Re-purposing museum experiences: A design-after-design approach

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Abstract (EN)

This thesis explores the conflicts of incorporating playful installations that make use of digital technologies in an exhibition space of a cultural institutions. The research is situated in the exhibition space of the Danish Architecture Center (DAC), a cultural institution about the dissemination of architecture. Museum experiences often employ digital technologies and support play to bring forward the qualities of exploration and free-choice, thus attracting visitors and improving the quality of their visit. Including play in their space is valuable but also controversial. Stakeholders seem to disagree on the value that play brings, and had trouble accepting some of its elements. The creative, personal, exploratory, and self-expressive qualities of play lead to visitors discovering new ways of interacting with the installations, based on their personal motives and interests; re-purposing them in the process. While established museum design processes often involve participation of visitors during the pre-deployment phase to inform the design of such experiences, those processes rarely re-design them once they are deployed; as a result, any use discovered by visitors during the post-deployment phase does not inform their overall design. Those newly discovered interactions can create new engagement opportunities, as well as technical and curatorial challenges. Because of that, there is a need for design approaches that can include that re-purposing by investigating and using it to inform the design of experiences.

To address that need, this thesis conducts empirical research on the re-purposing which happened during real use in the exhibition space of DAC. I approached those research endeavours by employing research-through-design while gathering in-the-wild data from the exhibition space of DAC, where I conducted three out of four of my studies. Initially, through the study of *Bio-sonic Sense*, I worked with elements of ambiguity to support exploration and free-choice. Then, through the study of *We Dare You* I gathered ethnographic data, which allowed me to build an understanding of the specific challenges DAC faces when deploying hybrid playful experience in their exhibition space. Finally, the subsequent studies of *City Lights* and *Light House* allowed me to try out a specific iterative design process which is built on the ideals of design-after-design. The process I tested aimed to use that re-purposing as a tool to re-design the artefact. That process is divided into two stages. First, the initial phase focus on creating undetermined artefacts by designing for flexible affordances that promote openness in the possible uses of the object. Second, during the post-deployment phase, those artefacts are followed and their re-purposing is used as a source for re-designing by through specific changes in their affordances. Specifically, the artefact is re-designed to highlight the discovered uses for future visitors.

This research contributes by using the results of that approach to identify three themes that led to conflicting expectations from play. First, there is a disconnection between the bodily-sensorial experience of those playful installations by the stakeholders and their cultural understanding of play when they observed visitors using the same installations. Second, their educational background seemed to affect their ideals on education, with some following realist ideals while others idealist ideals. Third, it was difficult for the ones following realist ideals to accept the unproductive and frivolous aspects of play in the exhibition space. Overall, incorporating play in museum installations that use digital technologies has challenges since it can lead to technical failure and it can be opposed by the stakeholder's views; however, since newer educational theories, visitor satisfaction, and contemporary museology ideals can benefit from including such installations into their space, there is value to explore further how to properly support digital technologies and play to create museum experiences. Further research can investigate potential design processes that can support the specific needs of exhibition spaces to address the occurred re-purposing of those installations.

Abstract (DK)

Denne afhandling undersøger, hvordan man kan anvende design til at understøtte museumsgæster i at omskabe hybride, legende oplevelser gennem brugen af ubestemte artefakter. Undersøgelsen fandt sted i udstillingslokalerne ved Dansk Arkitektur Center (DAC); et kulturelt center, der beskæftiger sig med formidling om arkitektur. Hybride museumsoplevelser (bestående af fysiske og virtuelle elementer) understøtter ofte kvaliteter som udforskning og det frie valg, der tiltrækker besøgende og kan forbedre kvaliteten af deres besøg. Disse egenskaber fører til, at de besøgende opdager nye måder at interagere med dem på, afhængig af deres personlige drivkraft og interesser, hvorved de omdanner dem i processen. Mens processen for etablerede museumsdesign ofte involverer deltagelsen af besøgende gennem implementeringsfasen til at informere oplevelsesdesignet, så er disse processer sjældent med til at omskabe designet, når det først er blevet implementeret; følgelig er enhver brug, der opdages af besøgende efter åbningsdagen, ikke med til at informere oplevelsens overordnede design. Sådanne nyopdagede interaktioner kan afsløre tekniske og kuratoriske udfordringer samt nye interaktionsmuligheder. Derfor er der behov for en tilgang til design, der kan inkludere denne ændrede anvendelse ved at undersøge og benytte den til at informere oplevelsens design.

For at imødekomme det behov foretog jeg nogle empiriske undersøgelser angående den ændrede anvendelse, der fandt sted i forbindelse med den faktiske brug af DAC's udstillingsrum. Min tilgang til undersøgelsen var, gennem anvendelsen af research-through-design, at indsamle data in-the-wild fra DAC's udstillingsrum, hvor jeg gennemførte de tre

ud af mine fire undersøgelser. Den første undersøgelse af We Dare You-udstillingen hjalp mig til at indsamle etnografiske data, der gjorde det muligt for mig at opnå en forståelse af de specifikke udfordringer, DAC står over for, når de implementerer hybride legende erfaringer i deres udstillinger. Derefter, gennem studiet af Bio-sonic Sense, arbejdede jeg med elementer af flertydighed til at understøtte udforskning og det frie valg. Endelig muliggjorde de efterfølgende undersøgelser af City Lights og Light House, at jeg kunne foreslå en specifik iterativ designproces, der bygger på idealerne om design-after-design. Den proces, jeg foreslog og afprøvede, sigtede mod at benytte denne gen-anvendelse som et redskab til at redesigne genstanden. Processen er inddelt i to stadier. Det første stadie har fokus på at skabe ubestemte artefakter ved at anvende specifikke former for fleksible genstande, der fremmer en åbenhed i deres mulige brug. Gennem det andet stadie, der finder sted efter åbningsdagen, bliver disse artefakters gen-anvendelse fulgt og benyttet som en kilde til at redesigne ved hjælp af specifikke ændringer i deres anvendelsesmuligheder. Helt konkret bliver artefakterne redesignet til at fremhæve de nyopdagede anvendelsesmuligheder for fremtidige besøgende.

Jeg oplevede, at en sådan tilgang kan adressere problemstillinger og uoverensstemmelser, der opstår grundet interessenternes modstridende forventninger, ved at indlede en samtale allerede tidligt i udviklingsprocessen, der tillader, at beslutninger er kvalificerede i forhold til den faktiske brug, mens en iterativ tilpasning af artefakterne kan imødekomme interessenternes forventninger. En afgørende udfordring i denne proces er, hvordan man skal forholde sig til den indledende forvirring, der er forbundet med artefakternes ubestemte karakter. Mit bidrag udfolder denne problemstilling ved at identificere retningslinjer for design af sådanne ubestemte artefakter på måder, der kan hjælpe med at fremme de besøgendes engagement.

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After three years of research, I decided to leave this section for the night before my deadline. As I am writing this on the 12th of December 2023, I feel relief and gratitude. My feeling of relief comes from finally closing this chapter of my career. Three years ago I embarked on a project that required me to tackle situations completely new to me, both professionally and personally. Finishing up my thesis made me realize that even though things might looked similar day after day, they can add up to something larger. However, even though I am the author of this thesis, it became a reality through the support of many people, to which I would like to express my gratitude.

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CHAPTER 1. Introduction

The current thesis empirically explores the conflicts that occurred in the exhibition space of DAC due to that subjectivity, the support for re-purposing, and the incorporation of play; and how those elements were perceived by stakeholders regarding their educational value and their role in the exhibition space.

Amongst the many fields that have used digital technologies, is the field of Museology. GLAM[1]s strive to provide their visitors with new ways of engaging with their artefacts. Attracted by the potential of those technologies, GLAMs employ them to create experiences which support social engagement, participation, play, personalisation, and sensory engagement. Through those experiences, their exhibition space becomes a dynamic, interactive environment inside which visitors can tell their own stories and pursue their personal motivations and interests. That visitor participation requires GLAMs to re-think their role in cultural dissemination, and to give space to visitor voices to occupy space in their exhibition through those experiences. Often, these interactive experiences contain both physical and virtual elements, which are used by GLAMs to augment their physical collections, creating new ways of interaction with their exhibits [66,102,127,129]. At the same time, exhibitions spaces are spaces of leisure, inside which visitors spend their time learning about the exhibits, engaging with each other in discussion, or just spend time with their families and friends. As a result, some visitors are already in a playful state of mind when entering exhibition spaces. To support that visitor mood, some experiences contain elements of playfulness and free-choice, inviting visitors to explore them [12]. Indeed, play is often encouraged and designed for in the museum space [5]. However, certain aspects of play are seen as controversial from stakeholders, depending on their world-view: either following realist ideals, thus seeing the role of the museum to present reality "as is"; or idealist ideals, where they acknowledge the role of personal interpretation in the educational process [49]. Those two schools of thought affect the stakeholders' perceived role of play, whether the see it as solely a symbolic representation of an external reality [89], or whether they think that self-expression, creativity, and subjective ideals are important elements of the designed experience they provide [35,115,126]. Furthermore, due to the free-choice and frivolous character of play [108] visitors test the boundaries of those experiences, which often leads to them engaging with said experiences in unexpected ways; they discover new uses for those experiences, re-defining how they are meant to be used. That adds to the high maintenance character of digital technologies for museums, due to technical failures that occur due to visitor interaction [52]. Maintenance issues might also arise when visitors discover new ways

[1] Galleries, Libraries, Archives, and Museums

to interact with museums installations, due to the unpredictable nature of such re-purposing [57]. In addition, play's frivolity might invite visitors to behave in ways which stakeholders view as problematic (e.g. engaging with play in areas of art appreciation; focusing on the technology and the experience rather than the displayed artefacts).

In a similar turn towards exploring subjective interpretation, personal interactions, and self-expression, the field of Human-Computer Interaction (HCI) has argued for new values in the design of digital technologies. The third wave of HCI [10,47] gave space for subjective approaches, while also setting aside values of performance and clarity for pleasure and engagement [35]. In relation to those new values, appropriation and re-purposing of technologies is both expected and desired [23,105]. As a result, the boundaries between the user and the designer are being re-negotiated. Scholars in Design Research have suggested the significance of providing users with the opportunity to re-design artefacts after their deployment [8,9,25,30,95]. In that case, the designer assumes a supportive role to the user, helping them voice their own interpretations of how the artefact should be used during the post-deployment phase.

1.1 Research Question

This Ph.D. dissertation explores the re-purposing of playful experiences in the space of the Danish Architecture Center (DAC) — a cultural institution about danish architecture. The project was part of the Industrial PhD program, which means that DAC employed me to conduct research in their space, regarding how to incorporate digital technologies and playful engagement in their exhibition space. The established design approaches employed by DAC have been developed for traditional objects of architecture dissemination (e.g. posters, physical architecture spaces, architectural models). Those objects rarely involve digital technologies, and when they do, they consist of simple interactions, where visitors take a rather passive role. Displaying architecture creates a situation where the visitors are exposed to representations (models, posters, etc.) of the actual buildings rather than the buildings themselves. They are also exposed primarily to the creative process of architects and learn about their challenges. Therefore, the potential for digital technologies here is not just to engage the interest of visitors, but also to bring them closer to the artefacts in ways that traditional means cannot.

The focus of my research then was to working with such experiences in DAC, while understanding and addressing the challenges associated with the design and deployment of those experiences in DAC's exhibition space. The primary challenge was the frequent re-purposing of those installations by the visitors. They often engaged in uses unforeseen — and

often playful — by the designer and the stakeholders, leading to technical issues and complaints voiced by said stakeholders regarding the role of such playful experiences in the exhibition space. To understand better the "controversial" nature of the playfulness that emerged in the exhibition space, I approached that challenged by employing a design approach which focused on the values design-after-design and tried to embrace that act of re-purposing which was the root of that controversy — enjoyed by visitors but opposed by most stakeholders. Specifically, I designed and deployed undetermined artefacts to support — rather than oppose — the discovery of new uses by visitors. Observing those discovered uses, I then re-designed the artefacts as part of an iterative design process. This thesis addresses the following research questions:

> How can DAC manage the tensions that arise from employing digital technologies to support play in its space? How do those conflicts manifest and how can they be addressed?

The thesis is a research-through-design endeavour. Its goal is to employ a design-after-design approach to develop DAC experiences and then use the results to understand the conflicts that arise in GLAMs related to playful installations that involve digital technologies. My thesis contributes by discussing the conflicts that arose between the stakeholders and the visitors due to their different understanding on play. There are four articles associated with this thesis and are included in the second part. In the following section, I summarise each of those articles.

1.2 Overall Contribution

Incorporating play and digital technologies in the exhibition spaces is valuable since they can support personal, engaging, educational, and pleasurable experiences [5,5,6,15,62,71,74,76,76,98,100,103]. However, designing for play in the context of museums is a challenging task. Play can lead to recurring technical difficulties [57]; can lead to disagreements among stakeholders regarding the value proposition of play in their institution [78]; can oppose non-constructivist educational models that are still in use [49,52]; it requires balancing educational values and play [127].

This thesis contributes by setting up design experiments to empirically uncover the conflicts that emerge when incorporating installations that support play through the use of digital technologies in the exhibition space of DAC. My contribution lies on identifying three main themes in my observations regarding the circumstances that led to conflicting expectations by DAC stakeholders, from play, through those installations. Those themes discuss the difference between the reaction stakeholder had when trying the installations themselves as opposed to seeing visitors trying the same installations; how their approach on education —

realist or idealist — affect whether or not they accepted personal interpretations and subjective interactions (supported by those playful installations) as educationally valuable; and how they reacted to the frivolous and unproductive nature of play.

1.3 Publication Contributions

The aim of publications 1 and 2 was to unfold the design situation associated with the re-purposing and real use of playful hybrid experiences. The aim of publications 3 and 4 was to test a design process created to address that specific situation by employing a design-after-design approach.

Publication 1 and 2 describe my preliminary work, during which I explored possible interesting research directions. Those publications focus on unfolding the details of the design situation. Publication 3 describes a design approach based on design-after-design. It also presents the findings of me using such an approach to construct and deploy an artefact. That publication builds on the results of publications 1 and 2 by using their findings to inform the details of the presented design process and the interaction elements of the artefact. Finally, publication 4 challenges the suggested design process by publication 3, through building an object with different interaction mechanics. In the next sections, I am providing a detailed summary of the publications. I also further expand on the ways they relate to each other.

1.3.1 Publication 1

Title: Exploring the Cross-Species Experience and the Coevolutionary Capacity: Sensorial Transcoding and Critical Play Design of *Bio-Sonic Sense* [59]

Status: Published in the proceedings of *RE:SOUND 2019 – 8th International Conference on Media Art, Science, and Technology*.

Artefact: *Bio-sonic Sense*

Artefact Description:

> *Bio-sonic Sense* is a short, sensorial experience which focuses on how plastic and sound pollution affects marine mammals in their navigation of the oceans. The exhibition visitors first encounters a box and a headset and are instructed to put both on their head. Once they do that, they are deprived of their visual sense (due to the box), while the headset gives them feedback regarding their distance from any surrounding objects — through an proximity sensor that is attached to the box. In the space close to the apparatus, various plastic objects are placed as obstacles, mimicking common plastic things once could

find floating the oceans due to human caused pollution.

Publication 1 explored how hybrid technologies and play can support a self-reflective experience of the effects of human-caused noise pollution on marine mammal navigation (see section Study 1: Bio-sonic Sense). To develop such an experience, we employed a research-through-design method together with Flanagan's critical play design model [32]. The resulting experience comprised an apparatus which block the visual sense of the user. The apparatus used sound to convey the user's distance to the objects of the surrounding environment. The experience also contained three environmental objects mimicking common trash found in the ocean.

Bio-sonic sense employed elements of openness and ambiguity to create a sensory playground where visitors can navigate in a free manner, following their own motivations and interests. *Bio-sonic sense,* through ambiguity, employs boundary play [83], which focuses on the boundary of human-animal relations. It does so by limiting the sense of sight, while also drawing attention to the sense of sound (a sense employed by marine mammals to navigate their environment). By doing so, it blurs the identity of the user.

Relation to the overall project: Through that publication, I explore the elements of openness ambiguity. I experimented with how they can support visitors to play and pursuit their personal interests when engaging with said artefact. I, then, use those two elements in the last two designs.

1.3.2 Publication 2

Title: We Dare You: A Lifecycle Study of a Substitutional Reality Installation in a Museum Space [57]

Status: Published in the *ACM Journal on Computing and Cultural Heritage*.

Artefact: *We Dare You*

Artefact Description:

We Dare You is an installation which connects the physical exhibition space with a virtual exhibition space through the use of virtual reality. The physical exhibition space is mapped through photogrammetry to create a visually accurate virtual recreation of that space. In both spaces a metal plank with railing is placed in such a way that when a visitor wears the headset and reaches out to touch the virtual railing or steps on the virtual plank, they touch and step on the physical one. The visitors then can walk on the plank that is placed facing the building window. As they do, the virtual plank extends — initially it looks shorter in the virtual space than the actual length of the physical one

> — breaking the window. At that moment, both planks have the same length. The visitors can then walk "virtually" on the outside of the building to admire its facade, and then they can jump of the plank. That results into them "falling" 2 centimetres in the physical space (the height of the plank in comparison to the floor), while at the same time "falling" two floors in the virtual space, in front of DAC's entrance, performing a superhero style landing by breaking the floor. *We Dare You* uses the feeling of vertigo to spark excitement to the visitors, while also giving them the opportunity to admire the building's facade from a new (and normally inaccessible) view angle.

In publication 2, I expand on the findings generated by the study of *We Dare You* (see section Study 2: We Dare You). Its research purpose was to explore the challenges associated with hybrid playful installations deployed in GLAM exhibition spaces. It did so by following the *We Dare You* installation through its life-cycle. The study explored in depth how DAC stakeholders perceived play and the associated re-purposing of the installation. Specifically, it focused on how the free form of play, that visitors engaged in, raised questions about its role in the exhibition space.

To understand how the installation was developed and perceived, I interviewed five key stakeholders that were involved with *We Dare You* (either during its pre-deployment or post-deployment stage). I conducted systematic and ad hoc visitor observations. Finally, I consulted a questionnaire that was filled daily by floor staff. The data revealed that play resulted in visitors re-purposing the use of the installation, often in destructive or (according to DAC's stakeholders) inappropriate ways. However, the culprit here was the design process. The institution felt comfortable employing a process which has worked with other non-playful exhibits. That process, however, did not account for re-purposing or maintenance.

Relation to the overall project: That publication helped devise the initial hypothesis that a design-after-design approach can create playful hybrid installations in exhibition spaces. Identifying that need for flexibility to accommodate for the re-purposing of such installations helped me to start drafting the design process I employed on publication 3 and 4. Since the study was a DAC installation developed without my involvement, it revealed DAC's established approach before my project took place.

1.3.3 Publication 3

Title: Designing for Design-after-Design in a Museum Installation

Status: Published in the proceedings of *NordiCHI 2022*.

Artefact: *City Lights*

Artefact Description:

> *City Lights* is an installation where visitors are able to use light together with a variety of geometrical and architectural small objects — such as plastic houses, cubes, soft spheres with bush-like texture, and others — to create urban tableaus (i.e. miniature versions of urban locations, such as parks, neighbourhoods, and busy city streets). It consists of a hexagonal table with three smart bulbs mounted on it, and a tablet to control the light settings of those bulbs. The table contains shelves that, on them, visitors can find various small objects of different textures and materials. They can use those objects to set up their urban tableau and then experiment with the appropriate lighting and how it would affect the overall mood of the scene. In a later design iteration, the tablet also contained challenges, through prompts, to create specific moods (such as, warm, cold, summer, winter, and others). *City Lights* focused on providing the visitors with a creative experience that supports their self-expression by giving them the "tools" to openly — with minimal constraints — play with the present materials to design their miniature city.

Publication 3 reports on study 3 (see Study 3: City Lights), a research-through-design experiment "*City Lights"* set in-the-wild. The purpose of the study was to test a design process that would support the re-purposing of DAC visitors. That design process followed the proposal of publication 2: incorporating design-after-design when designing for hybrid playful installations [58].

Following the interactive installation of *City Lights* for three months, I tested a design-after-design approach which supported re-purposing by deploying an initial undetermined artefact and leaving it up to the visitors to discover its possible uses. Once deployed, I followed that artefact by conducting visitor observations; stakeholder interviews; and floor staff questionnaires. I then re-designed the artefact three times, each time using that data to inform the re-design process. I, specifically, aspired to transform the initial *allow* affordances to *encourage* and *discourage* affordances [20]. By doing so, I attempted to keep the possible interactions the same, while also highlighting to new visitors which uses past visitors have discovered. A key aspect of *City Lights* was its support for creative engagement through the tangible objects.

Overall, the study of *City Lights* raised some concerns regarding the design of that initial undetermined state. In the initial observations, the artefact was confusing for many visitors to engage with. Its lack of constraints proved to be an obstacle. However, with each re-design cycle, the artefact became less confusing and visitors constructed more and more elaborate urban tableaus. To that extend, the tangible artefacts emerged as a significant source of creative inspiration for the visitors. Adding the prompt constraints supported that creativity. We concluded it is important to strike the balance between the initial undetermined state and constraints that can help users by scaffolding the initial interactions.

Concluding publication 3, we suggested either accepting that initial confusion (in case there

is enough time and resources to deploy the artefact long-term) or employing different approaches when re-designing. Furthermore, we concluded that a key aspect that helped visitors to re-purpose *City Lights* was its capacity for self-expression. Our alternative design approaches were: (1) radical and frequent re-designs; (2) re-designing existing artefacts to contain *allow* affordances; and (3) employing "impossible" constraints to provoke users into trying and break them. Through publication 3, I could test and reflect on a design-after-design approach set in DAC's space. While the previous studies were informative regarding the design situation, the artefacts that I studied did not follow such an approach. Publication 3 then allowed me to see such an approach from its beginning until its end.

Relation to the overall project: This publication discusses the details of the design approach (which embraces design-after-design ideals) that I employed by developing *City Lights*. It highlights design considerations that can help DAC to address issues that are related to the re-purposing of its playful installations. The empirical results of that experiment allowed me to identify potential opportunities and challenges when designing for re-purposing, and showcases how a resulting artefact from such a process looks like.

1.3.4 Publication 4

Title: Exploring affordances through design-after-design: the re-purposing of an exhibition artefact by museum visitors

Status: Published in the proceedings of *14th ACM conference on Creativity & Cognition*.

Artefact: *Light House*

Artefact Description:

> *Light House* is an interactive small house installation were children can enter while other children or their guardians can, from a control panel mounted on the house's exterior, change the light settings of the house by specifying the season, time of day, intensity, and light warmth. The house is lit by a smart LED strip light that is placed between two plexiglass panels on the window to emulate the natural light of the sun, and by a smart bulb that emulates indoor lighting, both controlled by the panel on the house's exterior. The children inside the house can then experience how the space feels based on the different settings. Inside the house there are some small scale furniture that they can use to use, or rearrange. The goal is for them to learn how natural and artificial light affects architecture and the interior design of a house.

In publication 3 we concluded that tangible objects and the focus towards creative interactions that afford self-expression (i.e. the design of urban tableaus) helped the visitors to interact with the artefact even if they did not understand its purpose. Following that, publication 4 discusses study 4 (see Study 4: Light House), a research-through-design

experiment "*Light House*" set in-the-wild [14]; the purpose here was to challenge the design process presented in publication 3 by developing an artefact that was designed without explicit support for self-expression. The goal here was to uncover how would visitors re-purpose such an artefact, as opposed to *City Lights* where visitors re-purposed, almost exclusively, its self-expressive elements.

Having detailed a design-after-design approach in publication 3, I set out to use that approach to construct *Light House*. I began by designing for *allow* affordances in the artefact; then, I deployed in DAC's exhibition space. I followed the artefact, gathering observation data, while also having discussion with floor staff and stakeholders. I wanted to gather specific insights on how visitors would re-purpose those *allow* affordances, as suggested by publication 3. However, visitors rarely seemed to engage with the artefact's interaction elements. Instead, they explored new purposes for the space of the *Light House*. They brought their activities in the house (e.g. reading books; playing hide and seek), and using the houses furniture in the surrounding space of the *Educatorium* (i.e. the educational space for children and families). In other words, visitors seemed to engage with the affordances of its **space** rather than the affordances of its **interaction elements**. In retrospect, visitors had limited expressive control over the artefact, since its interactions provided hardly any variation to the artefact's state. Conversely, they had quite an extensive expressive control over its space, since they could bring inside (or take outside) whatever they wanted.

Even though we hypothesised that the visitors would re-purpose the artefact's interaction mechanics, they did not. They ended up focusing on its space affordances (the element with the more self-expressive affordances). Moving forward, we suggested that attention should be given to coordinating the interaction affordances with the space affordances. Our results also suggest that we failed to predict how users would re-purpose the *Light House*. Indeed, trying to do so seems to oppose the design-after-design ideal of undeterminability. Still, visitors seemed to be drawn towards elements that support self-expression, even though the artefact was not designed with an intention to support that, which revealed a possible strategy to design for possibilities of re-purposing.

Relation to the overall project: This publication contains the second study in which I employed my suggested design-after-design approach. I designed the artefact in this study with the goal of challenging my approach. By not designing for self-expression I wanted to make the artefact's interaction elements inherently different in order to provide grounds for comparison between the two studies. The empirical results allowed me to explore re-purposing in a different context.

1.4 Kappa Overview

This kappa consists of five chapters. *Chapter One* (Introduction) gives an overview of the project details presented in this thesis. *Chapter Two* (Related Work) provides an overview and state-of-the-art of the four main research fields inside which my research is situated: Digital Technologies in Museums; Educational value of Play in Museums; Participatory Design; and Design Theory of Affordances and Constraints. *Chapter Three* (Methodology) describes the methodological consideration of my work, expanding on how I employed the method of Research-through-Design using in-the-wild-data; the implications of my relationship with DAC; how COVID-19 affected my research; and the overall role and details of my studies. *Chapter Four* starts a discussion relating to the findings of my studies. The chapter expands on the implications of designing for undetermined objects, along with three design principles I employed for the two main artefacts I deployed in DACs space (*City Lights* and *We Dare You*). Then, the chapter analyzes the stakeholders' conflicting expectations from play; it discusses what were those expectations, what was their role, how did they manifest in my project, and what were their root causes that led to the conflict. Finally, *Chapter Five* (Conclusion) summarises the work presented in this thesis.

CHAPTER 2. Related Work

In this section, I am presenting research from relevant academic fields I engage with through my work. I elaborate on the theoretical and empirical context that situates my work. I begin by discussing the role digital technologies in the contemporary museum. After that, I expand on the educational use of play in museums. Then, I continue with the participatory design practices that have been established in addressing design projects which focusing on the role of *re-purposing.* I am also expanding on how the recent concept of *design-after-design* that sees users and their use of artefacts as an extension of the design process. Finally, I explore the role of affordances and constraints in the overall design of artefacts and what possibilities of use they create for the user.

2.1 The Relationship of Museums and Digital Technologies

Over the past decades the field of Human-Computer Interaction (HCI) has entered a new paradigm, what scholars refer to as the "third-wave of HCI" [10,47]. That third-wave turn reflects the move of digital technologies from the workplace to our personal homes, making the values of culture, pleasure, and social engagement central in the design of such technologies [10]. Museums as spaces of culture, leisure, and education have started using digital technologies in their space, since those newly unlocked values supported by that third-wave helped museums to create meaningful experiences using those technologies. Indeed there has been a plethora of museum experiences which employ digital technologies to support visitor engagement [5,15,62,74,76,98,103]. Those experiences have the potential to support visitors in creating their own meaning, transforming them into active participants [129]. With scholars searching for specific design guidelines to support interaction in museums [63], it is important to understand what are the benefits and challenges that those experiences bring to the museum space.

Digital experiences have the potential of supporting various forms of expression and ways of interacting with the world [85,109]. Museums use digital technologies to support social experiences in their space, using them to allow visitors to share personal stories, anecdotes, and digital artefacts with each other [67,74,101,122]. Digital technologies have a strong potential to bridge the gap between museums exhibits being designed with the individual in mind, and museums being social spaces composed by active participants [27]. Adding to the discussion of museums as social spaces, Løvlie et al. [74] argue for using such technologies to facilitate a dialog between visitors by helping them tell their own stories. Museums have adopted values of sensory engagement [17,18], with more and more of experiences designed

to include the senses in creative ways [73,93,94,130,131]. By providing a malleable layer of interaction, those technologies can help visitors' experience museum artefacts in new ways, through constructing hybrid experiences of mixed reality [7,53,54,64,64,116,120] — i.e. experiences that contain both physical and virtual elements, connected with each other in real time. These technologies can augment the "traditional" senses of sight and sound with the use of haptics. Taking advantage of that, museums have already employed Virtual Reality (VR) and Substitutional Reality (SR) installations to bring visitors closer to artefacts that are not there [4,42,57,104,121]. With the use of digital technologies visitors museums can "transport" visitors to inaccessible places — as did the museums of the Sea in Caorle by setting up an installation that allowed its visitors to explore the shipwreck of the Mercurio [104]. Also, museums can use such technologies to better showcase historical places — conveying the past mood of a historical house [15], allow visitors to explore the first photography exhibition [121], or explore a historical Labyrinthe while walking in the area that it was placed [42]. Overall, museums use digital technologies to create interactive spaces that emulate physical spaces, making them important tools for disseminating the elements space --- a key goal for architecture museums.

At the same time, these technologies are often fragile and are used in an experimental state they are frequently inadequate to support a play environment [38,57]. Furthermore, their design invites visitors to explore them, enhanced by their experimental nature. Gaver [35], has identified a need towards designing for humans as playful creatures. He suggests a shift towards newer design methodologies, ones which focus on the unproductive, playful, and subjective nature of humans. He highlights the goal of "pleasure" as opposed to the established goals of "performance". This shift has also spanned new ideas of using ambiguity [37] and openness [105] as design values. The argument here is that, by incorporating those values into the design of technological artefacts, the use of those artefacts can be personalised, since users will approach them differently based on their personal experience. Other design principles for such technologies in museums come from Hornecker & Ciolfi [52] which identify three key interaction frames: support visitor mobility (an installation that is in place or a mobile interaction); form of augmentation and experience (how they augment the exhibition space and the visitor's senses); and whether or not the interaction extends beyond the physical visit. They raise attention to the associated design and development challenges: the need for robustness and stability under real-use conditions; frequent maintenance; conservation of the museum artefacts that are involved in the interaction (if any); and curatorial challenges when visitors generate creative contributions as part of their interaction. Despite those challenges, museums often employ digital technologies in their spaces to support a variety of play [5,6,71,76,100].

To summarise, the values of third-wave HCI align with the values expressed in contemporary

Museology, making digital technologies a useful tool to support museum exhibition spaces. Through those technologies, museums can deploy experiences that promote participation, social engagement, sensory exploration, personalisation, and play in their space. However, designing and deploying digitally enhanced playful experiences in museums is still challenging. It often requires dedicated technical maintenance, high costs, and a re-thinking of the relationship between curators and visitors.

2.2 Educational Use of Play in Museums

Following a turn towards the "experience economy" [91], which has been enacted in contemporary museum spaces, museums have adopted the narrative, the affective, and the ludic — i.e. play — as core elements of their experiences [66]. Museums as spaces of leisure and education often want to support play in their spaces for its education values and for creating an overall entertaining experience for their visitors [124,22]. They not only want to find creative ways to educate their visitors, but also want to bring their visitors closer to the artefacts through interactivity, and help them contribute to the museum archive through their personal stories [5,22,75,76,132].

Incorporating play and games in the museum context, is a valuable tool to support the dissemination of values and prove an educational experience. Play is often targeted towards children, to support meaningful interactions that are engaging while valuable in terms of learning. With roots in learning theory focused on young children, Conner Prairie [3] set up *Animal Encounters* and *Discovery Station* to create a playful kid's farm. *Animal Encounters* set up an open and free-flowing space where children could interact with animals surrounded by the context of a historic barn. *Discovery station* was a recreation of a 19th century town in a smaller scale that was meant to expose visitors to that historical era. Inside that space, children and parents could engage in pretend play, socialising, and solving daily problems of that era. Their goal was to inspire learning through play and hands-on engagement with history. The *Walker Art Center* [1] re-imagined the classic game of *I Spy* to developed three different experiences for families to engage with their gallery. Briefly, the first experience prompted visitors to explore and find artworks, the second encouraged storytelling using small objects that related to the exhibits, and the third one provided visitors with wax sticks so they can freely create. The center developed those experiences to be visitor-oriented. In other words, they wanted to help visitors pursue their own goals, and support them to have an open and exploratory visit. *Casa do Infante*, a museum in Porto, Portugal, set up an activity — *Porto through the game* — for children to interact with the city Porto and its history, during their visit [2]. The activity was a puzzle of cushions made of fabric. Those cushions resembled parts of the city and they were chosen for their sensory qualities. The goal was to

create a personal connection between the children and the city, through play. Focusing on free exploration and embracing misuse, *Scitech*, a science museum in Perth, Western Australia, developed 16 playful exhibits built around the physics of light and optics to educate visitors around those scientific topics while fostering a playful and social environment [12]. With the goal of helping visitors explore the psychology of bullying and aggression, the *Illinois Holocaust Museum & Education Center*, set up an installation called *Bully Frogs*. It features a short video game on projected on a wall. During that game, visitors can interact with digital frogs to encourage them to stop an instance of bullying that takes place in that fictional world. A second installation called *Lunch Table* explores the same theme around bullying, centered around a digital cafeteria table where the players need to rearrange the 10 table puzzle pieces and create responses to address the bullying that takes place. Play is used here to initiate a meaningful conversation on the role of actions and words in addressing bullying [50]. *EcoTarium* has employed simulation games to allow its visitors to engage, explore, and learn about the complex systems of bird communication and the effects of fishing practices. Through *Fish Boxes* they placed the visitors in the role of a fishing team, where depending on their fishing efforts, the fish population would be affected accordingly. In *Bird's World* they set up three different interactive experiences that showcase how birds communicate with each other. In the first one, visitors assume the role of predators, and like that get to see how birds would react to their presence using their calls. In the second one, they attempt to help identify the location of a hiker based on the bird calls present in the call. In the last one, visitors would try to sneakily approach a bird in a corridor, without alerting it, thus initiating its call. The institution tried to simulate aspects of reality that are engaging, as an attempt to educate its audience [43]. Overall, incorporating play can help visitors engage deeper with museum artefacts and can make museum experiences more engaging while also helping them learn [44,82,126,128].

2.3 Participatory Design, Re-purposing, and Design-after-Design

Design practitioners and scholars the past decades have developed participatory design as an approach to involve expert stakeholders in the design of artefacts. One of the first examples of participatory design was the UTOPIA project [26], a Scandinavian project with the goal of developing methods which involved end users during the design process of IT support targeted towards those users [114]. The merit of participatory design is that the stakeholder expertise can supplement the expertise of the designer; leading to designers achieving a better understanding of the stakeholders' needs. The process usually starts with the designers and stakeholders taking part in common workshops, where they collaborate in various design oriented activities. Those activities then generate materials and reports which the designers

can use to supplement their design practice. Participatory design has roots in democratic practices, giving voice to users while also helping them engage in design processes even when they do not possess the necessary technical knowledge [65]. In other words, participatory starts "from the simple standpoint that those affected by a design should have a say in the design process." [9:103]

Past scholars have argued for visitor participation in museum processes. They support a shift from seeing the visitor as a recipient to seeing them as an active participant in museum activities, requesting shifting authority away from the museum and towards the visitor [55]. Participatory Design can help museums approach their audience with a stronger focus towards visitors, helping them understand the needs of their audience on a deeper level [117]. Simon [110] highlights three main proposition regarding the merits of visitor participation in museum processes: (1) the relevance of audience-centered institutions; (2) creating experiences which help visitors constructing their own meaning; and (3) visitors can help during the project design to inform the design process. Involving visitors in the design process can initiate a conversation between curators, designers, and visitors. However, in such practices, the user is involved in the pre-deployment state of an artefact. This means that museum installations developed that way, have not been studied under conditions of real use [11]. Still, participatory design processes in practice remain highly relevant for museums [16,99]. It is necessary, then, to identify how to include real use in design processes for museum experiences, and how to involve visitors during the post-deployment period of artefacts.

To do so, we need to look into scholarly research that focuses on how users re-purpose design artefacts during post-deployment. Already in 1990, MacLean et al. [79] express a need for designing systems that can be tailored by the users, highlighting a necessary flexibility in their design. Even more important is their suggestion towards developing a tailoring culture that empowers the individuals to develop their own solutions based on their understanding of the system. Also building on the work of MacLean et al. [79], Henderson and Kyng [51] suggest a re-thinking of "design as a process that is tightly coupled to use and that continues during the use of a system" [51:793]. They highlight three reasons for that suggestion: situations of use change; the complexity of real use is impossible to predict; designs are built for different situations. Their suggestion is followed by three key challenges: the system needs to permit its re-design (including tools that can facilitate that); possible design activities are to be enacted by the users who most likely will not be professional designers; the aspects of the systems that can be tailored are still relevant to the overall use of the object.

Dourish [24] discusses that tailorability and customisation are processes of specific artefacts and, instead, proposes the concept of "appropriation" to refer to "adoption patterns of

technology and the transformation of practice at a deeper level" [24:465]. Building on that concept, Dix [23] identifies specific aspects to support appropriation in design. Both Dourish [24:465] and Dix [23] discuss its role in professionals adapting and adopting new tools in their practice, focusing on productivity and labor. However, the new turn in HCI identified by Gaver [35] looks into how subjectivity, play, and pleasure assume a central role in the design of digital technologies. Instead of seeing appropriation as adapting tools to new uses, he places appropriation under the context of play and the pursuit of "one's inner narratives in safe situations" [35:4].

Tailorability, customisation, and appropriation refer to how open an artefact is to be re-purposed during its use (here I propose that we see those concepts as "**openness of interaction**"). Another design element associated with the turn towards designing for homo ludens [35] is ambiguity (and here I propose we see these concepts as "**openness of interpretation**"). Ambiguity enhances the ludic aspects of an artefact, surrounding it with mystery, while leaving interpretation open for users to define it for themselves supporting a personal engagement with the artefact [37]. Supporting multiple interpretations reflects more accurately the diverse background of the various users, while also advocating for critiques of ludic design against supporting utility and efficiency as primary values of the designed systems [105]. Overall, that body of literature identifies two independent (but often intertwined) turns into the design of digital technologies: (1) a need to support the user's post-deployment artefact adaptations in real use scenarios; (2) play as an alternative value to functionality, efficiency, and productivity.

At the same time, scholars from the field of Design Research have been re-defining the boundaries of designer and user. Fischer and Scharff [31] build on that idea by presenting a consumer/designer spectrum, where on one end users are consumers while on the other end they are designers (engaging in meta-design). The goal here is to empower the user to act as designer through employing meta-design [30]. Not long after, Redström [95] argued for two types of design approaches: (1) use-before-use; and (2) design-after-design. First, he describes that there are two types of acts that define the use of an object: defining use through design — i.e. when a designer dictates the form of an artefact to support a specific use they have in mind — and defining use through use — i.e. when a user define the use of an object through the way they decide to use it. As an example, he discusses how the act of sitting is defined through a chair object. When designing a chair, the designer expresses what they define as "sitting" through how they decide to design the chair (defining use through design). At the same time, when the user sits on the chair, they also define the act of "sitting" (defining use through use). Those two definitions can be different. Based on those two ways of defining use, he moves to define two different overarching categories of design processes. First, **use-before-use** approaches refer to the designer's attempt to test before the artefact's

deployment how users will use the artefact once it gets deployed. Second, **design-after-design** approaches focus on setting up undetermined artefacts with the purpose of creating opportunities for users to decide how to use the artefact. Scholars have used design-after-design in empirical studies to describe the influence users have in the products or artefacts [9,29,48,86,107,123]. Those studies attribute designer characteristics to the users due to their ability to create new objects and interactions through re-purposing. Even though scholars associate these two concepts with participatory design (use-before-use) and meta-design (design-after-design) [8,9,25], incorporating design-after-design in participatory design processes has the potential to address contemporary design problems [11]. It is central to this thesis to explore that possibility, by using the ideals of design-after-design to involve visitors' post-deployment use in the design process. To do so, we need to look into possible design elements that can support those ideals.

2.4 Affordances and Constraints

The previous section expanded on an overall turn in design, towards focusing on how users re-design and re-purpose artefacts during real use. In this section, I am expanding on relevant literature on the role that affordances and constraints have in supporting potential uses of artefacts. Affordances and constraints are our two main tools when designing for playful museum experiences.

Affordances are a key concept that discusses the possibilities of action that users can take. Formulated by Gibson [39,40] in the field of ecological psychology, they referred to animal perception regarding the possible actions available to them in relation to an "object". Later, Norman [84] applied that term in the field of design. For him, affordances are relationships that connect users and objects. Specifically he mentions that "[a]n affordance is a relationship between the properties of an object and the capabilities of the agent that determine just how the object could possibly be used" [84:11]. He also distinguishes between visible (or perceived) and invisible affordances. *Perceived affordances* are especially useful, since they reveal possible actions to the users. Expanding on the theory of affordances, Evans et al. [28] formulated the concept of *imagined affordance,* which encompasses socio-technical relationships. In particular, they see those affordances "emerge between users' perceptions, attitudes, and expectations; between the materiality and functionality of technologies; and between the intentions and perceptions of designers" [28:5]. *Imagined affordances* help us analyse user intentions and, through that, understand the possible motivations beside acts of re-purposing.

Expanding on that theory of affordances, Davis [20] advances that discussion by classifying affordances into several types. She criticises past attempts to view affordances in a rigid,

binary way (i.e. an object either affords or does not afford), and instead proposes a different framework. She first divides affordances into three main categories based on their origin: (1) actions which originate from the artefact (**Request** and **Demand**); (2) response to user actions (**Encourage, Discourage, Refuse**); and (3) neutral, multi-directional actions (**Allow**). The first category of **request** affordances underlines specific actions that the user should take; since they do not enforce specific actions, they are flexible in nature. The second category of **demand** affordances is similar to the **request category,** with the only difference that they enforce the action. The third category of **encourage** affordances refers to cases when an artefact supports and suggests specific actions. The fourth category of **discourage** affordances describes affordances which try to obfuscate specific actions; those actions are still possible but are difficult to discover and execute. The fifth category of **refuse** affordances refers to situations where an action is impossible to do (forbidden by the system). The final sixth category of **allow** affordances encompasses all possible actions that can be taken, but are neither highlighted nor obfuscated. This last category also includes affordances that are unknown to the designer and/or the user.

Next to affordances, another concept that dictates possibilities of re-purposing is the concept of constraints. The role of constraints is to limit the set of actions a user can take. By doing so, they help users understand the possible uses of artefacts. Regarding the types of constraints, Norman [84] has expanded on the topic by identifying four types: **physical constraints**, **cultural constraints**, **semantic constraints**, and **logical constraints**. Each of those categories varies in what it communicates to the user. **Physical constraints** constrain specific uses by relying on the physical qualities of an object. For example, is very difficult (if not impossible) to connect the top sides of two Lego bricks, since there is a physical constraint in place preventing that from happening. **Cultural constraints** refer to how we allow ourselves to act in specific social environments and situations. In museum spaces, for example, they might discourage visitors from touching artworks, or to block each others' view when appreciating artworks. **Semantic constraints** relate to the conveyed meaning (or what interpretations they permit). For example, we are not allowed to cross a red light on the street. Finally, **logical constraints** are constraints on the possibilities inferred by logical reasoning. For example, when building some object and the user realizes at the end that one part is left over, then the user can infer that something went wrong in the process.

Constraints have an important role in the design of games and playful experiences. Constraints contextualize actions [60], helping players understand which possibilities are available to them. Tekinbaş and Zimmerman [119] associate constraints to pleasure; they consider important for the designer to strike a balance between too many and too few constraints when designing for meaningful play. Upton [125] sees play as "free movement within a system of constraints" [125:15]. He distinguishes between two types of constraints:

external (posed by the system to the player) and **internal** (posed by the player to themselves). Players constantly negotiate with the system which actions are allowed, using those two types of constraints as a guide. He also mentions that players when encountering systems with too few constraints, they create their own. Taylor et al. [118] suggest that constraints should be used in museum contexts to help scaffold visitor interactions rather than restricting how they can express their creativity. Constraints are a valuable tool to help a user learn how a system works.

The theory presented in this section can help in connecting specific design elements with acts of re-purposing. Both affordances and constraints can support or prohibit the discovery of new uses. Using the aforementioned framework helped me with my design choices during my studies.

CHAPTER 3. Methodology

In this chapter, I am presenting the methodological approach of my research. I expand on my relationship with DAC and my role as an Industrial PhD. I elaborate on the steps I took in the research process, and present the justifications in relation to the research question of my thesis. I will, also, expand on the details of the four studies I conducted. In the study sections, I focus on the design process and how I evaluated the results. An overview of the relationships between the studies is shown in figure 1 with figure 2 showing the timeline of those studies.

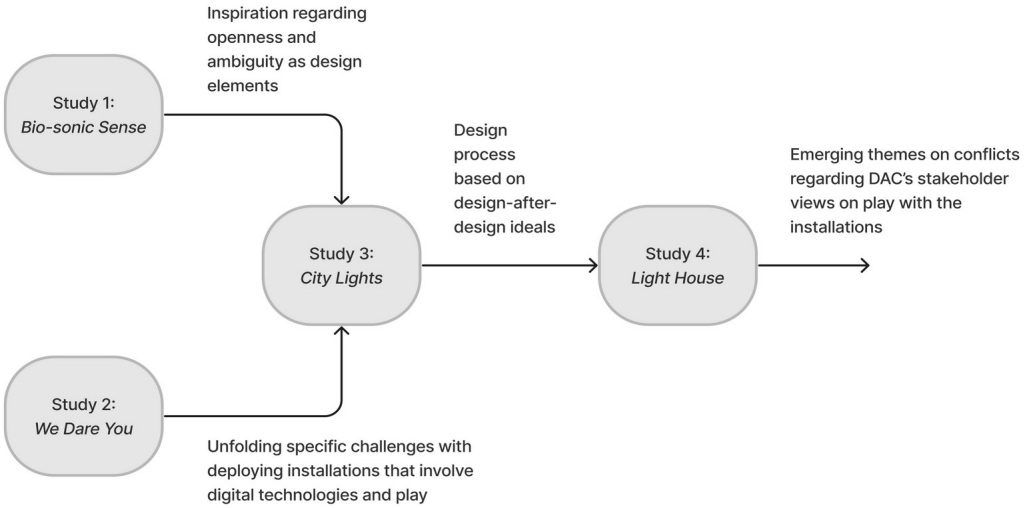

Figure 1: Relationship of Studies

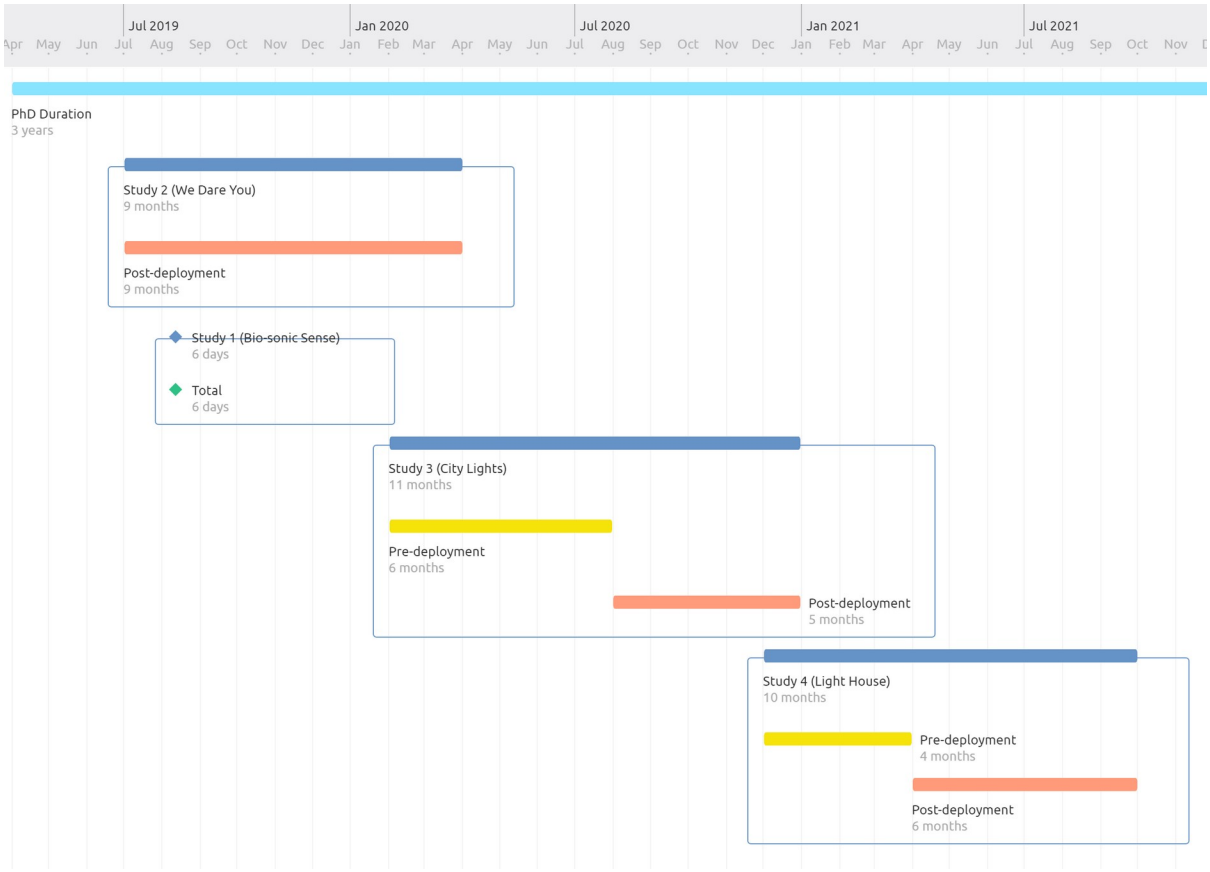

Figure 2: Studies Timeline

3.1 Research Through Design

Research-through-Design is an established method in the field of Human-Computer Interaction (HCI). It allows HCI researchers and practitioners to extract knowledge from the design of artefacts. As a method, it was originally suggested by Frayling [33] to study designed artefacts in combination with their design process. It was later adapted by Zimmerman et al. [133] to address interaction design research in the field of HCI. They suggest a method through which designers can employ generalised knowledge from the field of behavioural science and anthropology "as they attempt to make the right thing" [133:497]. Design deals with the particular and the specific, which causes issues when methods from other scientific fields are used to conduct design research [113]. Some suggest that design research instead should abandon established scientific research traditions and create new programmatic ways to demonstrate its validity [36,69,77]. Following that tradition, I built my research upon addressing the following problem that I discovered in the space of DAC:

DAC stakeholders want to provide an educational experience in the exhibition space of DAC.

At the same time, they want to provide an entertaining experience for their visitors. To support both of those values, they set up playful experiences with an educational goal. Even though they do so, some of them oppose some values that come with play — appropriation and self-expression — seeing themselves as the ones who should direct how the visitors engage with those experiences. Others embrace those values of play, and see them as supporting educational values, rather than opposing them. As an architecture institution they need to employ digital technologies to expose visitors to architectural "artefacts" (e.g. buildings, constructions, historical monuments). Those technologies enhance the conflict among stakeholders regarding play, due to their fragile nature, their unpredictable behaviour, and —occasionally— their novelty. Those elements enhance the destructive results of play — breaking the technology — and create a situation where stakeholders find it difficult to plan and curate their exhibitions, since they do not know what to expect.

To approach that problem, I defined some assumptions. As an industrial PhD fellow, I was employed to conduct this project in the exhibition space of DAC. I was part of their Kultur (Culture) team, and thus, the dissemination goals of the institution, along with their rules and guidelines for their space, had an impact on my research. Thus, the first assumptions became: (1) playful design can support educational leisure activities in exhibition spaces of DAC. In other words, even though I focused my experiments on leisure and play, they also need to have an educational value related to the dissemination goals of the institution. As a result, I sought out the expertise of DAC stakeholders to understand those goals. Continuing, I focused on the use of digital technologies to support exhibition experiences in DAC. That research direction stemmed from my expertise, and the need of the institution to understand the role of those technologies in their exhibition space. Which leads to the second assumption: (2) digital technologies can support experiences that promote playfulness and self-expression in exhibition spaces. Finally, it became clear from the *We Dare You* study, that a controversial aspect of such experiences was their invitation towards visitors to play with them, re-purpose them, and find new ways to express themselves through their use. The established design approaches that the institution had employed failed to accommodate for that playful technological appropriation and its consequences. That lead to my third assumption: (3) design to include possibilities of re-purposing by the visitors during the design process. Those three assumptions delimited my research endeavours.

3.1.1 Design Research Criteria

I will now expand on how my work encompasses the four criteria suggested by Zimmerman et al. [133] for evaluating a research-through-design contribution. Regarding **process** I am elaborating in the rest of the chapter, where I outline my overall process and give a rationale on my methods (further details can also be found in the attached articles). Regarding

invention, in my work I have looked into the fields of Museology, Human-Computer Interaction, Play, Education, and Design Research; in I situate my work (Chapter Two) into those fields and through my contribution (Chapter Four) I help to understand better the role digital technologies and play in the museum space, when designing for installations. Regarding **relevance**, the preferred state my designs attempt to achieve is support for self-expression, following personal motivations and interests for museum visitors, and re-purposing of DAC installations; here I follow design theories that suggest idiosyncratic values, pleasure, ambiguity, openness, and personal interpretations. Regarding **extensibility**, I have reported preliminary results of a process that focuses on undetermined artefacts and tries to support re-purposing of said artefacts; further research endeavours could use that process as an inspiration; mainly, I have also contributed knowledge, through my designs, regarding the conflicts that occurred when play supported through digital technologies was incorporated in DACs space; the knowledge derived from my results can be leveraged to set up a stronger foundation for those types of installations in museums.

3.2 Research Structure

My research consists of two main parts. The first part is a discovery period, during which I conducted two studies to identify the research the research problem. The second part was the define

3.2.1 Discovery Period

During the first three months of my research I spent time understanding the environment of DAC. This was the first step at gathering data that I could later use to establish my research problem. I took advantage of my employment status to gather empirical data through integrating into the daily work and life of the institution. My focus was mapping how the organisation and its stakeholders operate to build an understanding on the opportunities and constraints that were associated with designing for DAC's exhibition space. I did so by having meetings and discussions with stakeholders, observing visitors, and learning about the organisation through official documents about upcoming exhibitions and overall strategy — overall gathering ethnographic data. At that point I had not yet formulated my research question.

During that period, I participated in a summer school, where I run an experiment — *Bio-sonic Sense* — which combined digital technologies, art, and play. Following the research-through-design approach suggested by Zimmerman et al. [133], this was the first iteration of engaging with the aforementioned research problem, since that experiment was my first

attempt on designing for play in exhibitions.

At the same time, around the middle of the third month, DAC unveiled the *We Dare You [57]* installation, designed and developed by *Immersive Studios*. That acted as my entry point to gather *field data* on the organisation's process of developing experiences involving digital technologies. The initial parts of my research on *We Dare You* unveiled the conflicting opinion of stakeholders regarding digital technologies and play in their space. Its frequent technical failures, along with the "controversial" ways visitors played with it lead to the forming of different opinions and plenty of discussions on its role in DAC's exhibition space. That gave me inspiration on leaning into that conflict to understand more about it. It also unveiled their approach on developing and maintaining those experiences, which helped me plan my experiments later on.

In the following two sections I will present the two studies of that period in chronological order, first *Bio-sonic Sense* and then *We Dare You.*

Study 1: Bio-sonic Sense

On the 11th of August 2019, I participated in a PhD School organised by the Catch Collective in Helsingor. During that, the goals were to develop an interactive experience as part of the upcoming exhibition held by the Collective. The theme of the exhibition was *Technogenesis and Sound*. In the team I was part of, we made a playful embodied installation. We wanted to use technology to bring human and non-human senses together. That led us to develop *Bio-sonic sense*, an installation which exposed the issue of sound pollution caused by humans and its effect on marine mammal sonar navigation.

Through *Bio-sonic sense* I wanted to explore the themes of openness and ambiguity in interactive art installations. *Bio-sonic sense* is designed around the element of exploration. It lacked a specific goal; It rather placed the visitor in a "new" or "altered" environment that was governed by slightly different rules. The partial sensory deprivation cause by *Bio-sonic sense* invited the visitors to explore the surrounding environment in different ways. It was my goal to use *Bio-sonic sense* to explore how and **ambiguity** and **play** can lead to visitors using the installation in new ways. I was interested into designing an installation without prescribing its use, but rather fleshing out the details of its environment that visitors would then occupy and discover its possible uses based on their own personal motivations and interests.

Bio-sonic sense was an exploratory experiment; I used its results as an inspiration to guide the next designs. Both studies helped me develop a clearer understanding of how visitors and stakeholders perceived openness and ambiguity in practice. They also draw my attention

towards the role that re-purposing has in the design of playful hybrid museum experiences.

Data Gathering

Preliminary observations: *Bio-sonic sense* was developed in five days. During that period we iteratively tried out the installation in order to fine tune it, and invited the other participants of the PhD summer camp to try it out the preliminary versions during the those days of development, since we were all developing our installations on the same space. Once the exhibition opened, we also spent an evening observing people (summer camp participants, and workers of the art space) trying out our final design. The data came from self-reporting our experiences with the installation, observing people who tried it out during that last evening, and during its development.

Study 2: We Dare You

As an Industrial PhD, I was employed by DAC. Thus, I could take part in stakeholder meetings, interview specific stakeholders, and perform observations on visitor interaction with various exhibition artefact in-the-wild. As part of my introduction to the organisation, I had individual meetings with all the different department heads: Culture, Sektor, Marketing, Activities, Visitor Experience (VX), and Digital Development. The purpose of those meetings was for me to understand current challenges that the organisation faces, and for them to be aware of my work and whether it applies to them. Furthermore, I was included in monthly organisation meetings where visitor data and future strategies were present, as well as bi-weekly meetings of the Culture department that mostly focused on specifics regarding the exhibition space. During the first six months of my project, I employed specific ethnographic methods [46] with the purpose of exploring the following problem:

> Displaying architecture outside of its context is problematic, since architectural works occupy large amounts of space, and are constructed with that specific space in mind. As a result, reconstructions or other traditional exhibition means — photographs, renderings, text — do not capture the sensory aspects of those works. How can we employ digital technologies in exhibition experiences to recreate those sensory aspects?

DAC had a new installation in the making: *We Dare You*. As part of understanding better the issues related to the aforementioned problem, I was involved in evaluating the process of the development, as well as the post-deployment visitor engagement. After the opening date of the installation (July 2019), it became quickly apparent that it was very popular with the visitors. On the other hand, stakeholders had conflicting opinion regarding the role of its playful elements. Some praised the visceral embodied experience it facilitated; others criticised the absence of traditional educational content (e.g. educational text regarding architecture). Furthermore, the installation constantly malfunctioned. Virtual Reality (VR) headsets frequently disconnected, requiring a full restart of the system; connection cables snapped; VR headsets broke down. At the same time, the institution did not employ an expert

on such systems. Moreover, the contract cleared the studio which designed the experience from any technical support requirements. All those issues revealed an opportunity to investigate the established design processes of DAC, and why did they fail to accommodate for the playful nature of *We Dare You*.

Data Gathering

Interviews: To understand the established design process, I interviewed key stakeholders that were involved in the development of *We Dare You*: the head of culture; the project manager responsible for *We Dare You;* the designer of the experience; a floor staff representative; and a member of DAC's IT Support team. The goals of those interviews was to gather individual perspectives about the project; trace the steps of the design and development process; and to identify its role in DAC's exhibition space.

Observations: As part of my evaluation I observed visitors interacting with the experience. That way I wanted to explore the types of behaviours that led to the conflicting stakeholder opinions. Also, I wanted to understand which specific behaviours the design process failed to account for. I conducted my observations for over a year; more frequently during the first weeks, but kept following its development until November 2020. Most insights came from observing approximately 150 visitors during three hour long daily observations from the 11th to the 13th of February 2020.

Questionnaire: Another important source of data were the daily questionnaire filled by floor staff once their shift is over. Even though that questionnaire was generic, it often mentioned *We Dare You* (in 101 questionnaires out of 276 in total). Those questionnaires cover the time period from 20 July 2019 until 12 January 2020. The responses helped me identify interesting or problematic interactions that floor staff observed. Furthermore, through deductive content analysis I classified the sentiment of those comments, thus getting an overall understanding of the floor staff's experience with the installation.

3.2.2 Define Period

After six months I left for my study abroad in the Mixed Reality Lab (MRL) situated in the University of Nottingham. I spent five months there — returning on March 2020. During my period there I was exposed to many different projects, all related to digital technologies being employed in the cultural sector to create playful experiences. I spent those months thinking, discussing, and experiencing what other researchers have built. At the beginning of that period, I was still conducting interviews with some of the stakeholders and the designer of *We Dare You*. Then, I continued with processing the data from those interviews while working on that publication. It was during that period that I defined the overall themes of my

research and planned out my next experiment: *City Lights* (ref).

Returning from Nottingham I set to start developing what I had sketched the previous months, and what would be my second *iteration* that would approach my research problem: *City Lights*. However, after eight days of being back, DAC went into lockdown due to COVID-19. Thus, I spent the next three months building up the experiment at home. During those months I also worked on my second publication, which helped me reflect on the various concepts that I wanted to explore with *City Lights*. I, then, used the results of *City Lights* to refine my research direction and build the last design experiment iteration of my research: *Light House*. In the following two sections I will present the two studies of this period in chronological order, first *City Light* and then *Light House.*

Study 3: City Lights

Motivated by the ideals of sensory museology, I was exploring ways to include sensory engagement in the exhibition space of DAC. I decided to work with light because of its strong significance in architecture — which fit well the educational goals of DAC. During the study of *We Dare You* we suggested that a potential design-after-design approach could help with the issues that occurred while supporting play. Following that, I set out to employ and test such an approach. My idea was to create an installation that had an initial undefined state. What I considered as an undefined state was a state that supported openness of interaction and openness of interpretation. In other words, I wanted to construct an initial object that supported many possible interactions to be discovered, and many interpretations regarding its purpose. Thus, supporting visitors on discovering their own interactions and interpretations. I would then observe those discovered interactions and re-design the artefact to support them. Furthermore, during the previous studies I found interesting how visitors expressed themselves through performing for the surrounding audience. That inspired me to look for ways to support the quality of creative expression in interactions with the artefact. Another key aspect of the design process was the design for flexible affordances (cf. 2.4). The initial state of the artefact aimed to support *allow* affordances, with in mind to later on re-design elements to help transformation those allow affordances to *encourage*, *discourage*, or request ones [20]. The iterative design process can be seen in figure 3.

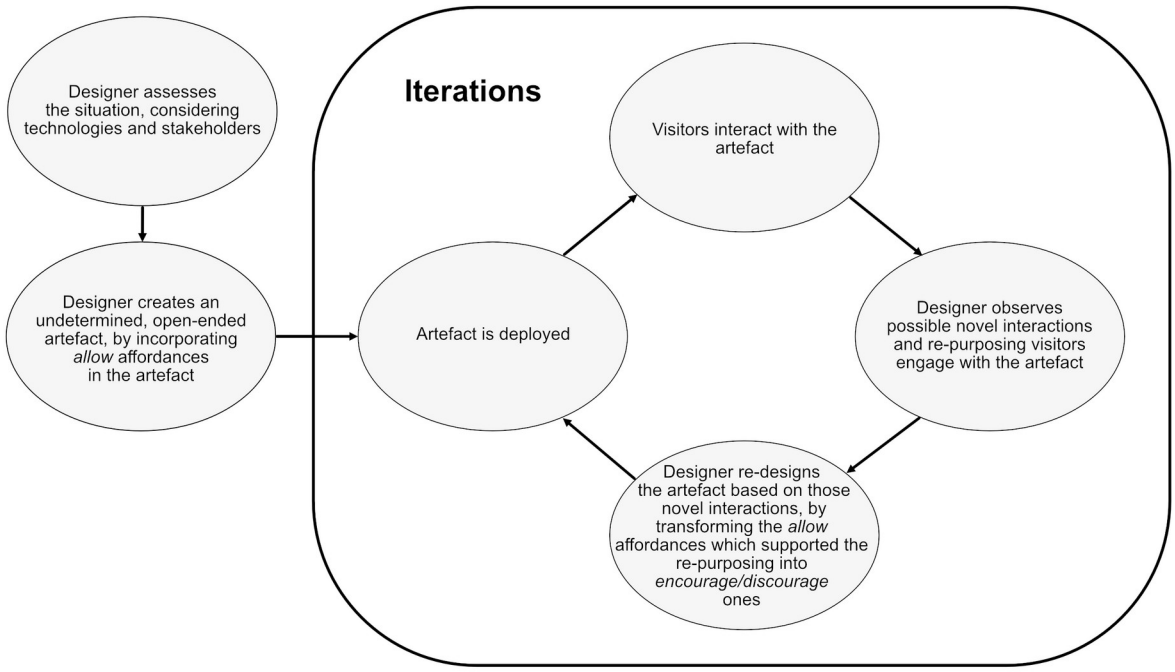

Figure 3: Design-after-Design Process

While considering ways to include light interactions in my design, I conceived the original form of *City Lights* which was called *PhotonBox*. That original design was composed by a box placed on some shelves. The box contained smart bulbs while the shelves contained various maquette tangible objects — human miniatures, furniture et cetera. The visitor could then control the light settings through an iPad, and they could use the object to create different maquette scenes — e.g. a concert or a playground. I conceived that initial idea while I was in my study abroad in the University of Nottingham. I returned on to DAC in February 2020 and presented my idea to the exhibition team. The initial plan was to begin development immediately, and deploy the installation on April 2020. On March 2020 that plan was interrupted due to the COVID-19 pandemic. DAC — along with most of Denmark — went on lockdown, thus postponing deploying the installation indefinitely. During the lockdown, I continued developing its essential interaction element: the controls of the smart bulbs through a web application. Once the institution re-opened, the digital system was ready. However, the initial idea of the *PhotonBox* was scrapped, since the institution wanted an installation that would be part of their current exhibition *Kids City*. That exhibition focused on seeing the architecture of cities from the perspective of children. Thus, it was important for the experience to accommodate families and children, since they were the primary visitor group. That requirement led to the design of *City Lights*.

I deployed the initial state of *City Lights* (see figure 4) during August 2020, and invited

visitors to use the tangible objects and the light settings of the smart bulbs to create simple urban-tableaus — i.e. maquettes of different city settings. *City Lights* undergone three re-designs. Each time I re-designed the artefact, my decision were informed by the various uses the visitors engaged with. To discover those uses I conducted ad hoc and scheduled visitor observations, engaged in discussions with DAC staff, and ask floor hosts to fill questionnaire data after their shifts. I also archived personal stories of floor staff through note-taking. *We removed city Lights* from the exhibition space in December 2020. It was deployed for approximately three months.

Data Gathering

Observations: I captured Interesting visitor behaviours using note-taking, and I took photographs of the associated urban-tableaus. In total, I photographed 73 of those tableaus. Furthermore, I observed 33 visitors interact with the artefact during 15 scheduled hour-long sessions. During those sessions I acted as floor staff.

Discussions with DAC stakeholders: Using note-taking I captured the various opinions and discussions I had with DAC stakeholders regarding the design — both during the pre-deployment and post-deployment phase. That data helped me identify how stakeholders responded to the individual interaction elements of the original installation and its re-designs.

Questionnaire data: A specific sentence was added in the floor staff questionnaire during *City Lights*' deployment: "Describe in a few words what you observed regarding how the new City Lights installation was used by the visitors." There were 33 answers to that sentence. Those answers helped to capture observations from staff with different perspectives and backgrounds. This is valuable since they often observed things that I might miss, because of their expertise.

Figure 4: *City Lights*

Study 4: Light House

After the study of *City Lights* I wanted to test the results of the theorised design process when designing an installation without explicit self-expressive elements. By doing so I intended to challenge the process. I already had a digital system in place, and through the study of *City Lights* I had some knowledge of what people found interesting when engaging with lights. However, contrary to *City Lights*, I set out to design a playful space for visitors to discover, similarly to what was achieved through the designs of the first two studies.

The discussions regarding *Light House*'s design had already begun in June 2020 (before deploying *City Lights*). During our initial discussion with the stakeholders, we agreed on using a wooden house that was available at the current exhibition of *Kids City* to create a home environment which would be customisable. As seen in figure 5, The house's size was large enough for a standing adult to enter with its furniture being 1:1 scale (same as regular furniture). The specific interactions of the artefact were not determined yet, but its concept already taken form. On December 2020, after the study of *City Lights,* I began the design process of *Light House* on December 2020. However, the stakeholders altered its original concept. Even though *Light House* was conceived to be deployed in the next exhibition of DAC, instead the stakeholders decided we should instead place the *Light House* in DAC's dedicated space for families and children — called the *Educatorium*. Their reasoning was that the installation would be better suited for that space because of its playful nature. We agreed that the overall theme would be the effects of natural and artificial light in architecture.

Figure 5: Adult-size wooden house

Before I developed a prototype, the design concept changed (see figure 6). I replaced the adult sized wooden house with a children sized wooden house (see figure 7) because of the lack of space in the Educatorium. When deployed, the *Light House* consisted of a small (130cm x 100cm x 100cm) wooden house whose space I augmented with a smart bulb; a smart LED strip; and a panel mounted on its roof which controlled its smart lights (see figure 8). Using the panel's controls, visitors could change the light settings. The buttons controlled the LED light's settings, changing its color and intensity to mimic the environmental light conditions of different times of day during the different seasons. The potentiometers control the intensity and temperature of the indoor light, mimicking common light settings found in households. Aimed towards children and families, the installation invited children to enter the house while other children or their guardians controlled the light settings through the panel while observing the changes through the window.

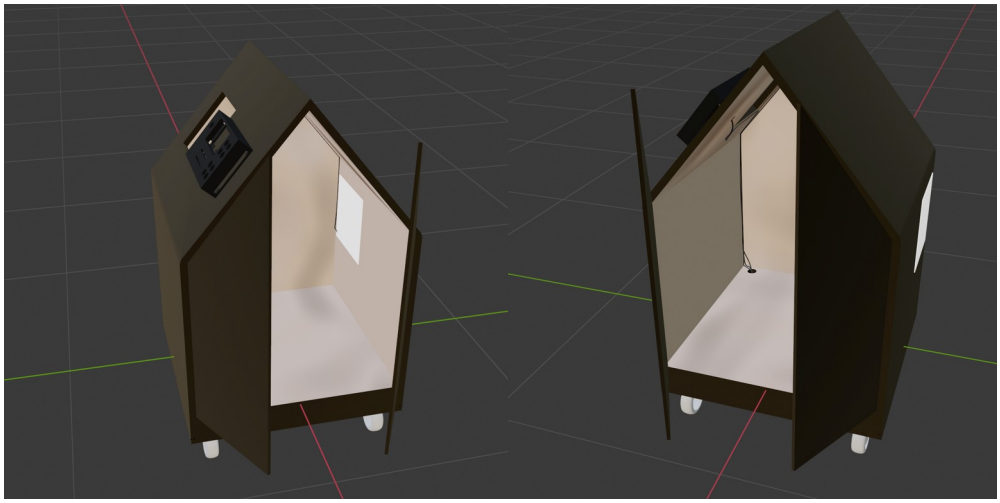

Figure 6: Wooden House Concept

I deployed light House from the 23rd of April 2021 to the 11th of October 2021 for a period of six months. During that period, I gathered data through note-taking. The data consisted of meeting discussions or informal discussions with stakeholders — mainly the ones from the exhibition team, education team, and floor staff. I also noted down personal observations of visitors interacting with the artefact. I carried out four scheduled observations of approximately two hours each. I also engaged in daily ad hoc observations as part of the institutions' staff. I documented interesting visitor behaviours through note-taking and photographs.

Data Gathering

Observations: I archived Interesting visitor behaviours using note-taking. I did so during four scheduled sessions, two-hour long each; ad hoc observations also took place. I used photographs to capture the results of interesting behaviours, looking into instances where visitors used the artefact in some novel way.

Discussions with DAC stakeholders: Note-taking also was used to capture discussion with DAC stakeholders during meetings or informal settings. Specifically, I conversed with floor staff during or after the shift to discover if they observed anything interesting for them.

System logs: The Raspberry Pi that I used to process the input of the visitors, acted also as a data logger, logging that input. Specifically, it capture which button was pressed and the time-stamp of when it was pressed. However, that data were not useful in the end, as it was difficult to associate those logs with the observed actions in some meaningful way. Visitors re-purposed aspects of the installation that were not part of the main interaction, and did not produced any input associated with the panel.

Figure 7: Child-size wooden house

Figure 8: *Light House*'s Interactive Elements

3.3 Methodological Considerations Related to DAC

Working as an Industrial PhD had affected my approach in three main ways. First, I was an employee of DAC which gave me full and continuous access to their space and audience. I was also involved into their internal processes, meetings, and discussions. Second, I was able to set up experiments which took place as part of their exhibition, leading to collecting in-the-wild data. Third, the institution's processes were heavily affected by COVID-19, and that had an influence on how I ended up conducting my studies. In the following sections I am expanding on these considerations in detail.

3.3.1 Relationship with DAC

My project was part of the Industrial PhD program. That program involves a partnership between a private institution and a university. As an industrial PhD fellow, I was employed by the Danish Architecture Center (DAC) and affiliated with the IT University of Copenhagen. As an employee of DAC, I was part of the exhibition team. That team handled the concept, design, development, and evaluation of past, current, and upcoming exhibitions. As part of the exhibition team, I was involved in bi-weekly meetings, which included stakeholders both from my team but also from the activities team (responsible for special

events and educational activities that were organised in DAC). I was also involved in monthly organisation-wide meetings where the overall organisation plans, strategy, and evaluation metrics were presented and discussed. During the overall process, it was my responsibility to design, deploy, and maintain the *City Lights* and *Light House* artefacts. I was also involved with the formative evaluation of the *We Dare You* installation. *Bio-sonic Sense* was never deployed in the space of DAC.

Being part of DAC meant that I had access to their exhibition space to conduct my studies. That situation had some implications regarding my freedom as a researcher. First, during the design process of the artefact, I received many ideas and inputs from the stakeholders regarding what elements should the artefact have. Second, before deploying a designed artefact in the exhibition space, that artefact had to be approved by the person responsible for the specific space or exhibition that my artefact would be situated in. Third, the visitors' feedback and perspective affected the response stakeholders had in relation to my artefacts (occasionally requesting changes and features that could "satisfy" visitors). Fourth, the stakeholders had a diverse professional and educational background which affected how they viewed specific artefact elements; that, in turn, limited the possibilities when designing those artefacts. DAC stakeholders are experts in their field, thus their opinion is highly relevant to the design situation at hand. At the same time, when a possibility arose for experimentation, I often had to follow a "safer", less controversial path, since they feared possible implications in the overall visitor experience.

That impact-oriented focus of the organisation influenced the structure and details of potential experiments. The timeline of upcoming exhibitions, along with the constant rethinking of organisation strategies, posed constraints on the possible designs that I could deploy in the exhibition space. The study and experiments followed an impact oriented approach, taking advantage of exhibition settings and current challenges that organisation was facing — leading to what Krogh et al. [70] call a *probing* method of experimentation. That method is characterised by a choice of experiments seemingly ""illogical", "artistic" and "impact oriented"" [70:9], and is closely related to methods of professional design, thus establishing its relevance when conducting research in an industrial setting.

3.3.2 In-the-Wild Data Collection

As an industrial PhD, I was in a strong position to perform empirical studies in the exhibition space of DAC. That opportunity allowed me to observe visitors into an actual exhibition space and gather data from that space, thus performing research "In the Wild" [14]. Given the focus of my research towards emergent interactions and re-purposing of artefacts, accessing this type of data was imperative to uncover user behaviours that require time and a "natural"

environment to occur.

In my work, I analysed the three design artefacts by conducting fieldwork. I followed each of those artefacts for extensive periods of (at least) three months. During those periods, I captured (1) audio-visual resources — photographs, and, in the case of *We Dare You,* stakeholder interviews — (2) and physical resources — field notes. Furthermore, because of the industrial nature of my project and my employment in DAC, my methodology also contained ethnographic elements. During my project, I captured extensive oral accounts from DAC informants. I was treated as their co-worker, which allowed me to have extensive informal discussions with many employees belonging to different teams of the organisation. Due to that, I employed the empirical data collection I described to supplement my research-through-design approach. That helped me explore how various stakeholders saw those designed artefacts, and what was their opinion regarding the design situation at hand, while being their co-worker.

3.3.3 COVID-19 Complications

The end of 2019 began the COVID-19 pandemic. This resulted in an extensive period were DAC was closed — along with all the museums and cultural institutions in Denmark. The first lockdown period of DAC occurred from March 2020 until June 2020. The second one occurred from December 2020 until the end of April 2021. Both lockdowns occurred during the period in my thesis which I had planned to do experimental work. Due to the museum space being unavailable, I had to adapt and restructure my process. In my original timeline, I had planned to conduct five studies in total (see figure 9). When the first lockdown occurred, I had to postpone deploying *City Lights*. I did not have access to the space to build and evaluate the artefact. The exhibition space was closed both for me and the visitors. Consequently, I had to delay the overall development of the artefact, since some parts had to be built in DAC. The institution re-opened in June. At the same time, they changed their exhibition plan because of the lockdown, thus we had to figure out how the installation would fit with the current exhibition. As a response to that, I removed the last two studies from my plan. I did so because I anticipated that another lockdown might occur (which it did). I expected to have access to DAC's exhibition space for less time than originally planned. I also considered that hygiene issues might arise, since visitors might have been hesitant to interact with devices touched by others. However, DAC addressed that by sanitising the space in frequent intervals, and having disinfectant tissues and gel available in its exhibition space for visitors to use. The second lockdown resulted in a premature shutdown of *City Lights* (approximately one month earlier than expected). That caused both my re-design iterations and visitor evaluation to come to a sudden end. Since the installation was part of a specific exhibition, it was not possible to re-deploy it once the institution re-opened.

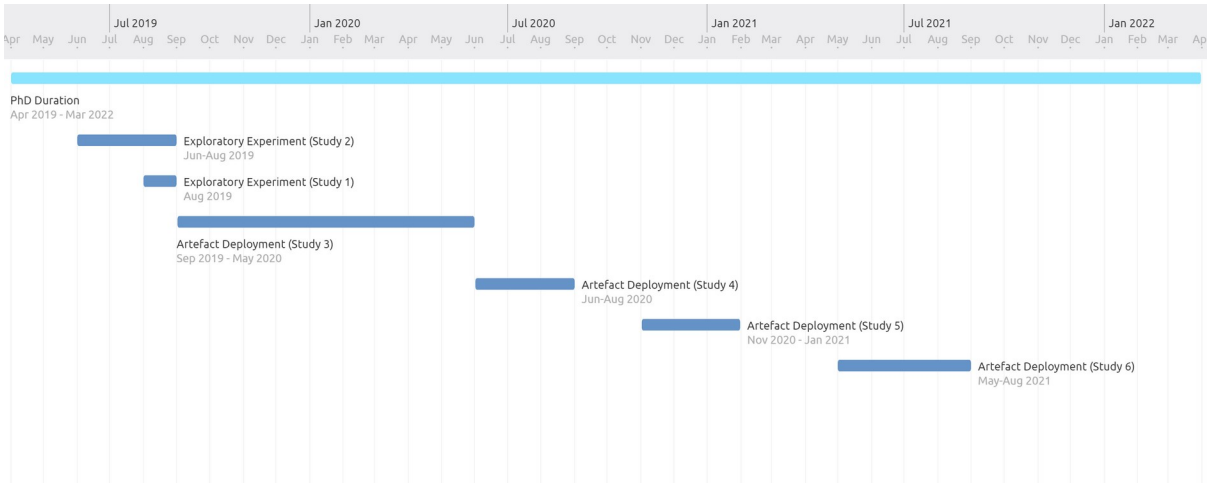

Figure 9: Original Studies Timeline

CHAPTER 4. Discussion

In this chapter I discuss the themes that appeared on the data and the publications. I start by drawing similar design aspects among the artefacts that I presented in this thesis. Drawing from the overall theme of undeterminability, I discuss how the different artefacts facilitated ambiguous and undetermined interactions. I also expand on how I approached that as a designer in my design process for the installations I designed myself and deployed in DAC's exhibition space (*City Lights,* and *Light House*). Then I move on to the main contribution on this thesis: expanding on the observed conflicting expectations from play that the DAC stakeholders had amongst themselves, and in relation to the visitors. There I discuss different theoretical directions on the relationship of education and play, how that relationship manifest in the museum space, and how it connects to contemporary approaches of design. I argue why it seemed challenging for DAC to accept play in its exhibition space, and why it might be worthwhile the effort to find ways to incorporate play.

4.1 Designing Undetermined Artefacts

This section discusses the design aspects of the installations I presented in this thesis. The aim of this section is to expand on the ambiguous, undetermined nature of those installations which led to the emergence of play. All the artefacts presented in this thesis supported various forms of play. All are free, "not serious", materially unproductive, and have self-imposing boundaries in the exhibition space [41,13]. Free, since — as installations in a museum space — visitors can choose whether they want to interact with them; "not serious" since their interaction is centred around pleasure; they have no material output; and the interactions are all contained inside the exhibition space. They are also contextual, appropriative, carnivalesque, disruptive, autotelic, creative, and personal [108]. They exist in a museum context, inside which visitors self-imposed creative goals based on their own motivations and interests. The results were interactions that challenged the boundaries of what was accepted in DACs space. They were placed in DACs exhibition space (set-outsideness) governed by specific ludic forms (interaction mechanics afforded by each technology), with an ambiguous purpose [106].

To briefly summarise the undetermined aspects of each installation:

In the case of (1) *Bio-sonic Sense*, based on the limited user observations we performed, its primary appeal was playing with one's senses and trying to navigate space in a different way. We could see the playful exploration that the users/players engaged with when wearing the

device. The users had to rely solely on their auditory sense to navigate space, which is something they were not used to, creating an ambiguous interaction.

In the case of (2) *We Dare You*, since I did not design the installation, I will only be referencing design information derived from my discussion with the designer and observations I did regarding the decisions the institution made post-deployment. Its primary appeal was its simple yet visceral experience it created. The instructions on the description outside the installation were clear: "Put on the VR glasses and then walk the plank through the glass". However, what was novel and ambiguous was how would that interactive space — mapped to be almost identical to the physical one — would react to the person in the headset. Furthermore, it was also unclear how would the people in the headset would react to what is happening outside, and vice versa, how would people on the outside would react to someone with the headset. This stemmed from the fact that VR was a new technology for many of the visitors, thus its uses were undetermined for them.

In the case of (3) *City Lights*, it was initially released without any instructions, leaving it largely undefined. Some aspects of the initial artefact state were confusing for the visitors (e.g. what are the supposed to do with the models), while others were engaging but stakeholders considered them irrelevant in regards to its educational value (e.g. the various color choices for the light without any specific educational direction). What was undetermined here was how to interact with the artefact. The various small elements (plastic houses, small geometric objects, etc.) created a sandbox interaction, where visitors were let free to be creative and design their own urban tableaus. The absence of constraints made that interaction with the artefact undetermined

In the case of (4) *Light House* visitors engaged with different affordances than the ones I predicted. They saw the house as a toy for their surrounding activities. The purpose of its space was undetermined, with visitors re-purposing that space to support other activities, such as reading, or playing hide and seek.

The design process I employed for installations (3) and (4) tried to align the embodied experience of play with the cultural expectations. By setting up an initial undetermined artefact a conversation begins; Stakeholders have the opportunity to express their opinions and worries regarding the values instilled in the artefact, while at the same time visitors (and stakeholders) get to use it. During the design process, those values expressed by the stakeholders take some form as part of the artefact's design. We can then observe in practice if the resulting form benefits the overall experience of the artefact. Then, based on the results, we can adjust the form those values take with the purpose of making the artefact engaging while preserving them.

In my design process the initial key step was to deploy an undetermined artefact (as suggested by *design-after-design* approaches [95]). My initial goal was to create an artefact state that is neutral and open. My approach regarding that was to focus on *allow* affordances and minimal constraints when creating that initial state. Suggestions discussed by past researchers inspired this type of approach. Humphrey et al. [55] suggest that museums should look into open-ended exploration; minimize instructions and explanations to support speculation and play. Dix [23] suggests allowing multiple interpretations through design elements with multiple possible meanings. He calls for "openness, making things that allow themselves to be used in unexpected ways" [23:29]. Sengers and Gaver [105] suggest that one way to support openness is communicate the usability of an artefact while at the same time designing for unconstrained use. For them artefacts should resemble a "blank canvas which can be interpreted by users in many possible ways" [105:102]. However, that idea of clearly communicated usability without constraints clashes with what the role constraints have in design. Constraints situate the artefact into specific knowledge frameworks, helping users to understand how that artefact can be used and help with the construction of meaning or interpretation [84]. In other words, constraints, by limiting some uses, they help users navigate the interaction space in order to find how to engage with an artefact. There seems to be a close relationship between openness and constraints. The more constraints we add to an artefact, the more we limit its possible uses, and consequently its openness. There is an underlying subjective balance between what should be open and what should be constrained. Too many constraints and the user becomes a passive consumer engaging only with predefined uses; Too much openness and users cannot discover possible uses or meanings, since they might be overwhelmed by the extensive possibilities.

In my work, I created that initial undetermined state through designing for *allow* affordances [20] in the artefact. I intentionally chose interaction elements that either could take many possible states (e.g. the tangible objects in *City Lights* visitors can move around freely); or the interaction elements had a secondary role and did not dictate the purpose of the experience (e.g. the lights in *Light House* set the mood but did not dictate how visitors should interact with the house).

However, it is hard to identify a clear boundary between *allow* and *encourage* interactions. Davis specifies that for *encourage* affordances:

> Technological objects *encourage* some line of action when that line of action is made easy and appealing. The action is generally obvious, expected, and seamless to execute. Those lines of action that are encouraged often represent the very things a technology was built to accomplish. Users need to employ little or no creativity, deviance, or subterfuge to engage the technology in encouraged ways. [20:chapter 4]

While *allow* affordances:

> Allow is distinct from other mechanisms of affordance due to its neutral intensity and multidirectional application. A user may take a line of action, but there is no pressure to do so, and there are no significant obstacles in the way. Allow is like a fork in the road. A traveler may just as easily opt for one route as another. The traveler is not faced with enticements from any direction, and the traveler does not need to overcome any extra blockades to access the pathways. [20:chapter 4]

The difference between the two is subjective. We can easily see an *allow* affordance as an *encourage* one and vice versa. As described by Davis "[a] feature may sit ambiguously between encourage and allow" [20:Chapter 4]. That is because both of those affordances do not have any specific obstacle associated with them. The key difference is whether the system is designed to expect and facilitate specific action. There are various possible origins for such an expectation to form (e.g. cultural norms, association with similar objects, expectations from the designer). Due to that distinction, there is an issue when a designer tries to implement *allow* affordances in an object. Either (1) the designer implements the affordance in the artefact (if so then extra care needs to be given to avoid ending up *encouraging* specific interactions) or (2) the affordance is a byproduct of some other interaction elements and thus unknown to the designer (which makes it quite difficult to design for). Even though my suggestion was to implement *allow* affordances in the beginning of the design-after-design design process, I believe that special attention needs to be raised when designing those affordances since they might already fall into the *encourage* category. In retrospect, regarding *City Lights*, some models already had architectural forms which *encouraged* building urban tableaus, even though I consider them as supporting *allow* affordances during the study. This matters since I wanted to support the discovery of uses which were new to me. An *encourage* affordance would bias the visitor to a specific direction.

During my studies, my goal was to have DAC visitors re-purpose the affordances I implemented. However, now I see as more fruitful to look at the possible affordance "byproducts" (i.e. accidental affordances). Since the goal is to discover new uses for the artefact, those accidental affordances are solely the result of visitors' creativity, which can reveal what they found more interesting about the artefact. That became especially apparent on *Light House* where visitors did not engage with the affordances I set up on purpose (i.e. panel and lights), but rather with the ones they found interesting (i.e. integration with the surrounding space). Even though I aimed to set up *allow* (or arguably *encourage*) affordances, DAC visitors discovered other "accidental" ones. Using open and flexible affordances was one way to create such possible "byproduct" affordances. However, my approach had the shortcoming of creating initial confusing states were many users did not know how to interact with the artefact and quickly lost interest.

During the course of my research it seemed important, then, to balance openness and

constraints when designing the initial undetermined object. Simultaneously, implementing affordances and constraints in an artefact implies that there is an intended use that we highlight. If we already envision a specific set of uses for our artefact, how can we adhere to the ideals of *design-after-design* from a designer perspective? To address that question I accepted that employing openness can result into a confusing artefact in terms of usability — in *City Lights* and *Light House*. In return for that confusion I managed to involve visitors as early in the process as possible, observe their real use, and deploy the artefact inside the actual exhibition setting. At the same time, that confusion lead to visitors being dissatisfied with their visit, if the artefact is not somehow engaging from the beginning. In the case of *City Lights* the initial interaction was confusing but also engaging, leading to visitors interacting with the artefact from the beginning. In the case of *Light House* the interaction proved to be not particularly engaging, and thus led to visitor complaints. An alternative approach was to invite re-purposing through creating those "byproduct" affordances unknown to the designer — which occurred accidentally by *Immersive Studios* in their design of *We Dare You*. The designer had not intentions to encourage the performative elements (e.g. people scaring each other, pushing each other "off the building", et cetera), but it resulted from putting a single player Substitutional Reality experience in a social setting. Even though that revealed new affordances and playful uses, it also left the overall design in a controversial state because of the technical issues and stakeholders' reaction. In the following paragraphs I will expand on four design principles that are present in the bibliography and appeared in the design aspects of the installations presented in this thesis — either on purpose or by accident.

4.1.1 Support for Self-expression

One of the primary interaction mechanics I designed on *City Lights* was the support for **self-expression** (i.e. generating creative personal contributions using the interaction elements of the installation). The primary interaction available for visitors was creating urban-tableaus. I choose to implement self-expression since it is in par with suggestion by Sengers and Gaver [105] that an artefact should be designed as a blank canvas allowing multiple interpretations. Self-expression allows a variety of outcomes without changing the constraints of the system. Self-expression is also a way to ensure the possibility of immediate play [90] since it allows visitors to jump in and out of the interaction by building on each others creative work. That type of interaction is valuable for museums spaces, since visitors need to easily figure out how to engage with the artefacts [52]. Self-expression is also associated with helping users appropriate technologies [80], which was the primary goal in the design of *City Lights*.

Comparing the empirical results of *City Lights* and *Light House* (studies 3 and 4) provokes an interesting discussion regarding self-expression. I developed *Light House* with the purpose of

challenging my design process in creating an artefact that was not designed to support self-expression. With *City Lights* visitors still interacted with it, even when confused regarding its purpose. There were cases of people — reported by the floor staff — which entered, played around with the tangible objects, expressed their uncertainty regarding the purpose of the installation to the floor staff, and then left. In comparison, when visitors were confused regarding the purpose and use of the *Light House*, they disengaged almost immediately (after pressing its buttons briefly). In both cases visitors did not engage meaningfully with the object. However, the element of self-expression might have helped them try to use the installation a bit more. Furthermore, in *Light House*, visitors still seemed attracted to self-expressive possibilities (e.g. deciding what the house should be, bringing in surrounding furniture, etc.), even though the interaction elements of the installation did not support that. Rather, they discover those possibilities by including elements of the surrounding space (*Educatorium*). Interactions based around self-expression (e.g. drawing, building a maquette, performing) ensure that there are some aspects designed in the artefact that give the opportunity for the user to create something by following their own motivations. In a way, self-expression helped visitors interact with the artefact even when its purpose was confusing. To borrow again from Sergers and Gaver [105], designing an artefact as a "blank canvas" (i.e. artefacts which support multiple interpretations) supported a larger space of possible interaction outcomes (limited by the creativity of the visitors), which supported that self-expression. In the case of *City Lights*, the free space on the table, together with the various different tangible objects allowed visitors to build their own interpretation of an urban tableau. In *City Lights,* visitors continued each other's urban tableaus. The table was always "in motion" constantly exhibiting different urban tableaus (or other creations) made by visitors. Similarly, the *Light House*'s space supported multiple interpretations. Visitors used it to engage in various other activities (e.g. hide and seek, reading, playing with the toys available in the surrounding *Educatorium* space, et cetera), even thought it was not in my intentions to design for that. Initially, I tried to limit the capacity for self-expression in the *Light House* by constraining its interactions elements to a small set of possible states (i.e. controlling the state of two lights with limited options). Those limits on the interaction elements seemed to either (1) alienate visitors which then quickly lost interests; (2) encourage visitors to engage with its space, re-purposing it to accommodate for their other activities.

So there seems to be a dilemma: on one hand including self-expressive interactions can give the tools to the users to express themselves inside the limits set by the artefact; on the other hand limiting self-expression in the interaction elements but placing it in a playful space can push users to re-purpose unexpected elements of the artefact (possibly due to the lack of an obvious use in place). That is not to say that an installation with self-expressive interactions will not be re-purposed. Rather, the point here is that self-expressive interactions set up a large space of interactions based around specific interaction elements. Even though that

might be desired, that might also hinder the unexpected re-purposing of other elements which can reveal new directions for re-design.

4.1.2 Re-designs Supporting New Ways of Engagement

The main aspect here is to select some characteristics and re-design them in ways that support new ways of engagement. In my work I did this in two ways. (1) One way was to *include characteristics that deviate from the norm*. For example, in *City Lights* during the re-design step where we included the prompts, instead of suggesting common architecture themes (*winter scene*, *cozy scene*, et cetera) we could have implemented prompts which suggested unique unfamiliar themes (*tableau from hell*, *a city in mars*, et cetera). (2) Another way was to *change the form of the artefact extensively*. An example here is what came to be the design of *Light House*. Initially, I conceived it as a re-design of *City Lights*. The theme of light remained the same, the interface was slightly similar, but the space and the main experience was different in many aspects. Thus, it also had its own unique character, even though it was heavenly influenced by *City Lights*. That re-design uncovered new behaviours that can be compared with the ones in *City Lights* because of those similarities. As a result, by drawing on the similarities of the two artefacts we managed to built an overall understanding of what aspects are interesting in the overarching theme of light. In *City Lights*, visitors enjoyed being creative with the tangible artefacts and seeing them under colourful light. In *Light House*, visitors enjoyed engaging in various activities inside that space. They seemed drawn to the atmosphere created by those lights. Overall, the end goal was to create a series of installations around a common theme, with each artefact being drastically different from the others while also building on each other's interactions. Some challenges with this approach were (1) how to decide which characteristics should be re-designed; (2) which forms would be acceptable for the institution to include in their space; and (3) to what extend the design of those elements should be informed from visitors interactions or from the designer's creativity.

4.1.3 Ambiguity

Another important value I tried to support in my design process was ambiguity. Ambiguity can invite users to re-think what the role and use of artefacts by conveying unclear information; having unclear roles in relation to their surrounding context; or making the user uncertain regarding their relationship with them [37]. In that case, the user might rethink the purpose and uses of a familiar artefact due to present unfamiliar qualities. That ambiguity is highly relevant when thinking about **cultural**, **semantic**, and (occasionally) **logical constraints** [84], since those types are strongly connected to how users interpret proper behaviours and interactions. It is often that art [81,87] and design [61,96,112] employ constraints to inspire creativity. However, ambiguity is risky due to possible visitor reactions.

It is difficult to challenge visitor norms [76], and difficult to use exhibits can be perceived as broken which, then, leads to visitor dissatisfaction [52,68]. In all the three studies situated in DAC (studies 2, 3, and 4) many visitors were visibly annoyed when they felt that installations malfunctioned (often complaining directly to floor staff). However, specifically in the cases of *City Lights* and *Light House* visitors found the artefacts confusing due to their extensively open nature and absence of constraints, and often thought they were malfunctioning even when they were working properly. Even in the case of DAC stakeholders, during the first weeks after *Light* House was deployed, they often approached to inform me that the installation was not working. When I went to verify and fix that I would often discover that the installation would be working properly. Its purpose was confusing even for the them, and when confused visitors approached them, inquiring for instructions, the stakeholders assumed that the installation was broken. Those reactions demonstrate how such an approach posed challenges for DAC since it lead to visitor dissatisfaction and disengagement.

At the same time, ambiguity is strongly connected with play. Play requires visitors to approach the installations by embracing the unproductive nature of play, what Sharp and Thomas [106] call "set-outsideness": "when we enter a play experience, we set aside certain expectations of utility, efficiency, and expediency. In fact, we *desire* uselessness, inefficiency, and impracticality as part of the play experience"[106:6]. Visitors come to museums for pleasure and education, as a result they might not be open to unproductive play, which in turn prohibits the aforementioned "set-outsideness", creating a state where the visitor interacts with a play experience while not in the mood for play, only to "learn" what there is to be learnt in accordance to the motives of the curator. In other words, the goal for the visitor is to finish the task at hand to unlock the "knowledge" behind that exhibit. Then, engaging with the necessary ambiguity required to play becomes confusing and a nuisance, since the visitors are not there to play. Those different attitudes — having fun as opposed to learning — might be the reason why some visitors found *City Light*, and *Light House* confusing, while others did not have problems engaging with them.

4.2 Conflicting Expectations from Play

In this section, I will expand on the conflicting expectations from play that I observed during my studies. In my research, I set out to explore the re-purposing enacted by visitors when they engaged with the playful installations in the space of DAC. I did so by releasing artefacts to visitors while those artefacts were still in the development process, thus still malleable. Similar processes can often be found in game design, where studios provide "early access" to their games in order to engage with their community and discover how users will play while the game is still under development and easy to re-design its underlying systems

[72]. Visitors had the opportunity to express their expectations from the artefact through they way they try to use it. However, those expectations did not always align with what DAC stakeholders had in mind. DAC stakeholders had specific perspectives regarding the educational and dissemination value of the artefacts; visitors then "challenged" those perspectives indirectly, through engaging in play. Stakeholders had different expectations both amongst themselves and with visitors regarding the role of play in DAC's exhibition space. In my work, I observed that those conflicts arise due to three main themes: (1) bodily-sensory experience conflicting with the cultural understanding of play, (2) realist and idealist views on education, and (3) the frivolous and unproductive nature of play inside DAC's cultural space. In the following three sections I expand on these themes.

4.2.1 Stakeholders' Perception on the Experience of Play

In my observations there seems to be a disconnection between the stakeholders reporting how they felt when trying the installations themselves, and what was their opinion when they observed visitors trying out the same installations. Stakeholders when trying the installations themselves enjoyed the engaging nature of play on an embodied level. On the other hand, the open interactions those installations supported a visitor experience that raised doubts on the educational values of those installations, possibly because of their educational and professional background. For example, during the opening of *We Dare You* we all got to try the installation (me and the rest of the DAC employees), and everyone had a joyful and interesting experience, with some stakeholders trying the installation multiple times. At the same time, once the installation became available to the visitors, some stakeholders' opinions changed. Indeed, once they observed how visitors played with it, that stakeholder subset doubted its educational value and whether or not its design elements support the dissemination values of the institution. Another example comes from *City Lights* where stakeholders reacted positively on the effect that light had on them, and enjoyed how the materials present where affected by that colourful light. Yet again, once they observed visitors trying out *City Lights* and "failing" to produce something meaningful (according to the stakeholders' taste), they doubted the educational value of the designed elements and wanted to do changes — add a sign, add prompts, etc. Continuing on another observation, the stakeholders evaluate how visitors perceive the exhibition, by relying heavily on using the Net Promoter Score (NPS) method, focusing on visitors' overall satisfaction with the exhibitions — which is highly affected whether or not they enjoyed their interaction with the exhibits, and is something that increased due to the playful elements present on those installations as per the questionnaire comments which they fill on their way out. At the same time, those same behaviours and activities that raised those NPS are criticised by the stakeholders.

Looking at those examples, the first aspect of this conflict is the bodily-sensory experience of those installations — i.e. what Ihde [56] calls microperception. Both stakeholders and visitors when they engaged with the artefacts, they enjoyed their interaction with the artefacts and considered their overall experience as positive and fun. In *We Dare You* there was a unanimous consensus that it had a positive impact in the visitor experience. In *City Lights* stakeholders enjoyed playing with the lights and the models. In *Light House* they kept on pressing the buttons and observing the light. All those examples reveal the embodied aspects of play. The second aspect of this conflict lies with the stakeholders cultural understanding of those installations based on the observed behaviour — i.e. the cultural-hermeneutic dimensions: macroperception (ibid.) — which did not always align with their embodied experience. First, on a microperception level, stakeholders understood and agreed as to why visitors enjoyed the installations — since the stakeholders also had fun playing with them; Second, on a macroperception level, stakeholders either assumed a position where DAC and its curators should explain the true nature of architecture through all parts of the exhibition, or assumed a position where they saw DAC helping visitors form their own opinions about architecture in a curated environment. This dichotomy hints to an underlying cause: their approach on education. That is the focus of the next section.

4.2.2 Realist and Idealist Approach to Education

A potential root of those conflicting expectations is the different educational approaches DAC stakeholders had. Hein [49] in his work, discusses how views on education and epistemology are interconnected for museum curators, and affect whether the curators take a realist or an idealist approach regarding the dissemination role of their institution. A realist approach would see the institution as disseminating reality to the visitor “as is”, while an idealist approach would acknowledge that reality is constructed not externally but internally, through personal interpretation of the exhibits — both in the case of a curator and in the case of a visitor. On that basis, older didactic views — namely didactic expository and stimulus-response — tend to oppose playful experiences since they thwart the possibility of personal interpretation. On the other hand, constructivism contrasts those older approaches through following idealist ideals. Given those two approaches, different institutions and even stakeholders within an institution, can have starkly opposing views on how museums experiences should operate to have educational value. For Hein, a key issue regarding those two approaches is that they are bound to an individual’s views, beliefs about society — what he calls “world hypothesis” — and ultimately one’s construction of reality. As a result, he continues, each stakeholder can have very different preference regarding which educational approach they want to follow. The nature of the controversy regarding if, when, and how to include play in the exhibition space might be affected by the idea that the time spent playing might be used in more efficient forms of learning.

In line with what Hein suggests, the DAC stakeholders' individual backgrounds might have led to conflicting beliefs regarding the role of play in the exhibition space:

(1) On one side having the stakeholders — with background on Architecture — who saw play as a way to attract visitors, help them have fun, but ultimately disseminate knowledge through some didactic expository means. An example comes from stakeholders requesting to add signs with architectural information in *We Dare You*, *City Lights* and, *Light House*, so that visitors can learn about architecture through reading them. It was a requirement for both the installations I developed (*City Lights* and *Light House*) that they would contain a sign curated by the stakeholders, explaining its purpose and containing text about the knowledge they wanted to disseminate. In the beginning *City Lights*, was released without that sign with the agreement that a sign will be placed later on after is delivered by the graphic designer. Another example comes from the fact that stakeholders criticised *We Dare You* on its educational value; they disagreed with the absence of explicit information regarding architecture. Regarding *City Lights* its openness run into the same disagreement. *Light House*'s purpose was often questioned. All three DAC installations were frequently subjects to a common question: "What do they teach the visitor about architecture"? Some stakeholders with background in Architecture seemed more critical regarding *We Dare You* because they believed that its interaction does not teach people anything about the principles of Architecture, and rather it is just a fun experience. Those stakeholders often expected those experiences to be bounded by specific rules and functions, seeing education as a productive result, possibly facilitated by play to engage the audience. For example, in *We Dare You*, when encountering children playing intensively and chaotically with the VR headset they concluded that they do not seem to learn anything about architecture through that activity. This is an example of how some saw play as an incentive that encourage children to learn, rather than a learning tool by itself. In the case of *City Lights*, some urban tableaus were accepted by the stakeholders as having architectural value while others discarded as not serious enough, wondering if visitors actually learnt something trying to make those tableaus. They were happy with the seemingly purposeful urban tableaus in *City Lights* but not with the chaotic tableaus that evolved after multiple visitors placed different objects on the installation. They commended families and children using *Light House* according to the rules set up by the interface and description, while rejected its value as a playful prop to support other activities, such as *hide and seek*, even though such an activity could potentially invite children to engage with the space of the *Educatorium*, an interactive space designed for exploration.

They wanted to control how visitors interact with their experiences, with self-expressive and creative instances of visitor engagement being evaluated and accepted only if they align with

the learning goals of the exhibition. This thinking opposes the qualities of play, and rather supports a state of gamification [34] with a specific end-goal: motivate visitors to read about architecture or experience in a pre-determined "proper" way architecture. It perceives play as a way to wrap learning in an engaging package, without changing the structure of how they help visitors learn. Deviating from the intended interactions is opposed, rather than celebrated. Play encourages visitors to interact with the artefact in their own terms in ways they find meaningful. By doing so, visitors will break established boundaries.

(2) On the other side, stakeholders with a background in Education agreed that the artefact succeeded in its goal by educating visitors through the embodied elements of its interaction. It is important to mention here that those with an Education background often engage in workshops with schools and children, so they are closely familiar with play and its role in education, while the ones with an Architecture background are responsible for curating and building exhibitions so they would not be closely in touch with children and play. I observed similar results during the deployment of *City Lights* and *Light House* they raised concern regarding how much visitors can learn through playful interactions (when stakeholders had an Architectural background). A comparable reaction took place amongst floor staff. Floor staff with architectural background often expressed concerns that they do not know how to relate the installations to architecture in order to engage in meaningful discussions with the visitors. At the same time, other floor staff enjoyed playing with the visitors and helping them construct urban tableaus or hide in the house. Both "sides" agreed that engaging with he installations was fun and that it supported a pleasurable experience in DAC. Overall, stakeholders that came from an architecture background — and consequently worked less with children since they focused on setting up exhibitions — saw the personal interpretation afforded by the playful artefacts as deducting from the reality they want to disseminate to their visitors; while stakeholders with a background on education — and as a result, frequently working with children in the context of DAC — valued the support that play gave to visitors to construct their own meaning seeings the same artefacts as a valuable educational tool that enhanced the traditional means of dissemination.

Looking into the relationship of play and education can help us understand why those two conflicting approaches occurred. Following the realist and idealist conflict, two similar views appear in the connection of play and education. First, we have play as an abstraction, symbolism, or model of an external reality, with the purpose of understanding — assimilating — that reality. In his discussion on the learning aspects of play, Piaget [89] separates games into two large categories: (1) practice games and (2) symbolic games. Practice games make use of sensory-motor skills while symbolic games are games which also involve imagination. The former highlights sensory-motor intelligence while the latter highlights representational intelligence. Representational intelligence relates to thoughts in which "the "signifier" is

differentiated from the “signified”” [89:163]. For him, the role of symbols in play (what he calls ludic symbols), indicates something that is different that its own representation. So, when in play, one uses symbols to signify something coming from the perceived erality and it is different than the symbol itself. As a result, according to Piaget [88], play results in a simplified model as decided by the one who plays, to the level they can understand and model reality, which then changes with age due to the development of one’s brain and capacity to model the world. According to him, a key aspect in play is that players will either accept established rules or construct their own rules during play. Part of children’s play is to renegotiate the rules of what they are playing, posing new rules when necessary and removing older ones.

Second, while Piaget [89] argues that the educational value of play lies on its symbolic nature, which can help children create a model of reality during their formative years, his model has been criticised by Sutton-Smith [115], where he argues that, since Piaget’s theory and research primarily concerned the understanding of physical causality and physical relations, it does not properly explore the relationship of play in learning activities concerning creativity — in other words, the idealist ideals of personal interpretation. Vandenberg [126] on the other hand, expands on the impact of play on children’s learning by arguing that play’s flexible attitude supports learning problem solving and stimulates creativity. This idealist approach is also present in newer theoretical works in the field of design. Gaver [35] discusses how to design for Homo Ludens suggests idiosyncratic approaches to design, along with focusing on pleasure and possibilities of appropriation. He highlights the benefits of supporting the intrinsic motivations of the person interacting with an experience, rather than extrinsic ones that come only from the outside world; in other words, working with ambiguity that stems not from an external reality but from many possible personal interpretations [37]. Sengers & Gaver [105] also suggest supporting users to find their own personal interpretations, rather than prescribed ones. I would argue here that those theories suggest that a designer should enhance the possibility for the user to creating their own signifiers and symbols when using interactive technologies. Thus, the user here is not only using symbols to assimilate reality but also contributes symbols to that reality by pursuing what they have interest in and what brings them pleasure. The conflict here with Piaget’s theory is that subjective, ambiguous approaches on design and play focus on intrinsic values while Piaget was concerned with play only symbolising an extrinsic reality.

When approaching education, exhibition curation, and overall artefact design with a focus on individual interpretation and ambiguity, creates an inherently playful environment for the visitors to explore. Whether we look at play as a free activity, materially unproductive, and having self-imposing boundaries defined by the individual [41,13], or an act that is defined by how players decided based on personal, autotelic interest to be creative and appropriate

the surrounding context [108], it seems to apply very well in exhibition spaces governed by an idealist approach to education and artefacts designed with subjective and ambiguous elements that focus on pleasurable interactions. It is then expected to see artefacts that support play, and the emergence of play, to be a divisive issue among DAC's stakeholders, depending on where they stand on the realist-idealist epistemological view, and what educational and institutional values they want to support using play in the exhibition space. This realist and idealist dichotomy seems to be enhanced by play, partly due to its personal, creative and self-expressive elements; and partly because of its frivolous and unproductive nature which are seen as problematic in older education approaches. The aspects of that unproductive and frivolous nature are the focus of the next section.

4.2.3 The Frivolous and Unproductive Nature of Play

DAC stakeholders seem to struggle with the seemingly unproductive nature of play. That is hinted by their multiple attempts to introduce educational text (both at the beginning of *City Lights* deployment and already in the design stage of *Light House*), seeing the installations as a way to attract visitors using play, in order to have them also read and learn the text produced by the curators, thus learning. It seems challenging for DAC to forgo traditional approaches and create spaces in which visitors dynamically engage with. DAC stakeholders that hold realist views on education, seem to see the role of play is to help you explore the reality surrounding you and memorise information about it.

However, this view fails to include the free-choice that comes with play. Visitors can choose when, how, and if they engage in play. And even when they do, it is based on their own personal ideals and goals, which might not be aligned with how stakeholders see that same activity. Indeed, behaviours in the study of *We Dare You* require a different stance on play. For example, when children approached *We Dare You*, they frequently challenged the rules of the installation either by walking backwards, jumping, running, and generally testing the technical limits of what this new for them system (VR) had to offer. As technical limits, I refer to the multitude of technical issues associated with *We Dare You* because of the performative interactions visitors frequently engaged in. The installation was designed with a boundaries set up by the affordances of the technology. Since those performative behaviours were overlooked during testing, and instead the designer and stakeholders expected a structured experience, the installation was not ready for the resulting behaviour, thus the equipment would frequently break. Those interactions not only tested the technical limits, but also tested the social limits of the exhibition environment. They performed (dancing, engaging in comical movements) for the audience (the visitors waiting in line for their turn) while wearing the headset. They scared their friends and family who were using the headset by pushing them, tickling them, and touching them. What occurred was a re-negotiation of

what is allowed in the exhibition space. That re-negotiation was informed on occasion by personal interest or by observing and copying what other visitors did; thus, visitors contributed to the meaning of the installation, discovering new uses for it, and performing those uses for others to observe. Another example comes from *City Lights*. There, visitors spend time "perfecting" their tableaus, putting everything exactly how they imagine it, and adjusting the light to match a specific mood. Those acts can be interpreted as the player exploring the material and light, thus learning about the world, but they can also reveal an interest in creating something that is aesthetically pleasing and leaving it there for others to see — and inspire them on their own tableaus. All those different behaviours indicate that their design supported multiple interpretations with their ambiguous nature supporting visitors in constructing their own meaning and engaging with play. Employing ambiguity creates interactions which are governed by uncertainty and openness which in turn support play.

Finally, in *Light House* that process was more spontaneous and intertwined between visitors (children) who played with it. Since it was part of an education room for children that meant to support play and interactivity, children would play with each other discovering new uses and inspiring each other in the process of interacting with the artefact. Instead of leaving something behind, or perform for others, they would directly involve each other in playing with the artefact. A big part of the dissatisfaction that some architecture stakeholders had, was that they saw play as a vessel that makes one's visit pleasurable and help them understand difficult concepts through signifiers and symbols coming from the field of architecture, opposing its autotelic nature. They also hoped to contain play inside specific boundaries, both in terms of location and in terms of what behaviours and activities are allowed to emerge. Overall, the unproductive and frivolous nature of play established it as controversial and destructive for DAC's exhibition space.

4.2.4 Closing Remarks on the Conflict

Those conflicts are easier to encounter in the space of a cultural institution as opposed to other museums that focus on natural sciences. A cultural institution — like DAC — disseminates artefacts and ideas whose meaning is heavily influenced by the interpretation of the individual. Whether a specific architectural scene looks warm or cold has to do with how the individual interprets that scene in their cultural context. Therefore, when interactions support self-expression in a public space like DAC, the results of visitor's expression through play can be as educational as the curated content of the institution. Allowing the visitor to structure and display their thoughts and ideas facilitated by play expands the educational content of the exhibition to include a plethora of voices, supports critical thinking, and promotes democratic knowledge — visitors indirectly conveying their ideas to other visitors.

Instead of controlling the designs of their exhibits, DAC curators need to accept a certain support for free-choice and misuse by visitors, if they want to design playful interactions that allow the visitors to interact based on their own motivations. In the studies presented in this thesis, visitors gladly participated in that exchange. They were curious about what other visitors did, they were excited to share their own perception, and they found their visit entertaining end educational (as reflected by the customer satisfaction surveys DAC conducted). In general, for museum stakeholders to accept those installations in the exhibition space, it is important to balance the values of education and play [127]. It is the case that many curators are still taking a more traditional approach of communicating pre-decided knowledge in their exhibitions [52]. Even in institutions where play is a core part, it is often the case that "[f]or some, play was a mechanism or process by which learning is achieved. For others, play represented particular aspects of learning, such as intrinsically motivated or free-choice" [78:9]. Having those different theoretical approaches creates conflicts since stakeholders can have opposing views on how the museums experiences should be structured and how they should be evaluated [57]. In addition, the design of playful educational experiences is quite complex and requires multiple perspectives of learning [92]. The challenge of working with the ambiguity that comes with play stems from how play itself can oppose the established norms in the museums and subvert the exhibition space [32].

Overall, since play can be frivolous, carnivalesque and ultimately subversive it can be difficult to include it in the museum context, since it can challenge the cultural norms of museum visits and the curatorial authority of museums [76]. The boundary between what the curators have set up as the game space, and what visitors socially construct as a play space can be unclear since it is hard to establish boundaries in play spaces [111]. All these contribute to the challenge museum educators face when they try to set up a dynamic learning space that moves away from traditional approaches on education [45]. The effort is worthwhile though, since play is valuable in educational theories that support constructivistic education, with modern museum curators seeing value in such an educational approach and try to invoke fun and pleasure [21], capitalising on the opportunity that museums are exemplar spaces that those constructivistic educational values can be expressed [97] due to their ability to educate visitors by facilitating interactions with the artefacts.

CHAPTER 5. Conclusion

Ever since the third wave of HCI created a focus towards designing for personal, social, and pleasurable uses of technologies, contemporary museums have benefited from incorporating digital technologies into their space to support new ways of visitor engagement. Museum stakeholders see an opportunity in using those technologies to support sensory engagement; create social experiences; incorporate play in their space; and to augment their exhibits with digital elements. However, installations based on those values can be challenging. Stakeholders — depending on their views on education — might oppose the unproductive nature of play; criticize its frivolity; and generally be uncertain regarding its role in the exhibition space. Furthermore, its exploratory nature can produce technical difficulties and a frequent need of maintaining the installations.

In the present thesis, I set out to explore the following research question:

> How can DAC manage the tensions that arise from employing digital technologies to support play in its space? How do those conflicts manifest and how can they be addressed?

I did so by setting up four studies using a research-through-design method [133]. *Bio-sonic Sense* took place in the exhibition space of the Catch Collective, while I set up the other three studies: *We Dare You*, during which I gathered field data for an experience developed by Immersive Studios as a permanent installation in DAC's exhibition space; and two design experiments I designed and deployed in DAC's exhibition space: *City Lights*, and *Light House*. Being employed in DAC during that period allowed me to gather data in-the-wild [19] and to draw upon various ethnographic data (e.g. informal conversations, meetings with stakeholders, et cetera) to support my studies. Overall, *Bio-sonic Sense* acted as an inspiration, the We Dare You study analyzed the surrounding design context in DAC and helped me gather field data, while the later ones (*City Lights* and *Light House*) employed a specific design process (see figure 3). The process was to, first, deploy undetermined artefact in the exhibition space; then, observe the uses discovered by visitors; and, finally, re-design the artefact to highlight the uses that have been discovered so far.

A key element of the design process I employed was the initial design of an undetermined artefact. To create that initial state I focused on designing for allow affordances [20] and minimal constraints, thus creating a large space for potential uses. To do so, I follow three main design principles: first principle was support for self-expression in the interaction elements of the artefacts either through its interaction elements. The second principle was to re-design artefacts — i.e. City Lights and Light House — to support new ways of engagement. The third principle was to employ ambiguity which make an artefact to support play to emerge and help visitors form their own interpretation on how to use the artefact. One

of the main challenges I faced due to that decision was that the initial state was confusing for visitors to interact with, or understand the purpose of the artefact. That led to visitors having trouble engaging with that initial artefact. It is necessary then to find the balance between openness and constraints to address that confusion.

In my studies I consistently observed that DAC stakeholders had conflicting expectations from play. From my observations I identified three main themes. First, how stakeholders perceived playing with the installations themselves, was in contrast with how they perceived visitors playing with the same installations. Their individual bodily-sensory experience was engaging and satisfying, however their cultural understanding of play when observing others raised doubt on the role of those installations in DAC. Second, another conflicting factor was that some followed a realist while others an idealist approach on education [49]; this means that the former rejected the personal, self-expressive elements that the latter embraced. While the realist stakeholders looked for clearly stated educational value based on the architectural body of knowledge DAC disseminates, the idealist stakeholders saw playful engagement and creativity as educationally valuable. Third, the frivolous and unproductive nature of play raised concerns regarding what was acceptable in the exhibition space, whether or not people learn, and how to deal with the unpredictability of interaction that led to many technical issues.

In summary, play can turn visitors into active participants which is something museums strive for, engage their creativity, and give them space to express themselves. At the same time, those installations are costly to maintain; controversial for curators; and difficult to maintain a balance of engagement and educational value. Visitors come from diverse backgrounds with different interests and motivations. Given free-choice, they will pursue those interests. It is impossible to predict what visitors will try to do when institutions present them with interactive artefacts. Neither is possible to completely prescribe the uses of an installation without sacrificing the emergence of play, since play requires the existence of ambiguity. Instead, museums need to clearly define the role of play in their space, understand its qualities and the challenges that it come with.

Further research should look deeper into how, potentially, design-after-design approaches can help alleviating those challenging issues. It relies on iterations where visitors discover new ways of using the artefacts. As a result, it seems more suited for experiences that are set for longer periods of time, so they have time to mature and grow, with many visitors trying them out. It would be interesting for further research to follow such a process for a longer period, to see how that process will develop the artefact, and whether there will be a point of equilibrium (i.e. the overall artefact will feel that it has taken a “final” form). Finally, such an approach could also be useful for other institutions which seek to incorporate play in their space, outside of the field of GLAMs. For example, children’s hospitals or schools often use playful installations while to fulfill specific purposes (education, or helping children with the stress of medical exams). It could be fruitful to research if such an approach can help them discover engaging interactions for their context, while supporting their specific purpose.

CHAPTER 6. References

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Publication 1

Exploring the Cross-Species Experience and the Coevolutionary Capacity: Sensorial Transcoding and Critical Play Design of Bio-Sonic Sense

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Exploring the Cross-Species Experience and the Coevolutionary Capacity: Sensorial Transcoding and Critical Play Design of *Bio-Sonic Sense*

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This paper investigates the concept and development of *Bio-Sonic Sense*, an artistic interpretation of bio sonars, as an attempt to create a cross-species experience. It examines the potential of sensory transformation through technology-specifically, transcoding visual to audio-with the purpose of communicating the mechanisms of ultrasonic communication employed by marine mammals. *Bio-Sonic sense* is the result of using artistic practice and critical play, in order to disseminate the effects of noise pollution on marine life. This paper proposes that those practices should be explored as methods that can design for the use of technics as tools that can expand the human senses, thus allowing the exploration of non-human "worlds".

Cross-Species Experience, Transcoding, Echolocation, Coevolution, Critical Play, Play Design, Bio-Sonic Sense (2019)

1. INTRODUCTION

The effects of the Anthropocene are shaping the planetary condition. Specifically, extinction of species, ocean acidification, global warming, climate change, and accumulation of technofossil. The concept of the Anthropocene argues that it may threaten the contemporary material existence and even the future of entities (Steffen et al., 2011, p. 862). At the same time, it also produces a tremendous amount of philosophical ideas and artworks (Parikka, 2018, p. 51). Davis and Turpin (2015) posit that the Anthropocene is "a sensorial phenomenon" and "art can provide a polyarchic site of experimentation for living in a damaged world" (pp. 3-4).

This paper discusses the possibility of creating a cross-species experience in response to an ecological issue on marine noise pollution and its effects (Farina, 2016, pp. 48-50). This interdisciplinary artistic research, Bio-Sonic Sense (2019), aims to make a prototype device and explores an ultrasonic communication system of marine mammals by expanding human perception using transcoding to provoke embodied experiences of animal life.

In the following, this study introduces the concept of coevolution that has formulated our prototype relation and describes methodological approaches in play design and discusses the operating systems and potential of *Bio-Sonic Sense*.

2. THEORIES AND METHODS

2.1 Exploring the Coevolutionary Capacity

The dichotomy of human-nonhuman has operated as a source of oppression and for non-human beings in the world by not acknowledging their agency (Grusin, 2015, p. xi). However, in response to this, several attempts towards listening to neglected entities including nonhuman and animal are being urged in varied disciplines.

How can we create an artistic practice which offers experiences of embodied marine mammals' life? Regarding beyond-human perception, Bio-Sonic Sense investigates whether humans can feel

echolocation or how human senses evolve in terms of sound.

The earliest artistic experiment on echolocation can be found in Vespers (1968) composed as a prose score by Alvin Lucier. The piece adapted portable pulse oscillators, which are designed for acoustic environments and the blind, to use echoes for orientation and the echoes could slightly reveal the topology of surrounding space. Besides, Vespers suggested an exploration of beyond-human perception to the performer: "Dive with whales, fly with certain nocturnal birds or bats, or seek the help of other experts in the art of echolocation." (http://alvin-lucier-film.com/vespers.html).

The concept of coevolution takes a significant position to outstretch the limits of human perception. According to Hayles (2012), coevolution refers to the continuous interwoven relations between humans and technics and explains the modification process which operates on each other–human and technology (p. 10; p. 30). Technics can be employed to enhance our senses to create transcendent experiences.

Therefore, the prototype of Bio-Sonic Sense decides to embrace technical knowledge to experiment with the coevolution of human senses. It encapsulates the early critical minds into technology spotlighting sonic sense since the aquatic environment is a sonic space that is filled with the sound produced both by submarine creatures and human interventions. It endeavours to an interactive hybrid space producing personal soundscape experience through bodily engagement regarding the sonic context in underwater and anthropogenic noise.

The methodological approaches in play design will augment the experience of this coevolutionary capacity.

2.2 Methods and Value Goals

Sicart (2014) describes play as carnivalesque, appropriative, disruptive, autotelic, creative, and personal. Being personal, play draws from the sentimental, moral, and political memories of the participant. By connecting those memories with the present experience, it allows the participant to discover their personal expression inside the environment–leading to a stronger "understanding of the world, and through that understanding, challenging the establishment, leading for knowledge, and creating new ties or breaking old ones" (Sicart, 2014, 18).

In their article, Gaver, Beaver, and Benford (2003) describe the effects of ambiguity in designs. One of the types of ambiguity that they describe is "Ambiguity of Relationship." This type of ambiguity exists when a design makes us question our relationship with a specific object and "what our lives would be in consequence" (Gaver et al., 2003, p. 237). As a design practice, this type of ambiguity induces self-reflection in regards to our aesthetics and morality–this aspect complements the personal effects of play, to create a self-reflective and emotional experience.

Flanagan (2009) describes the process of designing play as the process of designing for possibilities. Play is becoming more and more established in our society and culture, and designing for possibilities means having an inclusive, and fair design that participants with different playstyles can engage with.

In her book, Flanagan (2009) proposes a model to design for critical play. Her model consists of 7 steps: (1) Set a design goal/mission statement and values goals, (2) develop rules and constraints that support values, (3) design for many different play styles, (4) develop a playable prototype, (5) play test with diverse audiences, (6) verify values and revise goals, and finally (7) repeat.

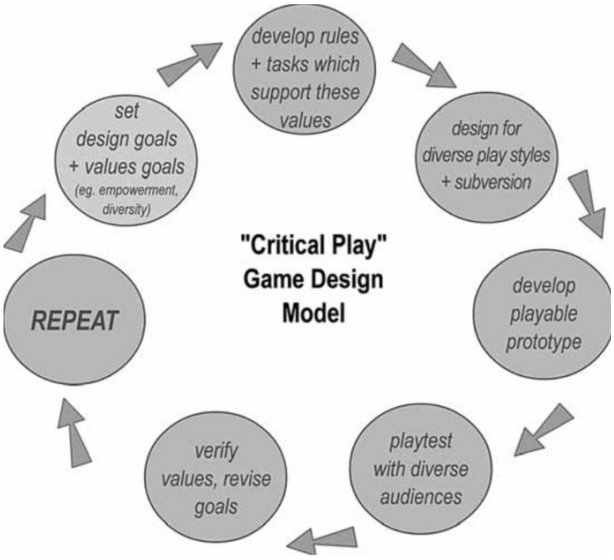

Figure 1: Critical Play Game Design Model (Flanagan 2009, 257)

The aforementioned design method allowed us to include critical play in our final installation, and to accommodate the diverse audience that is expected in an exhibition. Through playfulness though, participants can appropriate the artwork, allowing them to engage in a deeper level with it.

The next section describes the artistic exploration that we developed, using those methods, to explore our theoretical questions.

3. TECHNICAL FRAMES AND SOUNDS

3.1 Technical framework

In order to apply, Flanagan's (2009) method (Figure 1) to the artwork, first we had to set our mission statement. Our goal is to create an underwater experience to the participants that exposes them to the effect of underwater noise pollution, thus creating compassion and understanding towards the effects of human architecture and engineering to marine life.

To support our value, our installation focuses on the auditory and haptic sense–auditory since it emphasizes sound pollution and haptic to allow for exploration of the created space–while constraining the visual sense. The main interaction mechanic is emulated echolocation–auditory feedback that the participant can use to understand the location of other objects in the surrounding environment. The interaction mechanics are designed to provoke ambiguity of relationship, creating an environment in which participants will project their own values and imagination, try new identities, and question those values (Gaver et al., 2003). In order to design those mechanics, the following three design principles were used, as described by (Gaver et al., 2003, p. 239):

(i) Offer unaccustomed roles to encourage imagination.
(ii) Point out things without explaining why.
(iii) Introduce disturbing side effects to question responsibility.

By constraining the visual sense, along with our underwater narrative-experienced through the soundscape-we create an unaccustomed role to the participant, as described by the first principle. In regards to the second principle, the installation needs to be playfully appropriated by the participant, the interaction is sensorial and embodied. No prior explanation is given to the participant-the participant is only presented with the objects of the installation. Finally, in regards to the third principle, hitting an object or the wall by accident is a disturbing side effect that asks the following question: "Was it the participant's or the designer's fault?" This relates back to the effects of noise pollution to the submarine creatures.

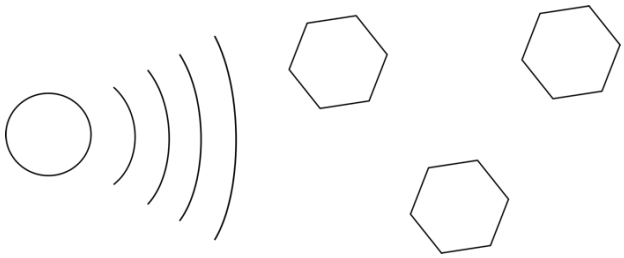

Figure 2: Concept drawing of the prototype

Excluding the participant, the overall experience consists of 2 elements: the apparatus and the environment. To accommodate a diverse audience, we focused on creating three elements to be explored by the participants:

- a soundscape in apparatus that emulates an underwater sensation.
- objects in the surrounding environment to be explored haptically.
- a box that acts as a protection to the head of the participant, allowing them to move freely in space in any manner they wish to.

The experience we created during the Summer Camp 2019 in the space of CATCH in Helsingør consists of the following elements: sonar apparatus, and 3 plastic objects.

Figure 3: Image of Sonar apparatus

Sonar apparatus:

- A Raspberry Pi 4 with an ultrasonic distance sensor (SainSmart HC-SR04) and a pair of headphones (Sony MDR-XB550AP)
- A box, to stabilize the device on the person's head, and to restrict the person's vision
- A powerbank to power on the Raspberry Pi

Figure 4: Image of the Environment

Installation environment:

- A dark room surrounded by walls
- 3 plastic objects hanging from the ceiling

In the beginning of the experience lies the Sonar apparatus. To participate in the experience, a person positions the apparatus on their head and enter the room. Once in the room, the participants receive audio feedback from the apparatus regarding the distance of the objects that are in front of them. Using that feedback along with their haptic sense, they can navigate and explore the space.

In the environment there are 3 plastic objects hanging from the ceiling that can be located using the audio feedback given by the sonar apparatus, and can be explored haptically. In order to create different interactions in the environment those 3 objects were designed to have different materiality:

- The cube is surrounded by cellophane wrapping and is light.
- The keyboard is plastic and heavy.
- The biodegradable cups are one unit when in equilibrium, however, they are connected by strings that allows them to separate when they are touched.

By including these 3 objects we attempt to create a playful and interactive environment that invites the participant to explore it.

Figure 6: Prototype in action.

3.2 Sound and soundscape

We intended to collage the natural sound source and computer signals as a means to generate soundscape. First of all, we collected sounds (e.g., a helicopter, leaves, birds, seawater and, footsteps) around CATCH, Helsingør and selected sounds of birds and seawater lapping by the small waves since *Bio-Sonic Sense* is related to the biosphere.

Figure 5: Recording sounds around CATCH in Helsingør, Denmark.

Second, the sonar sound uses a bird chirping as a sample. The sample is then processed with Pure Data, a graphical sound programming environment in real-time. The distance is transcoded into sound by altering the following elements of the playback:

- The duration of the feedback delay,
- the amount of feedback of the reverberation,
- how often the sound is repeated.

In the as background sounds in the prototype there is a sea soundscape. That sea soundscape was created by capturing the sounds of the sea of Helsingør. A preview of the sound elements of the prototype are available here:

https://archive.org/details/bio-sonic-demo.

4. DISCUSSION

The initial motivation of *Bio-sonic sense* was to create an experience that explores "how marine life is affected by noise pollution." Marine mammals use echolocation as an auditory stimulus in order to understand space. Noise pollution in the marine environment disrupts their spatial understanding. In order to communicate that to the participant, we needed to create an experience that will transcode visual elements to auditory elements, thus removing our need to rely heavily on visual stimuli to understand the surrounding space and its objects.

For the participant, the moment they wear the apparatus, they enter the magic circle (Stenros, 2014). Their senses become disconnected from the exhibition environment, and their experience of their surroundings is affected by the feedback of the apparatus. Bio-sonic sense is set in an immersive exhibition space and on the boundary of human-animal relations, with both of those elements causing the emergence of boundary play (Nippert-Eng, 2005). By its design, Bio-sonic Sense requires participants to possess the 2 elements described by Nipperd-Eng (2005) in order to engage in boundary play. First, players must share the normative expectation of where is the boundary between human and animal. Second, they need to find the exploration of that boundary amusing. That emergence of boundary play blurs the border of play and non-play, corrupts the experience, and communicates to the participant that the ideas presented are non-fictive.

For Grusin (2015), human identity "has always co-evolved, co-existed, and collaborated with the nonhuman" (p. ix). *Bio-sonic Sense*-by invoking that co-evolution, coexistence, and collaboration-transports the participant to the world of marine mammals allowing them to experience the identity of those animals, and see "what it is to be them and what it is to be ourselves in their eyes" (Lugones, 1987, p. 17).

In terms of *Bio-Sonic Sense,* a critical play design process, our research is preliminary, with further evaluation required to research the effects of the prototype. However, our attempt was to explore the use of technics through artistic practice and critical play, in order to create installations that afford the exploration of non-human "worlds" (Lugones, 1987, p. 17).

5. CONCLUSION

Bio-Sonic Sense is an interactive prototype that transcodes the visual to the auditory sense. The prototype is the result of an attempt to employ artistic practice and critical play in order to create a cross-species experience and explore the concept of coevolution: the continuous interwoven relations of humans and technics. Our prototype is an artistic interpretation of the bio-sonic abilities of marine mammals along with the conditions of their surrounding environment, with a focus on the effects of noise pollution. It produces an explorative space regarding non-human entities while evoking critical awareness on anthropocenic issues.

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Publication 2

We Dare You: A Lifecycle Study of a Substitutional Reality Installation in a Museum Space

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We Dare You: A Lifecycle Study of a Substitutional Reality Installation in a Museum Space

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In this article, we present a lifecycle study of *We Dare You*, a substitutional reality installation that combines visual and tactile stimuli. The installation is set up in a center for architecture, and invites visitors to explore its facade while playing with vertigo, in a visual virtual reality environment that replicates the surrounding physical space of the installation. Drawing on an ethnographic approach, including observations and interviews, we researched the exhibit from its opening, through the initial months plagued by technical problems, its subsequent success as a social and playful installation, on to its closure, due to COVID-19, and its subsequent reopening. Our findings explore the challenges caused by both the hybrid nature of the installation and the visitors' playful use of the installation which made the experience social and performative—but also caused some problems. We also discuss the problems *We Dare You* faced in light of hygiene demands due to COVID-19. The analysis contrasts the design processes and expectations of stakeholders with the audience's playful appropriation, which led the stakeholders to see the installation as both a success and a failure. Evaluating the design and redesign through use on behalf of visitors, we argue that an approach that further opens up the post-production experience to a process of continuous redesign based on the user input—what has been termed *design-after-design*—could facilitate the design of similar experiences in the museum and heritage sector, supporting a participatory agenda in the design process, and helping to resolve the tension between stakeholders' expectations and visitors' playful appropriations.

CCS Concepts: • **Human-centered computing → Empirical studies in interaction design**; **Empirical studies in HCI;**

Additional Key Words and Phrases: Appropriation, play, design-after-design, museum, sensory museology, substitutional reality, mixed reality

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1 INTRODUCTION

In recent years, the museum sector has increasingly used digital technologies to facilitate immersive experiences, leading the media scholar Jenny Kidd to describe this development as an "immersive turn" [45] in the GLAM

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sector (galleries, libraries, archives, and museums). Frequently, such experiences rely on **Virtual Reality (VR)** and similar technologies. However, the use of VR in museums often comes with challenges: according to Hornecker and Ciolfi, "VR has been one of the most problematic technologies to bring into heritage settings in terms of cost, physical and technical setup, and obsolescence" [36, p. 45].

In this article, we follow the lifecycle of a **Substitutional Reality (SR)** [64, 68] installation, a type of installation that makes use of VR technology and maps the virtual experience onto the physical environment and physical objects, setting up a combination of visual and tactile stimuli sometimes referred to as "passive haptics" [41]. SR experiences allow users to touch and feel physical objects while viewing virtual counterparts of these objects inside the virtual environment through a VR headset. By having the physical and virtual overlap and diverge at critical moments, SR experiences enhance the total user experience, allowing both the physical and virtual elements to support each other.

SR is a promising technology that has been explored in artistic and technological experiments [66, 71]. However, it also introduces some challenges for visitor experience design, where digital experiences and physical installations are often approached in different ways, both technically, organizationally, aesthetically, and with regard to individual GLAM stakeholders' dissemination goals.

In this article, we explore these challenges through a study of *We Dare You*, an SR installation at the Danish Architecture Center (DAC) in Copenhagen. *We Dare You* places visitors inside a virtual/physical environment that sets up a sensory illusion of walking on a plank extending out from the building's facade, daring visitors to jump. Experiences from the design and deployment of *We Dare You* offer great potential to explore the challenges involved in designing an SR experience in the GLAM domain. Using an ethnographic approach, we studied the design process, implementation, and day-to-day running of *We Dare You* to analyze the ways in which various key stakeholders and visitors affected the design and use of the installation. Drawing on the empirical data we have gathered, our article discusses the challenges and design opportunities of designing a SR installation in a GLAM space through the installation's lifecycle, including a period of lockdown due to the COVID-19 pandemic, which mandated new procedures for safe use in a COVID-19 context.

Our analysis shows the ways in which the combination of virtual and physical stimuli allowed for playful engagement among visitors, yet how this also became a point of contention among stakeholders. We discuss how similar projects could work strategically to meet similar challenges, by opening up the post-production experience to a process of continuous redesign based on the user input through what has been termed *design-after-design* [60], thus supporting a participatory agenda [65], which is of key importance for contemporary GLAM practices. Such design processes may help GLAM actors discover and benefit from the successful design elements of playful SR installations while simultaneously alleviating the tension between stakeholders' expectations and visitors' playful appropriation of those installations.

1.1 *We Dare You*

"Do you dare to walk the plank?" This is the invitation greeting visitors to the *We Dare You* installation. *We Dare You* offers a short, playful experience and has been extremely popular with visitors since its launch on July 20, 2019.

Visitors arrive at the installation after passing through the main exhibition space, where temporary exhibits are presented. They encounter a neon sign saying "*We Dare You*" in large glowing letters, in front of a wide staircase that leads down to a yellow metal plank and railing, ushering participants toward a window on the facade of the building (Figure 1). A large sticker on the window makes it look like it is cracked. A VR headset hanging on the railing is connected with a long cable to a computer mounted high behind a metal pillar. When visitors put the the headset on, they encounter a space that is a near-perfect replica of the physical space in which they are standing, except the window appears a bit closer than in real life (Figure 2). This illusion makes it possible for the visitor to walk up to the virtual window while still remaining at some distance from the physical

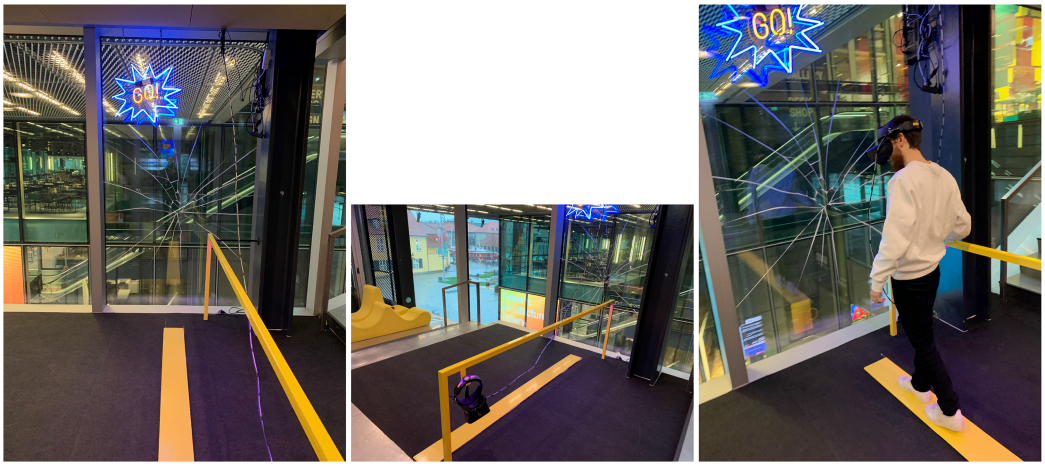

Fig. 1. The physical environment of the *We Dare You* experience including handrail and plank.

Fig. 2. The virtual environment of the *We Dare You* experience.

window in real life. As a visitor approaches the virtual window, the glass cracks, then breaks, and the virtual plank extends outside of the building—extending to match the actual length of the physical plank the visitor is walking on. For participants, this creates the illusion that they are walking out of the window and observing the building from the outside, three floors above the ground. As the visitors reach the end of the plank, they can jump off. This jump is just a short drop in physical space (2 cm), but in the virtual space, it is a long fall to the virtual ground, which breaks as they land, mimicking a "superhero landing." The participants are free to look around for a moment, and then they are prompted to take the headset off.

2 PLAY, PARTICIPATORY ENGAGEMENT, AND EXPERIENCE DESIGN IN MUSEUMS

GLAM institutions have shown an increasing interest in using new technologies to create playful experiences in their spaces [1, 5, 6, 52]. Viewed from the perspective of museology, this is part of a broader shift in the museum sector from physical collections toward stories and experiences [20, 73] or from artifact appreciation to a participatory agenda [65]. Kidd describes a turn toward "immersive heritage encounters," including "a ludic turn . . . characterized by increased interest in the application of play and game mechanics" [45, p. 1]. Opportunities for participation and engagement have become central issues for museums [16], and digital solutions such as displays, touch interfaces, games, and augmented reality and VR now proliferate [5, 79].

Arguably, engagement and participation are key elements in tackling the challenges that modern museums face, such as remaining relevant, modern, and democratic, becoming creative spaces, and facilitating a social experience [36, 65]. Museums are often reliant on attracting visitors to become financially viable; offering new technological experiences and play becomes part of that struggle. Visitors can play and engage in the museum and also interact with objects not present in the museum [3, 16, 17, 51, 52, 61].

Even though the concepts of participation, social interaction, creativity, and personalization are all present in the activity of play [4, 13, 39, 63], museums often struggle with incorporating play: games are seen as non-serious and are often perceived to be disconnected from the subject matter of the museum [24]. However, research has demonstrated that play, if left open, offers visitors new ways of engaging critically with museum exhibitions, and these attempts can be interpreted as acts of resistance that create new meaning [8]. These properties make ludic engagement suitable in a participatory agenda; through playful engagement, users can make the experiences their own. However, play is in its nature hard to control and tends to resist structure [63]. Hornecker and Ciolfi [36] identify the loss of authority and control as a point of concern among curators. That play can come in conflict with curatorial practices is often seen as a challenge for the design of playful museum experiences (cf. [2]). Indeed, much research has pointed out how hard participatory values in general have been to implement in GLAM institutions, which historically gained their values through a focus on artifacts and collections rather than offering visitor experiences (e.g., [12, 54]).

3 SUBSTITUTIONAL REALITY AND SENSORY EXPERIENCES IN MUSEUMS

A key problem with incorporating digital experiences in the GLAM sector is a common concern among museum professionals—that the new digital experience might subsume the physical collection or space, which is the GLAM actor's main attraction and responsibility [2, 38, 50, 57, 76, 78, 80]. Thus, enhancement of existing resources is a central challenge in digital design in these spaces, if GLAM sectors are to keep their physical relevance. Much attention has therefore been given to VR as a technology for visitor experiences in cultural heritage institutions [6]. VR and augmented reality have the potential to enhance what GLAM actors already possess, and these technologies have, for example, been used to visualize buildings in archaeology [28, 30, 46, 62] and architecture [47, 48]. One of the advantages of these mixed-reality technologies [55] is that they offer connections between the physical and virtual.

In recent years, there has been increased interest in the GLAM sector toward experiences that involve more of the senses than just the visual. Losche [49] suggests that visceral engagement through the senses is a key element to immersion and authentic experience, which has disappeared from the museum space due to dominance of the visual sense, a sense centered around rationality and detachment. Feldman [25] discusses how the absence of sensory engagement inhibits the unraveling of the sensory complexity of artifacts, prohibiting the understanding of our cultural past, and ultimately rendering museums spaces where cultural memories are subverted. Dudley [21] further calls for a focus on materiality and sensory engagement and criticizes the absence of physical interactions in the museum space; even when they are present, they tend to be paired with textual information. Furthermore, she comments on how the interesting elements of the materiality of objects are ignored in museum exhibits, along with "the intimate details of people's physical, sensory—visual, haptic, aural, oral, gustatory, kinaesthetic—engagements with the physical things in question" [21, p. 6]. Classen [17] suggests that attempts to engage with the museum space in a tactile way are to be expected and should be viewed "as meaningful acts of sensory communion with deep cultural roots" [17, p. 24], and that the spaces within museums and galleries are material environments full of possibilities. Western museums are primarily dominated by the sense of sight, and incorporating other senses "can open up a space for traditional non-Western and women's art forms" [17, p. 117] resulting in a culturally inclusive space [17, 18, 21, 49]. Toward that vision comes sensory museology, suggested by Howes [37], in which sensory experiences are designed to offer visitors an increased aesthetic appreciation of museum exhibits. This turn to incorporate a wider array of the senses in GLAM digital

designs is mirrored in the concept of embodied museography of Kenderdine et al. [43]. Embodied museography highlights the importance of multisensory qualities, and the authors argue that through embodiment and digital technologies, museums "can create new levels of aesthetic and interpretative experience" [43, p. 3]. Neves [56], Randaccio [59], and Classen [17] further discuss how those multisensory qualities create an inclusive museum experience by rendering its space accessible to audiences with disabilities. Wang [77] states that the engagement of the senses beyond the visual in the museum space has a central role in the creation of immersive experiences, and may positively impact visitor satisfaction and stimulate "emotion, reminiscence, and education" [77, p. 16].

Studies have explored the question of how to incorporate the senses beyond sight in VR experiences. Skola and Liarokapis [82] suggest that VR techniques can create the illusion of touch even without any tactile stimuli. Marshall et al. [53] explore the creative potential in misaligning sensory stimuli using VR in conjunction with physical movement in the art installation *VR Playground*, [70] where the user sits on a swing using a VR headset to traverse a set of abstract environments. Each environment re-maps the motion of the swing differently, using the kinesthetic qualities of the physical swing as a core part of the experience.

As early as 2001, the concept "passive haptics," in which a visual virtual environment is augmented with physical objects, was suggested to have a strong effect on the user's sense of presence in a virtual environment [41]. More recently, passive haptics has been explored by Harley et al. [34], using physical solutions to diegetically engage the senses in VR experiences using the ambient sensory qualities of physical spaces. Chagué and Charbonnier [15] employed, among other elements, passive haptics to create a strong feeling of presence in their Real Virtuality platform. Similarly, Campbell et al. [14] use a wheelchair as a tangible user interface, exploiting its passive haptics to create the feeling of physical presence inside a virtual space.

Harley et al. [33] have discussed the concept of Tangible VR, where they attempted, through tangible, material objects, to connect the physical with the virtual. Tangible VR is closely connected to another recently introduced concept in the spectrum of mixed reality that attempts to draw on the opportunities of sensory experiences: SR [64, 68]. In SR, physical objects are matched with virtual objects in VR so that a user can physically touch and feel a physical object while experiencing a digital version of it through a VR headset. In a recent project, Tennent et al. [71] used SR to create an art installation with passive haptics in which users could explore a recreation of a museum exhibition from 1839. In the *VRtefacts* project, SR is used to heighten a visitor's sense of connection and engagement with items from a museum's collection [66]. For the museum sector, SR holds potential to re-create inaccessible objects, spaces, and experiences, facilitating sensorial engagement as well as enhancing the existing locale and physical collections of GLAM actors.

4 TECHNOLOGICAL APPROPRIATION, DESIGN-AFTER-DESIGN, AND LUDIC ENGAGEMENT

To create meaningful engagement between the visitor and the museum collection, museums rely on the field of design [11]. Contemporary GLAM goals often include active and engaged visitors who co-produce their experience, yet these goals have been hard to achieve in practice [20, 36, 45, 65, 73]. This problem is mirrored in digital design where a participatory view on users has not always been self-evident. Dunne [22, p. 71] argues that when it comes to the design of electronic products, the design field could benefit from considering "the user as a protagonist and co-producer of narrative experiences rather than a passive consumer of a product's meaning." That critique is supported by Gaver, who describes playfulness as "an antidote to assumptions that technology should provide clear, efficient solutions to practical problems" [29, p. 1]. Hornecker and Ciolfi warn that design must take into account the technological appropriation that can emerge in the museum context, and that "designing interactive visitor experiences must allow for a degree of flexibility, and of freedom for visitors to adjust the experience (and related content) to their own evolving interests" [36, p. 7].

Redström [60] refers to that appropriation as "design-after-design": the redesign of an object by its users, as they reformulate and change the meaning and purpose of the object through use. He criticizes dominant

practices of user-centered design for relying on user testing of prototypes rather than actual use of the designed object ("use-before-use")—a process that does not account for the appropriation that often occurs through use. Redström suggests, among other things, the concept of tactical formlessness as discussed by Hunt [40]. This means designing things that are not finished, that can change their form after what we traditionally call the design phase of a project is finished. Several scholars have contributed to a rethinking of the relationship between designed object and user in the design process to account for appropriation [23, 42, 72]. Frauenberger [26], adding to the concept of "design-after-design," argues that our design methods need to adapt to those ideas and cease to distinguish between design and use, and instead treat the "design-use" of things as a process that continually affects the resulting technological artifacts and our relationships to them.

Tactical formlessness and design-after-design promotes dissolution of boundaries which, we argue, is pertinent when trying to support active participation, co-creation, and human activity as amorphous as play. In other words, we can acknowledge that what we design is not finished once the product leaves the hands of the designer. This is an idea well explored in studies of digital games. Games, it is argued, come to be as they are played; thus, the player is part of making a game what it is, and sometimes games are changed fundamentally by players playing "wrong" and adding on to the game [19, 58]. In this study, we interpret the design-after-design approach as broadening the design space to also include the decisions that happen after the traditionally named design phase in a project. Concretely, this implies looking at specific aspects, namely use, implementation, and maintenance as part of design. Use, in this sense, is seen as co-producing the experience. By dissolving some of the boundaries in the design process—that is, the strict division of stages as design, implementation, and maintenance—we can acknowledge how user appropriation is a kind of design (see the work of Björgvinsson et al. [10]). We argue that such an approach may support a participatory agenda in the GLAM sector. Furthermore, it creates an environment for learning that is based on constructivistic principles [35, cf.]. Finally, this approach has the potential to address the emergence of appropriation that comes with play.

5 METHOD

For this qualitative study, we employed specific ethnographic methods [32]. During this study, the first author has been working as an industrial researcher at the DAC as part of his Ph.D. program, starting 4 months before the opening of the installation and ongoing. As an employee, he has had privileged access to documentation and could conduct interviews with staff and observations of the installation. We draw on knowledge gained from being immersed in the center's work, participating in informal conversations with the DAC's staff, as well as formal, structured interviews with five key project stakeholders and two members of the floor staff (Section 5.1) and observations of the experience (Section 5.2). However, it should be noted that the first author was not involved in the commissioning, design, or maintenance of the *We Dare You* installation. The role of an industrial Ph.D. gives him an independent role as researcher, allowing him to view the project from a critical distance. The other two authors are university researchers with no direct involvement with the DAC.

5.1 Interviews

Three months after the installation was set up (October 2019), we interviewed five key stakeholders from the *We Dare You* project to evaluate the results of the whole process of implementation. We interviewed two project managers, the head of the program, the designer, and the IT support staff. We conducted the interviews via audio recording during working hours at the DAC, and they were subsequently transcribed. To thoroughly compare different perspectives of the various stakeholders, we crafted a set interview guide for structured interviews [7] where as much relevant information as possible could be gained in the limited time slots set aside for our interviews, due to the schedules of the stakeholders. A set of introductory questions mapped the informants' background with VR and the project itself. We wanted to see through which lenses each participant would view the installation. Understanding their experience with VR, and the specifics of their involvement

with the project, allowed us to understand their values, desires, concerns, and motives. In addition, it served as a means to facilitate the construction of a narrative by the person being interviewed. Through that narrative, they were able to describe their experience with the *We Dare You* project. In a second set of questions, the goal was to explore the successes and challenges of the collaboration and project cycle. The questions were designed to gain information about the specific aspects that interested us: the roles of the various stakeholders, including the designer, the role of the DAC, and reflections on the experience. It is important to note here that even though we refer to this installation as an SR installation—as explained earlier—the stakeholders refer to it as VR. Two more interviews were conducted with two of the "hosts"—floor staff responsible for interacting with the visitors, both to provide help and answer questions, and to have stimulating and critical discussions about architecture. Those interviews aimed to get direct information and insights about what occurs in the exhibition space on a daily basis. In the presentation of our findings we draw on quotes from the interviews, and all informants were made aware of this and gave their permission. A few participants wanted the opportunity to read through their own quotes before publication. To protect the informants, we use pseudonyms instead of their real names.

The interview data was analyzed using a content analysis [7] approach, which combined deductive and inductive elements. Thus, themes were drawn out based on our engagement with the data as well as previous literature. In the inductive process, we identified several themes relating to the work with *We Dare You*. The interview results were compared with insights from observations. In particular, we were interested in instances where the DAC's staff and the designer's opinions and impressions seemed to differ from what visitors did with the installation. Thus, we searched the data for key points of disagreement and disruption, points where tensions could be identified and explored.

5.2 Observations and Documentary Data

Informal observations of the installation happened regularly where the first author observed both visitor and staff interactions with the exhibition. From February 11–13, 2020, the first author spent 3 hours per day conducting formal observations with systematic note-taking, observing approximately 150 visitors using the installation in total. For 2 of those 3 days, the first author was doing the observations while operating as a volunteer floor staff, standing by the installation and assisting with any technical issues that occurred. This option was preferred as a less intrusive way of gathering observational data. The observations were written down as they were observed during the 3-hour shift and later analyzed in conjunction with the results of the interviews.

The DAC also gave us access to data from a set of standard questionnaires that the floor staff routinely filled out every day, wherein they report their impressions and feedback from visitors as well as technical and practical issues that emerge. These data cover the time period from July 20, 2019, to January 12, 2020, and provided us with insights about how the installation was experienced by visitors during that time (as seen through the observations of staff).

6 THE LIFECYCLE OF *WE DARE YOU*

In this section, we present a rich description of the lifecycle of the installation, connecting together insights from interviews, observations, and floor staff questionnaires.

6.1 Conception

We Dare You was the result of an open call for submissions for a new VR exhibit at the DAC.

> We always try to find new ways of making representations of architecture more interesting. So, VR is interesting for me as a project leader and also for DAC as a new way to explore how to communicate and create spatial experiences for our guests. (Robin, Project Manager)

The center was interested in creating something new for their visitors, something that went beyond their regular exhibits. They wanted to show the building from a new perspective that was inaccessible from the physical space. To achieve this, they announced an open call for collaborators and settled on a proposal from the *Immersive Stories studio* [67] and the *Khora studio* [44] to collaboratively develop the *We Dare You* experience. After the software development was finished, a team from the DAC created the physical environment where the *We Dare You* installation was placed, in dialogue with the designer. It was set up in July 2019 and has since been located on the third floor in the exhibition space, in front of a glass wall that overlooks the entrance to the center (see Figure 1).

The experience has a physical and a virtual part, and is accessed through VR Goggles (Oculus Rift S). The virtual elements were developed in the Unity environment [69]. Similar experiences have been developed in the past, such as Richie's Plank Experience [74], an experience that allows the player to experience walking off the top of a skyscraper. In this experience, players use their own physical plank laid out in their home while a virtual plank inside the virtual game environment is automatically adjusted to fit the physical plank. A key difference between these two experiences is that Richie's Plank Experience takes place in a fictional space that has no connection with the physical space of the user (other than the plank), whereas the virtual space of *We Dare You* is an accurate recreation of the physical space the visitor is standing in. Using photogrammetry, the physical space of the DAC was mapped to be replicated in its virtual counterpart. That process was done prior to the installation of *We Dare You*, and therefore photogrammetry was used to capture the building's facade and exhibition space without the physical elements of the installation. The designer and the DAC thus took different responsibilities in the project, and executed their designs at different times, with the designer first creating the virtual environment and the DAC then building the physical interaction elements. Those physical elements initially consisted primarily of the signage material, plank, window sticker, and a hand railing for the visitors to hold onto to make sure they would be able to walk on the plank and not fall off while wearing the headset.

As stated in the preceding quote from the project manager, the DAC expected the installation to allow visitors to engage with architecture in new, interesting ways. This was also the designer's intention:

> [*We Dare You*] reveals the important elements of what architecture does to you because it triggers your senses in a way that you feel the anxiety when you enter the virtual outdoor room. It shows how the senses are triggered and what a physical room does to you. And it also reveals to you perspectives of the architecture of [the DAC building] since you are not able otherwise to stay at this tunnel outside the window. And then on the fun side, it aims at a youth audience as its target group. (Simone, Designer)

The stakeholders saw the SR technology as attractive for visitors due to the novelty of the technology. That attraction was especially appealing to the type of visitors they wanted to attract: families and younger audiences. The project was seen as helping the institution to offer a cutting-edge experience, which would make the DAC seem up-to-date and relevant.

> It's interesting because there is a nice energy in the VR environment. People are excited, trying out new things, I really feel it is some sort of frontier so that kind of energy was nice. (Robin, Project Manager)

During development and as the project led up to launch, a sense of excitement and doing something truly innovative characterized the project. The DAC's staff saw the experience as an opportunity to engage visitors—in particular younger audiences—in new ways; to give them a "fun" experience in contrast to the more serious character of the rest of the exhibition. All stakeholders connected the installation with words like fun, interactivity, and experience.

6.2 The *We Dare You* Launch: Audience Hit, Technological Failure

Once the experience launched, the installation was highly successful in terms of visitor satisfaction. Staff reported that visitors enjoyed it, were excited to try it out, and that some of them visited the DAC specifically to try *We Dare You*—this is mentioned frequently in the visitor feedback given to the DAC staff as reported in the floor staff questionnaires. Often, long lines of visitors waiting to try the experience were observed. However, during the first 3 months, the exhibit frequently had problems with software and hardware failure. First, the VR headset required frequent recalibration. The floor of the exhibition space is slightly reflective and, combined with the fact that the natural changes in the light throughout the day, caused the sensors to require recalibration. This issue was addressed by placing a non-reflective carpet on the floor of *We Dare You*, significantly reducing this problem. The experience still requires recalibration occasionally but significantly less often than before. A second issue arose from the way the software was configured to trigger the start of the experience, which did not adequately take into account the behaviors of users. The software was configured to start when a new player put on the headset and then stepped in front of the plank. However, many visitors would first step on the plank, then put the headset on. Unfortunately, the software was not adapted to this situation, as the signs prompting visitors to move into the starting position would now appear behind them in the virtual space. Thus, these visitors would walk on the plank without the virtual experience running, leaving them either on the VR idle screen or on the second part of the experience (after the super-hero landing). This software behavior was a source of confusion, causing the visitors to walk back, trying to find the beginning of the experience, and occasionally, when that did not work, they would abandon the installation altogether. To address this issue, the DAC placed a sticker on the floor, indicating where visitors needed to stand when they put the headset on to start the experience (see Figure 5). A more flexible software solution would have been difficult to implement, as the DAC does not have access to the Unity source code nor the expertise to edit it. Therefore, the software remains the same since the release day.

A number of issues also occurred relating to the Oculus headset and the cable connecting it to the stationary computer. *We Dare You* requires the visitors to walk forward, jump, take off the headset, turn, and walk backward. Since people would typically turn toward the same direction, the cable tended to twist and eventually break. Sometimes visitors would also move too far from the computer that the headset was connected to, causing it to disconnect. Both of these issues were addressed by supporting the cable with a metal cable that prevented excessive twisting and kept the cable in place. The headset was also frequently dropped and damaged, either by accident when visitors would take it off their heads or due to children running with the headset and jumping at the edge of the plank, hitting their face and the headset on the window. At the point of writing, four headsets have needed to be replaced due to the resulting damages. Due to this problem, a sticker was placed on the floor, prompting parents to not leave their children unattended, and to take care of the VR equipment. Since then, the headset and the cable suffer less damage; however, it is uncertain if that is due to that sticker that acts as a reminder or if it is due to the metal cable making the installation more robust.

Most of these solutions were implemented over the first 3 months. During this time, constant IT intervention was required. The solutions greatly reduced the attention the installation required, but even at the time of writing, *We Dare You* requires occasional IT intervention due to malfunctions.

> With *We Dare You*, I think it has probably been available to visitors less than 50% of the time. I think if you look at the records from the exhibition hosts, they are calling facilities at least 3-4 times a week, maybe more. (Chris, Project Manager)

Around half of all comments in the floor staff questionnaires report technical errors or visitors being frustrated about not being able to try the installation when it was out of order. In their feedback to the hosts, visitors reported disappointment or anger that they were not informed in advance that the installation was not working on the day of their visit.

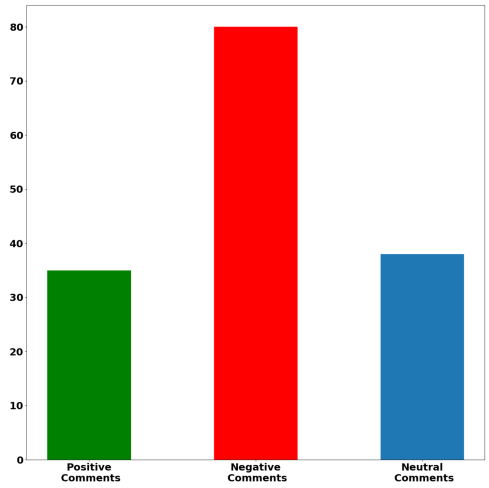

Fig. 3. Deductive content analysis on comments in floor staff questionnaire responses that mention the installation (N = 153).

Some of the nature and extent of these problems can be captured by looking at the data from floor staff questionnaires, covering the first 6 months after the launch of the installation. These questionnaires are filled out by the center's "hosts," who are an important part of the center's offering to visitors. Their role is not only to assist the visitors and answer their questions but also to engage in critical discussion about architecture. Furthermore, they are responsible for fixing minor technical issues that may arise in the exhibition space, and to inform facilities of more serious technical difficulties. After their shifts, hosts answer a set of questions that describe what occurred during their shift. In that dataset, the installation is mentioned numerous times. Figure 3 displays the amount of comments that mention the *We Dare You* installation: in the 276 questionnaires filled out in the time period, there were 101 questionnaires mentioning *We Dare You*, with 153 comments in total (some questionnaires included more than one comment about the installation). The large amount of comments related to *We Dare You* clearly demonstrates that the installation has had an important impact on the visitor experience, from the perspective of the hosts. Furthermore, the figure also shows the results of a deductive content analysis separating the comments into positive, negative, and neutral comments.

Figure 4 separates the *We Dare You*–related comments into categories corresponding to different questions in the questionnaires. The color of the columns indicate the sentiment of the majority of comments in the relevant category: green for positive, red for negative, and blue for neutral sentiment. Most of the comments that are related to problems—represented as red in the figures—are related to technical issues with the installation rather than other aspects of the experience the visitors had with the installation. In other words, even though there are many negative responses to the question about "Quality of visitor experience" relating to *We Dare You*, these comments generally refer to technical problems with the installation. It is worth noting that *We Dare You* was mentioned many times under the category "What's most interesting to visitors?", as well as a few times under "Best Thing!" (see Figure 4)—reflecting the generally positive response from visitors when the installation was not affected by technical issues.

> Then, I think that for our visitors, VR is not new, and they are quite familiar with putting on glasses or using different kinds of digital equipment, and that also means that they are quite rough on the equipment. . . . Today children—and also grown-ups but especially young people and children—are so used to them, so for them it is like grabbing any other kind of instrument. That creates some new

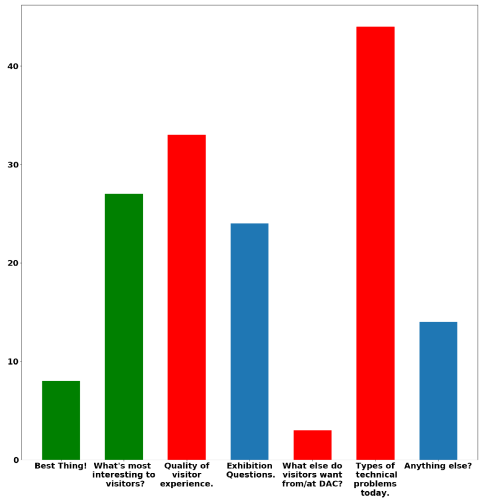

Fig. 4. Number of floor staff responses per questionnaire category that mention the installation (N = 153).

> demands: hardware and the user robustness. That's something that we have to solve. (Terry, Head of Program)

The DAC's preconceived notions of careful use of equipment did not match up to the reality of what people did with the installation, nor with the attitudes and experiences people had. Once launched, visitors used the full installation or just elements of it in various playful ways that diverged from the predicted use. For example, we observed children hanging from the handrail without the headset on or running on the plank with the headset on, jumping at the end of it, and on rare occasions even hitting the physical window. The social and performative elements of watching others engage with the experience have rendered it successful with groups of visitors such as families or friends visiting together. As can be read in the preceding quote, visitors, and particularly children, do not treat the VR objects with the same reverence that the DAC perhaps expected. Instead of having serious, profound experiences with architecture, play reshaped the meaning of *We Dare You* from technologically ground-breaking and offering visitors new experiences with architecture to playful appropriation.

> I think the evaluation is quite clear, we need to figure out some more robust hardware that can actually take all the people coming in, wanting to explore. (Terry, Head of Program)

As in the preceding quote, some of our stakeholders saw what visitors were doing as something to which the institution could adapt. Others raised concerns as they were trying to make sense of the new experience in relation to the DAC's mission to educate—and not just entertain—visitors about architecture.

6.3 Success and Tensions with Play

After the initial period of constant breakdowns and subsequent redesign of the physical elements, the DAC managed to increase the robustness of the installation. It was clear that *We Dare You* was a great success according to visitors, and it did succeed in attracting a new, younger demographic to the DAC, evident in both interviews and observations. We commonly observed crowds during peak hours sitting on the staircase located next to the installation (Figure 5). That staircase was appropriated by visitors in two distinct ways. They used it to queue when waiting to try the installation, or used it as a resting point after having been through the main exhibition space, which offered them an entertaining view of the people using the installation. It was also common—especially for

Fig. 5. Stairs next to the installation, where visitors wait in line and watch the users of the installation.

children—to try the installation multiple times, so the stairs served as a point where parents relaxed and watched their children play with the installation.

> We still could have had that playful moment of the jump, but I would have liked to see the steps before that, of how do we help people understand the architecture, and that I think is missing right now. . . . If we had asked the question of "how do we want people to better understand our building, the design of our building, and use the technology to go and see those places and those views that I cannot see other ways" then we still could have had the last step being "jump off the building." (Chris, Project Manager)

As the technical problems were solved, other concerns remained. The playfulness that made the exhibit a success was a contested point among DAC staff. As in the preceding quote, play became positioned as the opposite of a meaningful experience with architecture. As visitors interacted with the exhibit, they did not do so in a way which favored serious engagement but rather playful exploration.

> I don't think they [visitors] get that much out of it architecturally, to be honest. It is a way to experience architecture of course and people also look around as they have fallen and it is a way to experience architecture but I don't know if people are that aware of it. It is a way to be aware of the building, but mostly it is a fun experience. (Oliv, Floor Host)

Play came to be contrasted with properly experiencing the architecture. The preceding informant expresses that most visitors simply see the fun in the experience, and play rather than engage with it to have more serious experiences. A playful exhibit cannot be controlled or contained in the same way as a non-playful one. As soon

as the DAC invited visitors to engage and to play, they lost control over how visitors behaved. These playful experiences did not match the expectations the stakeholders had.

6.4 New Perspectives: An Embodied and Social Experience

The sensory engagement afforded by SR offered a new quality to the visitor experience. *We Dare You* was designed to invoke the senses and create a feeling of vertigo when walking the plank. Many visitors had intensely embodied experiences with the *We Dare You* installation. A host explained that many visitors using the experience held hands with a friend or family member to gain courage to engage in the experience and combat the fear of heights, which sometimes stopped people from engaging.

> You know that you are here [in the exhibition] but it tricks you! It's too scary! (Comment by a visitor during observations on February 11, 2020)

Contrary to many conventional exhibitions that rely primarily on objects and text and thus focus on stimulating the mind, *We Dare You* engages the visitor's body as part of the visit. This embodiment holds the potential of making the experience extraordinary and memorable.

> VR is a way for us to engage the bodies of our guests and that's a good thing because the body remembers and the brain remembers. (Robin, Project Manager)

Although unforeseen and not planned for, once installed, *We Dare You* became a social experience. Due to the physical elements of the plank and handrail (see Figure 1), it was easy for visitors to see what was going on, and the digital experience became externalized through the physical elements. As visitors engaged, others could sit on the staircase and observe, and the built environment made that observation interesting. The absence of the virtual environment revealed the illusion for observers, which made the visitor's behavior such as stepping nervously, hesitating before jumping, and so on, seem comical.

> [It's] more immersive and fun …because it's not many people who want to be overloaded with information about the material and the construction and all the other technical drawing or thinking behind a building like this. (Terry, Head of Program)

Due to its playful and performative nature, the installation serves as a location in the exhibition where visitors choose to film each other: parents film their children, friends and couples film one another. We attribute this behavior to the aspects of performance afforded by the physical elements of the installation. Those physical elements allow visitors to act out their responses to the virtual stimuli in such a way that is entertaining for the surrounding audience. This is not unique behavior, but it gave the installation a further performative dimension as users acted out for the camera: an artifactual status that comes from the elements of physical interaction (plank, handrail) from the behavior of the user of the installation having elements of performance—being brave, being scared, screaming, laughing, and so forth.

> The nice thing about the installation is that it's fun to see people wearing the goggles because you can see they are scared and they don't know whether they want to jump or not. So it is exactly with this experience and the exhibition design, that makes it fun to watch. The user becomes part of the installation. (Robin, Project Manager)

The physical setup of the experience created a spectacle for onlookers, drew attention, and created a social atmosphere for visitors waiting or just passing by. The staircase next to the installation, in which visitors would line up to try the experience, gave the effect of a small spectator stand, setting the space of the installation up as a scene for a performance. This setup helped solve a common concern with experiences that use VR headsets in GLAM spaces: the isolation of the visitors from their companions, since what is in the headset can only be

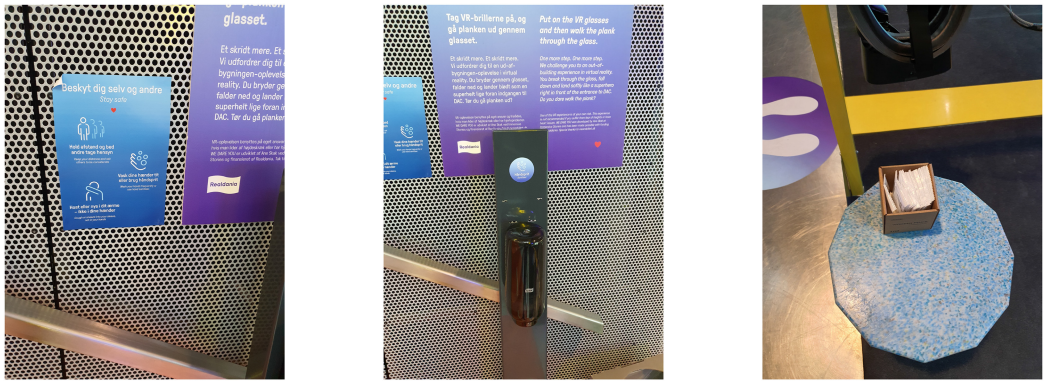

Fig. 6. COVID-19-related information and sanitizing equipment.

experienced by the one wearing it. The *We Dare You* installation demonstrated that SR has the potential to afford stronger social experiences than typical VR experiences.

> I am not worried about the technologies or the experiences themselves, I am more worried about how do we design the physical structures around it, how does it become a social activity, or how does it become fun for people who are lost in the VR goggles. We always bash VR experiences for being private experiences that are boring for onlookers, but in the case of *We Dare You*, it is fun for onlookers. As an architectural museum, how can we take it further than the goggles so that the physical environment is also interesting? (Robin, Project Manager)

Although many VR experiences have problems with virtual motion sickness, no such issues are present in our data. However, we do not know if that is because the visitors did not experience motion sickness or because it was too mild to report on, since the experience was so brief.

6.5 *We Dare You* and COVID-19

On March 13, 2020, the installation—along with the rest of the DAC—was shut down temporarily following orders issued by the Danish government in response to the COVID-19 pandemic. On June 1 2020, the DAC reopened, and *We Dare You* opened shortly after. To follow new hygiene regulations and public demands on measures to combat further spread of the virus, the DAC placed hand sanitizer and disinfectant wipes next to the installation (Figure 6). Additionally, a government-issued sign reminds visitors to keep their distance and use sanitizer frequently.

The DAC has also changed their cleaning procedures and now cleans the entire facility once per day. *We Dare You* is currently open and in operation. At the time of writing (November 2020), technical issues such as the cable disconnecting or the sensors requiring recalibration still arise on a weekly basis; however, the processes set in place by the institution are more efficient, addressing those issues quicker than they used to, partly due to practical know-how built up from past experiences.

7 DISCUSSION

The *We Dare You* installation was a success among visitors; however, it also brought a number of challenges for the DAC. First, the fragility of the technological setup caused much downtime and a need for constant repairs. The installation also required several adjustments to the setup. These problems were exacerbated as the contract released the designer from all responsibilities to help maintain and update the installation after launch. The reason for this unfortunate arrangement can probably be found in the DAC's regular procurement process, which

normally contracts physical exhibits that are easier to maintain, and for which the center has significant in-house expertise. Such challenges are likely to arise in GLAMs using similar project-based approaches, if those procedures do not include plans for maintenance and continuous involvement from the designer after the launch.

Second, visitors used the exhibit in ways the stakeholders had not foreseen, playfully exploring it and engaging in performances that challenged the DAC's intentions with the exhibit. Visitors playfully explored the installation: running, jumping high, walking backward, walking outside the plank, and so on. Although these creative uses may have contributed to the technical problems, they were also the source of joyful engagement for visitors and created space for play, performativity, social interaction, and spectacle. However, some of the stakeholders and floor staff were concerned that the entertainment value of the experience had come at the expense of the DAC's core mission: that visitors should learn about architecture. The ludic turn [45] in cultural institutions creates demands that professionals engage with play in settings often valued on providing education and dealing with serious topics. Play, although often being positioned in opposition to seriousness and rationality [31], has strong transformative potential. Play can transform how we look upon and define activities going on in GLAMs. This goes some way toward explaining the uneasy relationship with play we see at the DAC.

One might imagine a number of strategies for handling such challenges in future projects of a similar kind. First, the issues relating to technical fragility and maintenance seem to call for an improved procurement process tailored to the needs of interactive installations, especially those that invite physical play with fragile technology. Such a process might include a more robust, iterative design process with rigorous testing and approval before launch, a use-before-use approach focused on user testing, and problem solving before launch. However, there is no guarantee that such a process would catch all of the problems; in the case of *We Dare You*, most of the issues arose from the exhibition environment and the unexpected behaviors of museum visitors, which would be difficult to fully replicate in a testing situation prior to launch. This is a common problem when it comes to interactive museum installations [36]. Second, the concerns regarding education might similarly be addressed by incorporating such concerns in the design process, for instance by specifying the learning requirements as part of the design brief, and developing procedures for evaluating the educational outcomes of the installation. Such an approach would have the advantage that it would force the organization to make explicit success criteria for the educational dimension of interactive exhibits, which might help designers and museum staff explore the trade-off between learning and other qualities such as engagement, playfulness, and curiosity. However, an increased focus on education would risk coming at the expense of the fun and engaging qualities of the installation, a focus that also cannot be enforced in "free-choice learning" spaces like museums [36], where visitors follow their own interests.

Instead, we suggest that it might be more productive to reframe some of the issues described here, seeing them not only as problems but also as a productive set of tensions that can be used to create interactive experiences that offer visitors more freedom to play and explore while also facilitating contemporary forms of learning. This could be achieved by adopting a design-after-design approach, by perceiving the appropriation from visitors as a reinterpretation of the museum experience—design through use. Such an approach could be employed by GLAM actors to fulfill ideals of visitor participation [65] and support a constructivist pedagogical view [35, 36] where visitors are encouraged to make their own meaning while supporting the fun and engagement that emerges through play.

Redström [60] describes "design-after-design" as an approach that entails designing artifacts without a clearly prescribed use, creating a space of possibility that leaves it open to users to define the use of the object. Following a design-after-design approach in the process of conceptualizing, developing, and deploying installations can allow GLAM actors to explore what happens as visitors use their exhibits as opportunities for participation and appropriation. This opens up concrete strategies for co-designing and co-creation through including visitors in shaping their visit. Design-after-design can act as a catalyst helping GLAM actors to provide interesting experiences for visitors, by opening up a dialogue between the institution and its visitors that alters and guides the design of an installation.

Such an approach entails designing interactive installations that are open for a wide variety of uses. The institution can then evaluate those interactions and their effects on the institution's dissemination goals. Using the results of that evaluation, the institution can adapt the design to accommodate the interactions that the visitors choose to engage with while continuing to support the institution's dissemination goals. This process shares similarities to a traditional prototyping cycle, but it differs in the fact that it maintains a constant dialogue, even after the deployment of the installation. That constant dialogue between visitors and GLAM actors affects the role of an installation in the actors' spaces. We can learn from the changes visitors make and, instead of trying to resolve the contrast to the imagined use, look upon it as part of the design.

A design-after-design inspired development would entail that future exhibits make explicit a participatory agenda, and this is already an active policy goal for many GLAM institutions. This entails accepting that the institution in question does not have full control over the experience they are offering visitors, nor can they predetermine exactly what visitors will take away from the experience. However, as the *We Dare You* example shows, this may often be the case anyway. Using this as a guiding principle from the start, much of the tension arising between various goals and expectations by designers, GLAM professionals, and visitors could be resolved through dialogue and awareness of the active part visitors play in shaping the final experience.

Designing installations that are open to appropriation can be achieved in several ways. Some key guiding principles are flexibility, openness, and configurability [23]. Through such a design-after-design perspective, it is possible to change the expectations of the exhibit's outcomes while the use of the exhibit renegotiates its intended meaning. The key is empowering users to engage in meaning making themselves, with the GLAM providing an open framework rather than a fixed experience.

A design-after-design approach has the potential to support visitor agency through participation in the act of design-through-use. Established use-before-use approaches fall short in accommodating the needs of a GLAM context, from the multitude of target groups that are present to the dynamic environment that changes during various exhibitions of different characters. The type of design thinking suggested by design-after-design results in a co-creation process for installations, establishing the role of GLAM sites as democratic and creative spaces that can provide interesting experiences that adapt to the ever-changing exhibition environment and can be enjoyed by different visitor target groups while supporting the GLAM actors' individual dissemination goals. We aim to explore the challenges and potentials of this endeavor through an ongoing research-through-design [81] project.

8 CONCLUSION

By all accounts, the *We Dare You* installation has been a great success with the DAC's visitors—aside from the frustrations with the technical problems. However, as shown earlier, DAC stakeholders had somewhat diverging views of the installation: some see problems mainly of a practical nature (e.g., a need for more robust hardware, more testing, and resources for maintenance), whereas some take issue with the lack of educational content in the experience and the dominance of play. This illustrates that the GLAM stakeholders, depending on their role in the organization, have diverging—and perhaps even conflicting—demands for the installation. To some, it is most important that it attracts audiences (particularly young people), and to others, it is more important that it supports learning, whereas to yet another group, it may be more relevant to see this as an experiment showcasing the organization's research and innovation efforts. In our experience, these conflicting views are quite typical of efforts to set up playful technologies in museums [2, 75], and highlights the complex demands placed on GLAM actors by funding bodies and society at large regarding project budget, engagement of broad audience groups, dissemination of knowledge, research, marketing, and more.

Although one might argue that these demands make GLAMs a challenging domain for playful installations in general, the case at hand brings out some considerations of particular importance when designing for SR. First of all, the fact that SR is a hybrid technology with both physical and virtual components means that the

design process may need to combine two different design disciplines—on the one hand, interaction design (and software development), and on the other hand, product design/exhibition design with physical materials. The first area includes a wide variety of concerns familiar to HCI scholars, such as the need to set up agile/iterative design and development processes, including users in design and testing, and to design for unexpected behaviors and appropriation by users. The second area includes a number of concerns and expertise from curators and other GLAM sector professionals, such as the connection to the physical space, the robustness of materials, physical safety rules, universal access, and more. The DAC and other GLAM institutions have much experience and expertise with the latter area but not much with the former; in the *We Dare You* project, the DAC chose to delegate the responsibility for the design of the virtual components to an external designer, whereas the organization itself took charge of designing the physical components. This division of labor, common for GLAM actors, may have complicated the process. As an implication for design, designers of SR installations should be wary of design processes that decouple responsibility for the physical part of the installation from the virtual, and instead plan design processes that provide for close coordination in the design of both physical and virtual components. Furthermore, the responsibility for the design should not stop at the launch of the installation but rather should allow for continuous work to adapt the installation to the emerging behaviors of users and corresponding challenges that arise from this—as suggested by the design-after-design perspective.

Second, the *We Dare You* installation demonstrates a promising solution to a common problem with VR installations: that of providing an interesting experience to people who are waiting for their turn. Often, this is done through screens that display what the user can see with the VR headset, offering the onlookers a window into the VR experience. *We Dare You* does not do this. Instead, the SR's close mapping between the physical and virtual space, as well as the fact that the user is interacting with the virtual space by moving through the physical space, means that it is possible for onlookers to directly observe the user's movements through the installation. The discrepancy between physical and virtual space—leading users to feel like they are balancing on a plank high above the ground outside the windowwhile in the physical space the plank is just two cm above the floor—makes the situation comical. As noted earlier, this has been a great source of entertainment for the visitors and has contributed to the popularity of the installation. A similar effect was achieved by the creators of Thresholds [71] where those standing in line could look into the exhibition space through a window in the wall, whereas the participants wearing VR headsets would, instead of the window, see a particularly eye-catching painting, often leading them to come close and lean toward the window, giving the onlookers a comical view into the SR space. This demonstrates that SR offers additional design opportunities compared to VR: as GLAM visits are usually social experiences, it is an important (albeit often overlooked) requirement to design experiences that can be shared. VR is challenging in this regard due to the reliance on headsets that block interaction with those outside the virtual space. The physicality of SR thus offers opportunities that might be valuable both in the GLAM context and in other contexts where the social experience is important.

The closure and subsequent reopening of the *We Dare You* installation due to the COVID-19 crisis also points to a challenge for SR and VR that is pressing at this point in time but may also have far-reaching consequences. The current pandemic has posed a whole new set of criteria for sustainable experience designs in the GLAM sector and elsewhere. In a recent piece in *Smithsonian Magazine*, Billock [9] maps out how public life and architecture changed in New York after the war on tuberculosis in the late 1900s. Billock uses this analysis to ask what changes museums and other public spaces will need to implement in the years to come to combat the ongoing and future pandemics. Hygiene concerns, situations with queues, and buildup of large gatherings of people are key problems going forward. These issues have particular implications for SR and sensory museum experiences as the pandemic has "forced a de-prioritization of touch and physicality" [27, p. 298]. A key challenge is this: how can GLAM institutions deploy and maintain playful SR installations or indeed any installation relying on VR headsets or similar technologies? Two issues merit particular attention. First, to accommodate for the constant flow of visitors, it must be possible to sterilize devices quickly and easily. At the DAC, this is currently solved by

giving the visitors the responsibility for disinfecting the equipment before and after use. Whether this will be acceptable in the long term remains to be seen. Second, the social element of play poses a design challenge, since it often has the effect of gathering people closer together through playful interaction, sometimes among strangers, or through audience formation. Anecdotal evidence from observing the exhibit since its reopening suggests that visitors often forget to hold the mandated distance while looking at and engaging with the installation. These are issues that need to be addressed so that installations like this can find stable places inside exhibition spaces in the foreseeable future. Although this is an urgent need in the current crisis, it is likely that the pandemic may lead to a heightened awareness toward the risk of contagious diseases in general for many years going forward, making contagion-safe interaction a long-lasting requirement for experience design in public spaces such as GLAMs. It is an important task for HCI to document cases such as this to provide education for future design projects.

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Designing for Design-after-Design in a Museum Installation

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ABSTRACT

Design-after-design focuses on facilitating the re-purposing and re-design of an artefact by its users. In this article, we explore the challenges of designing for design-after-design through a research-through-design experiment set up in an architecture exhibition for a duration of three months. During those months, we aimed to facilitate the re-purposing of the design artefact by the museum visitors and use that to inform design iterations through which we redesigned the artefact. We gathered in-the-wild data about the novel uses discovered by some of the visitors, but also found that many users were confused by the undetermined nature of the initial artefact. Our research contributes by applying design-after-design in practice and reporting on design implications when developing similar open-ended experiences for museums. Specifically, we discuss implications for balancing openness and constraints in such processes, and suggest further research directions for exploring this challenge.

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in HCI**; **Empirical studies in interaction design**.

KEYWORDS

design-after-design, in-the-wild, museums, play, research-through-design

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1 INTRODUCTION

Participatory design projects strive to involve users and stakeholders extensively in their design processes. However, such processes typically end with the final deployment of artefacts. It has been argued that research should explore the ways users engage with artefacts after the design process is finished, at which point the users may re-purpose, redefine or even redesign the artefacts - sometimes referred to as design-after-design [52]. Design scholars have argued that designers should explore how to extend design processes to incorporate that post-deployment phase [9, 10, 19, 28, 53].

In this article, we explore this theme through a research-through-design [25, 53] process by creating an interactive installation for visitors of the exhibition space of the NN architecture center. Working in-the-wild [11] we created *City Lights*, an installation that uses smart bulbs and models to disseminate the role of light in architecture. Following a design process inspired by Redström's design-after-design principles, we design an initial undetermined state for that installation. Through its deployment we aimed to facilitate its re-purposing by the visitors, thus uncovering novel uses that we then incorporated in the artefact, through an iterative re-design process. Building on Davis' theory of affordances [15], we explore how this process led us to move from designing an undetermined artefact, towards a gradually more defined design with affordances that encourage certain interactions, while staying open for other types of re-purposing.

Redström [52] suggests that the ways in which users appropriate an artefact - potentially redefining its use, or even redesigning it entirely - should be viewed as a part of the design process, coined as *design-after-design*. Design-after-design has been discussed in the context of participatory design [9, 19] and data generation [22], and has been explored in the domains such as health care [62] and product design [50]. In past literature, however, there is an absence of long-term in situ studies on design processes that focus on design-after-design. This article contributes by applying design-after-design in practice as a structuring principle for a design process taking place over an extensive period of time, allowing us to explore the users' acts of re-purposing through several iterations. This approach allowed us to gain in-depth designerly knowledge about the challenges and benefits of a design-after-design approach, as well as offering some insights to guide further development of design approaches structured around design-after-design and users' re-purposing of artefacts.

2 RE-PURPOSING AND PARTICIPATORY DESIGN

Scholars in Human-Computer Interaction (HCI) and interaction design have long been interested in how users re-purpose and appropriate technologies [7, 18, 24]. Henderson and Kyng [33] introduced the concept of tailorability — which refers to the quality of a system to provide tools so that user can modify (tailor) it post-deployment to fulfill their own individual needs. Both tailorability and the similar concept configurability [2] refer to qualities of the system, whereas the concept of appropriation refers to the user's action of re-purposing artefacts in novel ways not envisioned by the designer [17, 18, 58]. Appropriation is also central to understanding ludic experiences [24] since it is a key element of play

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[63]; a topic that is of increasing interest to designers of museum experiences [5, 40, 41]. Understanding the role of that re-purposing and incorporating it in the design process has been suggested when museums aim to develop playful experiences [14, 37] or educational ones [43].

Much research in HCI and design has explored the use of participatory design (PD) as a method to create interactive experiences for museum visitors [3, 12, 16, 29, 35, 54, 55, 59, 64]. Scholars have also discussed the role that re-purposing and appropriation play in Participatory Design (PD) processes – how users refine, configure, or even re-design artefacts through the discovery of new uses during the post-deployment phase [10, 28]. Redström [52] introduced the concept of Design-after-Design to describe how users may re-design an artefact through the various ways they decide to use it after it has been deployed – thus "designing" new uses for it. Redström and other design scholars have suggested that in order to support such actions of re-purposing, design approaches that focus on design-after-design should leave an artefact undetermined — or unfinished — in order to let the user define its use (or purpose) through the various ways they decide to use it – in other words, leaving the artefact open for appropriation and re-design through use [9, 19, 52, 53]. Binder et al. [8] suggest meta-design and design as infrastructuring as potential directions for a Participatory Design future which would account for "Design-after-Design". They continue by suggesting infrastructuring strategies. Even though those strategies are relevant when designing infrastructures that relate to artefact ecologies, they operate on a generic level which is not always useful when designing for individual playful artefacts in museums that are not part of a larger ecology. What is highlighted however is that, ultimately, designing for design after design calls for a re-thinking of what should be considered the final products of design processes [28].

Empirically, researchers from various fields have explored the implications of design-after-design in various designs and design activities. Working with local health practices in Tanzania, Shidende and Mörtberg [62] saw design-after-design as a link between the local needs of a user and the needs that the designer predicted regarding a software system in the field of Healthcare. They tried to accommodate for that by "[p]ostponing final design decisions until they are in their use context" [62, p. 69]. They concluded that studies at the local level of the user can address the challenges designers face regarding connecting design and use. Feinberg [22] explores a variety of datasets to analyse data generation as a design activity. In her resulting framework, she sees the ways that users collect data as instances of design-after-design, where users become designers of said data, especially in activities which do not support a single interpretation, but rather consist of a variety of different approaches. Following design students during a university course, and studying their co-creation process of assistive devices, Ostuzzi et al. [50] discuss designing for product adaptations as a form of empowering the user through supporting a design-after-design process that can adapt the product to the optimal solution for the user, what they call "open-ended design solutions" [50, p. 9]. Even though they focused solely on generating instructions during their research, they suggest that further research should focus on transferring those concepts into commercial products rather than instructions. Bjögvinsson et al. [9] have explored design-after-design in practice, by installing Bluetooth technology in public buses to distribute music to its passengers, while at the same time reducing vandalism in the community. Through that a number of different specific projects emerged, via the input of the community. They conclude that designers who employ design-after-design in their process need to consider how to set up such processes so that they can be continuously ready for the changes that come through user appropriation. Developing a digital service related to loneliness and social isolation in rural locations Hayes et al. [32] discuss how failing to accommodate for design-after-design threatened the sustainability of their design, by assuming a certain future regarding their product which in the end was proven possible after the deployment of the product. Tomej and Xiang [68] in their study of holiday traveller groups discuss how design-after-design is related to what they call "improvised affordances", affordances that were not designed intentionally and are discovered by the user. All those studies support the notion that users possess an active design engagement role on the deployed product through the various possibilities of re-purposing, which can, then, lead users to innovate or create novel objects and interactions.

3 DESIGNING UNDETERMINED OBJECTS

The design of undetermined objects, as suggested by proponents of design-after-design, can be viewed from (at least) two perspectives: undetermined interactions (technological appropriation) and undetermined interpretations (ambiguity). Dix [17] offers recommendations for designing for undetermined interactions (or appropriation), stating that designers should focus on supporting the user instead of controlling their experience. He suggests that exposing the intentions of the designer and providing visibility to the various functions of the artefact can help the user to adopt and adapt those technologies according to their personal interpretations. Mäkelä and Vellonen [48] mention that appropriation relates to how designers enable users, specifically through possibilities for self-expression in the designed artefacts. Regarding the design process of such objects, Tchounikine [66] suggests a life cycle perspective in which (1) an initial artefact with adaptation features is deployed, then (2) the designer performs an analysis of uses that result from user appropriation, and finally (3) the designer re-designs the system to support those novel uses and to help the further discovery of new uses.

The second perspective - undetermined interpretation - emerges from research in the cross-disciplinary area between art and design, where Gaver et al. [26] have argued that ambiguity may sometimes be a useful resource for design. An ambiguous artefact can be engaging and thought-provoking, suggesting different perspectives to the user that are connected with their personal experience. Further expanding on these ideas, Sengers and Gaver [61] argue that designing artefacts that "stay open to interpretation" has a potential to empower users and support them in their individual meaning-making and appropriation of technologies. Exploring complexities of interpretation and ambiguity is central to humanistic research, and thus has also formed an important part of humanistic approaches to HCI [4] such as artist-based research [6] or experience design [31, 45]. Thus designing for open interpretation has

been central to much research in design and HCI that explores aesthetics and museum experiences [29, 30, 34, 57, 60].

However, designing artefacts that are undetermined - both in their possible interactions, and in their interpretation - comes with the risk that the resulting artefacts are harder to understand and use. Constraints, through limiting the set of possible actions, can help users determine possible courses of action in novel situations. Constraints are important in order to teach the user how to interact with an object and what they are able to do [49]. They often play an important role in artistic practice, where it has often been discussed how constraints can be used as techniques for stimulating artistic creativity [21, 36, 44, 47]. Such debates have also been brought into the design of participatory experiences for museum contexts, e.g. Simon emphasizes the need for constraints to scaffold participation in meaningful ways [64].

Arguably, constraints are of particular importance for the design of games and playful experiences, as pointed out by numerous scholars [13, 38, 67]. Characteristically, McGonigal quotes the philosopher Bernard Suits' definition of playing games as: "the voluntary attempt to overcome unnecessary obstacles." [46]. Løvlie [42] suggests that constraints play a central role when games are used for rhetorical purposes. The balance between constraints and freedom is also central to the distinction between games and play, which is normally seen as an activity that relies less on rules and constraints [63]. Upton describes play as "free movement within a system of constraints" [69, p. 15], where players constantly negotiate with the system what is allowed by the (1) external constraints — posed by the system — and (2) internal constraints — posed by the player. He argues that in order to facilitate play, design should aim to give few constraints:

> "In practice, underconstrained systems tend to have more play value than overconstrained ones. When players encounter a system with too few constraints, they often compensate by inventing their own on the fly." [69, p. 53]

Given that design-after-design invites users to re-purpose artefacts, a central concern for such processes should be to explore the degree to which the designer should aim to minimize constraints from the outset or whether some constraints are needed in order to scaffold interaction; and if so, how such constraints should be designed, communicated to the user, and how these constraints should be open for negotiation, revision, re-framing or removal by the user when they engage in design-after-design.

The balance between open and constrained interaction can be examined using the concept of affordances, initially introduced in a design context by Norman [49]. Davis [15] suggests that we can divide affordances into six categories:

- *request*: artefact requests specific actions from the user.
- *demand*: artefact demands specific actions from the user.
- *encourage*: artefact encourages specific user actions.
- *discourage*: artefact discourages specific user actions.
- *refuse*: artefact refuses specific user actions.
- *allow*: artefact allows specific user actions.

Some of these types of affordances - in particular the *demand* or *refuse* affordances - are rigid, in the sense that they leave little freedom for the user to deviate from the intended action. The other types are more flexible and are oriented towards guiding the interaction, and offer more freedom for the user. Among the **flexible** types, three of them (*request*, *encourage* and *discourage*) provide a specific direction of action, while the fourth type (*allow*) does not. This category describes affordances that are there but the design of the artefact does not directly suggest or oppose actions related to those affordances. Seen in this perspective we theorize that creating an undetermined, open-ended design entails minimizing **rigid** affordances and aiming instead to design for **flexible** affordances. By doing so, we provide the user with opportunities of re-purposing.

In the following we will present our Research through Design exploration of designing for design-after-design in the context of a playful museum installation. Based on insights from the design process and evaluation we will discuss how the users' re-purposing led us to redesign the constraints and affordances of the artefact, and what implications this may offer for designing for design-after-design.

4 METHOD

In this study we explore the issues set out above through the design and deployment of an interactive installation for the NN architecture center. We worked in a Research-Through-Design [25, 53] approach, to gain insights regarding possible design-after-design processes which can support the re-purposing of artefacts through user appropriation. Our purpose was to discover a process which can help us design undetermined playful hybrid artefacts in exhibition spaces.

The first author was employed by the NN architecture center as an industrial PhD student. As part of his employment he designed and developed *City Lights*, the design experiment presented in this article, together with the exhibition and education team of the center. His research position presented an opportunity to conduct the experiment in-the-wild [11], gathering data from visitors in the center's exhibition. For re-purposing to emerge, we considered it important that the experiment would be exposed to the regular visitors of the center for an extended period of time, allowing different behaviors to emerge.

Our design process was divided into two main periods: before deploying the installation, and after its deployment. During the first period our aim was to design an undetermined object that would encourage re-purposing. To do so, we incorporated affordances in our artefact which aimed to enhance its ambiguity, and support possible technological appropriations – as discussed in Section 3. We theorized that by doing so, the visitors would discover various new ways of engagement with the installation during the second, post-deployment period. In the second period we observed the visitors' behavior and tried to identify novel ways of engagement. In other words, we wanted to leave it up to the visitors to express, through their actions, what interactions they found engaging. Those observations then guided our re-design of the installation. It should be noted that the educational goals and other aspects of the institution's policies imposed constraints on the possible re-design iterations, both regarding how often we could implement changes and how much we could change each time. However, we argue that even quite small changes in design can lead to interesting changes in the interaction with a game or a playful installation [1, 27, 38].

4.1 City Lights

City Lights was a design experiment set up in the space of NN architecture center from the 3rd of September 2020 until the 8th of December 2020. It was part of an exhibition called "Kids City", which aimed to present urban architecture as seen from the perspective of a child. The exhibition was targeted towards children and families, and many of the exhibits had been designed to be playful and interactive. The project was under development since February 2020, and its deployment was delayed multiple times due to the COVID-19 related lockdown which began on the 13th of March 2020 and ended on the 8th of June 2020. That lockdown prevented the authors from accessing the museum's space and thus delayed the on-site work that was necessary to build the installation. Once the installation was deployed (3rd of September 2020) it run continuously until its closing date (8th of December 2020). Following a second lockdown initiated on the 9th of December 2020, the installation was shutdown prematurely together with the exhibition it was set in since the institution started working on the next exhibition that would be put up in their space. The purpose of the installation was to allow visitors to explore the effect that different qualities of light have on how we perceive architecture.

4.1.1 Original Implementation. For the initial design we aimed to create an interactive installation about light and architecture for an exhibition environment targeted towards families and school groups. Our ideas for the design were developed through discussions with the museum stakeholders in order to align the design with the dissemination values of the institution.

The installation was designed to provide visitors with the building blocks of a small urban tableau, along with a setup of lights that could be manipulated to provide different intensities and colors - allowing visitors to play with different light settings and create different moods on that tableau. The installation (Fig. 1) consisted of a hexagonal table with a collection of small objects and figurines. On the table there were three lamps installed with smart bulbs which could be adjusted using a control interface on an iPad mounted on a stand next to the table. The objects were made from different materials to showcase how light reflects on those materials, an important consideration when it comes to architecture. In order to create an initial undetermined installation, we included a number of abstract shapes as well as some objects that resembled houses, people, plants and other elements of an urban landscape. However the installation did not offer any instructions to visitors, leaving them free to ignore the thematic ideas and instead play freely with the materials and light.

Our initial implementation (Figure 1) of *City Lights* consisted of the following elements:

- a hexagonal table
- three smart bulbs mounted on the table
- an iPad running a web application to control the color and intensity of smart bulbs
- one large metal black house
- one medium 3D printed plastic house
- one small 3D printed plastic house
- ten plexiglass figures of humans, cars, and trees
- eight plastic human architecture models
- a large amount of cubes and spheres of different sizes and materials
- four small plastic chairs and one plastic table

The initial implementation afforded two basic interactions: change the light properties of the smart bulb, and place objects on the table. We intentionally designed the installation to offer as few constraints as possible, and to allow rich opportunities for play and creative expression while giving minimal instructions regarding how to use the installation. We hoped to inspire visitors to explore and play with the installation as they tried to make sense of it, and by that helping us to discover (or design) possible novel uses of *City Lights*.

Furthermore, the installation was designed to facilitate collaboration between several users simultaneously, partly out of consideration for the main target groups of the exhibition - families and school groups - and their presumed interest in socialising and playing together; and partly reflecting research arguing for active visitor participation and interpersonal experiences [20, 34, 57, 64].

In the initial deployment there were no instructions present in the physical space regarding the installation. However, the control interface on the Ipad included a menu option to open a small '*Introduction*' page that when accessed would reset the color of the smart bulbs to the default (white with maximum intensity) and display the following text:

```
Instructions
1. Choose three objects from the shelves
2. Use the iPad to play with the light and color settings
3. Notice how the mood changes
```

There was also an "About" page displaying the following text:

```
In architecture light and materials create different atmospheres. It
can be a brightly lit city square, a vibrant park, or a dark alley.
Build a small city scene and explore how light, scale, and materials
can create different spatial experiences. You can create your own
experience by placing the objects from the shelves. Then, use the iPad
to control the colour and the light intensity of the three lamps.
```

The main view of the control interface allowed visitors to control the color and intensity of each smart bulb (Figure 1).

4.2 Evaluation

Our evaluation strategy focused on observing visitors' interactions with the installation and identifying novel uses in order to understand how visitors engaged with the artefact, and which of its aspects were re-purposed. To do so, we relied on both scheduled and ad-hoc observations, as well as daily surveys of the institution's floor staff, supplemented with conversations with other employees about their observations in the exhibitions.

For the duration of the exhibition, the first author engaged in daily ad-hoc observations of the exhibit to look for specific instances of that re-purposing. Working in an office space on a higher floor with a view down to the exhibition area, he was able to observe when a visitor engaged with the installation, and when that happened he would go down to the exhibition space and observe, as well as documenting the results of the interaction with photographs

(a) (b)

Figure 1: *City Lights*

and note-taking. 73 urban tableaus were photographed during these unscheduled daily observations.

In addition, the first author carried out a series of 15 scheduled hour-long sessions in which he volunteered as floor staff, allowing him to observe visitor interactions continuously and inconspicuously. Whenever interesting behaviors were observed, they would be documented by note-taking and photographs of what the visitors had created. During those scheduled sessions 33 visitors were observed in-depth during their interaction, with their approximate age, group, time spent in the installation, and the specifics of their interaction noted down, along with photographs of what they created.

The center employs floor staff, called "hosts", that are present constantly in the exhibition space during opening hours. Each host fills out a questionnaire at the end of their shift. During the period that *City Lights* was set up, the following sentence was added in the questionnaire form: "Describe in a few words what you observed regarding how the new *City Lights* installation was used by the visitors." That sentence was answered 33 times over the time period that the installation was deployed. In our analysis, we draw from those answers in order to understand in more detail the visitor behavior, since the hosts are present in the exhibition at all times. Through their expertise, the various NN stakeholders – i.e. floor staff, project managers, and department heads – offer valuable insights on evaluating how closely the various re-purposing by visitors and the various re-designs by us align with the institution's goals to educate visitors about architecture.

During the evaluation period the installation went through three iterations driven by the visitors' uses of the installation. For each of those iterations we used the same type of evaluation methods to analyze it.

Unfortunately the COVID-19 pandemic caused some challenges for the evaluation. The pandemic led to periods of low activity in the exhibition space. Furthermore, concerns regarding social distancing policies made it impossible to approach visitors for interviewing.

5 POST-DEPLOYMENT RE-PURPOSING AND RE-DESIGN ITERATIONS

Once the installation was deployed, we observed a variety of visitor behavior. The installation was especially popular with groups of children and teenagers, and for many of them the interaction appeared to be intuitive. The ones that engaged with the installation used the physical props to create small tableaus such as that seen in Figure 2 (a), which was constructed during the first day of the installation's deployment by a group of 3 children. During their engagement with the installation–which lasted around one minute–they created an elaborate scene incorporating a multitude of objects. Other people focused more on the light and its effect, as indicated by Figure 2 (b), a setup left behind by two adults that concentrated on experimenting with different light conditions. Finally, another pattern of behavior that we observed was stacking (Figure 2 (c)): visitors spending time stacking objects on top of each other. This was a common and popular activity, especially among families with children and groups of children.

(a) (b) (c)

Figure 2: *City Lights* Interactions before re-design

However, many visitors did not spend a lot of time using the installation. Floor hosts told us that many visitors appeared uncertain about how to engage with the installation: "Many do not understand it and move on, especially the children quickly lose interest". Other hosts suggested that the installation was not sufficiently clear regarding its purpose: "Most people seem interested and try out the installation, but they are in doubt about what it will convey" one host noted, with another commenting that "People are confused. They spend more time on Instagram photos than experimenting with the houses and the people". It appeared that the ambiguous and open-ended nature of the installation left visitors confused. However, one of the exhibition hosts told us that he had experimented with presenting the installation to visitors as a game, in order to help visitors make sense of how to engage with it:

> "People like to stand and play with it, but they have to be guided in during the first steps otherwise they do not get the point. In particular, I have succeeded in giving people a small task, for example: 'can you create a cozy atmosphere' 'or can you make it eerie?' to show what light can do to an object."

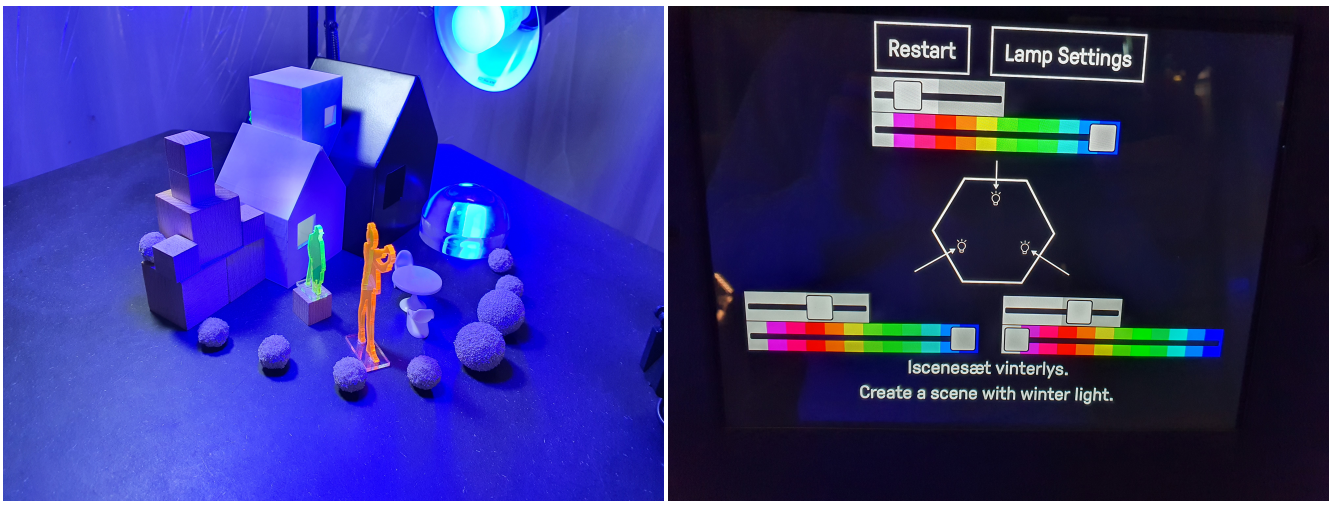
These observations led to the first re-design of the installation, which was implemented two weeks after the initial deployment (on 18 September) and consisted of two small adjustments: First, in order to offer visitors some initial information as they approached the installation, we put up a physical sign which contained the text from the Introduction and About pages in the control interface (see above). Second, we added an element to the control interface through which the visitor was presented with a challenge, such as "Create a scene with winter light" (Figure 3 (b)), in order to inspire visitors to explore and play with the installation.

These changes turned out to be quite effective, leading visitors to create a variety of designs that were inspired by the prompts, such as that in Figure 3 (a), which was set up by an adult and a child together, spending approximately 10 minutes in the installation responding to the prompt in (Figure 3 (b)). According to a host, visitors seemed to respond with more engagement than before: "I asked some girls who were very preoccupied with it if it worked well and they answered a resounding yes. They used the houses as a kind of dollhouses and put the human figures in there and played family - and then they changed the light". Other hosts offered similar comments, indicating that the changes had made the installation more intuitive and engaging for visitors, in particular due to the prompts. People started to create more elaborate designs, using the collaborative affordances of the installation to experiment and play together. Floor hosts also reported that the suggested challenges initiated interesting conversations between hosts and visitors regarding the properties of light in relation to architecture.

This enabled us to observe more clearly which aspects of the installation the visitors found more engaging and creative. Visitors stacked cubes to create towers (Figure 4 (a)) and other types of buildings, which indicated to us that visitors might want to play with more building-like objects. At that moment, the only objects that looked like buildings were the three simple houses seen in Figure 2 (a). In addition to that, visitors wanted to play with the shadows cast by the light, which was problematic because many of the figures were made of transparent Plexiglas and did not cast shadows.

Some visitors also "transgressed" a barrier by mixing elements from *City Lights* with other parts of the exhibition. For instance, one visitor–a toddler–took three of the plexiglass figurines and placed them in another part of the exhibition space on a zebra line (Figure 4 (b)). The physical objects matched the exhibition space–humans walking and a zebra line–and allowed a creative connection of those two exhibition elements. Another visitor left a small robot figure behind on the table, indicating that they had involved the robot in their play with the installation (Figure 4 (c)). These examples demonstrate that the physical props of the installation inspired and enabled the children to easily re-purpose them for their play, allowing them to incorporate the props in their exploration of the wider exhibition space.

Based on those observations, our focus in our second re-design of the installation was to introduce more tangible artefacts of humans



(a) (b)

Figure 3: Urban Tableaus after first re-design

and houses. We choose that re-design path, since visitors seemed to engaged more actively – and in more ways – with those models rather than the abstract ones.

The third iteration was deployed a month after the second, on 19 October 2020. The main change at this point was that we introduced eight more 3D printed opaque houses and six 3D printed opaque human figurines. This was done in order to provide more non-abstract objects that represented actual buildings and people, as well as offering opaque objects that could enable visitors to play with their shadows.

Perhaps unsurprisingly, these new props led visitors to play more with the figures - but interestingly, we also observed more families playing together, parents and kids collaborating in stacking and building tableaus. It seemed that visitors now found it easier to make sense of the installation, and we saw an increased engagement from adults as well as kids. It seemed clear that this change towards more specific models rather than abstract opened new possibilities for visitors to express themselves with more creativity and detail (Figure 5). More people spent time interacting with the installation, some creating elaborate urban tableaus.

6 DISCUSSION

In this section we will reflect on what insights *City Lights* can offer regarding designing for design-after-design, and present a model of our design process based on our exploration of different types of affordances and constraints.

From the outset we focused on designing an installation which was open and undetermined, both in the sense that there minimal constraints on the types of interactions it afforded, and in the sense that the installation was open to interpretation with little information to reduce the ambiguity of it. However, in spite of our intentions this undetermined state seems to have been an obstacle for engagement. This points to a dilemma for design-after-design approaches: How should one balance between the need to leave the artefact open and undetermined, on the one hand; and on the other hand, the need to design constraints in order to scaffold interactions and help users engage with the artefact?

To explore this problem, we turn to Figure 6 which shows a simplified overview of our design process. Our goal was to move from an undetermined design towards an increasingly more engaging one, through iterations of re-design. A key aspect of our design process was to instil the discovered uses in the artefact through the re-design iterations. In other words, once visitors discovered novel interactions, our goal was to change the artefact in such a way that it would be clearer to future visitors that such interactions were available.

To examine this process more closely, we refer back to Davis' theory of affordances [15], which we introduced above. The initial version of *City Lights* offered a wide range of *allow* affordances: physical props that could be used freely, an open space to move around, free movement of the lamp, a variety of color choices, and so on. The installation did not indicate any goal or rules for the interaction, and did not encourage or discourage specific uses of the objects or the lamps. The first re-design made the instructions more easily accessible in the physical space and introduced challenges. As a result, the installation now *encouraged* and *requested* specific behavior: such as creating a winter scene or placing three objects on the table. Thus, while the possible interactions remained unchanged, the artefact now gave some directions to the visitor. That seems to have helped visitors come up with ideas for things they could do with the installation, which helped new interactions to emerge. After the second re-design – i.e. the introduction of more houses and human figurines – visitors started to create even more elaborate tableaus (Figure 5), demonstrating creative exploration in new ways. Those new objects *encouraged* a more detailed approach by the visitors, while also supporting more complicated forms of self-expression.

In our design process we started with what the artefact *allowed* and gradually transformed it into something that the object *encouraged* or *requested*, thus, highlighting to new visitors interactions

(a) (b) (c)

Figure 4: Novel interactions

(a) (b)

Figure 5: Urban Tableaus after second re-design

that past visitors had found engaging. However, we still designed for **flexible** types of affordances rather than **rigid** ones, so that the installation would stay open to re-purposing and appropriation by users. Our observations indicated that the installation became more engaging with each re-design iteration.

In their paper Gaver et al. [26] mention that ambiguity can lead to confusion and frustration. They also raise a point that ambiguity is not an excuse for poor design decisions. In our work we encountered confusing users (guests) that had issues figuring out how to engage with the affordances of *City Lights*. What we found was that a strength of working with such a process based around design-after-design is that the designer can afford to make those poor decisions in the initial states. They can do so since figuring out those poor decisions and re-designing them is in the core of such a process. As a result, the designer does not have to rely on their intuition to understand what is confusing in the object they design, but rather they can test it in practice with the actual users. At the same time such a process requires an initial unfinished object in a refined prototypical, and thus unstable, state. In our work, the primary designer was maintaining *City Lights* full time which can be an issues for teams that cannot dedicate someone in that role. Also, designs that are based around a strong theme and a lot of already created content – e.g. desert rain Gaver et al. [26] – may not be possible to design them through such a process since that initial unfinished state already requires a lot of work and might not be as malleable once the design is ready to be deployed.

Specifically for our case, an important limitation for our study was the fact that the installation was temporary and had to be taken down once the main exhibition was over, which meant that we could only run the process for a limited time - and could only

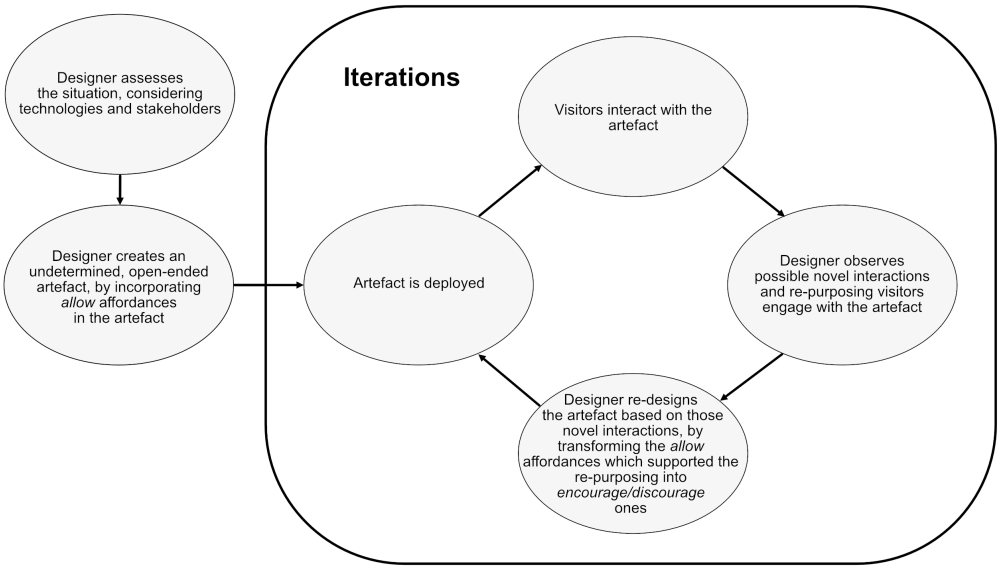


Figure 6: Our Design Process

fit three iterations into that period. This was frustrating as we felt that the installation was only just starting to find the right shape when it had to be shut down. Ideally, we would have liked to carry the process further and explore the design through more iterations. Future research should aim to explore design-after-design processes over longer time and more cycles of iterations.

7 CONCLUSIONS AND FUTURE RESEARCH

In this article we have explored a design process in which we deployed an undetermined artifact with the purpose of inspiring museum visitors to re-purpose its use, and used those instances of re-purposing to re-design the original artefact. While the undetermined initial state seems to have been a source of confusion for users, the absence of constraints also helped to uncover novel behaviors. Future research should explore how to carry out similar design processes in a way which avoids that the undetermined nature of the initial artefact becomes an obstacle to engagement - while maintaining sufficient openings for users to re-purpose and re-design the artefact. If the process is not limited by other circumstances such as time, resources and stakeholder involvement, the problem outlined above may simply be addressed by extending the process in time. This entails accepting that the initial undetermined artefact may be too confusing for users, and that take-up will be slow in the start - in the hope that users will gradually discover interesting uses for the artefact, which can guide the design-after-design process in a promising direction. However, if such a slow process is not possible, the process may need to be adapted in order to progress more quickly. We suggest a few ways in which such processes may be explored in future work.

An interesting possibility which we could not explore would have been to create more radical and more frequent re-designs to explore the space of possible interactions - for instance by trying out more radical variation in the challenge prompts (e.g. "create a hellish environment"), introduce a larger variation of tangible props from different environments (e.g. space, history, mythology), or re-designing the installation itself (e.g. instead of a table set up a small house that users can enter), in order to observe what type of behaviors these very different elements would support. Such redesigns were impossible in our case due to the educational goals and other constraints set by the institution. Exploring design-after-design processes with more radical and frequent re-designs would be an interesting avenue for future research.

A different direction could be to start the process not with an entirely undetermined artefact, but rather by redesigning an existing, determined artefact to add some new affordances of the most open *allow* category [15]. An example of how such a change might look like can be found in the design of *Drift Table* [27], where a coffee table was augmented with a screen which displayed an aerial view of landscapes in Britain. Through shifting the weight that was on the table, users could control the movement of that view. Such an addition in an already established object resulted in users changing their routine and engaging with new table activities – e.g. embarking on long virtual trips collectively and collaborating on the weight placement to reach the destination [27]. Another example of such a change can be found in the design of *Mood Squeezer* [23], where users could squeeze augmented stress balls in order to display the color they associate with their mood in a public display. That possibility of self-expression gave space for new behaviors to emerge in the work space – e.g. an otherwise private activity of squeezing the ball to relieve one's stress became social, sparking discussions and playful interactions [23]. Both of those cases showcase how an addition of an open, flexible type of affordance sparked new behaviors. Similarly, one could imagine a cultural institution altering one of their established determined

experiences with some *open* new function. Our suggested design process would then proceed to study what novel ways of interaction those new affordances might uncover, and how we could gradually translate those affordances to *encourage/discourage* ones. Such a process might help avoid the initial state of confusion we observed in *City Lights*, and could shed light on how to balance openness and constraints in the design-after-design process.

An even more radical change in the process could be found by taking inspiration from the use of constraints as techniques for stimulating artistic creativity. This type of approach was in particular made famous by the literary movement known as OuLiPo [44], where for instance the author Georges Perec wrote an entire novel without the letter 'e' [51]. However, the use of constraints to inspire creativity has also been discussed in relation to other types of creative endeavours [21, 36, 47], including design work and hackathons [39, 56, 65]. Applying this approach would entail to start the design-after-design process with an artefact that invites users to interact according to rules that appear near impossible - in the words of Matthews, to invite users to "play hard games" in the hope that eventually, "thanks to the impossible rules, we find ourselves doing and saying things we would never have imagined otherwise" [44]. Thus instead of starting the process with an undetermined artefact, the process would start with an artefact that appears *overdetermined* - or rather, impossible - in the hope that this provocation may inspire users to find creative ways to re-purpose and re-imagine the artefact. For instance, in the context of *City Lights*, users might be presented with a variety of building blocks representing non-natural objects such as houses, cars, roads, machines, etc - along with contradictory prompts such as "build a park" or "create a pleasant environment for cats". Constraints could also be applied to the lights, for instance by applying sensors that would only allow the lights to be turned on when artefacts are placed in certain configurations on the table. Experimenting with such constraints would come with the risk that users might find it hard to engage due to the constraints, or that their interactions might be so constrained that the process would fail to uncover novel uses that could steer a redesign process. Such risks could be mitigated by enlisting floor staff to help users make sense of the installation, e.g. by encouraging them to break the rules.

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Publication 4

Exploring affordances through design-after-design: the re-purposing of an exhibition artefact by museum visitors

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Exploring affordances through design-after-design: the re-purposing of an exhibition artefact by museum visitors

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Museums have increasingly focused on digital technologies and play as means to provide personalized, engaging experiences for their audience. Balancing educational and playful values is often conflicting. To address that conflict, museums often employ participatory design strategies. However, those strategies usually end after the deployment of those experiences, thus they do not accommodate for what occurs during actual use. In this article, we follow *Light House*, a research-through-design experiment of an installation that was developed using an iterative design approach which expands on actual use by deploying undetermined artefacts to support the discovery of novel interactions by visitors. Through our findings, we explore the "failure" of *Light House* to support the discovery of such interactions in relation to its educational character, but rather it inspired people to incorporate it in the activities supported by the surrounding space. Finally, we discuss the implications those discovered interactions in terms of potential re-design directions.

CCS Concepts: • **Human-centered computing → Empirical studies in HCI**; **Empirical studies in interaction design**.

Additional Key Words and Phrases: design-after-design, participatory design, museums, play

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1 INTRODUCTION

When developing playful experiences involving digital technologies in museums, there has been much interest in employing participatory methods [10, 21, 32, 34, 36]. However, those approaches often stop at the point of deployment [37]. Since, traditional lab-based usability tests fail to mimic the conditions of visitor behaviors in exhibition spaces [22], design approaches which account for the post-deployment functional phase of the artefact are necessary to address unpredictable technical issues [24] and discover new ways which visitors might engage with an artefact [1]. In other words, it is necessary to expand participatory processes to accommodate for that post-deployment state and engage with "design-after-design" [6] – a concept developed by Redström [29] which refers to the re-purposing of an artefact by the users after that artefact has been deployed. Such an approach, then, can capture the new uses that are discovered by the visitors and use them to inform potential re-designs of the artefact. For that to occur, the artefact itself needs to be open and undetermined, giving the opportunity to the user to define it through their use based on their own motives and interests [5, 14, 29, 30].

In this article, we are presenting our findings regarding a research-through-design [18, 30] experiment we set in-the-wild [8]. Our experiment consists of *Light House*, an installation set in the space of the NN architecture center

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for a period of five months. The installation's focus was to help visitors explore the effects of natural and artificial light in architecture. Our work explores a design process which focuses on inspiring people to discover novel uses of the artefact at hand through facilitating the re-purposing – and design-after-design [29] – of the artefact. Through discussing the various design implications revealed by our artefact, we contribute to the ongoing discussion regarding the incorporation of the post-deployment re-purposing of artefacts by users, in participatory design processes.

2 RELATED WORK

Museums have increasingly employed digital technologies as means to create personalised [2, 22, 26], educational [7, 31, 38, 40], and playful [3, 4] experiences that engage the senses [11, 16, 19, 24, 39], as means to position themselves in the experience economy [25] and move towards a participatory agenda [10, 36]. Designing for play may give users rich opportunities to appropriate technologies [17], but may also create conflicts with norms and stakeholder views of appropriate museum activities [24, 27]. Therefore, it is necessary to establish design processes that can support the need for play in museums, while addressing those issues that are associated with it.

To support the development of those aforementioned experiences museums turn towards participatory design (PD) processes [2, 9, 13, 20, 23, 32, 33], specifically when focusing on exhibition development and evaluation of deployed exhibits [37], or as means for discovering the motives, expectations, and interests of visitors [36]. However, those processes do not accommodate for the "design in use" – i.e. what happens once an artefact is available to the user – and thus failing to incorporate in the design process the re-design which happens through the re-purposing of the artefact by the users [6]; what Redström [29, 30] refers to as "design-after-design". Regarding that, he [29, 30] suggests the deployment of "unfinished", undetermined, and open to interpretation design artefacts when focusing on design approaches that facilitate design-after-design. Empirical uses of design-after-design are explored in studies that range from software targeted towards healthcare [35], to data collection frameworks [15], to supporting user's product adaptations [28] or as a tool to generate new designs from users' re-purposing [5], with all those studies attributing an active design role to the user, due to their ability to discover new uses and re-purpose artefacts. Design approaches which focus on design-after-design in museums have the potential to incorporate that active design role in the visitor experience, supporting the visitors in pursuing their interests when it comes to engaging with the interactive artefacts. Furthermore, such a process can address the tension between stakeholder' expectations and playful visitor behavior [24], by using the post-deployment re-purposing of museum artefacts by the visitors as inspiration for re-designing the artefacts in ways that both visitors find engaging and stakeholders see value in their dissemination qualities [1].

3 METHODOLOGY

For the purposes of this experiment, we adopted the method of research-through-design [18, 30] as part of a research program which explores designing for the re-purposing of playful artefacts in the exhibitions spaces of cultural institutions. That method has the potential to submit artefacts that generate a discourse regarding the role of re-purposing in museum spaces, the design implications of releasing open-ended artefacts, and how to use the resulting re-purposing to re-design those artefacts.

Our approach follows an iterative design process that we proposed in a previous research effort [1] (figure 1). Employing Davis' theory of affordances [12], we have suggested that the process of designing for design-after-design may be conceptualized as initially designing *allow* affordances – i.e. neutral affordances which do not directly support or deny specific behaviors – and in later iterations transform these into *encourage* or *discourage* ones – i.e non-neutral affordances that either suggest or oppose specific behaviors, while never prohibiting them.

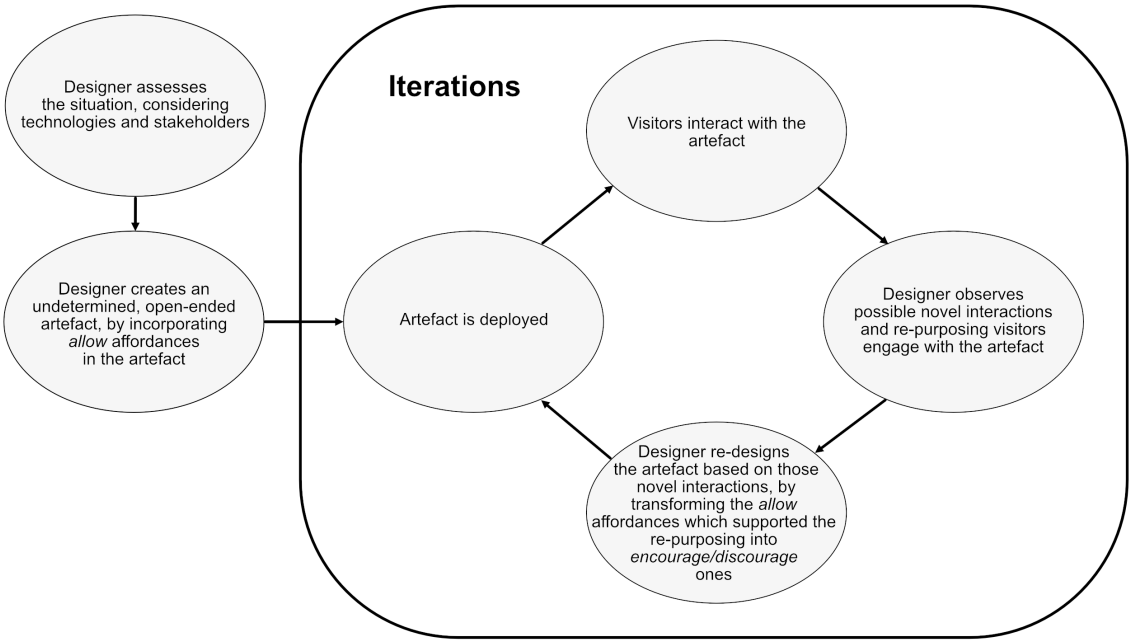

Fig. 1. Design Process

Initially, the designer assesses the design situation at hand and, then, deploys an undetermined, open-ended artefact which primarily supports *allow* affordances – specifically regarding the elements that the designer wants the user to re-purpose. Following that, the designer observes the user interaction with the artefact looking for novel uses and re-purposing. Finally, the designer re-designs the artefact based on what was observed, looking for ways to transform the *allow* affordances which were used in those novel uses into *encourage/discourage* ones, thus giving future visitors support to uncover those discovered uses easier. The idea behind that transition is that *allow* affordances are neutral and do not suggest specific ways of interacting, while *encourage/discourage* are suggesting possible uses of the artefact to its user. By transforming those affordances the object now provides "suggestions" through encouraging the visitor, or discourages the visitor away from specific behaviors. Through that transformation, we still maintain the open-ended quality of the artefact since we do not prohibit any specific behavior – all previous behaviors are still possible – while we also highlight its engaging qualities as discovered by past visitors. Maintaining that open-ended quality helps the further iteration of the process to reveal further novel uses.

To test that process we developed and deployed in-the-wild [8] *Light house*, an installation about Architecture and playing with natural and indoor light during the various seasons in Denmark. Through that, we went through one iteration of the suggested process. *Light House* was developed as part of the first author's PhD project in collaboration with the NN institution – an institution dedicated to the dissemination of architecture. Our experiment began in December 2020, once its development began, and ended in October 2021, once the installation was removed from the exhibition space. During that period, as part of the evaluation of *Light House*, we gathered data – through note-taking – from meetings and discussions with the NN management stakeholders, and *hosts* – i.e. floor staff that are responsible for

having conversations with visitors regarding architecture and facilitating their experience. We also conducted personal observations of visitors interacting with our artefact, with the primary author carrying out four scheduled observations of approximately two hours each, while also engaging in daily ad-hoc observations as part of the institution's staff, both for observing novel uses and perform maintenance of the installation. Interesting behaviors were documented using photographs and note-taking.

During the design process, the first author was responsible for the design decisions and was largely free to make those decisions. The stakeholders held an advisory role, providing suggestions regarding which design elements fit their exhibition space, raising concerns based on their observations. The analysis of the results was conducted by both authors.

Due to the ongoing pandemic of COVID-19 there were difficulties when studying visitor interaction, both due to reduced visitor numbers as well as social distancing policies.

4 LIGHT HOUSE

In our previous endeavor [1] we employed the suggested design process to design an installation that focused on visitor creativity and self-expression – i.e. interactions through which visitors can create something – through the supply of tangible artefacts. That support for creativity proved to be fertile ground for re-purposing. Following that experiment, we wanted to challenge our design process by designing an artefact that aimed to be a playful and interactive, while minimizing possibilities of self-expression on its core interaction. By doing so, we wanted to capture how the visitors would re-purpose the artefacts interactions when self-expression is not in the center of the experience, and what do those results tell us regarding potential re-designs – step six in the proposed design process (figure 1).

With *Light House* we aimed to set up a small installation inside an exhibition space dedicated to family interactions and learning. That decision was made primarily because *Light House* was going to be a playful installation, deemed as a good fit for families. The core elements of that installation were agreed to be the following four: (1) the installation should focus on the senses and, specifically, light, (2) its interaction elements should be oriented towards families with children, (3) the installation should be open-ended supporting the discovery of novel interactions by visitors, and (4) interaction elements which support interactions related to self-expression should be kept to a minimum, thus, challenging the activity of re-purposing.

Our development of the *Light House* installation began in December 2020 with a conceptual design that was subsequently turned into 3D renderings (figure 2). The institution's stakeholders wanted to explore the theme of light and architecture. That focus was motivated by the potential for interactive lights to expose that architectural element, contrary to traditional means of architectural dissemination. As a result, the *Light House* was designed around helping visitors explore the following question:

> How can the combination of natural and artificial light affect the mood of indoor spaces?

We wanted to support interactions between children and their guardians, since the installation would be placed in the educational space targeted towards them. That led us to use a small plywood house model (130mm tall, 100mm wide, 100mm deep) which was re-purposed from a previous exhibition. The house had a window on the right wall and another window on the left side of the roof. That choice was based on the different sizes between children and guardians. Children could enter the house and experience it in the inside, while guardians can reach the roof window and look inside.

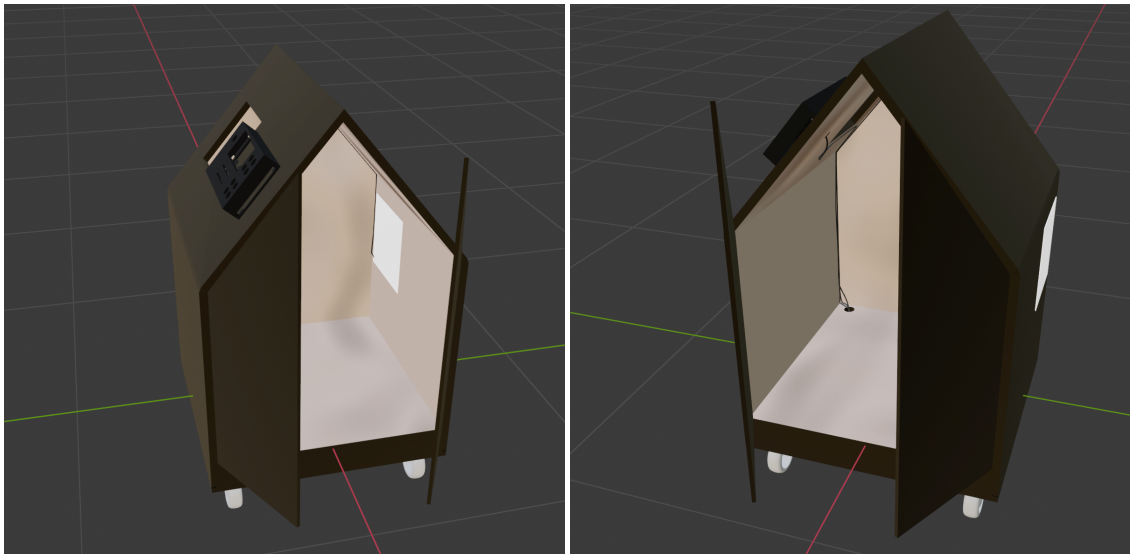

Fig. 2. 3D rendered sketches of *Light House*

Another aspect of *Light House* was its lighting. The installation had one smart bulb – emulating indoor artificial light – and one smart LED strip – emulating outdoor seasonal light. The visitor could control the settings of the lighting through the control panel that we installed on the roof of the wooden house. We selected that location for the panel to give the controls to the guardian, while children can experience the changes from the inside. The control panel (figure 3) consisted of (1) a 3D printed case, (2) eight buttons that controlled the light settings of the LED strip, (3) one showcase button, (4) two potentiometers which controlled the light settings of the indoor light bulb, (5) a Raspberry Pi and Arduino pair that process the inputs of the panel, (6) a screen that was was connected to the Raspberry Pi and acted as a digital label which displayed the current setting of the lights. Through the panel, the visitor were able to select the season (Winter, Spring, Summer, and Autumn) and time of day (Morning, Noon, Evening, Night) using the white buttons on the right of the screen. The selection would determine the color and intensity of the LED strip. They were also able to change the color temperature and intensity of the indoor light using the potentiometers. The transparent button on the left initiated a sequence during which the LED strip light would go through all the settings, beginning on *Winter Morning* and changing to the next chronological setting every two seconds – *Winter Noon*, *Winter Evening*, and so forth. We designed the panel to fit the design of the surrounding education space. That space contains various buttons on its walls that all initiate different interactions. Due to that, we used buttons as a central interaction element, so that the interactions would follow those of its surrounding space.

A set of curtains was added to create an enclosed space for two reasons: (1) to make the effect of the artificial light stronger by blocking the ambient light of the educational space and (2) children regularly play hide and seek in the educational space – multiple hiding spots due to how the space is designed – and we wanted for *Light House* to facilitate the common interactions that occur in the surrounding space. Finally, we included a set of furniture inside the house – a chair, a table, and a stool (figure 5) – to create a home setting as seen through the window and when children enter inside – and a small black stool outside.

(a) Control Panel and Sign (b) Outside Space

Fig. 3. Initial Deployment of *Light House*

To support playfulness we focused on elements of exploration and social interactions. Regarding exploration, we left the installation largely open for people to pursue their own intrinsic motivations (i.e. set up their own goals). Regarding social interactions, the installation invited multiple visitors to cooperate (one using the panel while the other one experiencing the house from the inside).

5 FINDINGS

The *Light House* (as seen on figure 3) was deployed on the 23rd of April 2021. In our observations, the installation was mainly used as a space that visitors used to support of their regular activities in the educational space. Children enjoyed using its space for various activities – e.g. using it as a hide and seek spot, taking out its furniture in the surrounding space, bringing books or toys and using them inside the wooden house instead of the surrounding chairs and couches (figure 5). Visitors would occasionally also interact with the control panel for the lights, however most seemed to be confused and would quickly give up and turn their attention elsewhere. They seemed uncertain regarding the purpose of the installation and what was expected of them during their interaction with it.

In fact, the installation was confusing not only to the visitors but also to some of the stakeholders of the institution. For instance, when visitors asked the floor staff to assist them, staff members often struggled to help them. One staff member explained that visiting parents wanted to use the educational space to teach something to their children but

when it came to the *Light House* they could not understand how to use it in order to educate their children – with the floor staff being uncertain of the same thing. Another staff member brought her own three years old daughter to the educational space and found that she very much enjoyed playing in the *Light House*'s space, however she did not understand the changes in the light as different seasons, but rather seemed to enjoy experiencing its enclosed space and the changes in the light color.

Fig. 4. Interior of *Light House*

After some time (14th of July 2021) the installation was re-positioned and the curtain was removed (figure 6). That decision occurred after meeting discussions with stakeholders regarding how to make the installation more approachable and less confusing to the visitors. Initially, the visitors encountered the panel side of the installation when they entered the space. With the new position, the visitors encountered the entrance to the house instead. This seemed to enhance children's use of the installation as a physical playground. Children were more engaged in running in an out of its space and bringing toys to play with in the wooden house. However, without the curtains visitors used it similarly to the rest of the educational space objects, and did not seem as engaged to explore its interaction elements of light or use its space, rather they used it as another physical object of the educational space. On the 11th of October 2021 the installation was removed from the exhibition space.

Fig. 5. Integration with educational space

6 DISCUSSION

The *Light House* was designed as an object that would help visitors discover new uses of its interaction mechanics – control panel and lights. However, when it came to interaction with the features that the control panel supported, visitors rarely spent more than ten seconds interacting with the panel. Instead, the visitors re-purposed its space by

Fig. 6. *Lighthouse* without curtain

engaging with other activities in the house – as a hide and seek spot, a reading spot, playing with puzzle pieces, or taking its furniture out into the surrounding space. To explain why its interaction mechanics were not engaging while at the same time the re-purposing of its space was, we first need to distinguish between two main classes of affordances. The **first** class relates to the **interaction elements** of the installation. Affordances in this class are the buttons of the panel that change the light and mood. The **second** class relates to the **space** enclosed by the installation. Affordances in this class are the possibility of moving furniture and objects in and out, and its possibility to act as a hiding space, a reading space, and generally a space that invites visitors to incorporate it in their activities.

We will now analyze those affordances in terms of *allow* and *encourage/discourage* [12] as described in our design process. Regarding the first class of **interaction elements** affordances, it only contains the interaction with the buttons and potentiometers which control the light. Those interaction elements only accept specific inputs – press for the buttons and slide for the potentiometers – while *refusing* others. *Refusal* can be problematic since it limits the amount of possible undiscovered uses. The tactile elements of the buttons, *encourage* the visitors to press them, and it is difficult to imagine how a visitor could re-purpose such an interaction. Buttons generally do not *allow* other uses than pressing. To that extend, we failed to employ *allow* affordances in the **interaction elements** which could be the reason why visitors did not re-purpose those core interactions. Comparing that to the second class of affordances related to **space** we can see that on that second class all the observed behaviors – using it as a hide and seek spot, a reading spot, playing

with puzzle pieces, or taking its furniture in an out to the surrounding environment – are results of *allow* affordances. Specifically, they stem from the quality of the installation to encompass the surrounding playfulness of the **space** while also having an individual character – the colorful light attracts attention, while there is no other small wooden house the educational space. Visitors have limited expressive control over the *Light House*. The buttons control the state of the two smart lights, and no matter how many choices there are in the forms of buttons and potentiometers, in the end there are only two elements that the visitors can control and that is the status of those two lights. That stemmed from our purpose to challenge the design process and limit the expressive control that the core interaction supported. On the other hand, the **space** of the *Light House* does not impose the same limits, which could be the reason why visitors were able to discover ways to use that **space**. It seems possible that these results are due to visitors being drawn towards re-purposing elements that indeed support self-expression – the **space** in our case. It might be important then to consider not just whether or not there are *allow* or *encourage/discourage* affordances in place, but also if those affordances can be combined to create diverse self-expressive interactions. In our case the visitors found engaging to integrate the house's **space** in their other activities – e.g. hide and seek, reading books et cetera – while did not actively engage with the panel settings. Those two interactions seem disconnected, since one is focused on learning about light and architecture through altering light settings, while the other sees the *Light House* as a colorful enclosed sensory **space** with various uses. A possible solution here would be to re-adjust the light options to enhance those new uses of the house's **space**. For example, instead of focusing on the seasons, we could focus on activities: reading setting, blackout setting, disco light et cetera. Through that, we could highlight the sensory aspect of its **space** that were its main attraction. Overall, we made a number of false assumptions in our design. First, we tried to make the design open by leaving its purpose open. At the same time, we purposefully tried to limit the expressive possibilities of the **interaction elements**. In our observations, that seemed to hinder visitors' re-purposing of those elements. Second, even though we considered possible interactions with the surrounding space, our considerations were limited. Visitors seemed drawn into those possibilities. A better incorporation of the surrounding space could potentially support new uses by supporting visitors using external elements in combination with the installation.

Our original purpose was to initiate a design process that would support the re-purposing of our artefact's **interaction elements**. We hypothesized that visitors would discover new ways to interact with the elements of our artefact due to the open nature of its interaction. To that regard, we failed to discover new uses for those elements – i.e. the interactive lighting through the control panel. However, we ended up discovering new uses of its **space**. Our findings show that visitors might be drawn to self-expressive mechanics of interaction when it comes to re-purposing artefacts, and by shifting our focus towards supporting those mechanics through the **interaction elements** of our installation, we can potentially assist visitors to discover new creative and playful ways to incorporate that installation into their visit in ways they seem fit, based on their personal motives and interests.

7 CONCLUSION

In summary, through our research we set out to explore the need for extending participatory design processes to include the re-purposing that occurs when a user interacts with an artefact in post-deployment real use settings. To do so, as described on our methodology, we employed one iteration of an iterative design process that focuses on design-after-design (presented in our previous work [1]). Wanting to challenge our design approach, contrary to our previous work [1], we set out to deploy an installation that self-expression is not a part of its core interactions.

Our results show that, when distinguishing between the affordances of the interaction elements of the installation and its space, visitors re-purpose the latter. A possible explanation for this might be that the space interactions engaged with

allow affordances and provided larger expressive control – contrary to the rigid interaction elements which provided limited expressive control that *refuse* new uses. Furthermore, those two types were disconnected and, as a result, did not support each other. In other words, although we expected the visitors to re-purpose the interaction elements, instead they disregarded them and engaged with what they found the more interesting and expressive of the two, the space of the installation. A greater focus on understanding the connection of re-purposing, self-expression and *allow* affordances could produce interesting findings that account more for how can museums and designers employ those three elements to inform participatory design processes that extend through the post-deployment phase of artefacts. Our failure suggests that not including self-expression in specific elements challenges possibilities of re-purposing. It uncovered an unexpected re-purposing that we did not design for. Our research is preliminary and further research should look into how supporting or blocking self-expression can act as a potential strategy for designers to support the re-purposing of specific elements in their designs. When designing for design-after-design, blocking expressive possibilities in specific elements may lead to visitors re-purposing other elements. That has the potential to help with redirecting visitors away from experimenting with fragile elements, or revealing new uses of other interaction elements.

Furthermore, our experiment uncovered that the institution could benefit from setting up a space that includes similar architectural small structures where visitors can play around and include them when engaging with other activities that they find interesting. Related to that discovery, we believe that in the future it would be fruitful to explore how our process can be applied to extract details regarding what type of activities visitors find engaging with the surrounding space, with the goal of using those details to inform possible future projects that institutions can initiate.

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