. We mostly looked at the "Archaeology in Switzerland" Exhibition. One part was the people's archaeological remains. These items are displayed in glass cabinets. In front of the glass cabinets were touch screens that could be pushed along the horizontal axis to the object that the visitor wanted to investigate. A lot of people did not realize this and the museum person had to mention it to the visitors.

Another part of the exhibition is the part about the domestication of animals and plants. This part caught our attention quite quickly as it was the most interactive and multi-sensory experience in the museum that we have seen. On the website, they described as follows:

"Animated projections and interactive research stations make the exhibition come alive and invite both children and adults to embark on a fascinating trip into the past."
- (National Museum Zurich, 2024)

In the previously mentioned statement, the term „interactive research stations" was used to describe these exhibits. This terminology perhaps suggests the concept behind these stations, which could be their main approach to the exhibition. The so-called stations were tables in a room divided by topic, for example, wheat production and cow domestication. What all tables had in common was the text-based information, drawers to pull out with more information, pictures, diagrams, a surface to touch to start an animation in the projection, and some real objects matching the topic. Not the same as the interactive part of the station itself. Some had moving parts to align and get more information if you aligned it correctly. Others had buttons to light up more text. Then there were stations where you could touch wood and some just played back the audio matching the station. These sensory inputs gave the whole exhibit another dimension. They were purposefully placed in relation to the topic. The visitors would actively interact with those. Another part of the exhibition was a huge wall projection showing a drawing of a Swiss valley. There wasn't much happening in the animation until a visitor would activate additional animated content by standing on marked places in the room or touching a marked surface on the stations. On the marked place is written: "find more on the wall projection". We thought this to be quiet misleading because there would just appear animation of cows or wheat swaying in the wind. Maybe they wanted to put the topic more into context, but we don't think it added a lot more value. Only the children wanted to find and start every animation.

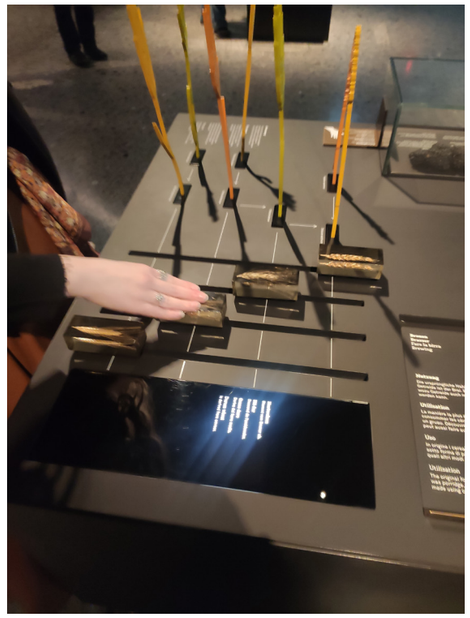

Figure 11 Landesmuseum wheat production

Figure 13 Interactive wall projection

Figure 12 Landesmuseum wood production

7.4.5 Findings of field research

The field research findings can be summarized as follows: exhibits that feature interactivity such as light touch screens, tactile elements like fur or moving parts tend to attract visitors. However, if an exhibit lacks functionality or usability the initial appeal quickly diminishes. Social groups, particularly parents and children tend to approach their visit collaboratively and supportively. The Natural History Museum taught us that making comparisons can help visitors better understand complex concepts. Additionally, combining games and quizzes with physical models can also attract visitors as can animations with interactive and physical components. At the science museum, for example these types of exhibits were extremely popular. The Landesmuseum's „interactive research stations" concept was also a hit as users were able to explore topics together through interaction. Overall the key finding seems to be that exploring with the senses is a crucial aspect of these interactions.

INTERVIEWS 7.5

To expand our knowledge and seek expert opinions we engaged in conversations with various individuals. We sought the insights of insect specialist Michael Greeff to attain a broader understanding of insects. Following that we conducted a more refined interview with Wolf Blankenhorn to explore the senses of insects. For our inquiry into museum development, we consulted with Sophia Prinz, who conducts research on this topic for the digital initiatives of Canton Zurich. Additionally, we spoke with Luca Tori, the curator of the „Archelogy Switzerland" exhibition at the Landesmuseum to gain insights into the process of creating exhibitions which we also experienced through our field research. All the science experts we talked to had also some experience in curatorship, which was really noticeable and an additional help in the exchange we had with them.

Sophia Prinz 7.5.1

Sophia Prinz is a member of the DIZH research team, which focuses on digital initiatives for museums and schools. During our interview, we had the pleasure of discussing her perspective on the role of digital media in museums and the key factors necessary for the successful implementation of technology in these settings.

During the interview, we gained valuable insights into effective mediation techniques. Incorporating various forms of media, including digital interfaces, is essential for success. Visitors are a valuable resource and can provide unique knowledge and perspectives. To ensure the effectiveness of digital media, content must be considered in conjunction with the appropriate exhibition types. Sensory design methods are an emerging trend that should be explored for their targeted use. Coordination between content and design is crucial to fully utilize the potential of storytelling in digital media. Multidisciplinary collaboration is the key, within all disciplines considering each other's perspectives. Gamification is an intriguing approach that can maintain complexity when applied effectively. Current trends include collection, immersive spaces, multisensory experiences and gamification. Visitors can learn not only through explicit means but also implicitly. Providing something of value can raise interest and inspiration. Media selection should consider the surprise effect and which media evokes specific impressions.

7.5.2 Michael Greeff

During our recent visit to ETH Zurich we were fortunate enough to explore their entomological collection with the guidance of Michael Greeff. As newcomers to the intricate world of insects, our curiosity was piqued and we were eager to absorb as much knowledge as possible. By recognizing the value of seeking assistance in areas where we lack expertise we were able to successfully navigate the project with ease.

Michael Greeff graciously welcomed us into his office before leading us down to the cellar, where the collection was stored at an optimal temperature of 7 degrees Celsius. The facility houses a staggering of 600,000 insects available for study, with some specimens being loaned for exhibition purposes. Our introduction to the collection began with iridescent butterflies whose wings are blue and shiny due to their physical structure. We learned that the butterfly's wings allow every wavelength of light to pass through except blue light which is why we perceive their wings as blue. Michael next showcased different species of moths which fly in the dark and have fascinating fan-shaped antennas that capture the pheromones of their mates. He also exhibited beetles that roll up their eggs in dung, enabling the hatchlings to develop inside. We were struck by the sheer diversity of insect species and the intricate details that distinguish one from another. Michael's expertise allowed him to differentiate between species that appeared identical to us but had unique adaptations that enabled them to survive in their environment. We also gained insight into the extensive documentation and maintenance required to sustain the collection. Although the facility accepts insect collections from hobbyists the identification and sorting processes are delicate, often requiring the facility to request donations from the collectors to cover expenses. Michael also highlighted the dwindling popularity of insect collecting as a hobby. Only individuals above the age of sixty still actively participate. He speculated that this decline was due to the belief that nature should be protected and left undisturbed. However, the study of biodiversity and the impact of climate change on ecosystems relies heavily on insect collections. Michael also shared fascinating research conducted by his boss on the pheromones emitted by insects. For instance, a firm wanted to create insect flowers and sought advice on the least painful method to kill insects. They consulted Michael's boss because insects release pheromones when subjected to physical impact. After experimentation, they found that freezing the insects resulted in the least amount of pheromone release. Nevertheless, the question of whether insects experience pain like humans remains unanswered, and whether freezing prevents pheromone emissions entirely. Michael also explained that pheromones are not exclusive to insects because plants also utilize them. For instance, when a cabbage is attacked by an insect, it emits a warning pheromone that alerts neighboring cabbages who do the same. This pheromone then attracts the enemies of the cabbage attacker. Michael's boss is currently researching the relationship between insect-human pheromone interactions. Furthermore, mosquitoes transfer malaria by causing hosts to emit pheromones that attract additional mosquitoes to spread the virus. This pheromone admission can now be used to detect asymptomatic malaria patients and further curb the spread of the disease.

7.5.3 Wolf Blankenhorn

In the fascination of pheromones and the senses of insects, we invited Wolf Blankenhorn for an interview. He gave us an in-depth insight into the diversity of insect senses.

We asked Wolf Blankenhorn specifically about the olfactory sense of insects. He explained that most insects have an antenna that is used to detect pheromones. Another option in the insect world is the ability to sense smell over touch on their body. A lot of insects use these senses to find a mate. For example, the male moth uses pheromones to attract the female moth over quite some distance. Then female mosquitos smell CO2. This is how they find their blood source in mammals which all admit CO2 by breathing. He went on to tell us that insects often only smell just specific molecules. Plants use this to their advantage and produce those molecules to attract insects so that they spread their pollen or attract the enemies of the plant attacker. For example, plants produce the same pheromone as the female insect, so the plant attracts the male of that insect. Some plants produce many different fragrances, but these often only attract one insect at a time. Then again, some plants only produce one fragrance and only attract one species. This can be to their advantage, as they can survive very well in an environment with a high proportion of one species. However, this can also be the downfall of the plant if the insect species dies or moves away. The plant has no alternative to turn to. These plants produce those pheromones by trial and error followed by mutations because they often have to change just one connection in the molecule to smell completely different and attract another insect. This explains also the huge diversity

in the insect and plant world. In general, for insects their main drive and motivation is mating and finding food. If they use pheromones, it is really dependent on the wind. If the wind comes from another direction two insects would not find each other or find food. On the other side, you have the insects that smell by touch. These pheromones can be really heavy because they do not have to travel through air. This smell by a touch of pheromones is used for a two-step identification in the mating partner finding. The diversity in insects is so big that it is hard to differentiate between mates and not compatible mates. So, over the volatile pheromone insects sometimes attract a lot of species. When they find each other they test for further compatibility with the smell by touch. This is also beneficial for the females because they want to choose who is their mating partner. This redundancy of sense could be inefficient, but often it is beneficial when you first attract a lot and then filter out the good partners. The senses like smell and sight or smell by touch help in those cases. But often in nature you have mixed senses like the mentioned smell by touch but they still feel the surface. There are also things that we as humans cannot sense in comparison to insects. For example, some insects can see in the infrared spectrum of light wavelengths. Very often the mechanics or physics are quite similar but the spectrum or the molecule you can or cannot sense is different. Here evolution plays a big part because you want to save energy where you do not need a sense to survive. For example, night-active insects see only bright and dark. Another aspect that Wolf Blankenhorn finds important is that there are so many solutions for different functions in nature and they do not work all the same. Some of these solutions are more efficient than others. But they all have the same physical principles as an underlying foundation. A very interesting aspect of insect smell is that they can smell underwater. The chemical molecules get transported through the water. Water and air have similar physical properties but to be able to transport through water they need not to be too light and not too heavy. Otherwise they would float on top or sink to the ground.

Luca Tori

Our intention for the interview was to obtain insightful perspectives from the highly regarded curator, Luca Tori, regarding the curation of the „Archelogy Switzerland" exhibition at the Landesmuseum. Our primary goal was to extract valuable knowledge from the exhibit which we had the privilege to observe during our fieldwork.

Luca Tori was responsible for curating the exhibition content which was tailored to the school curriculum. The main challenge they faced was the limited space requiring a drastic reduction of content to avoid overwhelming visitors with too much information. It was learned that for an exhibition of this size a team of diverse professionals with various expertise was essential. This included experts for display cases to prevent damage from vibrations, as well as a team of designers to develop interactive workshops and games suitable for different ages since the target audience was schools and families. Another challenge was creating adaptable content for permanent exhibitions aiming to connect digital and physical elements. Encouraging interaction between technical and non-technical individuals is a key focus. This encompasses future plans to incorporate community participation in exhibition planning and implementation, including engaging supervisors to provide information to visitors and generate reports for curators.

The key learnings are the importance of reduction of content not to overwhelm the visitors. Using the digital layer to create reusable exhibition objects. Striving to go more into

8

IDEA DEVELOPMENT AND IDEATION

We started the project with little constraints and stayed very open to different approaches and ideas for a while. Through our research and the interviews we had with various specialists on the side of museum curatorship and entomology we were able to start narrowing down our ideas for the project. The Natural History Museum gave us the freedom to come up with and decide about the specific contents of the exhibition ourselves alongside the creation of the exhibition design. This was in some ways a challenge but mostly it also made the process very delightful, as it allowed us to develop the content and the design simultaneously and according to each other, which was something Sophia Prinz mentioned as desirable for museum experience design in the interview we had with her.

FREE FLOW IDEATION

8.1

Alongside the process of specifying the content of the exhibition we were playing with different ideas for the designed experience. This project is situated within a design space that includes a big body of possibilites. Which was of course very exciting and excitatory but also one of our biggest challenges in the beginning of the ideation phase. Design Methods like mind maps, rapid prototyping, clustering, experiments and crazy eight helped us in the process, as well as the continued field research we did. In the beginning we mainly relied on the crazy eight method and just general idea sketching and discussions to get all our ideas out into the room and on to the paper. Through that a big body of ideas and approaches to this project formed, which we were then able to cluster. Not perfect, some not even good or useable but in-between there were some promising and intriguing aspects. This process helped us to iterate through ideas quickly, as well as to discuss and align our wishes, expectations and interests as a team. To tackle the challenge of the open possibility space we faced, we had to flesh out our own criteria and values for this project. Here are some of the questions that helped us to navigate our different ideas as the ideation process further unfolded (In no specific hierarchical order):

A) Is this something that makes us excited?
B) Is this something that is realistic and feasible in the projects time frame?
C) Does this potentially bring meaningful insights into the world of insects and their way of living to the visitors of the exhibition?
D) Is there a unique voice to how we imagine this experience?
E) Can we provide new knowledge and value to a diverse audience?
F) Does this imply a social exchange for the visitors?
G) Could this be an inspiring and memorable experience for our audience?

As we didn't have many external constraints to our project and not a classic problem to solve for a specific user group it was very important to create a rough frame for ourselves to be able to identify the project's needs. So here we were with the whole world of exhibition design possibilities and a great number of ideas before us. Now, was the time to start experimenting and creating, to help us move forward with our ideas. This turned out though to be very cumbersome, as it was quite difficulty to find feasible ways to experiment the sometimes technically and spatially very complex ideas we had. We were searching for a promising idea that would bring us from thinking to doing. This time was an intense phase of ideation in which we had the challenge to keep our minds fresh to the project. It was then the exchange and co-design with peers and external experts that enabled us to keep moving forward.

8.1.1 Experimenting with embodiment

The first experiments we conducted were surrounding the notion of embodiment. What is it like to be an insect? How could a human experience to see like an insect? How could we simulate the sensation of flying or being as light as a feather? To work with the fascination of becoming a different life form was an obvious and promising first approach to the project for us. It was this notion of embodiment that our first experiments revolved around. In a first quick prototype we explored a way to simulate the sensation of standing on water, which is a very extraordinary ability of the water strider. The short hairs covering their body allow this insect to move across the water surface and notice vibration patterns of other forms of life in the water. These water vibrations provide them with important information about prey, mating partners and opponents in their surrounding area. Water striders use these sensory information inputs in navigation to find resources for their survival and reproduction. In a quick attempt we tried to figure out if we could create a similar experience of lightness and wave movement. We worked with wood panels and foam to test this. The test person would stand on the wood panel equipped with foam, to replicate a feeling of standing on waves and a piece of cloth was tied around the persons waist and elongated away from the persons body to represent the water surface. A second person would walk around the test person, which had their eyes closed, and tap the cloth to replicate the vibration. The test person had to feel the cloth to determine the direction of the movement. From this arose the question if we could find a possibility for people to perceive directions only with the sense of touch and a vibration/movement input.

Though we liked the physicality of this first prototype we also had some concerns around the idea. We weren't sure if embodiment was the right approach for us to this exhibition. We had a discussion about thematic ideas for the installation with our collaboration partner at some point in the ideation phase, where we had the finding that creating such a literal embodiment experience of an insect is quite impossible. Due to the fact that insect senses are so fundamentally different than ours and that also experts sometimes can't tell exactly how these sensations work or feel to insects, all our efforts to create such an experience would always be just an attempt. This also opened moral and philosophical questions, that didn't fit within the framework of this project. We saw that the attempt to embody an insect could also in some ways be inappropriate. But we weren't quite going to let the idea go yet. Not only morally but also scientifically we sensed that this approach would only make sense if we would try to make a translation of an insect sense and its use for them rather than a replication of a sensation. And that it would have to be communicated very clearly as such.

8.1.2 Sensory trace translation

So, we continued with this idea and fascination for the senses of insects and their use in navigation and brainstormed further experiments. We were still intrigued by this notion of navigation and orientation through following traces and patterns. We wanted to make this notion experiential to humans through their senses. We came up with the idea of a sort of sensory labyrinth and sketched some possible installations for it. The ideas was to have a platform that could produce air blasts or temperature in different intensities. While diving deeper into the idea, we also found similar projects, like the olfactory labyrinth, a space installation by Yukiko Shikata which we talked about in further detail in the related projects section. The two experiments we conducted next, served as a means to test how easily humans could differentiate sensory inputs. First, we attempted to find ways to create such traces and patterns ourselves.

8.1.3 Experiment 1

As a quick way to find answers to our design question: How well can humans perceive sensory inputs and use them for orientation?, we used an air pump to create air blasts around a person. Noise cancelling headphones functioned as a way to restrict the persons hearing, to prohibit any other sensory help in the orientation. Additionally, the person was asked to keep their eyes closed, to solely concentrate on the sensation of the air blast on their body. The pump was placed on the ground close to the person, pointing upwards to create air blasts around them. We gave the person the task, to figure out which direction the wind is coming from, to find out if this air blast method could be used as a way to make people navigate in space. What we found was that it is possible to perceive the general direction of the air blast though it was quite challenging. The error rate in the accuracy of the direction though was reasonably high, as the test person got it wrong multiple times. We also found that the amount of clothes the person was wearing significantly changed the difficulty of the task. With less clothes covering the skin the person noticed the air evidently easier. This posed a difficulty, as we wouldn't really have the possibility to influence peoples wardrobe in the exhibition.

Figure 14 Experiment 1 air flow

Experiment 2 8.1.4

Through the second experiment we were able to explore more the notion of traces. We wanted to test the possibility of perceiving temperature gradients. While the first experiment was restricted to just the direction, a simple 0 or 1 question, we now also wanted to see if we can differentiate between the intensities of the sensory input. As well as with the first experiment we had to find a quick and easy way to try and test our idea. We thought about possible ways to create controlled heat and cold, without a lot of effort. So, we filled containers with sink water in different temperatures and created a grid with them. In the 3x3 grid a gradient was formed with rising water temperature. A test person was then ordered to find the hottest container. The test person was informed in advance about the trace and that they could use this to conclude the task. The person then used their hand to feel the temperature of the water inside each container. This time it was not necessary to restrict any other senses, as they didn't influence the conclusion of the task. Compared to the first experiment the task here was completed by the test persons with much less effort. A bigger grid would have potentially increased the level of difficulty of this task. Generally the participants were able to easily distinguish between the different levels of temperature.

Figure 15 Experiment 2 heat path

After the conduction of these experiments, we ended up moving away from the embodiment approach for different reasons. Though it was interesting to see the findings from these quick experiments we still didn't find that spark we were looking for in the embodiment approach. We found that the ideas we had in this framework didn't align strongly enough with the guiding questions we established for ourselves, especially point A and D. And as we got new inspirations from our field research as well as new interesting insights into the world of insects, we shifted our attention back to an older idea we had in the very early stages of the project. In the next chapters we will talk about our course of action to define the thematic topic and mediation content for the installation, as this informed a lot of our next steps in the process to determine a more concrete design concept.

8.2 CONTENT DEVELOPMENT AND CURATORSHIP

Now of course all the research and process we conducted as described above would be worth nothing, if it wasn't to be connected and used in regard to the topic of the exhibition: Insects. We obviously aren't scientists or biologists, and it was impossible that we would become experts for insects in the short timeframe of this project but it was evidently very important that we would learn quite a bit about insects to narrow down the thematic development but also to generally form an understanding for the subject matter, to be able to make good design decisions within this thematic framework. Our collaboration partner and the entomological specialists Michael Greef and Wolf Blanckenhorn unclosed the fascinating world of insects to us. First, we went to the entomological collection at ETH, where we had a tour with Michael Greef. Through the conversation with him we got an insightful introduction to insects, their behavior, their classification, their bodies, their way to interact with other species and much more. We were captivated by some of the things Michael told us about, the very different lifespan of insects to ours (spending much less of their lifespan in adulthood than as larva), the way ants allow larva of other species into their lair and look after them and how cabbage releases pheromones when it's eaten by an insect to protect itself are just some of the compelling things we learned from our visit. Many of these findings could have served as possibly interesting topics for our project. More detailed information about our visit to the entomological collection and our discussion with Michael Greef can be found in the interview chapter.

It was no easy decision, in which direction to continue but it was essential that we concretized our topic for different reasons, time constraints not being the last. So, after we left the entomological collection with saturated brains, we sat together and discussed the new material gathered. And what we found is that among all the fascinating insights what intrigued us the most was the insect's senses. To see the

differences and similarities in these bodily functions that we share to some extent with this other species was just astonishing. We felt that this concept had a lot of potential to spark the visitor's curiosity, as humans tend to want to understand and relate to other life forms. Also, since we were already intrigued by multisensory experiences in museum exhibition design, we saw a great opportunity to connect the two.

But senses generally was still too broad of a topic for this project. We talked a lot about pheromones and olfactory functions of insects with Michael and since this is a sensory function that for humans is so often overlooked or perceived as less relevant (McLean et al., 2018), we found it more promising. We were intrigued by the meaning the olfactory organs have for insects and how it relates to their behavior in navigation and communication for nutrition and reproduction. And there again was the concept of following traces and navigation through sensory input.

8.2.1 Specifying

In a next step, we sat together with Wolf Blanckenhorn, who was able to give us more in-depth insights into the various fascinating functions of insect's olfactory organs and the differences to human olfactory sensory perception. One of the main learnings we were able to take away from the conversation was how insects have two kinds of olfactory organs, one being volatile picking up pheromones through the air often with antenna and the other with physical contact. This organ is located on the skin of the insect. Apart from that he talked about how insects use pheromones to attract mates and how some detect pheromones of plants to find blossoms or other food sources. Another core learning from our discussion with Wolf was how versatile the sense of smell is in different insect species and that no generalized statement can be made for all insects. So, we quickly realized it would be a shame to show only one insect in our installation. It would be beneficial to give an insight into the diversity of insect's olfactory behavior. It obviously was also not possible to show dozens of insects, as it would have gone beyond the scope of this project and would have possibly also overwhelmed the users. We decided together with Wolf Blanckenhorn that three to four insects are a reasonable number. If the insect examples were wisely chosen, the project would still be able to give various insights into the different interesting aspects of insect's olfaction.

The thematic content development was a challenging process. As already mentioned, our collaboration partner the Natural History Museum of University of Zurich gave us the freedom to decide about the thematic development around the exhibition installation. This can be a big enrichment for such a project so that design and content can be developed to their full potential together and in this design context very desirable. However, in the frame of this project it was also a very big task in and of itself, that would normally often be attended to or shared with a curator. Even

Idea development and ideation
Scentsory

though we could fall back on the collaboration and assistance of insect experts and were able to conduct a co-creation practice in that manner, the thematic development of the content was a challenging process in regard to organization and scope. We found that the content development could have been richer if we had more time for it or we could have shared this responsibility more with our collaboration partner. The content development was a very pleasurable but challenging task and we revisited it constantly throughout the process to develop it further. We'll talk more about our specific decisions in the section concerning the actual development of the installation as that's where these decisions came into play.

8.3 SCENTSORY: A SMELL GAME

When we settled for the olfactory perception of insects as the topic for the installation, we did another round of idea sketching, discussing and brainstorming where we partly also included some of our interaction design colleagues, to help with fresh eyes, or noses. And through this came the hour of birth of the idea that would later develop into the final prototype of the project: A smell-based memory game. The core principle was that like in a visual memory game users would have to find and match cards but based on their smell instead of visual patterns. However unlike in the usual memory game the players would not have to find matching pairs of cards but would have to find scented cards that match to a chosen insect. With this concept the notion of insect's orientation with and attraction to scents could be communicated in a playful, interactive and multisensory manner. Basically, the users could choose an insect out of a small selection to play as and learn about the needs of those insects and the role of their olfactory sense to satisfy those needs step by step through the interactive experience. The game shows how insects interact with scents and use their olfactory perception to find important resources for their survival and procreation and makes it experiential.

As mentioned at the end of the chapter where we talked about our first experiments with embodiment, we were also able utilize an older idea of ours to create an interactive table and combine it with this concept. There was the potential to implement this notion of the combination of physical and digital into our project that we observed in our field and desk research, to display the smell game on an interactive table. The main elements of the game could be physical for the users to grab, smell and move around and an additional layer of a digital GUI could enrich the learning and exploration experience through projections, display further information, respond to the user's actions and help guide them through the experience.

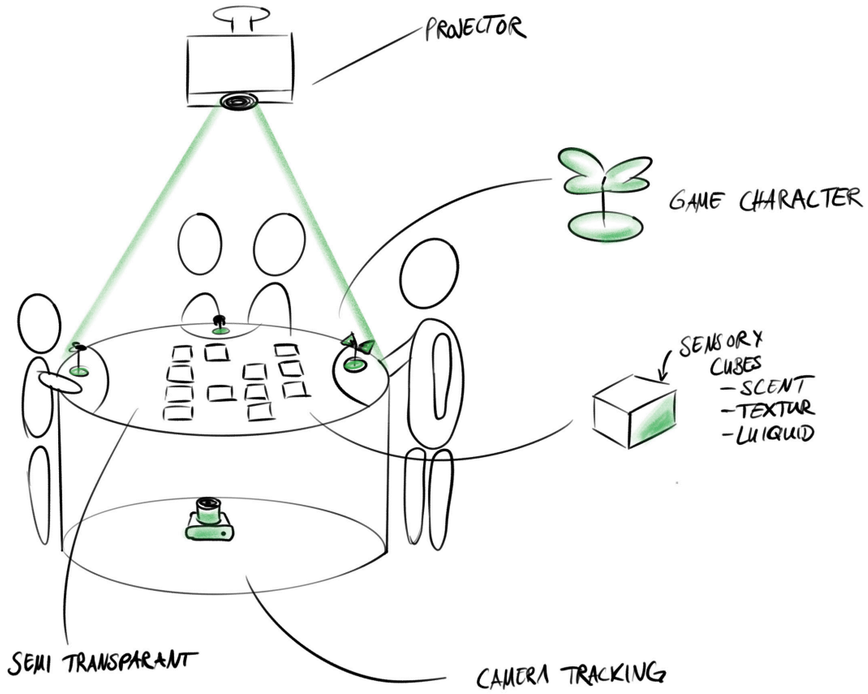

Figure 16 Concept sketch

8.3.1 General game mechanics and flow

To gain a better understanding of the experience and what we were working with we'll take a closer look at the general functionality and flow of the game in its early stage. The user picks a physical playing figure of an insect they want to play as and learn about. Their task is to find the essential needs of their insect for survival and reproduction. These are different for each insect but usually consisting of one or multiple food sources, Mates of the opposite sex for reproduction and nesting sites to lay the eggs. All those specific needs are represented by scented playing chips on the table, the play field, and have a digital ID for identification. For example, for the rose chafer there are cards representing plants of the rose family as food source and nesting sites and other rose chafers to mate with. Visually all the chips are the same, however each chip contains a scent which makes them distinguishable. A batch of example scents are provided to the user that enable them to compare the scents and find their matches. The user can check their choice and collect the resources by pulling the chips and their play figure together. Once a chip is matched with the play figure the projection informs the user about the identity of the chip and the compatibility with the user's insect. If the card matches correctly with the insect play figure the projection confirms the collection of that resource and displays further information about the scientific context concerning this resource and its use for the insect. If the card is not compatible with the users' insects the projection will inform the user about the incorrectness.

To communicate our idea in a text-based form we created a short, summarized description of each step of the game:

1. Each player choses an insect they want to play as.
2. Each player has an information card about their insect that will tell them their insects needs. On the table players will find examples of the scents they will have to look for.
3. The players take turns to smell the cards. In each move the player can smell as many cards as they like but can choose only one to validate. When the player chose a card and checked its content their move is over.
4. If the player chose the wrong card they'll lay it back on the playfield. If the player chose a correct card more information about their insect will be displayed on the table in front of them.
5. The first player to find all their insects needs wins.

In an early prototype of the game the rules were displayed on an ipad laying on the table and communicated to the users with a few slides in a step by step approach (See appendix 1).

FIRST PROTOTYPES 8.4

Smell memory game 8.4.1

To test our idea of a smell memory in a quick and simple prototype, we infused paper cards with perfume. We started out by drawing small sketches of insect's flowers and their mates on the cards. We created cards for two different insects. For each insect, you could find two matching mates and three matching food resources. At the same time you could uncover a not-matching insect or food from the other player as well as grass that matches to nothing. On the other side, we sprayed the paper cards with perfume or room scents based on oil. Every player got reference cards to smell with the matching sketch. The rest is mixed up and spread on the playground of the table. The cards are placed with the scented part looking up and the sketch looking down.

Figure 17 Smell paper prototype 1

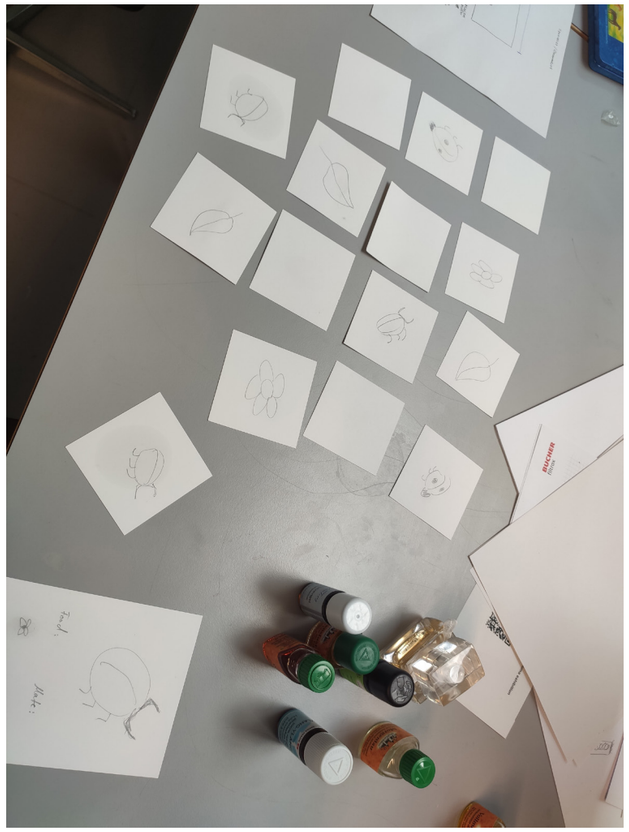

Figure 18 Smell prototype 2

At first we tried it on ourselves if we could find two mates and three food sources that match just by the smell. It was difficult and we made some mistakes but after some time we found them, and it felt great. So, we tried to come up with rules to further develop the game and make it clear what was expected. We started with the following rules:

1. Another player would set up the board with the cards.
2. You can sniff as many cards as you want.
3. You can check if you want by turning the card.
4. You win if you find all the cards.
5. Switch the roles and start from the beginning.

With this, we went into user testing and invited three game designers. We explained them how the game works so far and invited them to try it. At this stage of the game it could be played by two people. We wanted to get also some expert insights into game mechanisms as well as more people to test the smell of cards and play with them. The main learnings were:

- With this setup, one person waits for their turn which can take up to 5 minutes.

- Suggestion from the testers: keep the cards on the table and let the player put them back on another spot on the table to automate the mixing of the cards.

- The cards need to be placed in one specific field on the table to reveal the answer and more information. Such a field could be implemented for each user as a home base

- Leaning more to the original memory game and taking turns when searching for cards.

Second iteration 8.4.2

From those learnings we created the interactive smell memory prototype with a projector and a camera with image tracking. This was done with the program Reactivison (Kaltenbrunner, 2014/2024) and Processing. Reactivision is an image recognition program that detects images that look similar to QR codes which have a unique ID to track. The ID, position, rotation, and session ID get sent over the TUIO protocol. Processing will receive these data and based on the programmed logic it will display the game and insect information.

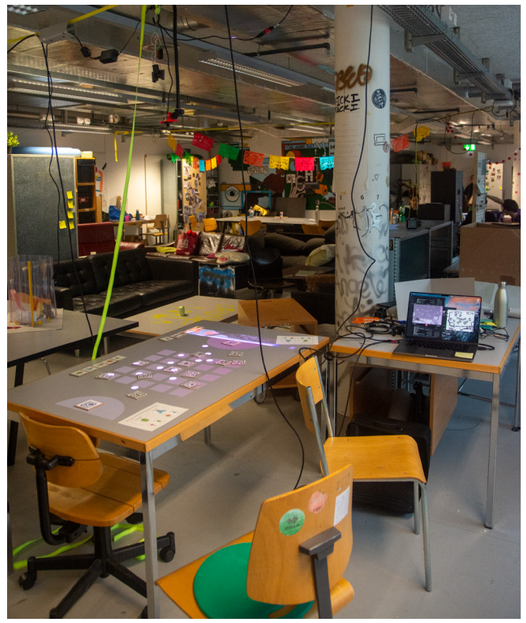

Figure 19 first technical prototype process image 1

We took the idea of a homebase and created a field where one could pull cards together and display the result if you were correct. At the moment this is a half-circle that lights up green for the correct answer and red for the false one. We created also a grid in the projection to create a place to put the cards back. We made the grid five by five even though we only had 18 cards. This lets the user decide where they want to place the card. For this prototype we added a white dot next to the card because the tracking of this particular camera was too slow to see if the card was even recognized by the program. This will be removed as soon as we get a better camera.

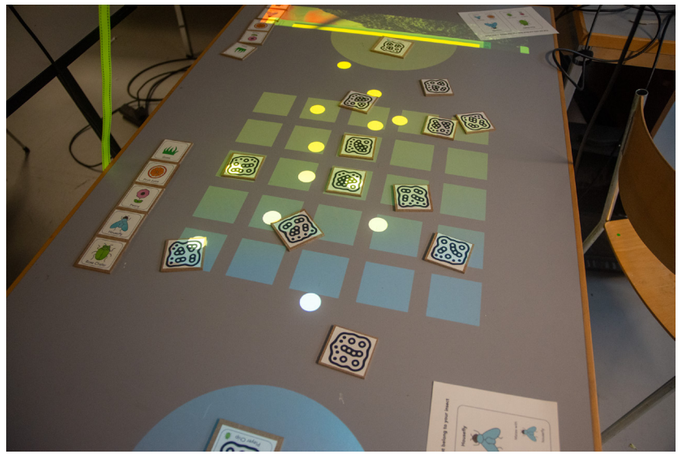

Figure 20 first technical prototype process image 2

Figure 21 first technical prototype process image 3

The main feedback to this was more suggestions on how to develop it further. One suggestion was to impair vision in order to focus more on the presented senses of our design. This is something we could test by having a blindfold option in the user tests. While using the prototype it became clear that the grid is unnecessary because users would use the grid to remember which cards they already smelled or checked. Then we need to find another option to mix up the cards or at least check if this is an issue. We also should keep in mind that in museums have workers who could mix up the cards once or twice a day.

Another important point was that we removed the possibility to move the player insect to each other by creating a homebase. Only the mate would move to the player insects, which does not represent the natural behavior of insects. One of our mentors mentioned also hygiene. This is an important point not to miss if you smell at things. But at the same time, the users did not shy away from sniffing the cards even though covid-19 was around two years ago. On the topic of scent, we used again the same scents for this prototype, because we wanted to test the gameplay and the card interactions rather than the smell. On that notion we also want to use smells that are pleasant for the user as they are probably pleasant or activating for the insects. One mentor mentioned they could be outer-worldly for us. This is interesting and we think we could consider it but in combination of pleasant is reasonable. An additional challenge that we uncovered was the fact that the user covers the QR codes with their hand or upper body quite frequently. Then the camera loses the card, and the user gets frustrated because nothing is happening. With this discovery it only makes sense to track the QR codes from underneath through a transparent material.

Idea development and ideation

Scentsory

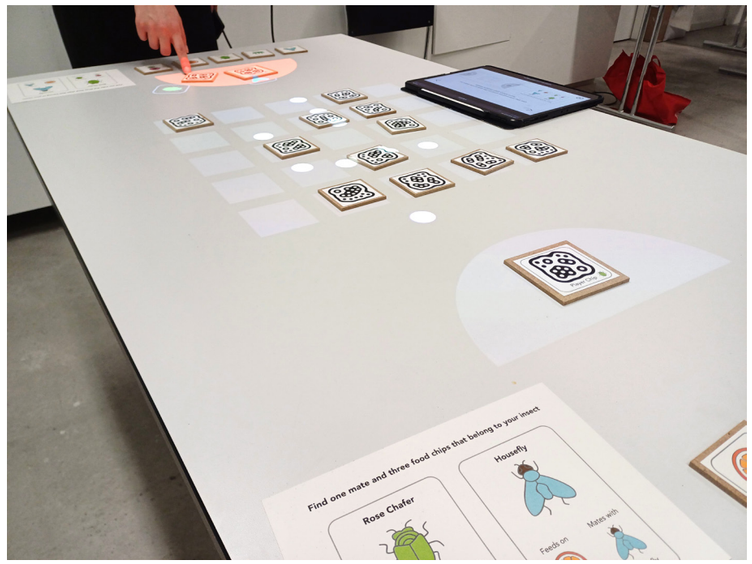

Figure 22 First technical prototype mid presentation example 1

Figure 23 First technical prototype mid presentation example 2

Figure 24 First technical prototype mid presentation example 3

8.5 TECHNOLOGICAL IMPLEMENTATION CONSIDERATION

We started to think about how we could achieve having projections from above and a camera underneath. There are already examples of implementations where infrared cameras are being used. They used infrared to avoid an interference of the projection with QR code detection. Another aspect of the challenge was the size of the table. We wanted multiple people using the table at the same time to promote social interactions between the visitors. Additionally counts the fact that the game and information all need to find their place as well. Therefore, we started with an estimate and built with tape and a table a prototype then used paper to plan out the arrangements.

At the same time, we need to test if and how we could technically make the interactive table possible. The constraints here are time and money. We work with a budget of 1000 franks for this project. With these challenges in mind, we still wanted to go for a table of 1 meter and 70 centimeters. Because we are projecting from above and filming from underneath, we can only support the semitransparent tabletop surface on the side and no support structure in the middle. Otherwise, either the camera or the projection is obstructed by the support. The material needs to be very sturdy not to sag in the middle of the table. With the size of the table, we needed either an acrylic glass with a diameter of 1.50 meters and a thickness of 20mm, so it does not bend. Another option is glass with the same diameter and thickness of around 8mm. Acrylic glass is almost double the cost of normal glass, but we were unsure if the infrared camera would see through the glass. Important was also the fact that the projector should not interfere with the recorded image of the camera. Another challenge was the semi-transparent property of the table surface. We need to find the best solution to reflect the projection to the user but let the QR codes pass through the table underneath to the camera. To solve these challenges, we created a test setup. The setup was a projector on a lather shining down on to five material combinations. The materials are glass with foil, frosted glass, acrylic glass with foil, acrylic glass frosted, and acrylic glass with double frosted surface. The foil was removable so we could test also the pure material. We placed on each material one QR code and then set up an infrared camera from below and infrared lights. This should all simulate the concept situation.

Glass with infrared 8.5.1

First, we checked if the infrared light would light up the QR codes from below. We saw some lights reflecting but not on the QR codes itself. Then we held them up closer. As soon as we did that, we could confirm that the light went through the glass on to the QR codes. The lights from the physical computing lab were not so strong so we needed to hold them up. We need to organize more and stronger UV LEDs and need to make sure that they do not proceed any reflections on the glass. Later we discovered that the glass is too expensive for us if we build it with the museums workshop. Next, we decided to go with a 12mm acrylic glass as it was way cheaper and 12mm was enough to support it self.

Figure 25 Reactivision material test

8.5.2 Projector foil material choice

For the projection on the table the sharpness, brightness and contrast were the most important. The frosted acrylic glass methods looked good. The contrast and brightness were the best on the foil. The only downside is at the moment the foil is too small for the whole surface, and it does not stick to the surface. It will be hard to fix the foil to the tabletop. But it was the best material for the projection and transparency to still be able to see the QR codes to track the position.

8.5.3 Camera material choice

One of the main requirements of this project was the detection of the QR codes through image recognition to get the position and the rotation of the tokens. We looked at QR codes through Reactivision on the different materials and checked if the program was able to detect the QR codes. All materials were good but the ones with less frosted surfaces were better.

8.5.4 Camera tests

We started with the webcam from the physical computing lab. For the first interactive prototype we used it mainly from an above position. Then we switched to the module camera borrowed from the physical computing lab with infrared capabilities. With that one we made the material tests as described above. We quickly realized that the lens of the camera module was not big enough in terms of the viewing angle. As a consequence we ordered more lenses and two more cameras just in case that the bigger viewing angle would lead to too much distortion. Maybe we could use two cameras at the same time to solve this. In Reactivision you have a camera calibrator for distortion to help with this through the software. But only for remapping the position and not for recognizing QR codes. We set up an octagon with a diameter of 1.70 meters and placed a QR code in every corner. The lenses we ordered were working perfectly and you could see all the QR codes. But they were too small for the program to recognize. When we tried the calibration, we could not see a difference. Next, we tried other lenses from the physical computing lab. They had either the same issue or they had a too small viewing angle even with two cameras. While googling on how to use two camera modules we stumbled upon a side branch of the project which is unfinished. There we realized that we installed and used an older version of Reactivision. The reason is that Reactivision created an installer for version 1.5.1 but they actually have a version 1.6 which is only on GitHub and first needs be compiled before using it. We tried to run it but got stuck on an error again. Even with googling and ChatGPT we could not solve it. We suspect that some libraries are too old. The project has not been further developed since 2017 and the last commit was two years ago. We tried setting it up on a windows 10 pc, but no luck either. We wrote an issue on the GitHub repository, but no response so far. We will continue using the version 1.5.1 on OSX and hope that it is sufficient. As for the camera viewing angle we had to choose a bigger focal length, as the distortion was too intense along the edges. So, to cover still the whole surface we used two cameras and start Reactivsion twice. That the information is still processed correctly we now must recalculate the positions of the QR codes based on which camera or which instance of Reactivision has sent the position data.

9

DEVELOPMENT AND DESIGN OF THE PROTOTYPE

IMPLEMENTATION APPROACH 9.1

Our quick paper prototype and the first low fidelity technical prototype we made to bring our idea to life and get a feel for the flow and interactions of the playful experience turned out to be very helpful. Through them we were able to communicate our idea with others and test its potential and in this process a lot of new ideas and future improvements formed. The people who saw our first prototypes or tested them themselves expressed mostly positive feedback. Many shared thoughts on how to further develop the game. There was a general excitement among ourselves as well as our participants for the concept of a smell-based game with physical elements in combination with projection. This gave us the confidence to continue with this idea and ensured us that the project was heading in the right direction.

Once this point of confidence with the general concept was reached it was time to iterate and further develop many of the details and functionalities of the experience. The user experience needed to be improved and evolved and the implementation of technical and constructional solutions for our ideas were necessary. Since our goal was to have a functional and playable prototype for the exhibition of the thesis, we needed to find the means to bring our idea to life. Also prototyping, experimenting and testing were powerful tools for us to iterate on the interactive game table. Our vision for this project consists of a big range of different aspects that come together to form the experience. Hence the to do list and the list of aspects to be developed and iterated started to grow steadily and at times grew to unreasonable measures and needed to be cut back. We continued to strategically prioritize tasks to keep the scope, which worked quite well. So, the scope of the project continuously fluctuated as we adapted things according to our abilities and progress. We distributed tasks among us in the phase of developing the final prototype to ensure all these aspects of our idea could be implemented and brought together. In this chapter we'll discuss the development of the final prototype and give insights into the challenges and design designs that were made within that framework. This chapter is an overview of the different aspects and tasks that this prototype is composed. Also, a more detailed description of them is provided.

9.2 DEVELOPING THE GAME INTRODUCTION

It was obvious from a quite early stage that the moment of first contact of the user with the table would be very crucial. Since users of such an interactive experience can lose interest quite quickly and become frustrated if the experience isn't clear and intuitive (Allen, 2004) we were very concerned about the understandability of the game. It was a challenge to communicate the general idea of the experience without making the user sit through a long explanation before they could start doing something. We needed to find a way to make the users understand the idea and functionalities of the experience as intuitively and entertaining as possible. Graphic and text-based UI elements, animations, physical affordances, playful interactions and visual and auditory feedback were some of the tools we utilized to tackle this challenge. We identified the core aspects of the game we needed to make the users understand to play the game:
A) I get a player character: An Insect
B) I'm on search for essential life resources (Nutrition, mates, nesting sites)
C) The cards on the play filed represent the resources
D) I am to use my ability to smell to find the right resources
E) I can compare the smells with the examples that are provided to me
F) I can collect or check the resources by pulling the chips to my player character

And to make this information clear we needed to find out to show it:
A) where: On a home base field, attached to the player chip or regular chip, on the side of the table?
B) when: in which order?
C) how: Text, animation, graphics, through the prompting of interactions?

So, in order to achieve this, we created a series of prototypes (most being wizard of oz prototypes) and user testings to iterate on the games intelligibility which were all conducted using a conventional desk. In a first approach we worked in a more optimist mindset and tested the assumption that users would understand the functionalities with very little input and a lot of intuition and just trying out. For this we created a simple wire frame like Figma prototype that consisted of some simple graphic icons, labels and a short description of the game, prompting the users to do certain tasks. Our intention was that users would try to smell and match things together and through the feedback of the projection would start to understand the idea. In this case the feedback was also triggered manually by us.

The user tests of this prototype were quite short usually lasting around 5 minutes per test person. We tested it with four participants and were able to quickly identify some of the short comings and problems. Only one of the four participants was able to understand pretty much all the games aspects we listed. Two participants understood some of the aspects like the smelling and comparing but had trouble with the matching and the general concept of collecting for their insect. The final participant was overall quite lost and had trouble understanding any of the game's aspects. We observed that the test persons were overwhelmed with the high amount of information that was attempted to be communicated to them with too little input. Aspects the participants struggled to understand most were:
- I get an Insect as a player character
- I need to collect resources for my insect
- The only indication to find the right resource is smell

We realized we would have to guide the users more and introduce the information step by step. We hoped to be able to avoid that as in doing so the necessity of some sort of navigation tool arose, which posed another game component to be designed and be understood by the users. The only way around this problem would have been to introduce the possibility of interacting with the table through touch but we were rather unsure about the feasibility of the implementation of touch interaction and didn't want to have such a technical uncertainty be such a crucial part of our prototype. We'll talk more about the challenges of navigation in a designated chapter.

We adjusted and developed many small aspects for the next iteration of the game introduction. We will not go into a lot of detail here, as the entanglements of all those small details are quite complex, we also cannot be certain about the exact impact of each of them. The biggest change was the switch to a step-by-step approach with each step designated to communicate a simple concept or task. Through this the process of understanding the experience could be integrated in a more playful manner and already be entertaining for the users. Furthermore, we implemented more animations to help guide the user and give them a sense of orientation around the different components on the table. In the development of these prototypes, we had to work a lot with our own assumptions as we could not possibly have tested all the aspects of the experience in the short amount of time. Also, at that point many small details about our vision of the final prototype (mostly technical and physical) were not implemented yet, the actual table that wasn't built yet being an obvious one, and we had to make predictions about how these would also eventually influence the user experience.

Through the process of iteration on the game mechanics, the decision was made to give the whole experience a guided approach. So, explaining the game by the system and the actual playing of the game merged into one experience. Some compromises had to be made due to technical constraints in the design and testing of this prototype.

9.2.1 Navigation in the prototype

In all games, you have the navigation of the gameplay; on the other hand, you have the interactions to start, stop and pause. For the navigation of the gameplay, we have the interactions between the player figure and the scented cards.

Another challenge is the restart part. When does the game restart? Can the user restart the game on its own? How does the restart look like? We think it may be possible that a user might abandon the game at any point of the game. So being able to restart is essential. We thought the user could turn the game character by 360 degrees to reset the game and start from the beginning. But how do you communicate this to the user?

We introduced the tutorial as an introduction. The user needs to navigate between the different steps, either going forward or backward. But only in the introduction phase at the beginning and at the end, as the game in the middle is playable with the game character and the scented cards by pulling them together. To solve this we wanted to introduce a navigation card for players. It would be its own card and one could turn it to select an item from the menu that is listed around the navigation card. To select you would turn the card and leave the card in the selected rotation in order to confirm the selection. This introduced another set of challenges. Will the user understand what the navigation card is for and how it should be used? Additionally, every player would need a navigation card, but then which navigation card belongs to which player? What if this navigation card gets lost on the table and the visitor is unable to navigate in the game? We thought about fixing it to the table. But then one could not choose any more where you want to play around the table which is important for us to introduce more social engagement between players and watchers. We even tried to remove the navigation mechanism by introducing timers and watching if the player figure is moved or not. But ultimately, we went back to the navigation around the player figure as it was needed to get the introduction started. If you don't know when the user is ready to start the introduction you need an interaction to trigger it. The navigation around the player figure would be "next", "restart", "back". The navigation options are only shown, if the user is allowed to use "next" or "back".

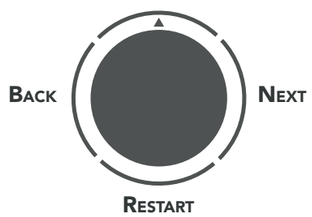

Figure 26 navigation UI wire frame

CONTENT DEVELOPMENT PHASE 2

9.3

As already mentioned in the content development chapter there was the necessary task to find and research the knowledge and information that would be mediated in the project. In the first phase of this the thematic topic was fleshed out and narrowed down. Our goal was to choose a specific topic about insects that we would be able to communicate in a strong and simple message and that would make the museum visitors curious and excited. And we think we have found this promising topic of the insect's olfactory world. But the work was not done there. The content needed more depth. The intention was that the users would explore different aspects around this topic and thereby learn more about it. Of course there is a lot of depth to this topic. Much about it is also still unknown to scientists and researchers in the field. And evidently for the users of the table it would be only possible to virtually dip in the great ocean of knowledge about insects and their olfactory habits. But as was graspable in our exchange with the Insect specialist Wolf Blanckenhorn there is much to tell about insect olfaction and the behavior linked to it and we were eager to do justice to the diversity at hand in this project and show an interesting and enlightening selection around the topic of insect olfaction to our users. So, the first task was to find the right selection (this was arguably the hardest and most crucial part) and then research and gather the accurate information about the selection of the insect species. In a first exchange with insect expert Wolf Blanckenhorn a range of interesting aspects formed through the discussion, and we were able to set some general criteria for the selection that was desirable to include in the story telling and mediation of the interactive experience. These were:

A) Communication of different reason for the olfactory attraction of insects to a scent or pheromone: Nutrition, procreation and nesting

B) Communication of the different principles or functions of insect's olfactory organs: Volatile and tactile pheromone perception

C) Communication of the notion of generalist and specialist insects. This concerns mostly the nutrition factor; generalists being attracted to many things and able to feed on different food sources and specialists being attracted only for example by a very specific family of plants

It was a huge challenge to find three insect species that would bring all these aspects together. With the help of the specialist a selection was made that could make the inclusion of most of these aspects possible. Here an overview of the chosen species and their characteristics:
1. The Rose Chafer:
The rose chafer is a specialist in the insect world. It is attracted through pheromones mostly only by plants of the rose family. These plants also serve the rose chafers needs for nutrition, mating and nesting as the larva of the rose chafer also feeds on plants of the rose family.
2. The house fly
The house fly is a generalist. It feeds on many different food sources. Mainly sweet liquids like jam and juice or fish and meat which are rich in protein that the females need for reproduction. Rotten organic materials like dejecta attract house flies for nesting.
3. Night moth
Night moths are very dependent on their olfactory organs and less on their vision, as they are active during nighttime. Their olfactory organ is their antenna. Many moth species do not eat anymore once they reach their adult form. For most moths it is the female of the species that produces a pheromone which the male moth then detects and follows to find their mate.

Proceeding with this decision there was a lot of knowledge to be researched, gathered and designed into tangible content that could be implemented into the projection. Each of these species had to be researched carefully and for each of them it was necessary to generate unique content to implement into the game. This task was attended to by our side and our reliable insect specialist partner offered to review our work and check the accuracy of our research. The final content then had to be assembled and designed to be implemented into the projection.

9.4 GAME COMPONENTS

For the exhibition, we will develop the following version of the game. During development and further testing this will certainly change, but for the time being this is currently the state of the prototype. Any changes and learnings that are not in this document will be presented at the final presentation. For example, something not being testable with “Wizard of Oz” will only be clear when the prototype is finally used. All of the progress we made in the previous chapters will be collected here as a descriptive wireframe, which will also support the development of the final prototype. Each frame represents a state in the game. Before going into the different frames and states we will describe the components of the game in the following paragraph.

Player figure 9.4.1

Each user can choose between two insects or four player figures as we want more people to play the game at the same time and represent male and female of each insect. The player figures are 3D printed insects.

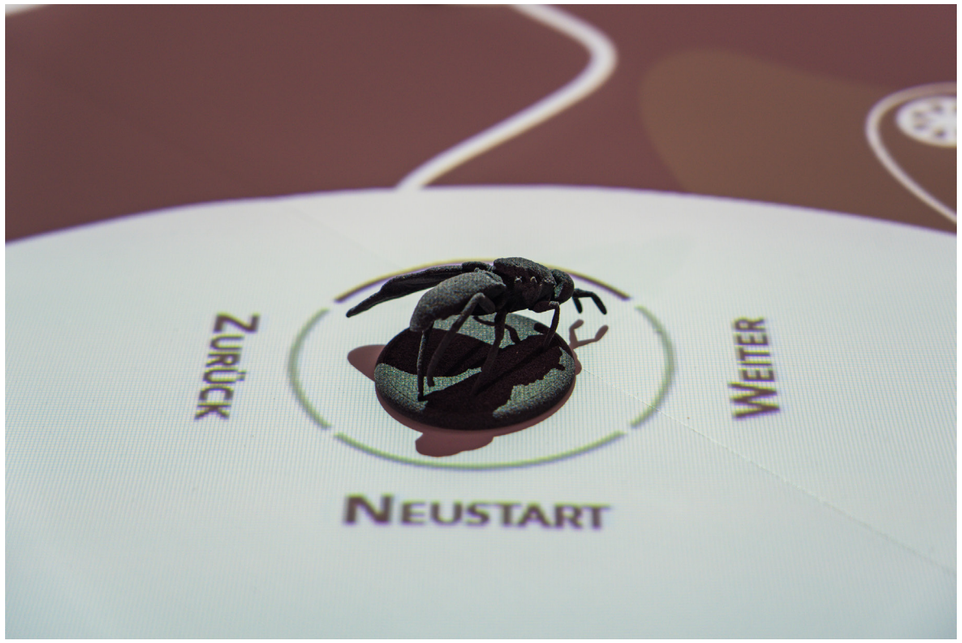

Figure 27 Scentsory interactive game table - play figure

Scented chips 9.4.2

The scented chips are MDF squares that lay on the table. There are two kinds of the example or reference scented chips and the scent play chips. The example chips are laid on the border of the table to have a reference. The scented play chips smell exactly like the example chips, which you can find in the smell memory game. The scented play chips are lying on the table surface where the game is played.

9.4.3 Matching

The main interaction of the game is the matching of the player figure and the scented chips, by pulling a scented chip and a player figure together the game checks if the user found a matching chip or not. You can match figures and chips anywhere the player wants.

9.4.4 Homebase

The homebase in this game is a half-circle area along the side of the table where the user interacts with the table. Each player figure has its own space. The homebase was introduced to produce a dedicated area where the user can match the chips or display information.

9.4.5 Inactive state

In case a user leaves the game early the game gets restarted after two minutes of inactivity.

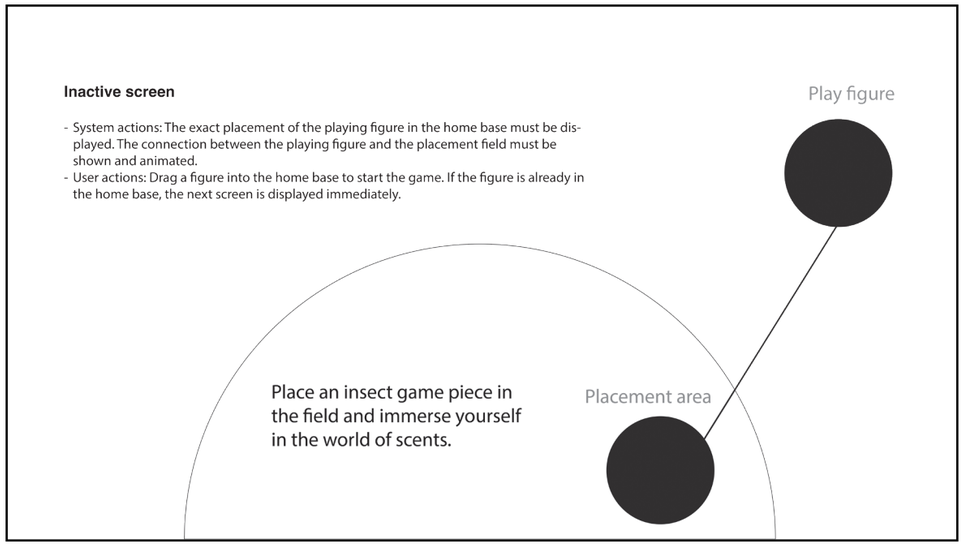

Figure 28 Game table UI wireframe: Interactive screen

Start of the game 9.4.6

The users get welcomed to the game when a player figure is pulled into the homebase field or if the play figure is already there this screen will be present. Then with the first turning motion of the player figure, the introduction is started.

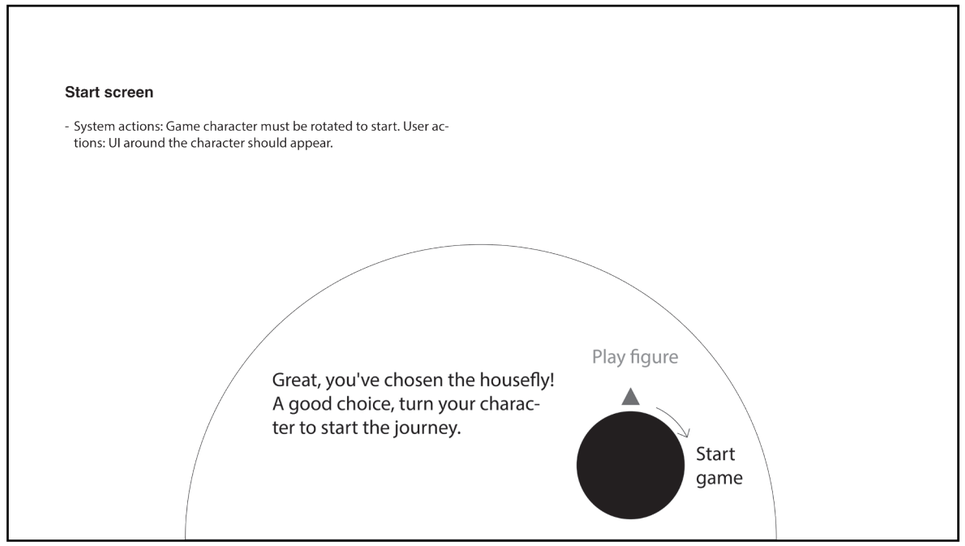

Figure 29 Game table UI wireframe: Start screen

9.4.7 Introduction

In the introduction the user gets introduced to the context and how navigation is turned to navigate to the next part.

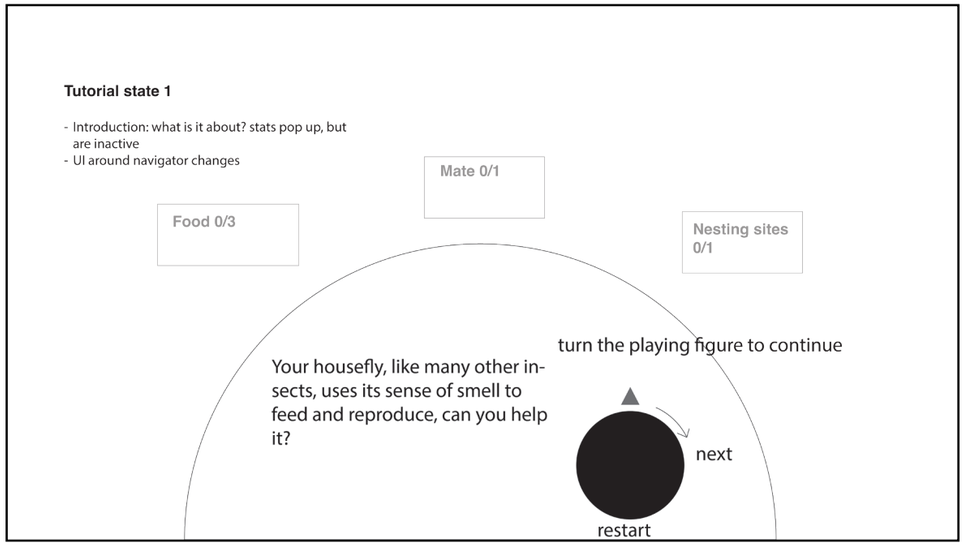

Figure 29 Game table UI wireframe: Start screen

9.4.8 Start smelling

The user starts smelling the scented chips and comparing them with the example chips. The example chips get highlighted through the GUI.

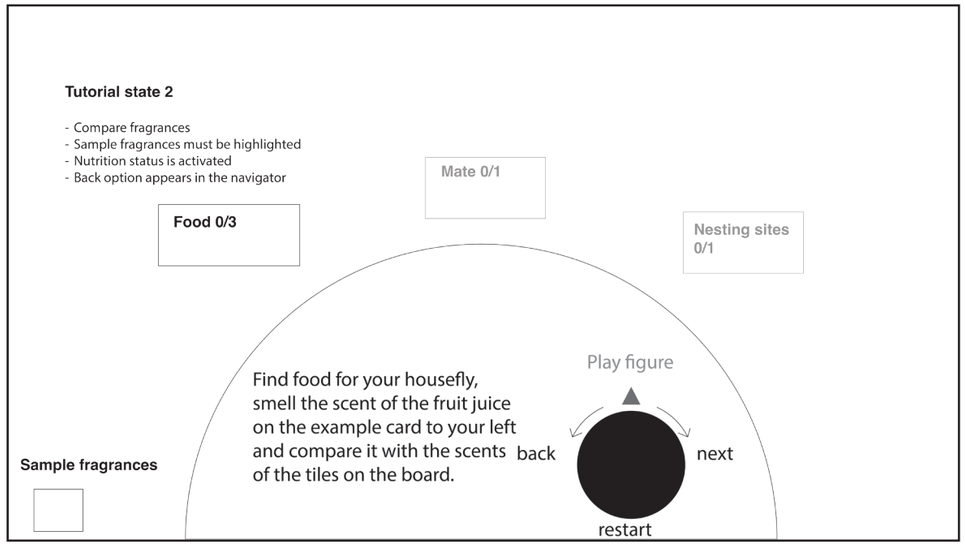

Figure 31 Game table UI wireframe: Tutorial state 2

9.4.9 Checking for match

Once the user finds a scent match, the user can check by pulling the player figure together with the scented chip. It does not matter where this happens in or outside the base because the information is shown next to the interaction.

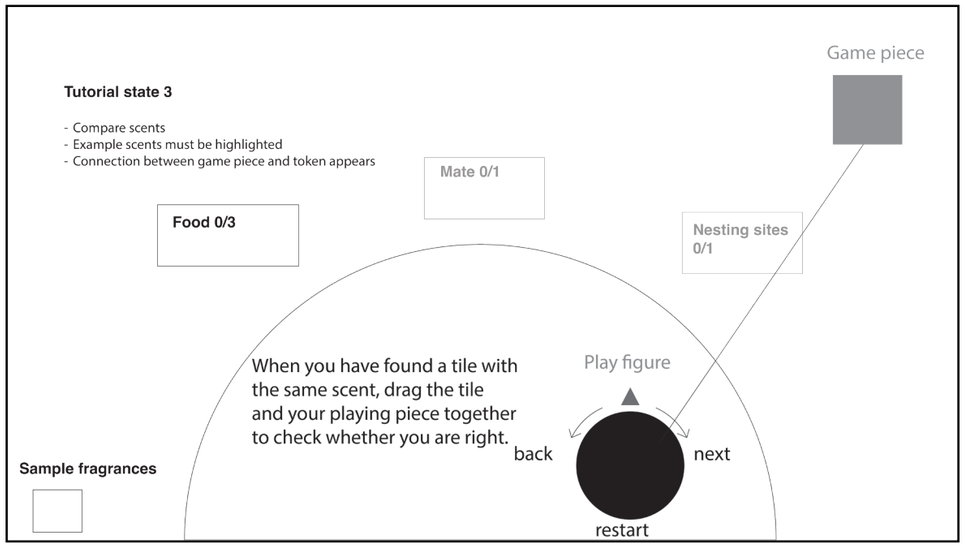

Figure 32 Game table UI wireframe: Tutorial state 3

9.4.10 Correct

If the answer is correct an info box will pop up with the result and more context about the insect.

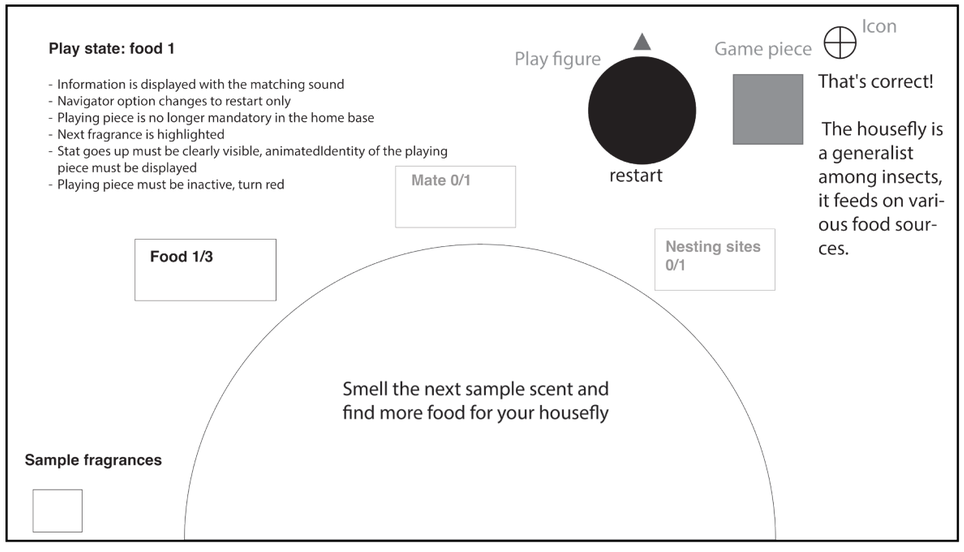

Figure 33 Game table UI wireframe: Play state food 1

9.4.11 Wrong

If the match is not correct an info box will pop up again and will inform the user and ask them to try again.

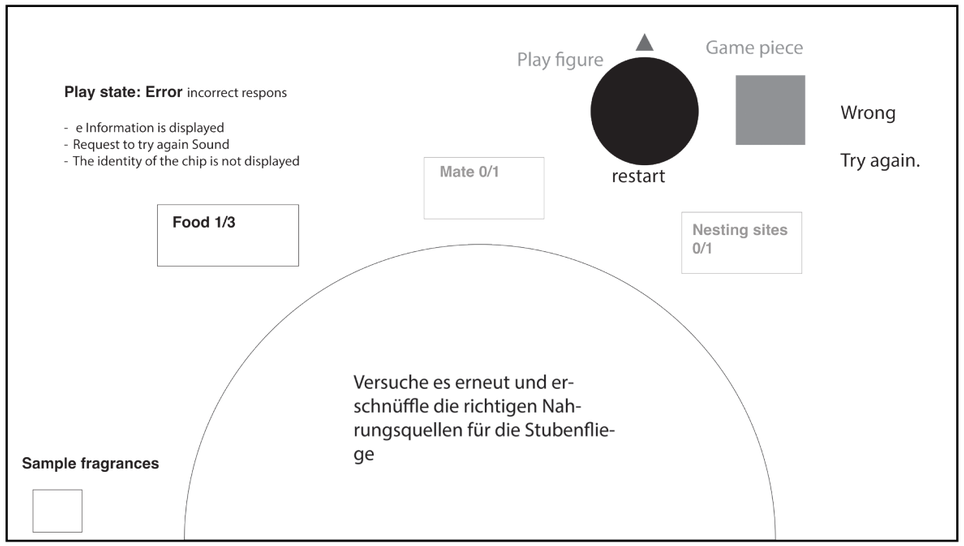

Figure 34 Game table UI wireframe: Play state error

9.4.12 Enter the next play stage

When the user found all the food resources by pulling and checking scented cards and play figure. The user gets introduced to the next play stage, where they can find a mate.

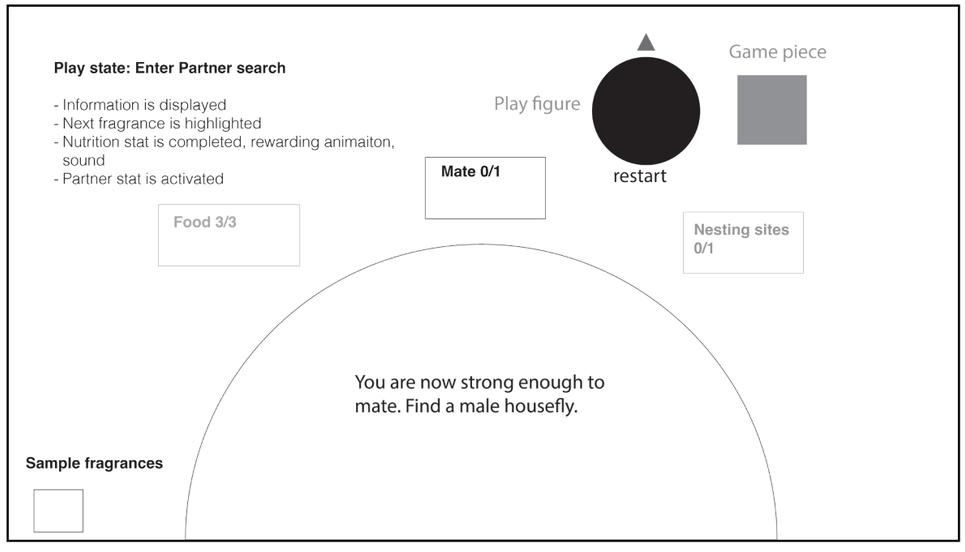

Figure 35 Game table UI wireframe: Enter partner search

9.4.13 End of Game

If the user found all resources of a housefly or the rose chafer like food, mate and nesting site the game has been successfully solved and an information box will pop up with small baby insects crawling over the screen. After some inactivity the game will restart from the beginning.

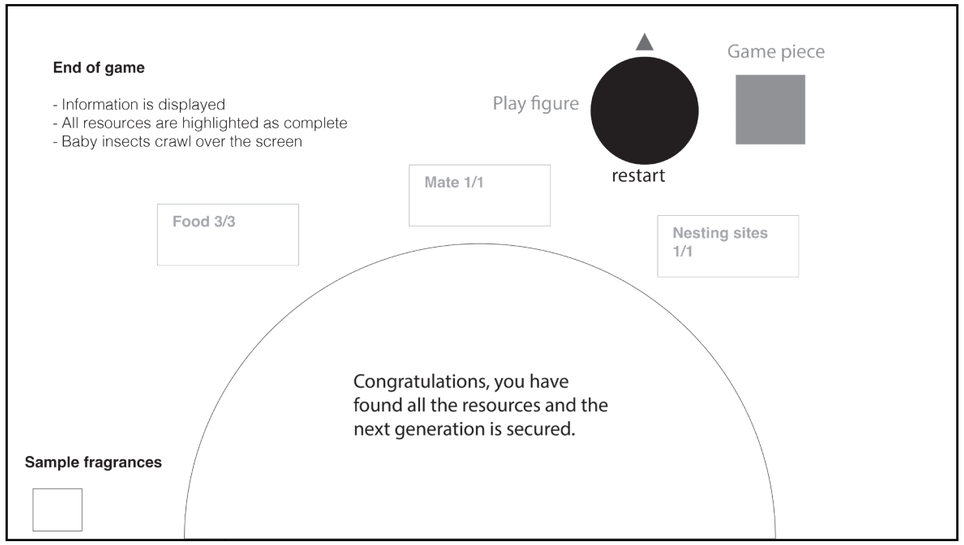

Figure 36 Game table UI wireframe: End of game

9.5 VISUAL DESIGN

In the design of the visual features of the game we imagined a rather simple implementation because we wanted the users to concentrate on the olfaction. Though we wanted to keep the visual design of the interactive table relatively plain and simple it was the more important that what would be shown was intentional, supporting the user journey and the immersion into the topic. For the aesthetic the vision was to create a visual language that would lean on associations with insects and scent to immerse the users into the topic. Also the visuals should feel natural yet a bit outer worldly as a way to depict the insect world. The first step in this process was to create a mood board to gather inspiration, for which we used the platform Pinterest to collaborate on this task (Pinterest, 2024). The intention was to implement also some animated aspects, that could also help the users to understand possible interactions. It had to be decided if this could be done with code or if

it was necessary to use another software and then implement the files in the coding environment. Eventually a combination of both had to be implemented. Additionally the visual design was informed by the technical constraint of the resolution of the beamer. To take this into consideration we continuously evaluated our design drafts with the projector.

9.6 MEDIATIVE AND INFORMATIVE UI

The UI elements had largely the function to inform the users in two ways, one being the education about insect's olfaction and the other being about the functionalities of the game, explaining how it works and guiding the users. The latter we've already discussed many aspects of in the section about the game introduction. We also had to design the points of mediation that would appear throughout the user journey. We intended to communicate the general theme of insect olfaction as a tool for them to navigate with the overall player experience, but we wanted to have an additional layer of information to communicate more extensive knowledge to the users if they were interested. For this we saw two options: the UI or Audio. We chose the UI over Audio because an auditory implementation would have needed headphones which we were inclined to avoid as we think it would have hindered the exchange between users. The points in the user journey with a stronger focus on mediation was implemented in the act of matching the scented chips with the player figure. The idea was that when a user would match the chips with their character some an information box would pop up that would inform them about the correctness of their matching but also why it was correct or incorrect and give more information around the context and connection between the two components.

The text-based UI also unclosed the possibility to implement a bit of storytelling into the experience. With the multiple home bases located around the frame of the table which functioned as a guide for the users a narrative approach was implemented into the texts on each step of this UI element.

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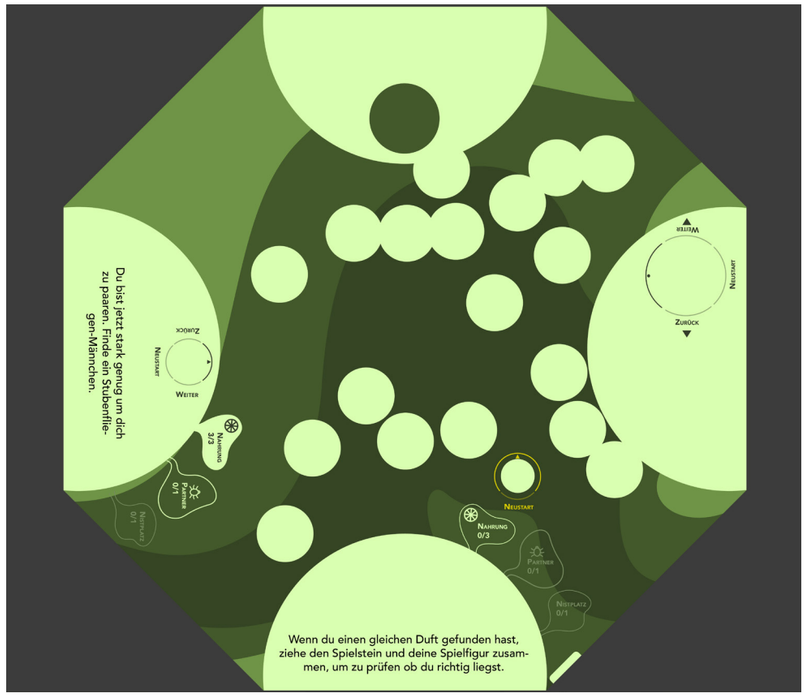

Figure 37scentsory interactive game table UI example digital

Figure 38 scentsory interactive game table UI example

SOUND DESIGN 9.7

Since the aim of the project was to experiment with and explore multisensory experiences adding another layer of sound was an obvious opportunity to enrich this concept. The olfactory elements of the experience were the main component of it but we saw a lot of potential in the implementation of sound as a way to give the users feedback to what they were doing and support the communication between user and the system, as it is often used in games. Our intention was to thus provide an additional layer of meaning to our users. Since the use of headphones was to be avoided, as already explained in the chapter about the UI, the sound had to be placed around the whole table and thus we had to make sure it would not be overwhelming. We had to work with the assumption that the users would be able to link the sounds to their actions and not be confused with the sounds of the other players, playing at the same time. But since this also applies in game arcades, we had some degree of reassurance in this assumption. Yet we wanted to avoid to fall into a stereotypical game sound aesthetic and make the sounds coherent to the visual aesthetic of the table. We chose the sounds carefully so they would align with the insect atmosphere.

EXPERIMENTING WITH SCENTS 9.8

As the smelling became such an important component in the project, it became obvious that we would need to bring our attention to the use and design of scents and especially scents combined with material. It unclosed not only conceptual but also a lot of technical and physical questions. Both of those challenges were handled somewhat simultaneously but we gave some more attention to solving the practical problems in the use of scents in museums first. We had to find a way to infuse the chips on the interactive play table with scents as sustainable as possible. At the time the exact number of playing chips was not definitely decided on but it was clear that the scents on the cards should last at least for a week, since refreshing the scents more than that seemed very unreasonable. So, we had to find scents composed to last and materials that would maintain the perseverance of it, while not evaporating into the room too much, in order to also not disturb the visitors passing the room. It turned out harder than expected to find answers to these questions in desk research. We tried to contact several designers and curators from different museums in the hope to find someone with experience that could give us helpful insights on how to handle such a task but with little success. The search on the internet was also rather cumbersome and not very fruitful. On the online forum basenotes.com we found some insights from people chatting about materials that could be fitting to make scents last long. We also found some more information about the requirements for the chemical composition of a scent that would last

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long on thefragranceworld.co.uk. And we also took chat gpt into council for a few insights into the composition of scents and suitable materials for our needed use. Eventually we decided to do a few tests ourselves to find more answers.

In one of our first quick paper prototypes of the idea we already gained the finding that oil-based scents last longer than alcohol based perfumes which could be confirmed by our web research. So, we decided to continue to work with the essential oils to test how long they would last on different materials. We gathered seven different materials, which we chose orienting ourselves on some of the findings from the desk research, which were: A) Cotton pads, B) MDF board, C) synthetic sponge, D) cardboard, E) natural leather F) synthetic leather G) polyester fabric. Four drops of essential oil were applied to small strips of the different materials and left in a room for seven days. Five of those materials were additionally put inside plastic jars to compare the difference in evaporation according to the amount of airflow.

After seven days we sniffed the materials and compared the intensity of the scents on the different materials and made a hierarchy from strongest to weakest:

1. MDF board
2. Synthetic leather
3. Cardboard
4. Cotton pad
5. Sponge
6. Natural leather
7. Polyester fabric

In Materials 1 to 3 the scent was still very noticeable, materials 4 and 5 smelled only very lightly of the essential oil and in material 6 and 7 the scent was pretty much gone. As expected, there was a huge difference between the materials that lay open in the room and the materials that were put inside a sealed jar. The scents were still much more present in the materials that were lying in the jars. This prompted us to find ways to confine the scents as much as possible. More of our decisions around the use of material and the further process in implementing the scents is described in section labeled Designing the chips.

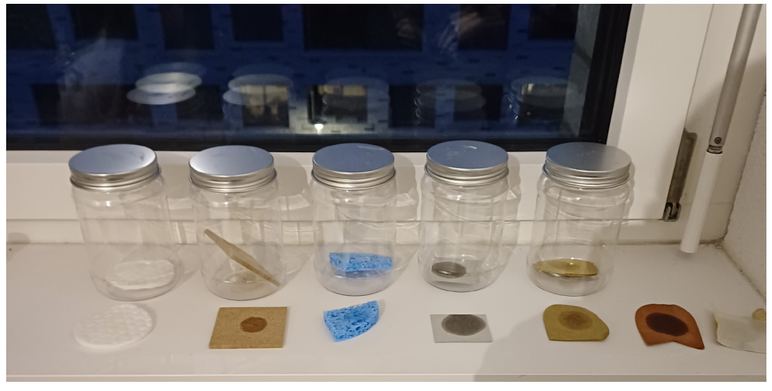

Figure 39 material test with essential oil

CHOOSING THE RIGHT SCENTS

Of course, one of the big questions in our design process was: What should it smell like? We would have to have a variety of smells in the game in order for the concept to work and we had to find and implement all these scents. This decision would also influence the difficulty of the game depending on the amount of difference between the scents. If all the scents smelled totally different the game would be quite easy and the other way around. This was one parameter we needed to respect in this decision. Other than this we were very free to choose the smells. But as creating our own scents in the scope of the project was not feasible, we would have to work with scents we could purchase. We were looking for oil-based scents since we found in our research and experiments that they are the longest lasting. One option would have been to try to find scents that smell like the things we want them to represent. This would have been very difficult and with the components like the smell of the insects close to impossible. Also, conceptually we believe it would not make sense to try to use the actual scents we humans would smell since the game was more from the perspective of an insect. Of course, we also could not implement a scent an insect would smell since we don't know what they really smell. So, we came to the conclusion that we would have to work with some sort of translation, with scents that would represent a general, more abstract concept. But we still needed to find a suiting translation. Since the general motivation of insects which is part of the game is the same concept for most animals, also humans, nutrition and reproduction or sex we could use scents that humans associate with these instincts. The pheromones which the insects follow trigger a reaction in the insect that could be similar as when humans smell a delicious cake or the scent of a person they're attracted to. So, the scents we chose to implement in the game lean on culinary and erotic associations. It was important that this notion would be communicated in the game.

9.10 DESIGNING THE CHIPS

In one of the early prototypes, we put the scents directly on printed QR codes that were glued to 6x6 cm MDF chips, which already worked surprisingly well. The essential oils needed to be refreshed very infrequently, after around 12 days. Still, we conducted the test with different materials as just described to have further references and we used these findings to develop the chips further. There was still the problem of the scents evaporating into the room. In our atelier this was much less the case than in the room we did the material tests in likely due to room size and air circulation. But we were still concerned about the scents gaining an overwhelming presence in the room in the final prototype, also since the amount of chips was estimated to increase. So, we brainstormed and sketched some more ideas to iterate on the design of the chips to match more of our requirements. We wanted to build them so they would contain the scent well. Furthermore, we wanted to utilize the visual and shape design of the chips to support a clear smelling affordance. With these requirements in mind, we created a few prototypes of our design ideas. The chosen materials for these prototypes were cardboard and MDF boards, since these materials had good outcomes in the previously conducted tests, and they were easily accessible for the project. As a part solution to the problem of the scents evaporating into the room too much another idea came up and was created as a prototype. A 3D printed box with small openings on the top to let some of the scents through but still comprise a lot of it that could be but on top of the MDF chip with a simple mechanism to easily remove the box again for refreshing the scents when needed. In the first iteration of this idea there was a mistake in the 3D print of the box as some holes were to close together the printer could not print them separately and fused them together ending up in a flower like shape. This accident in production prompted the idea to work with an icon like shape on top of the boxes that could be repeated in other parts of the game and function to help understandability. The final decision was made to proceed with this design idea for the implementation into the final prototype. In the later iteration the boxes were additionally increased a bit in hight to support the affordance to pick them off the table.

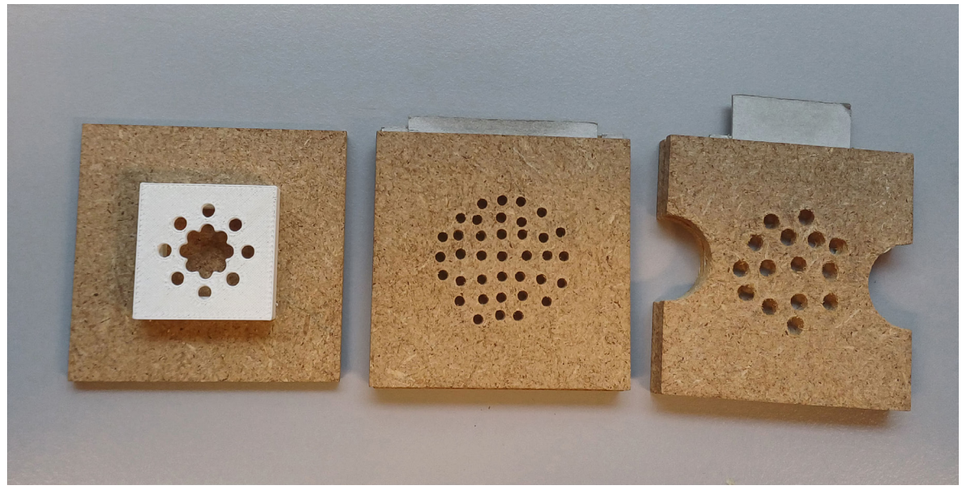

Figure 40 scented chips design iterations

Figure 40 scented chips design iterations

Development and Design of the Prototype

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9.11 EXHIBITION SETUP

9.11.1 Concept

For the final exhibition we want to create a usable prototype to experience our whole work from the past couple of months. The main focus gone consist of the explorative information access with our senses and with multiple people at the same time.

We started with a round table to invite people from every side to use the table. But as we thought about producing the table we quickly realized how hard it was to build a round table with a wall going around it. As a alternative we decided to go for an octagon. This allows six players plus two more people to watch what is happening at the table.

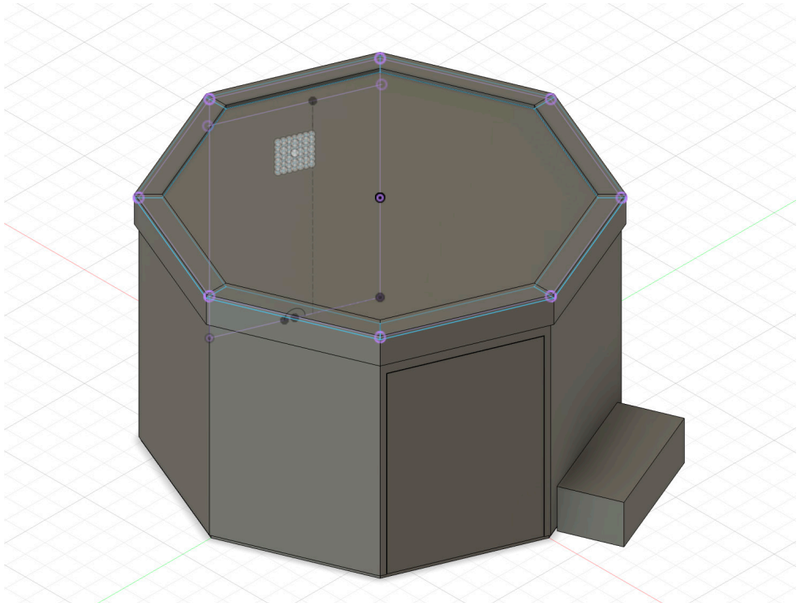

Figure 40 scented chips design iterations

The Material choice is described in the experiments section because we had to find out which one would work and be still in our budget which is 1000 franks. This is a lot of money but when you think about a 1.70-meter octagon pillar-like construction material cost with all of the electronic it adds up. We decided to use MDF for the sides. We included a step stool for children to use since the table is 1 meter high which is quite tall for them. This height was necessary to ensure that the viewing angle of the cameras functioned properly. A small door was planned for the superstructure and for maintenance. To prevent the electronics from getting too warm, ventilation holes have been planned through which fans blow the air.

On a pillar on the side, there will be our bachelor theses and the project description. To attract people to our octagon table we want to use the projection from above to project animated patterns matching our table on the side of the ground.

Figure 43 assembled table with MDF and plexiglass

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Scentsory

9.11.2 Projector

Getting all the technical equipment was a challenge. Figuring out which projector to use and where to get it as well as how to mount it was a never-ending story. It was clear from the beginning that we had to use a short-throw distance projector to cover the whole surface. Initially, we got a projector from Farblichtlabor which was the best in terms of the projected image size and brightness. However, when we hung up the projector in a vertical position it became so loud due to the fans that it was unusable for an exhibition. We had to search for another solution and found a mirror at the Immersive Art Space to keep the projector horizontal and project down with the mirror. Meanwhile, the Leihs (Borrowing services of ZHdK) has been organizing new projectors for the exhibition. The new projectors are exactly what we were looking for. As soon as they were available, we headed down to retrieve them. We were able to test the projectors, and the fans did not speed up. For a short moment we thought we had solved all issues until we realized that the resolution of full HD was too low for an interactive table of the planned size. Small text became quickly unreadable and one pixel was about 2mm big. As you would stand quite closely to the table, you could see the individual pixels very well. Due to that we had to find another solution. We investigated buying a 4K projector, but it was too expensive at around 1700 francs. We tried to borrow one from other borrowing services, but in June, it was the high season for fairs in Zurich, so none were available. We went back to Leihs and asked if we could borrow another projector for the exhibition, which we were lucky enough to get. Working and installing with two projectors is a challenge, but the resolution and the brightness is so much better.

9.11.3 Audio

We will once again set up a pair of stereo speakers for the audio, borrowed from Leihs, to enhance the interactions at the table. While the audio may not be 3D mapped, we believe that users will still be able to discern if the sound is related to their own actions or another user's.

Connecting the setup 9.11.4

We are currently showcasing our products in a room at ZHdK where we have already installed a mounting system for heavy equipment. Our only remaining task is to arrange the clamps needed to mount the projector and audio system to the ceiling. On the ceiling we will also need to connect the projectors, audio system and provide power for the electronics in the table. We have fastened extension cables for the audio and power supply. Additionally, we have obtained an SDI setup from Leihs for the projector as a ten-meter HDMI cable is not as reliable.

Object recognition 9.11.5

In order for the table to function effectively, the system needed to recognize the player figure and the scented chips. For this prototype, we utilized Reactivision, an open-source computer vision framework specifically designed for the development of tabletop tangible user interfaces (TUIs) and interactive surfaces. Reactivision allows for the tracking of fiducial markers which are unique symbols that can be detected and identified by a camera. The use of an infrared camera provides several advantages: Less susceptibility to changes in ambient lighting conditions, such as sunlight, shadows, or artificial lighting, which can impact visible light cameras. This consistency ensures more reliable detection of fiducial markers. Additionally, the use of IR illumination allows for precise control of lighting conditions, ensuring consistent detection regardless of external light variations. Furthermore, since infrared light is not visible to humans, IR illumination does not interfere with the user experience or distract users during interactions, making it particularly valuable in settings like museums or public displays where aesthetic considerations are important.

9.11.6 Game Prototype

The game itself for the exhibition was a Java application with a TUIO Client implemented containing the Processing library. Reactivision sends TUIO messages over UDP to enable the client application to track the QR codes. Game logic is written in Java, and the visualizations are drawn with the Processing language.

Figure 44 Scentsory interactive game table

Development and Design of the Prototype
Scentsory

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CONCLUSION

SUMMARY 10.1

In the framework of this thesis, we've explored and played with ways to use multisensory approaches in the design of a museum installation, communicating knowledge about insect olfaction. We've used tangible interfaces to implement scents into an interactive gamified experience and combined them with visual projections and auditory feedback to create an engaging experience that allows our users to learn about insect's olfactory behavior and make them curious about the topic. Thus, we've achieved our goal to create a multisensory learning experience within the context of a museum installation. Scents were intentionally placed and used in the game to engage the users into the topic and make the experience more memorable. Object recognition technology was used to create an interactive experience, where the users are actively taking part in the learning and exploring of a topic with their senses.
The final prototype is not yet exhibited in an actual museum but was exhibited in June 2024 in Zurich University of the Arts in the final diploma exhibition. If the prototype and concept will be further used and developed for the exhibition museum of the future by Museum für Gestating Zürich is yet to be decided. Suggestions and recommendations for the further development of the prototype in this case are given in the following chapter future steps.

10.2 EVALUATION OF PROCESS AND DESIGN

10.2.1 The multisensory experience

The multisensory experience we created in the final prototype consists in different parts of the use of smell, vision, audio and touch. The emphasis of the experience lies with olfaction, which was an obvious choice in regard to putting the topic into context and making it more tangible to our users. The scents in the final prototype play a big role in activating the users and engaging them into the experience and thus fostering an active and explorative learning style. Through smelling and comparing the game chips on the table users are able to explore the topic of insect olfaction step by step in a playful way and gradually form an understanding of the wider context. Designing with scents in an installation has its limitations and challenges. We've chosen the scents carefully according to some physical criteria they needed to fulfill in order for the interactions and game mechanics to work and furthermore with a greater concept and an emotional component in mind. Thus, the scents shall represent sensations triggered in an insect when picking up such pheromones but translated into a human context where similar reactions can be triggered. Many of the scents which ended up in the final prototype can be encountered in everyday life and are quite familiar to most of our users we believe like rosemary, jasmine or bitter orange. Through this the communication and learning can be reinforced when the scents are smelled again in a different context. Also, since using your nose is often not so important anymore in everyday life, the user experience of our final prototype satisfies museum visitors want for unique experiences, which will also increase the formation of memories.

The visual and auditory senses play a secondary role in the experience and mostly execute functions of user feedback and explanation. Nonetheless they are an important part of the experience for the users to make sense of information and navigate through the journey. With the visual and auditory feedback, we support the core scent elements of the game and strengthen the overall message and flow of it. Since audio and graphics are more commonly used in such experiences it was easier to find references and inspirations to design for these parts of our table.

Touch might be the least consciously noticeable part of the experience but crucial to make the whole idea work. First of all the implementation of scents would not have been possible without the physical elements displayed on the table. Furthermore, the use of these tangible user interface elements in the design help the users connect to the content and make the whole topic more tangible. Also, the decision to work with physical game elements was made resulting from the evidence found in the field and desk research that the possibility of physical interaction is more inviting and intuitive to people compared to solely screen based interfaces.

The social experience 10.2.2

The design of the table respects the need for multiuser experiences in museums. With the shape of the table multiple people are invited to play at the same time and exchange over their experience. The spatial dimensions also allow for two people to play together at one station. In this way the user's experiences can be enriched through the exchange and interaction with others. In a future iteration it would be beneficial to test this aspect more and maybe integrate a collaborative mechanism within the game itself to deepen this effect even more.

The multisensory approach also potentially deals with the challenge of a diverse user group. Since a multisensory experience invites for a more explorative interaction, we believe this will help to engage audiences of different ages. Sensory cues can be experienced and interpreted among various ages and thus create a more intuitive experience. Older users can have physical interactions additionally to digital interfaces to help lower the threshold of interacting with digital systems. While the use of novel technologies can often cause the exclusion or deterrence of elderly visitors, we lay strong emphasis on the combination of technology with physicality and sensory sensation in our implementation to avoid this problem. Younger audiences can be addressed by the playful nature of sensory interaction and have their need for entertainment satisfied. This might also advocate the differently aged users to interact with each other, which can be very beneficial for one of the biggest user groups of museums: families.

Game mechanics 10.2.3

Using a more guided approach to the user experience allowed us to implement an additional layer of storytelling to the experience and thus immerse the users further into the topic. Through the conversations we were able to have with colleagues concerning one of our early first technical prototypes we realized that a competitive approach could hinder the learning experience due to the user's motivation lying rather on winning than exploring or learning. Thus, the decision was made to avoid such competitive or challenging aspects to allow the users to be guided by curiosity and explore the content of the table on their own time. Still some notions of gamification such as collecting, and rewards maintained in order to motivate the players. This results in an engaging and immersive game experience. The game mechanics and interactions were carefully considered and partially iterated on and evaluated through user tests and feedback from the tests as well as feedback from game design colleagues.

10.2.4 Methods and process

With this project comprising of many different elements and tasks that needed to be figured out, the need arose to search for help in a lot of different places. Through interviews, discussions and feedback rounds with colleagues and experts from other fields, as well as field and desk research we were able to grapple with a lot of challenges and problems along the way and bring together many different aspects to the project and implement them into the final prototype. In retrospect the project could have benefited in regard to the richness of the content from a more extensive exchange and co design with the scientific experts. But this can also be conducted in the further development of the project.

Through our user tests we were able to iterate on the UI design and improve the games understandability and create intuitive interactions with the game elements. More such test would be advisable for future iterations of the table to improve the usability, immersion and flow of the experience. Furthermore, our practice of creating rapid prototypes with Figma, paper, perfume, fabric and other materials has proven to be an efficient way to test the potential of our ideas and communicate them to people to unclose interesting and helpful conversations.

A helpful habit in the early stages of our project was the visits we paid to many museums, which helped to inspire us and gave us a lot of interesting insights that came in handy later in the process. We also took advantage of reaching out to experts from different fields early on in the project to have interviews and discussions that were able to inform our project and help us with our research.

10.3 CONTRIBUTIONS

Our goal for this project is to bring the topic olfactory sense of insects closer to the museums visitor by taking a holistic approach to the museum's design and work with the benefits a museum has to offer. We want the visitors to be part of the experience, interacting with each other and bringing them to a table on the topic of insects. The other benefit is its physicality. The fact that you can see the insects close up in three dimensions and move them helps to grasp the world of insects and set it in context in comparison to our own. To enhance this experience, we added a digital interactive layer to combine the two. To not overwhelm the visitor and reduce museum fatigue, the information is presented explorable and split up into portions. We want to encourage the use of technology in a responsible manner by placing it where it is useful, without distracting from the actual exhibit. The gamification is used to invite the visitor to take a playful approach without forcing it on them. A user can play on its own, together with another person, or compete against each other to see who finds the matching resources first. To use the benefits of the human senses we focused on the human olfactory organ and how it can be integrated with technology, to enhance the experience and memorability of the content in the exhibit. With the scent-based exhibit, we strive to bring the topic of insect diversity as close as possible to the visitors. We live in this world side by side with other species, like house flies and rose chafer without noticing their diversity and complexity. We want to bring this perspective closer to the visitors and leave a memorable impression.

10.4 LEARNINGS

The complexity and size of the project presented a challenge, and we now realize that time and cost are the main reasons why museums opt for the usual and easy museum setup which has proven to work. However, we believe our work holds significant value because we aimed for an approach with many facets.

Due to the project's multifaceted nature, we had to collaborate with numerous experts who provided valuable insights based on their years of experience. However, engaging with experts and other stakeholders consumed a significant amount of time, whether it involved arranging meetings or gathering resources from them.

In retrospect, we should have either scaled down the project by reducing its scope or created a smaller final exhibition. The organization and planning of the final exhibition, as well as the testing and coordination of materials took up a considerable amount of time that could have been allocated to more testing.

Making decisions in a large, complex project was challenging. But often it was necessary to simply move forward. If we were to embark on a similar project in the future, we would start by narrowing down the research question from the beginning, developing more iterations of the prototype and carrying out more user testing overall. Despite the project's extensive scope, it holds immense potential for further development, making it almost regrettable to conclude it. However, we are pleased that the project reached its conclusion. What remains are the lessons learned and some ideas for future improvement.

10.5 FUTURE STEPS

10.5.1 Implementation of tactile game chips

When we learned about insect's olfactory organs and how some are located so to say on the skin of the insects and pheromones are picked up through physical touch the idea came up to translate this notion and implement it in a tactile way into the game. Some tests of this idea were of MDF chips with tactile patterns laser cut into the side of the chip with a similar notion of comparison and matching as in the scent-infused chips. In a future iteration of the game this concept could improve the content and storytelling of the game and deepen the communication of the topic. This feature was eventually not implemented due to challenges of hiding the visual indications of the differentiation of the tactile patterns and time constraints in finding solutions for this problem.

10.5.2 Content enrichment

As already mentioned for the further development of the project we would strongly recommend to have more extensive exchange and co creation with an insect expert to expand and deepen the content that is communicated within the game experience. Due to the big workload of researching the content for the game the final compromise was made to cut down the amount of playable insect species down to two. Unfortunately, this limits the variety of insect olfaction that we initially wanted to show in the final prototype. But we valued the quality of content higher than the quantity. It is also very realistic to improve on this in a future version of the project.

10.5.3 Technology

As technology continues to advance, older setups in museums can quickly become outdated. That is why we chose to integrate digital and physical elements with projections. By concealing the projector from the visitor's view we can ensure that the projection remains adaptable to new designs and has a timeless quality. Additionally, this approach allows for easy updates of the current exhibit or reuse the setup for a completely new exhibition without the need for new equipment.

Table-based tangible user interfaces (TUI) are a captivating way to engage users and interact with objects through an interactive information layer, allowing for a deeper understanding of concepts by placing objects in various contexts. This makes it an ideal solution for museums to present their didactic content. Our use of Reactivision to recognize object movement and rotation showed great potential. Unfortunately, there have been no further developments since 2022, and the only available packaged version dates back to 2016. This could impose challenges in a museum setting where the setup must run continuously without any issues for a long period of time.

Alternatively, a touchscreen table capable of detecting different objects, such as the interactive scape, could also be considered.(Interactive Scape, n.d.).

Figure 45 Interactive Scape Moveable (Interactive Scape GmbH, 2024)

Conclusion

Scentsory

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BIBLIOGRAPHY

Allen, S. (2004). Designs for learning: Studying science museum exhibits that do more than entertain. Science Education, 88(S1), S17–S33. https://doi.org/10.1002/sce.20016

Baumann, M. G. (2020). Analogies, Content Knowledge, and Implications on Learning.

Blud, L. (n.d.). Social Interaction and Learning Among Family Groups Visiting a Museum.

Bundesamt für Statistik. (2024). Besuche und Kulturvermittlung. https://www.bfs.admin.ch/bfs/de/home/statistiken/kultur-medien-informationsgesellschaft-sport/kultur/museen/besuche-kulturvermittlung.html

Calvi, L., & Vermeeren, A. P. O. S. (2023). Digitally enriched museum experiences – what technology can do. Museum Management and Curatorship, 1–22. https://doi.org/10.1080/09647775.2023.2235683

Çetin, Ö., & Erbay, F. (2021). Gamification Practices in Museums. Journal of Tourismology, 7, 265–276. https://doi.org/10.26650/jot.2021.7.2.1017009

Ćosović, M., & Brkić, B. R. (2020). Game-Based Learning in Museums—Cultural Heritage Applications. Information, 11(1), Article 1. https://doi.org/10.3390/info11010022

Cross, K. P. (1999). Learning Is About Making Connections. League for Innovation.

designboom, shuhei senda I. (2019, July 22). Exhibition in tokyo sight seeks to view the world of insects as models for design. Designboom | Architecture & Design Magazine. https://www.designboom.com/design/insects-models-for-design-21-21-design-sight-07-22-2019/

Do-Lenh, S., Jermann, P., Cuendet, S., Zufferey, G., & Dillenbourg, P. (2010). Task Performance vs. Learning Outcomes: A Study of a Tangible User Interface in the Classroom. In M. Wolpers, P. A. Kirschner, M. Scheffel, S. Lindstaedt, & V. Dimitrova (Eds.), Sustaining TEL: From Innovation to Learning and Practice (pp. 78–92). Springer. https://doi.org/10.1007/978-3-642-16020-2_6

Falk, J. H., & Dierking, L. D. (2013). The museum experience revisited. Left Coast Press, Inc.

Hatano, G., Amaiwa, S., & Shimizu, K. (1987). Formation of a Mental Abacus for Computation and Its Use as a Memory Device for Digits: A Developmental Study. Developmental Psychology, 23, 832–838. https://doi.org/10.1037/0012-1649.23.6.832

Haywood, N., & Cairns, P. (2006). Engagement with an Interactive Museum Exhibit. In T. McEwan, J. Gulliksen, & D. Benyon (Eds.), People and Compu-

ters XIX — The Bigger Picture (pp. 113–129). Springer London. https://doi.org/10.1007/1-84628-249-7_8
Interactive Scape GmbH. (2024). Multitouch Table Scape® Movable. https://shop.interactive-scape.com/cache/images/Scape-Movable-UHD-Multitouch-Screen-Table-with-Object-Recognition-by-Interactive-Scape-875x.jpg?timestamp=1715781567
Interactive Scape: Multitouch Displays & Object Recognition Solutions. (n.d.). Retrieved May 17, 2024, from https://www.interactive-scape.com?lng=en
Ishii, H., & Ullmer, B. (1997). Tangible bits: Towards seamless interfaces between people, bits and atoms. Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems, 234–241. https://doi.org/10.1145/258549.258715
Kaltenbrunner, M. (2024). Mkalten/reacTIVision [C]. https://github.com/mkalten/reacTIVision (Original work published 2014)
Kim, M. jeong, & Maher, M. (2008). The Impact of Tangible User Interfaces on Designers' Spatial Cognition. HUMAN–COMPUTER INTERACTION, 23, 101–137. https://doi.org/10.1080/07370020802016415
Kong, Y. (2021). The Role of Experiential Learning on Students' Motivation and Classroom Engagement. Frontiers in Psychology, 12. https://doi.org/10.3389/fpsyg.2021.771272
Krestanova, A., Cerny, M., & Augustynek, M. (2021). Review: Development and Technical Design of Tangible User Interfaces in Wide-Field Areas of Application. Sensors (Basel, Switzerland), 21(13), 4258. https://doi.org/10.3390/s21134258
Leinhardt, G., Crowley, K., & Knutson, K. (Eds.). (2002). Learning conversations in museums. Lawrence Erlbaum.
Levent, N. S., & Pascual-Leone, A. (2014). The multisensory museum: Cross-disciplinary perspectives on touch, sound, smell, memory, and space. Rowman & Littlefield.
Lloyd-Esenkaya, T., Lloyd-Esenkaya, V., O'Neill, E., & Proulx, M. J. (2020). Multisensory inclusive design with sensory substitution. Cognitive Research: Principles and Implications, 5(1), 37. https://doi.org/10.1186/s41235-020-00240-7
Ma, J., Sindorf, L., Liao, I., & Frazier, J. (2015). Using a Tangible Versus a Multitouch Graphical User Interface to Support Data Exploration at a Museum Exhibit. Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction, 33–40. https://doi.org/10.1145/2677199.2680555
Madsen, K. (2018). The Gamified Museum—A critical literature review and discussion of gamification in museums.
McLean, K., Medway, D., Perkins, C. R., Warnaby, G., & Henshaw, V. (2018). Designing with smell: Practices, techniques and challenges (First published). Routledge.
Mikulak, A. (2021, February 24). New experiences enhance learning by resetting key brain circuit. National Institutes of Health (NIH). https://www.nih.gov/news-events/news-releases/new-experiences-enhance-learning-resetting-key-brain-circuit
National Museum Zurich. (2024). Archaeology in Switzerland. https://www.landesmuseum.ch/archaeology-switzerland
Nofal, E., Panagiotidou, G., Reffat, R. M., Hameeuw, H., Boschloos, V., & Vande Moere, A. (2020). Situated Tangible Gamification of Heritage for Supporting Collaborative Learning of Young Museum Visitors. Journal on Computing and Cultural Heritage, 13(1), 3:1-3:24. https://doi.org/10.1145/3350427
Pinterest. (2024). Pinterest moodboard. https://ch.pinterest.com/mipmups/interactive-table/
Roppola, T. (2013). Designing for the Museum Visitor Experience. Routledge.
Rossetti, V., Furfari, F., Leporini, B., Pelagatti, S., & Quarta, A. (2018). Enabling Access to Cultural Heritage for the visually impaired: An Interactive 3D model of a Cultural Site. Procedia Computer Science, 130, 383–391. https://doi.org/10.1016/j.procs.2018.04.057
Schroyen, J., Gabriëls, K., Luyten, K., Teunkens, D., Robert, K., Coninx, K., Flerackers, E., & Manshoven, E. (2008). Training social learning skills by collaborative mobile gaming in museums. Proceedings of the 2008 International Conference on Advances in Computer Entertainment Technology, 46–49. https://doi.org/10.1145/1501750.1501760
Shams, L., & Seitz, A. R. (2008). Benefits of multisensory learning. Trends in Cognitive Sciences, 12(11), 411–417. https://doi.org/10.1016/j.tics.2008.07.006
Stevenson, R. J. (2013). Olfactory perception, cognition, and dysfunction in humans. WIREs Cognitive Science, 4(3), 273–284. https://doi.org/10.1002/wcs.1224
The Relationships and Responsibilities of Museums. (2024). 34.
Vaz, R. I. F., Fernandes, P. O., & Veiga, A. C. R. (2016). Proposal of a Tangible User Interface to Enhance Accessibility in Geological Exhibitions and the Experience of Museum Visitors. Procedia Computer Science, 100, 832–839. https://doi.org/10.1016/j.procs.2016.09.232
Velasco, C., & Obrist, M. (2020). Multisensory experiences: Where the senses meet technology (First edition). Oxford University Press.
Vermeeren, A., Calvi, L., & Sabiescu, A. (Eds.). (2018). Museum Experience Design. Springer International Publishing. https://doi.org/10.1007/978-3-319-58550-5
White, T. L. (2009). A Second Look at the Structure of Human Olfactory Memory. Annals of the New York Academy of Sciences, 1170(1), 338–342. https://doi.org/10.1111/j.1749-6632.2009.03878.x
Wilson, R. S., Wang, T., Yu, L., Grodstein, F., Bennett, D. A., & Boyle, P. A. (2021). Cognitive Activity and Onset Age of Incident Alzheimer Disease Dementia. Neurology, 97(9), e922–e929. https://doi.org/10.1212/WNL.0000000000012388
Winkler, T., Scharf, F., & Herczeg, M. (2014). Ambiente Lernräume: Lernen mit vernetzten, interaktiven, körper- und raumbezogenen Medien. Informatik-Spektrum, 37(5), 445–448. https://doi.org/10.1007/s00287-014-0817-1

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FIGURES