The new Soundforest

The role of lighting in inclusive interactive museum installations

Master Thesis by Ines Bartl
Architectural Lighting Design
KTH Royal Institute of Technology
2021/22
# INDEX

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>4</td>
</tr>
<tr>
<td>Acknowledgments</td>
<td>5</td>
</tr>
<tr>
<td><strong>I. Introduction</strong></td>
<td>6</td>
</tr>
<tr>
<td>1.1 Ambient lighting and peripheral vision</td>
<td>6</td>
</tr>
<tr>
<td>1.2 Immersive Museums and Interactive Installations</td>
<td>6</td>
</tr>
<tr>
<td>1.3 Sound Forest</td>
<td>7</td>
</tr>
<tr>
<td><strong>2. Methodology</strong></td>
<td>8</td>
</tr>
<tr>
<td>2.1 Research and Design Phase</td>
<td>8</td>
</tr>
<tr>
<td>2.2 Testing Phase</td>
<td>9</td>
</tr>
<tr>
<td>2.2.1 Process</td>
<td>9</td>
</tr>
<tr>
<td>2.2.2 Limitations</td>
<td>9</td>
</tr>
<tr>
<td>2.3 Evaluation</td>
<td>9</td>
</tr>
<tr>
<td><strong>3. Matrix</strong></td>
<td>11</td>
</tr>
<tr>
<td><strong>4. Case Study - Soundforest</strong></td>
<td>13</td>
</tr>
<tr>
<td>4.1 Spatial Analysis</td>
<td>13</td>
</tr>
<tr>
<td>4.2 Technical Analysis</td>
<td>13</td>
</tr>
<tr>
<td>4.3 Existing Lighting Situation</td>
<td>14</td>
</tr>
<tr>
<td>4.4 Universal Design Analysis</td>
<td>14</td>
</tr>
<tr>
<td><strong>5. Design Process</strong></td>
<td>15</td>
</tr>
<tr>
<td>5.1 Objectives</td>
<td>15</td>
</tr>
<tr>
<td>5.2 Materiality</td>
<td>15</td>
</tr>
<tr>
<td>5.3 Concept</td>
<td>16</td>
</tr>
<tr>
<td>5.4 Prototype</td>
<td>17</td>
</tr>
<tr>
<td><strong>6. Testing Results &amp; Observations</strong></td>
<td>18</td>
</tr>
<tr>
<td>6.1 Observations during the Interaction</td>
<td>18</td>
</tr>
<tr>
<td>6.2 Informal Interview &amp; Questionnaire</td>
<td>18</td>
</tr>
<tr>
<td><strong>7. Discussion &amp; Conclusion</strong></td>
<td>19</td>
</tr>
<tr>
<td>7.1 Ambient Lighting as additional factor for positive emotional experiences</td>
<td>19</td>
</tr>
<tr>
<td>7.2 SoundForest in comparison with other interactive installations</td>
<td>20</td>
</tr>
<tr>
<td>7.3 Further development of the design draft</td>
<td>21</td>
</tr>
<tr>
<td>7.4 Conclusion</td>
<td>22</td>
</tr>
<tr>
<td><strong>8. References</strong></td>
<td>24</td>
</tr>
<tr>
<td><strong>9. List of Figure</strong></td>
<td>25</td>
</tr>
<tr>
<td><strong>10. Appendix</strong></td>
<td>27</td>
</tr>
</tbody>
</table>
ABSTRACT

This thesis focuses on creating an interactive installation as immersive experience for hearing-impaired user. To date, little research has been conducted especially on interactive (sound) installation for impaired visitors, particularly these visitors with hearing impairments or who are hard-of-hearing. Based on literature research and a case study, a new lighting design proposal was developed for Soundforest, an interactive musical installation at Scenkonstmuseet in Stockholm, Sweden. The audio-experience is enhanced ambient lighting, which alters in brightness depending on the interaction of visitors. For evaluation, a prototype was set up in the installation space and tested by one participant. The first testing leads to the assumption that the additional layer of ambient lighting can enhance the emotional experience of the visitors. The results show that the test person had great pleasure in interacting with the prototype. Still, to develop a full picture of the consequences and emotional effects, additional research is required.

Key-words: light installation, interactive light, immersivness, inclusive design
ACKNOWLEDGMENTS

Firstly, I want to thank my tutor Lars Annersten for being so enthusiastic and supportive about this project, as well as Scenkonstmuseet Stockholm for giving me the opportunity to use their exhibition space for analysis and testing.
I would also like to thank my Supervisor Federico Favero, who not only introduced me to this real case project, but also supported and motivated me throughout the whole process.
I also want to thank my participant for his time and commitment to the prototype.
Finally, I am thanking my friends who always believe in me helped me through times of doubt.
I. Introduction

Lighting helps to create atmospheres [1], particularly when it comes to immersive light installations. These installations have a significant impact on the human perception of a space and the person in it, can create a truly emotional experience, and “shape the visitors behavior” [2]. Lighting can create fantastic or unreal situations and change the appearance of a space. How can this experience be measured and how do you analyze the light in such spaces? One of the aims of lighting a space is to provide adequate perceived brightness in order for all users to perform visual tasks safely. There are standards, codes and recommendations, which describe quantitative categories such as illuminance (lux), luminance (cd/m²) or uniformity to measure light. However, there is more to a well illuminated space than measurable units. What is the perception of it? How does it feel to be in the room? What kind of atmosphere is created?

I.1 Ambient lighting and peripheral vision

Richard Kelly described three principles of lighting: ambient luminescence, Focal Glow and Play of brilliance. Ambient luminescence refers to the general lighting of a space. It ensures that architecture, objects, tasks and users are visible and safe locomotion is possible [3]. Focal Glow can be described as task lighting. By creating contrast, it draws attention to a certain element or area. It helps to structure a space and to create a visual hierarchy. Play of brilliance is light as information, it is “the special something” to a lighting situation, like reflections from a glossy surface. It can be striking or dynamic or colorful. A space can consist of one, two or all of the mentioned principles.

The retina of the human eye is divided into different areas. The center of the visual field is called the foveal area and is responsible for focal vision. It is responsible for defining depth and position of an object [4] and takes up only about 3% of the retina. The foveal area also contains a high number of cones, which are needed to perceive color. The non-foveal area is located at the borders of the human visual field and is responsible for the peripheral vision [5]. In these areas, the retina contains a high number of rods, which are responsible for scotopic (night vision) and low-light vision. Furthermore, the peripheral vision detects general changes in the environment such as movement and changes in the size of objects. It also detects contrast, intensity and color of light [6], which are needed tools for creating any lighting situation. Therefore, one can derive that with the help of peripheral vision, the atmosphere of a space is perceived, but also the ambient lighting in it.

I.2 Immersive Museums and Interactive Installations

In Museums, the atmosphere is an important dimension for the experience of a visitor [2]. Still, not only museums are interested in creating atmospheric experiences. Immersive installations can be found in many areas, for example in public spaces or in the retail sector. More and more immersive, and also, audio-visual installations are commissioned that keep the visitors engaged and interested, which lead to a longer and more frequent stay, for example in museums [7]. This circumstance can likely be the reason for an increasing number of interactive museum installations: Different disciplines such as lighting design and sound design, coding, video and projection art and live-data analysis are being merged to immerse the visitor in a new context and her/him become an active designer of the environment within a certain context. The user becomes a creator. Still, the interaction does not only happen in relation to the art piece, but also in relation to fellow human beings [8]. Regarding the relationship between the interactive artwork and the audience, Edmonds [9] differentiates between the attributes of “attractor” and “sustainer”. An “attractor” is a property within the artwork or installation that creates curiosity among the audience, making it pause for a while and getting engaged. A “sustainer” sustains the user’s attention and gives the possibility or desire to explore, experiment or challenge oneself within the installation.
This raises the question of inclusivity. Who can experience and explore these installations? In the course of this work, few projects could be identified that simultaneously deal with both impairments and interactivity in the context of installations.

The 2030 Agenda for Sustainable Development from the UN includes two goals concerning this topic [10]. Goal 4 is Quality Education and states to “ensure inclusive and equitable quality education and promote lifelong learning opportunities for all”. Museums are educational institutions and “informal learning settings” [2]. Through the creation of accessible exhibitions and installations, museums can be used and enjoyed by all people regardless of their physical or mental abilities. Goal 10 wants to reduce inequalities within and between countries. The project in this thesis helps to create an immersive installation, which can be visited and enjoyed by everyone. People should not be excluded from positive emotional and learning experiences due to their condition.

Hearing impairments can be categorized into Conductive hearing impairment, Sensorineural hearing impairment (SNHL), Mixed hearing impairment and Central Auditory Processing Disorder (CAPD). SNHL indicates the damage or reduction of hair cells in the inner ear, which cannot be healed, supported by hearing aids. CAPD describes a difficulty to differentiate between sounds. The ears are not restricted, but the brain is not able to process the incoming information correctly. Please see Appendix E for more details on the different hearing impairments.

Another factor to consider when creating inclusive interactive installation is the possibility of light sensitivity. This means sensitivity towards visual stimuli. Around 20-40 % of the population are more sensitive in this respect than others. This can result in eyestrain, headaches, fatigue, migraines and pain in neck and shoulder [12]. If other factors such as dynamic and colorful lighting, music, projections, scents or touching surfaces and materials are added to this, it can lead to intense stress and make the installation unbearable for some people. A strobe light for example can generate a photosensitive seizure and result in discomfort and disorientation. Another example are people with autism, who can be overwhelmed by too many different influences. This may lead to a negative experience caused by the installation. The challenge is to find a good balance between an installation that is immersive and appeals to multiple senses, while at the same time not creating too many overwhelming stimuli.

**I.3 Soundforest**

*Soundforest* is an interactive sound installation, located in Scenkonstmuseet, the Swedish Museum of Performing Arts in Stockholm, Sweden [13]. It first opened in 2017 and includes compositions by various musicians and sound designers. Scenkonstmuseet was designed for visitors of different ages groups and diverse backgrounds. It manages to offer an accessible and approachable experience for young and old humans, impaired and non-impaired people, single visitors, and families. The museum aims to give all visitors the possibility to explore various branches of performing arts, like dance, theater, music making and performance, and at the same time “engage visitors, provide rewarding experience that stimulate learning and motivate visitors to return to the museum”[14]. *Soundforest* is focused to an inclusive approach. Accessibility was one of the main design principles when developed, according to Annersten, who is the exhibition manager at Scenkonstmuseet and was involved in the overall development of *Soundforest* [15]. The goal was to create a unique experience for visitors with impairments. Furthermore, with its responsive vibrating floor panels, *Soundforest* sets a focus...
on hearing impaired people. So does the existing lighting of the strings. Even though, the effect is small (the color of the strings changes from green to white) a change in environment is recognizable, when a user interacts with the installation.

This thesis aims to answer the research question *How can lighting support the experience of a sound installation for hearing-impaired visitors?* The goal is to create a rich emotional experience for hearing impaired visitors within the frame of *Soundforest*. Starting from an existing set-up, a new lighting concept is developed which intends to focus on immersive experiences, as well as translating the sound to light in an interactive way. The user is encouraged not only to watch, but to change the environment. According to [16], developments in technology “have the potential to increase access and enable opportunities for disabled persons, allowing these members of the public having more inclusive available ways to understand and interact with exhibitions, contributing to a better experience while visiting museums.”

The next chapter describes the procedures and methods used in this investigation.

### 2. Methodology

The process for answering the research question is divided into three phases.

1. Research phase
2. Design phase
3. Testing phase

#### 2.1. Research and Design Phase

During the Research Phase, a literature review of existing interactive light and sound installations is performed. Some research keywords are interactive museum installations, inclusive art installations, interactive light and sound installations. Based on that, a matrix is developed, which shows an overview, comparison, and connections of these installations.

(Fig. 03) *Process of Literature Review. It was conducted in the fields of sound installations, light installations, interactive installations and inclusive installations. The thesis project includes all four topics.*

Furthermore, a case study of the existing installation Soundforest is performed. Spatial and technical conditions, as well as the existing lighting conditions and limitations are analyzed. For analysis regarding inclusiveness the principle of Universal Design [17] is used.

In the Design phase, gained knowledge is used to develop a new lighting proposal for Soundforest on a conceptual level.
2.2 Testing Phase

For the testing phase, a prototype of the lighting concept is set up in the original space of the existing installation. The prototype is evaluated by one testing subject, who is invited to explore this very in person. The subject is male and has a hearing impairment since an illness with meningitis. In everyday life, the participant is using a Kanso 2 Sound Processor and a regular hearing aid in his left ear, which are also worn during the testing.

2.2.1 Process

Before the subject enters the space of Soundforest, the functionality of the existing installation as well as the basic design principles are explained. Firstly, the participant is testing the original function of the installation on cords placed outside the prototype in order to familiarize himself with the installation. Thereupon, three different lighting scenarios are carried out with the test person within the prototype. Between each scenario, the participant is asked to step outside the installation in order to adjust the settings. The participant is informed that there are changes, but not what they are. The changes to the lighting during the scenarios are done manually via a fader on the tablet.

Scenario A: No additional lighting is added to the existing installation. When interaction with one of the strings is detected, the brightness of the canopy increases. A single interaction (which results in a single sound response on the part of the installation) leads to an increase in brightness from 0 to 30% in about 2 seconds. A double interaction (which results in a two-fold sound response on the part of the installation) leads to an increase in brightness up to 60%. Multiple interactions (which result in a multi-layered sound response on the side of the installations) lead to an increase up to 100%. Once the participant stops “playing the string”, the brightness decreases again to 0% within 3-4 seconds (synchronal to the existing color change of the strings).

Scenario B: Static ambient canopy illumination on the lowest possible dimming level is added. When interaction with one of the strings is detected, the brightness of the canopy increases, following the same process as in Scenario A.

Scenario C: The brightness of the spotlights around the strings is set to 100%. When interaction with one of the strings is detected, the brightness of the canopy decreases. Single interaction leads to a decrease in brightness from 100 to 70% in about 2 seconds. Multiple interactions lead to a decrease up to 0%. When no interaction is detected, the brightness again increases to a 100% within 3-4 seconds (synchronal to the existing color change of the strings).

2.2.2 Limitations

Due to time limitation of this thesis to 10 weeks, only one run-through (light concept development, prototype, testing, evaluation) of an iterative design process is possible. With more time and resources, the principle of Iterative user-interface design could be conducted more detailed. After the first evaluation of the design, it would be revised and refined, resulting in a new design. This will be again evaluated. Such a process can last several rounds and helps to create the best user experience [8].

2.3 Evaluation

The evaluation of the participants experience is based on Bilda’s paper [18] and [19]. The prototype is evaluated via a questionnaire following the practical testing and an informal interview about the experience afterwards. The interaction with the three scenarios as well as the interview are recorded for easier evaluation afterwards. Herefore, consent form is filled out by the participant (see Appendix C). Even though, video-recording has been proven to be useful [20], it was waived for this testing procedure. Filming the whole space/scene was tested on the day of the set-up. The space was too dark to be able to recognize actions accurately. For displaying the emotional experience, the Circumplex Modell of Emotions by Russell (1890) is used. Furthermore, videos and pictures of the different scenarios were taken after the testing with the participant is done, in order not to distract the same.
Research Question
How can lighting support the experience of a sound installation for hearing-impaired visitors?

RESEARCH PHASE

Literature Review
Background & Reference Projects

Case - Study Soundforest
(spatial & technical analysis, Universal Design analysis, current lighting situation)

Matrix

DESIGN PHASE

Lighting Concept

TESTING PHASE

Prototype + Testing

Qualitative Evaluation

Results

Discussion

(Fig. 04) Flow-chart of methodology
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ginger Leigh, 2018</td>
<td>Durero Studios, 2015</td>
<td>Papersneaker Design Studio (Natalie Wong), 2019</td>
<td></td>
</tr>
</tbody>
</table>

**Location**
- USA
- Museo Nacional del Prado, Madrid, Spain
- HART HAUS, Hong Kong

**Description**
- Conduit [25]: This sound installation explores psycho-acoustics through layered harmonic frequencies. Six pedestals are arranged around a sculpture, which is made out of 6 panels. These are each etched with a symbol that corresponds to its relative wavelength in relation to the other frequencies and the fundamental. Each activated frequency lights up one panel. Each participant can choose, if the created sound will be added or excerpted from the combined complex tone which each person hears collectively through individual headphones.
- Touching the Prado [22], [23]: 6 paintings (among others by Leonardo Da Vinci, Francisco Goya and El Greco) have been reproduced 3-dimensionally in order to make them palpable and touchable. It includes text in braille and audio guides, as well as opaque glasses, which gives the same experience for fully sighted visitors.
- Playloop [24]: 12 cylindrical structures including 1000 LEDs and built-in speakers are arranged in a circle. Users start and stop the melody emitted from each structure in real-time via moving their hands above the surface. When the motion sensor is active, the color of the light changes as well. When no motion is detected, the installation remains silent, and the stems emit one uniform color.

**Used Technology**
- Conduit [25]: MaxMSP, Arduino, addressable LED’s (neopixels), etched acrylic, conductive materials
- Touching the Prado [22], [23]: Special ink, chemical treatment
- Playloop [24]: LEDs, speakers, motion-activated sensors

**How many people can interact?**
- Conduit [25]: 6
- Touching the Prado [22], [23]: 6 - 12
- Playloop [24]: 12

**Which impairment is addressed?**
- Conduit [25]: non-specific
- Touching the Prado [22], [23]: blind and visually-impaired
- Playloop [24]: non-specific

**Type of interaction**
- Conduit [25]:
  - Interaction with the installation
  - Participants can interact with each other
- Touching the Prado [22], [23]:
  - Interaction with the artwork
  - No necessary interaction with other visitors
- Playloop [24]:
  - Interaction with the installation
  - Participants can interact with each other
  - Users can take the position of an “active artist” interacting and a “passive observer” watching what other people are creating

**Expected response**
- Conduit [25]: Lighting up panels, changing in the sound composition
- Touching the Prado [22], [23]: None
- Playloop [24]: Turning sound on and off, changes in the color of light

**Similarities & Differences to Sound-forest**
- Conduit [25]:
  - Making the sound visible
  - Can be played alone or with several people
  - The light source is the element of interaction
  - No additional lighting within the space
- Touching the Prado [22], [23]:
  - No response is triggered by the interaction
  - Mostly likely not done together with other visitors
  - Located in an accessible museum
- Playloop [24]:
  - The element of interaction is the light source in the space
  - The installation motivates to move [4]
  - Can be played alone or with several people
  - No additional lighting within the space
  - The music only stops when the user “turns it off” it is not programmed

---

(Fig. 05) Matrix of chosen projects. From the resulting matrix, 5 projects were selected to be analyzed in more detail. The criteria for the choice are the following: inclusivity refers to both light and sound, the visitor can change the environment and the atmosphere that prevails in it, similar technologies are used, an inclusive design, approach is more or less part of the design, number of people that can interact at the same time ranges around five (part 1).
As can be seen in the selected projects, and as became apparent in the course of research for this paper, it seems like there are very few interactive installations specifically designed for user with impairments. Nevertheless, the issue of inclusivity in museums (or inclusive installations) has received more and more attention in recent years. There are fortunately some projects dedicated to this issue. For example, there is a research project supported by the EU Erasmus+ program that “aims to create opportunities for volunteers with distance to the labor market. By doing valuable volunteer work for museums in cultural heritage and education, people can develop themselves and be part of the society” [26]. Furthermore, there is the Inclusive Museum Research Network, which was founded in 2008 and includes various museums around the world. It is dedicated to the question of what the role of museums is in the future and how they can become more inclusive [27].

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Designer, Year</th>
<th>Interdisciplinary project at the University of Applied Sciences Mainz, 2012</th>
<th>Studio Joseph, in collaboration with 65 contemporary designers, 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>New York, NY (Cooper Hewitt Smithsonian Design Museum)</td>
<td>Old, empty container boat at Luminale (first version), Frankfurt am Main, Germany</td>
</tr>
<tr>
<td>Description</td>
<td>8 interaction objects (each made out of 68 elastic cords, a piezo sensor, LED chains, a speaker and a video Control unit fastened on a substructure which is weighted down by sandbags) are distributed around the room and connected by a net out of white cords, which are illuminated by ultraviolet tubes. When the visitors play the elastic cords of the interaction objects, animations start to play on the surface of this specific object. The sound is divided into two layers. The first layer is an eight-channel sound projection, which constantly moves through the space and is designed to be the base sound. The second layer is generated by interacting with the strings, which generates “a rhythmic and spatial counterpart”.</td>
<td>The exhibition includes 65 projects and 40 objects and installations to touch, feel and smell. It features direct sensory experiences incorporating haptic, olfactory, and auditory installations, like a touch-activated musical fur-lined wall, scratch and sniff paper, a food scent diffusing “clock”, that signals meal-time to peo-ple with dementia, color-chancing lights.</td>
</tr>
<tr>
<td>Used Technology</td>
<td>Piezo elements, LED lights, ultraviolet light tubes, speakers</td>
<td>Wind machine, motions sensors, projectors, touch-sensitive sensors, touchable maps, T-coil–complaint audio devices, audio descriptions</td>
</tr>
<tr>
<td>How many people can interact?</td>
<td>1 - 35</td>
<td>Depends on specific installation</td>
</tr>
<tr>
<td>Which impairment is addressed?</td>
<td>Non-specific, but not accessible for visitors with motor disabilities</td>
<td>Visitor with dementia, hearing-or visual impairments. Generally, it offers a multi-sensory design approach to include all people</td>
</tr>
<tr>
<td>Type of interaction</td>
<td>• interaction with the installation • participants can interact among each other • users can take the position of an “active artist” interacting and a “passive observer” watching what other people are creating • 2 modes of interaction: automatic moderation and manual moderation (see [5] for detailed description)</td>
<td>• interaction only with the installations, not necessary among other visitors</td>
</tr>
<tr>
<td>Expected response</td>
<td>different sound and light effect emitted from each element</td>
<td>changes in scents, lighting and sounds</td>
</tr>
</tbody>
</table>
4. Soundforest - Case Study

4.1 Spatial Analysis

The installation is located in a rectangular room, which measures around 10 x 5m. Each short side of the room offers an entrance/exit. Since the floor has an additional structure to the existing flooring of the museum, ramps with small rise form the two entrance areas.

The space is located next to the outer wall of the building. The walls are made of massive stone, plastered and painted in white. A small, covered window is placed in about the middle of the length of the outside wall. The inner wall generates several offsets, creating niches on this side of the room.

The walls next to the opening on short sides are covered with full-length mirrors.

The floor consists of a wooden construction built on top of the existing floor and is covered with a light grey carpet.

(Fig. 07) Floor plan of Soundforest. The green field marks the area where the prototype is set up.

4.2 Technical Analysis

The current music at the time of the testing is composed by Claudio Panariello, composer and PhD student at KTH’s Division of Media Technology and Interaction Design.

The general setup is the following. A piezo microphone is connected to each string. It detects when the string is touched. A short, single interaction leads to a single respond in the form of a single bell sound. A slightly stronger or more frequent interaction leads to a double sounding of bells. When the interaction continues, the bell sounds add up to a more advanced and longer harmony. By using a code, any desired output (sound and light) can be programmed. The light is controlled via OSC and DMX. Messages from the OSC are translated to DMX in order to control the lights as desired. The translation from touch to light is individually programmable. For maintenance, the connection between strings and microphones are checked every morning by the museum personal. Twice a week soft and hardware is checked and updated by external employees.
4.3 Existing Lighting situation

Entrance and exits to the room are lit with three ceiling-mounted downlights each. The beams create a crooked line on the floor, which is caused by the alignment of the fixtures (zone 1a + 1b). A downlight, consisting of 8 LED sources, 4 blue and 4 green ones, arranged in a zick-zack pattern, lights the two corners (zone 2a + 2b) before entering the room. The installation room is illuminated by the 5 strings, which form the sound installation. The strings are made from intertwined fiber optic and a LED-string. In the current exhibition, the LED strings are green during resting state. When touched or played, they turn white. One ceiling-mounted spotlight illuminates the covered window (picture). Another ceiling-mounted spotlight lights the textboard giving more information about the installation.

4.4 Universal Design Analysis

The term Universal Design was defined by the Center of Universal Design as “the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design” [28]. At the University of North Carolina, seven principles were established to develop a broad guideline for designers [17]. These principles were used to analyze Soundforest installation. In general, it can be said that Soundforest and the Scenkonstmuseet are consistent with many points of Universal Design. However, elements that would improve the circumstances are seating in Soundforest, an instruction for the visually impaired in Braille or an audio introduction to simplify the handling. The complete analysis can be found in Appendix H.
5. Design Process

5.1 Objectives

In recent years, researchers have investigated a variety of approaches to interactive museum installations, how to create a good user experience [19] and how to evaluate them [30], [31]. The most favored experience-creating installations foster productivity, creativity and communication [32]. Similarly, Paloranta and his colleagues state [7], how research has shown that layering different levels of engagement lengthens the duration of usage.

In this case, the current layers ambient sound, sound created by the user, haptic feedback via vibrations and focal light within the strings. The added layer will be ambient lighting.

The new lighting concept for Soundforest aims to

- Create ambient lighting and include the whole space for an immersive experience
- Amplify the visual output when the strings are played
- “Making the sound visible”
- Visually connecting the strings when they are played at the same time

During the design process, the author wants to keep in mind the original design principles that were developed when first planning Soundforest as well as principles for designing an interactive museum installation Please see Appendix F + G for complete listing.

In order to give the concept development a realistic framework, certain limitations are established. It should be a realistic and feasible design which can be used to apply for fundings for future implementation at Scenkonstmuseet Stockholm. It should also give the possibility to test at least one aspect of the design within the timeframe of the master thesis on a limited budget.

5.2 Materiality

The environment in the space consists of the materiality of the given architecture (floor, ceiling, wall, mirror) and the construction of the installation (strings, vibrating floor panels). These are static elements. In addition, there are immaterial factors such as light, sound, air quality, temperature etc. (mobile).

The space, in which Soundforest is set, mainly consists of hard materials and surfaces, such as wood and brick. Like Haderer [33] mentions in her article about Veronika Mayerböck’s work, the relation and interaction between the body (of a visitor) and the surroundings (the space) is an important factor in order to create an immersive experience.
Alongside to a new lighting concept, the author suggests adding seating options in the niches of the inner wall. This can extend the time visitors spend in the installation and promote discussions between users. Hornecker and Stifter state in their paper [32] that “the content of installations can consist of the users’ very own activity, both in creating novel content and in providing a performance that is watched by others and simultaneously provides the core experience for the active person.” Experiencing interaction together with other people can increase pleasure of users, since the reaction is not limited to the installation, but also to fellow humans [8].

This concept is designed to keep the room abstract. It wants to give space for the imagination of the visitor. An interaction with the string triggers an increase of brightness in the light, which is spreading circularly away from the string, like ripples on water. When more than one string is played, the rings of light overlap and connect the musicians. After a short period of no interaction, the light fades back to stillness, meaning that the brightness decreases again.

To create contrast to the materiality of the space and the strong, hard, linear, and tensed strings, a soft, wavey, flowy ceiling element is added. This canopy can consist of a light material with semi-transparency, like fabric or paper. The goal is to make the ceiling to be perceived higher and as to open upwards. Due to the overlapping in some places, a mixture between lighter and darker spots is created, resulting in a playful and exciting appearance.

**[Fig. 13] Moodboard**

**5.3 Concept**

**[Fig. 14] Design Concept applied to Soundforest.** The flowing canopy contrasts with the linear strictness of the existing strings and the materiality of the space. It is also adding Ambient Lighting to the space.
5.4 Prototype

Thanks to the courtesy of the museum, the area of Soundforest is blocked for two days for the public. On the day before the actual testing, the prototype is set up at Scenkonstmuseet Stockholm. A relatively small area surrounding two strings is selected in order to be able to handle the setup and programming of the luminaires within one day and with limited resources. Following fixtures are borrowed from the Architectural Lighting Design Lab at KTH and used for the prototype: 5 Phillip Hue LED Spotlights, dimmable and controllable via Bluetooth for dynamic lighting. These are used for mimicking the desired ‘light waves’ spreading from each string as soon as an interaction is detected. In order to control the light effect, the fixtures are connected to a tablet using the Phillips Hue App. One group of fixtures is created for each of the string (String A, String B) included in the prototype.

Secondly, 2 dimmable LED spotlights from Hidealite, characterized by 3000K color temperature and a 25° beam angle are used for static illumination of the ceiling elements. These are connected with a manual dimmer each. All fixtures are mounted on the platforms containing the technical setup for each string.

As ceiling element, a canopy is created. Paper elements in A3 and A4 are mounted on the ceiling. Correlating to the design principles (creating contrast between the existing strict linear, hard space and the proposed soft, wavey ceiling design), an organic and apparent arbitrary arrangement for the paper elements was chosen in order to create a complex scenario. Each paper has straight cuts that both increase transparency and create stimulating shadow plays on the ceiling and walls, supported by the spotlights.

Both the wooden beams and the suspended ceiling are protected architectural elements. Therefore, tape is used for attachment of all components. Please see Appendix H

(Fig. 15) Prototype construction. The sketch represents a mounting platform of one string in Soundforest. Top view. The black fixtures represent dimmable LED spotlights from Hidealite, which are used for ambient lighting. The orange fixtures serve as Phillips Hue spotlights that mimick the circular spreading of light (orange circles)
6. Testing Results

6.1 Observations during the interaction

<table>
<thead>
<tr>
<th>Scenario</th>
<th>String A</th>
<th>Single response</th>
<th>Double response</th>
<th>Multiple responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td>17</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>string B</td>
<td>8</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>B</td>
<td></td>
<td>22</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>string B</td>
<td>7</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>C</td>
<td></td>
<td>12</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>string B</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

(Table A) Amount of Interactions. The table shows the number and type of interaction by the testing participant while interacting with the prototype. The numbers are based on the evaluation of the recordings.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Time of interaction</th>
<th>Observed behaviour</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3 min 29 sec</td>
<td>familiar with the installation:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Surprised by vibrations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(“Is it electricity?”)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• sounds of surprise</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• sounded pleased</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• enthusiasm about the synchronization (“It’s perfect!”)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• repeated Laughing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• questions about different set-up for each string</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• singing the melody of the bells</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• recognizing a difference in the sound of the two strings</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• exploring the full potential of the installation and that the sound adds up, creating new sounds</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• recognizing that the intensity of the light changed depending on the level of interaction with the string.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• excitement</td>
</tr>
<tr>
<td>B</td>
<td>3 min 58 sec</td>
<td>• laughing before beginning to play</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• sounds of understanding</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• laughing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• comments on the timing (“no latency. It’s good. It’s perfect”)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• proposing future use</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• testing the vibrations on the two different floor panels.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• wondering about the scales of the created sounds</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• mentions sensitivity of the strings</td>
</tr>
<tr>
<td>C</td>
<td>2 min 26 sec</td>
<td>• feeling the vibrations more strongly</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• recognizing the opposite change of light (from light to dark)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• trying to measure reaction time of installation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• enthusiasm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• sounds of excitement</td>
</tr>
</tbody>
</table>

(Table B) Observed behaviour. The table lists all the types of interaction and the resulting observed behaviour during each scenario, as well as the recordings of the testing.

6.2 Informal Interview & Questionnaire

The Circumplex Modell shows the emotions the participant felt before, during and after interacting with the prototype. The experienced emotions are located in the right area of the model, always tending toward pleasure, but varying in activation and deactivation.

In addition, the participant’s statements and exclamations which were expressed during the interaction, are assigned to the corresponding emotions (orange area). They represent high activity and pleasure and range from being alert and excited, to elated and happy to contented.
The role of the light within the prototype
- Lighting helps to make the sound visible
- Connection between the “movement of light” and the sound
- Recognizing differences between the three scenarios
- Preference of scenario A and B over C (increasing brightness in case of interaction)
- Vibrations of platforms appear more strongly during scenario B than during scenario A
- Additional interaction with other people may led to overload

The transcript of the interview can be found in Appendix A.

7. Discussion

7.1 Ambient Lighting as additional factor for positive emotional experiences

The participant seemed very happy about the appearance and functionality of the installation. It came to laughter and describing the situation as beautiful during the testing of Scenario A. He also seemed to be satisfied with the way how the installation responded to his actions. Sounds of understanding let assume, that the participant gets the expected results of the installations and that it “is doing what he wants”. Based on words of confirmation and understanding during the testing (“Yes, okay,” Ah, it’s the opposite”), the participant also seemed to comprehend how the installation is working and how he can trigger sound and light responses. [34] mentions, that a good balance between motivation and demand, which is not overwhelming yet triggering to explore, is a feature of successful interaction design (see Table B).

Already during Scenario A, the participant realized that a greater interaction with the string results in a greater response regarding sound and light. He seemed becoming more courageous, since the interactions got more frequent and more intense (see Table A).

The shortest time of interaction was measured in Scenario C. This also corresponds with the
statement during the interview ("I think, I liked to better when I touch it and it lights up"). Which is referring either to Scenario A or B, where the brightness increases, when the strings are played. This seems to be the general way of dealing with interactive installations. While creating the Matrix, no interactive installation in the Matrix of this paper which works with decreasing a parameter as a response to interaction. What stands out is the big enthusiasm of the participant. Observation during the testing and the answers in informal interview clearly show, that the subject was enjoying the interaction and the idea behind the new lighting concept. This can be seen in the evaluation of the questionnaire as well as the interview. It can be assumed that the participant did not notice that the changes in the lighting during the testing were made manually. Several times the excellent synchronization of sound and light was emphasized. It can therefore be assumed that the added dynamic lighting has a positive influence on the experience of Soundforest.

One thing stood out from a technical point of view is: While string B was played, considerably more double or multiple responses were created than through string A. This can either be due to more intensive and more fear-free interaction on the part of the subject. It can also be ascribed to the sensitivity of the Piezo element and how tightly the string is tensioned. String B seems to be more reactive and create more intense (more than two) bell sounds.

Unfortunately, it was not possible to gather more than one participant for the testing. This could be done in a next and more extensive study. The more affected people give their feedback, the more inclusive the design can become. In general, to meet the principles of iterative design, more developing and rounds of testing are needed [8].

7.2 Soundforest in comparison with other interactive installations

Regarding the matrix, Resonate has the most similarities with Soundforest, especially after the new lighting design was set up as prototype. The installation has a lot of commonalities with Soundforest from a technical and functional point of view. However, it differs in the translation into tangible vibrations and the aspect of inclusivity. It doesn’t offer vibrating elements, e.g., the floor platforms. Especially the first version of Resonate, which was installed on a ship, it can be seen critically in terms of accessibility for visitors with motor-disabilities.

Apart from the exhibition The senses: Design Beyond Vision and Touching the Prado, there is are very limited amount of exhibitions and installations for impaired and especially hearing-impaired people.
This is, of course, a pity in terms of working towards equality and freedom from discrimination in our society. The UN Sustainable Development Goals are a very good point of reference here. At the same time, this opens a new possibility for exploring and discussion in the field of lighting design. As an example, two museums are listed here that are dedicated to accessibility and inclusion. The Nelson-Atkins Museum in Kansas-City, USA does not only have an inclusive website, special programs and events for impaired people, but was also part of the Deaf Culture Project, which is a grand “to provide quality, accessible, and inclusive interpretive and educational programs for visitors who are d/Deaf or hard of hearing” [35]. The Henry-Ford-Museum in Detroit, USA, offers about fifty accessible programs per year, including touch tours and virtual verbal description programs for people who are blind or have low vision, sensory-friendly events for people who are on the autism spectrum, and programs for people with dementia and their care partners [36].

![Visual comparison between „Resonate“ and „The new Soundforest“](Fig. 19) + (Fig. 20) Visual comparison between „Resonate“ and „The new Soundforest“. Both installations consist of strings. In „Resonate“ they also create the ambient lighting, whereas in „The new Soundforest“, a backlit paper-canopy is added. Both installations use colored light to highlight the points of interaction. Photographs: Ines Bartl, 2022

Another point for discussion can be interactive Installations as co-creation projects. For example, in [37], visitors are involved in the development of the installation. People helped folding paper lanterns or wrote personal wishes on them, before they became part of Aki Ishida’s illuminated paper installation series. “Participant co-creation brings the designers and public together in creating shared ownership of the work. And finally, the sound and lighting design serve to unite these into a cohesive interaction.”

7.3  Further development of the design draft

In the interest of improving the prototype and therefore the lighting design concept, the author suggests the following changes to the proposed draft. The round installation boxes (see figure 10) above each string and the paper canopy should be installed on the same height level. As seen in during the testing, with the current design, there is a dark gap around the string (see figure 18) and the light does not start spreading directly from the string. Since the existing ceiling has different heights and color (old wooden beams with grey suspended ceiling in between the gaps), it is recommended to create a homogenous and light-colored background.
for the canopy. This could be an additional layer between ceiling and paper elements.

Another point that has stood out regarding the appearance is the creation of shadows on the upper parts of the wall due to the canopy. These can create a positive aesthetic reference to the topic of „forest” and represent the patterns formed by branches and leaves (see figure 23).

(Fig. 21) Suggested ceiling structure. Inserted ceiling between wooden beams and canopy. Should be at the same level with mounting platforms of strings

(Fig. 22) Suggested options for seating. The recesses in the wall offer the possibility to add seating in different heights for people to remain longer in the installation space and to experience other visitors interaction.

7.4 Conclusion

This thesis aimed to explore the role of lighting in inclusive interactive museum installations. As literature research has shown, there are not many interactive projects, which specifically focus on supporting a musical experience for hearing-impaired and deaf people by using light.

An approach was presented where, based on literature research and a case study, a new lighting design proposal was developed. For evaluation, a prototype was set up in the installation space and tested by one participant. The first testing regarding a new lighting concept for Soundforest in the Museum of Performing Arts, Stockholm, leads to the assumption that the additional layer of ambient lighting can enhance the emotional experience of the visitors. The results show that the test person had great pleasure in interacting with the prototype. Still, to develop a full picture of the consequences and effects, additional studies will be needed that focus on the experience of hearing impaired and deaf people without using their hearing devices. The small sample size did not allow to make generally valid statements regarding the effect of light in this context.
(Fig. 23) Undersight view of canopy. Here, the spotlights next to the left string are activated. Photograph: Ines Bartl, 2022

(Fig. 24) Shadows created by the prototype. Photograph: Ines Bartl, 2022

(Fig. 25) The new Soundforest. The canopy prototype in combination with the existing lit strings. Photograph: Ines Bartl, 2022
8. References


9. List of Figures

Fig. 01: Human Visual Field, sketch by Ines Bartl
Fig. 02: Correlated Sustainable Development Goals. Graphic by Ines Bartl. Based on data from https://www.globalgoals.org/ (accessed Nov. 11, 2022)
Fig. 03: Chart to visualize Process of Literature Review, by Ines Bartl
Fig. 04: Flow chart of methodology, by Ines Bartl

Fig. 07: Floor plan of Soundforest, drawing by Ines Bartl
Fig. 08: sketch of the technical Process in Soundforest, by Ines Bartl, 2022
Fig. 09: left entrance to Soundforest, photograph by Ines Bartl, 2022
Fig. 10: Soundforest Installation, photograph by Ines Bartl, 2022
Fig. 11: Concept circuit. Relationship between user, space and installation, sketch by Ines Bartl
Fig. 12: The spreading of the light, sketch by Ines Bartl, 2022
Fig. 14: Design concept for Soundforest, sketch by Ines Bartl
Fig. 15: Construction of prototype, drawing by Ines Bartl
Fig. 16: Circumplex Modell, Graphic by Ines Bartl. Based on data from https://psu.pb.unizin.org/psych425/chapter/circumplex-models/ (last accessed Dec. 11, 2022)
Fig. 17: Canopy ceiling, photograph by Ines Bartl, 2022
Fig. 18: Canopy from below, photograph by Ines Bartl, 2022
Fig. 20: Soundforest with the new prototype, photograph by Ines Bartl, 2022
Fig. 21: Suggested new ceiling structure, drawing by Ines Bartl
Fig. 22: Suggested options for seating, drawing by Ines Bartl
Fig. 23: Undersight view of canopy, photograph by Ines Bartl, 2022
Fig. 24: Shadows created by the prototype, photograph by Ines Bartl, 2022
Fig. 25: The new Soundforest, photograph by Ines Bartl, 2022

Table A: Amount of interactions, table by Ines Bartl
Table B: Observed Behaviour during testing, table by Ines Bartl
Appendix A - Transcript of Interview

Informal Interview (duration: 6 min 19 sec)

Author: I wrote down some questions. About some of them we already talked before. So, you have never been in Soundforest before, right?
Participant: No, this is the first time.

Ok, first time.

I haven’t looked at the questionnaire, but you were really excited when inside the installation?

Absolutely. That was the first thing. I was just so excited before I even went in there.

Yes.

And also as soon as I got in there even more.

Ok, nice

That was the first expression.

Ok

Absolutely.

The main idea behind this testing is to make the sound visible. To emphasize the interaction, you have. So do think that the lighting had any, like, did it help you...

It lifts it up.

Ja?

It does help.

Yes, ok.

Especially for people like me.

Ja.

With this, ja...absolutely. I think it also, just, I am sorry. Just let me know if I am too loud.

No, no, no. You are completely fine. Nobody is here.

Ok.

(Both laughing)

3rd person: I am just...pretending I am not here

(all laughing)

3rd person: I can move, if you want

No, don’t worry

Ah, what was I saying?

Âhm, that you felt that there is a connection or, that you felt a change in the setting of the lighting.

Oh Yeah, yeah, yeah. For me as... with these things (points at hearing aids), it’s perfect with the light and with the movement

Yeah. Ok.

That’s exactly also what, the stuff that I am using for my, for my thing.

Nice. Nice.

That’s exactly all these other things separate from sound.

And you realized, I remember when we went in for the third scenario...

Ja.

...you already realized, what was different. So in the third one...

I’ve..

It was the opposite.

Absolutely.

So it was going down when you were interacting with it. Âhm

And no latency. It was perfect.

Nice.

And it was, what was it? Two seconds before it...Anyway, It was, timing was perfect.

How was it for you, that, you know, the light goes off, when you play? Was it weird that it’s the opposite?

You are asking, which one I like the best?

Yeah. Yeah..Or what was the difference?

I think, I liked to better when I touch it and it lights up.

Ja.

Maybe it’s just...I don’t know why though.

You don’t need to...It’s just your feeling...

Yeah, yeah, yeah

...That’s valid enough.

Did you feel any difference between the first and the second round?

It’s probably in my head, but...

No...

I felt more vibrating floors.

Okay. Yeah, nice. Really nice.

Actually, I did feel, it did feel just, it was a little bit more later than the...I actually did try a different, I changed around a little bit.

Yes, yeah.

And I did feel a little bit more from one of the plates.
Okay. Interesting.
But, it might be in my head.
Ja. Ähm, normally, I mean, my original goal was to also work with interaction, to have two people...
Yeah, interesting...
...interacting with each other. Do you think that, do you think it would be nicer or do you think it’s overwhelming? Because you are so focused on what you are doing? Do you think it be enough, ähh, too much, if there would be more people doing the same thing? For me, just for me it might be a little bit to much with the sounds.
Yes, yeah.
Ahh, because I need to concentrate on just one thing.
Yes, okay.
It, no, no, it would be too much for me. But I don’t think for other people.
But regarding the sound, not regarding the...
The light...
...the light?
Only regarding the sound.
Yeah.
Okay, nice.
Definitely not the lights. Those I love.
Okay.
I love, I love the whole thing.
But that’s good. I am happy I got to try it.
Yes. But if you have any other comments or suggestions, what would be better in the future. Or what you would like to...
I’m gonna think about that.
Yes. Yeah, you can also, you have my e-mail. So you...
Yeah, yeah, also I have other things after this. It just got me excited. So we gonna be in contact.
Yes.
For sure about this. And I got things I need to show you as well.
Okay. Yes.
But I am definitely gonna think...Ahh, this is perfect.
Nice. Do you have any other questions or things you’d like to know?
Not right now.
Okay. I will, I don’t have it now, but I have a consent form from KTH, you probably know it. I will send it to you and maybe you can...
No stress at all.
I think I need it for official reasons. Maybe you can sign it, that you are okay with recording and stuff
Absolutely. Should we do that now?
I don’t have it with me. I will send to you via e-mail.
Whenever you want.
Okay. The official part is over.
But this is good. I am happy that I got to try it.
Yes.

Appendix B - Scan of questionnaire
Appendix C - Consent Form

This document was signed online. For queries please contact the author.

Research Consent Form / Samtyckesformulär
Title of Research: The role of light in inclusive interactive museum installations

Researcher: Ines Bartl, ABE School of Architecture and Built Environment, KTH Royal Institute of Technology
Thesis coordinator: Federico Favero, ABE School of Architecture and Built Environment, KTH Royal Institute of Technology
Tutor: Lars Ammersten, Exhibition Manager, Scenkonstmuseet Stockholm
Contact Information: Tel: +49 179 4227640
Email: ibartl@kth.se

Dear participant,

The study is part of a Master thesis and involves testing three different lighting scenarios within the space of the interactive installation Soundforest at Scenkonstmuseet Stockholm, a questionnaire about your experienced emotions during the testing and a quick informal interview afterwards.

Your written responses and audio output produced while performing the tasks in this experiment and during the interview will be recorded. Please note that the data collected in this experiment might be needed in future studies. Your authorization will be requested before proceeding with the use of your data.

The experiment will require 30 - 45 min during one session. You are kindly asked to keep your mobile devices in airplane mode and do not use any private laptop or computer. Please do not change the position of sensors and devices in the room and in general follow the instructions given by the research assistants.

There is no right or wrong way to perform the tasks, you should just try to complete it following researcher's indications. You may discontinue participation in this study at any time. Your name will not be disclosed at any time, and the information will be reported in such a way as to make direct association with yourself impossible. The data will be encrypted and kept on a private computer, and any further use of the data will maintain the participants’ confidentiality. The findings of this research will be published in a doctoral dissertation and a journal publication.

If you would like to learn about the results of the study, please contact me.

We thank you for your interest in this study.

CONSENT:
My participation in the study ‘The role of light in inclusive interactive museum installations’ is voluntary.
I will commit to the procedure of the experiment and I understand that, only with my previous authorization, my data might be used for future studies, and that I can withdraw this authorization at any time.

I have read the above information and I agree to participate in this study.

Date: ______________________
Name: ________________________________ Signature: __________________________

If you have any questions or concerns regarding your rights or welfare as a study participant, please contact the KTH Royal Institute of Technology’s Ethics Officer (Personuppgiftsombud) at: Research ethics advisor fkar9@kth.se, 087908272

This verification was issued by Scrive. Information in italics has been safely verified by Scrive. For more information/evidence about this document see the concealed attachments. Use a PDF-reader such as Adobe Reader that can show concealed attachments to view the attachments. Please observe that if the document is printed, the integrity of such printed copy cannot be verified as per the below and that a basic print-out lacks the contents of the concealed attachments. The digital signature (electronic seal) ensures that the integrity of this document, including the concealed attachments, can be proven mathematically and independently of Scrive. For your convenience Scrive also provides a service that enables you to automatically verify the document’s integrity at: https://scrive.com/verify

- 29 -
<table>
<thead>
<tr>
<th>Name, Designer, year, location</th>
<th>Description</th>
<th>used Technology</th>
<th>How many users can interact?</th>
<th>type of interaction</th>
</tr>
</thead>
</table>
| Intraspection, Ginger Leigh, 2022, USA | Intraspection is an interactive light sculpture that invites the user to connect with the illuminated structure and generate unique pulses of light through the own heartbeat | custom-designed optical sensor and software, LED pipes | 1 - many | • personal interaction with one self’s heartbeat and the resulting light pattern  
• User interacts with the installation. No necessary interaction between users  
• Several “performer”, several “visitors” |
| High Arctic, UVA, 2011, USA | High Arctic uses a combination of sound, light and sculptural forms to create an abstracted Arctic landscape for visitors to explore. | UV Torch, Projected animations, Audio of a read poem | several | • User interacts with the installation. No necessary interaction between users |
| Jing Hua, Gifei Ou, 2010 | Projection on white bowl. Image moves, when bowl gets turned and/or tilted | Projection, accelerometer, Xbee module | 1 | • user interacts with the installation. Interaction with other users due to conversation and exchange about the event.  
• one “performer”, several “visitors” |
| Transient, Pablo Gnecco, 2012 | visitors silhouettes are projected onto a structure made out of 14m of tulle | Kinect (motion-sensor) | several | • user interacts with the installation through Kinect. No necessary interaction between users |
| Firefly Lighting, Vincent Moreau & Kevin Riou, 2010, Shanghai Expo | Projection alter (fireflies start moving), depending on peoples gesture and movement | projection | several | • user interacts with the installation. No necessary interaction between users  
• more users = more movement |
| Seated Catalogue of Feelings, Sosolimited, Cooper Hewitt Smithsonian Design Museum | Sensations are spoken into headphones and projected onto the floor, followed by sequences of vibrations that rise up from the seat of the chair and into the body. Part of the exhibition The Senses: Design Beyond Vision | Vibrating chairs and pillows, Projections that visualize the vibrations | 2: one person/ chair | • user interacts with the installation. No necessary interaction between users |
| **Pixelforest, Pipi-lotti Rist, 2016, New York**<br>source: https://necus-ejms.org/confronting-the-screen-pipilotti-rist-pixelforest-at-the-new-museum/ | **Large-Scale Installation with video projections, sound, haptic input and suspended LED-lights, forming round elements of light floating in space** | **many**<br>• user interacts with the installation. No necessary interaction between users<br>• user is invited to stay in the space and to explore it (chairs, pillows, beds, stairs) |}
|---|---|---|
| **Wise Stones - Interactive Interface Accessible Circuit, Federal University of Minas Gerais + the Mines and Metal Museum and the Polytechnic Institute of Bragança**<br>source: https://webmuseu.org/mengerdau-wise-stones/prototype/ | **When interacting with the exhibits, the interface presents augmented information about the pieces. Voiceovers provide to blind and other visual impaired visitors the same information to those that don’t have disability. When two pieces are handled at the same time, a comparison is shown** | **several**<br>• user interacts with the installation. No necessary interaction between users |}
| **White Rain, Takahiro Matsuo, 2011**<br>source: https://www.lucent-design.co.jp/artworks/white-rain/ | **interactive lighting installation which establishes an emotional atmosphere. In the space, LEDs and acrylic bars hang randomly in organic forms from the ceiling. The innumerable projected bits of light on the acrylic bars create an image of light with water texture. When participants join in the work, the lights of rain surrounding them become intensive. The lights visually attract participants and become the light source that beautifully illuminates the body. Rain-like lights trickle as the participant extends his/her hand. The light of rain changes its form as time goes by.** | **several**<br>The amount and placement of people influences the light and sound. Interaction with installation |}

**Vertical Acrylic LED-bars, programmed to vary in intensity, speed and pattern, Motion detecting camera, Color Kinetics**
White Rain, Tahiro Matsuo, 2011

source: https://www.lucident-design.co.jp/artworks/white-rain/

Interactive lighting installation which establishes an emotional atmosphere. In the space, LEDs and acrylic bars hang randomly in organic forms from the ceiling. The innumerable projected bits of light on the acrylic bars create an image of light with water texture. When participants join in the work, the lights of rain surrounding them become intensive. The lights visually attract participants and become the light source that beautifully illuminates the body. Rain-like lights trickle as the participant extends his/her hand. The light of rain changes its form as time goes by.

Vertical Acrylic LED-bars, programmed to vary in intensity, speed and pattern,

Motion detecting camera,

Color Kinetics

Several

The amount and placement of people influences the light and sound. Interaction with installation

Beyond the Lightflow, Bast collective

source: https://www.hellobastworkshop.com/hellobastworkshop/beyondthe-lightflow

Light Pollination installation

Universal Assembly Unit, 2016


A structure out of plywood, integrated LEDs

Stainless steel structure + plywood + water-proof treatment, programming led control

1 - 2 • user changes “stream of light” by stepping onto the structure • user interacts with the installation. No necessary interaction between users

A structure covered with fiberoptics to mimic the phenomenon of bioluminescence in nature

Fiberoptics, 20000 LEDs, sensor detecting intensity of external light source, custom built software

serveral • user uses light source (e.g. phone) to influence light patterns on installation

Appendix E - Additional information on Hearing Impairments

Hearing loss can occur unilateral (in one ear) or bilateral (in both ears). If the hearing loss is curable and temporary, it is called temporary threshold shift, whereas a permanent threshold shift is non-treatable and has permanent impact on the person’s life.

Hearing Impairments can be divided into four categories [38].

Conductive hearing impairment

The ability to transmit sound from the outer and middle ear to the inner ear is reduced or lost. = the sound waves can’t enter the inner ear
Causes can be for example a blockade (e.g. by ear wax) in or infections of the ear canal, a damaged ear drum, diseases or a deformity of the ear.
In most cases, this is a temporary condition and can be cured.

Sensorineural hearing impairment (SNHL)

Damage or reduction of hair cells in the inner ear.
There are different sub-groups of sensorineural hearing impairments, defining the frequencies, where the hearing is lost/ reduced.
Causes can be inherited, or caused by aging (age-related hearing loss), exposure to excessive noise over a long time for many times, certain diseases, some medications or injuries.
This type can not be cured, but the affected person can be supported by hearing aids.

Mixed hearing impairment

Is a combination of a conductive and a sensorineural hearing loss.

Central Auditory Processing Disorder (CAPD)

Not defined as hearing impairment itself but has effects on the hearing of a person.
It is difficult for that person to differentiate between different sounds.
The ears fully function, but the brain is not able to process the incoming information the right way.
It can be genetic or caused by trauma. It can also be related to certain diseases like Parkinson.
Appendix F - Initial Design Principles of the Soundforest Installation

The following principles were part of the original design process of the Sound Forest Installation [7], [14] and should also remain relevant for the new concept as far as possible.

- creating a digital musical instrument (DMI) that facilitates intuitive musical interaction, thereby enabling visitors to quickly start creating music either alone or together.
- pedagogical tool: visitors should be able to learn about concepts related to music and music making.
- creating an experience that will encourage visitors to return to the museum for continued instrument exploration.
- balancing simplicity and virtuosity regarding the interaction.
- encourage visitors without prior knowledge of musical instruments to experiment with the installation as well as being interesting enough for visitors with a musical background (easy to understand and use).
- creating the possibility to create music alone or in collaboration with other visitors.
- teaching visitors about music and music making principles (pedagogical tool).
- motivating the visitors to return to the museum and the installation to keep exploring.
- make the installation not only accessible for visitors with impairments, but also create an immersive experience for them (no barriers to experience music).
- easy to maintain.

Appendix G - Principles to design an interactive Museum Installation

When creating an interactive installation in a museum, it is necessary to consider certain aspects [32].

- prolonged or repeated interaction is considered positive.
- factors to measure the success of an interactive installation.
- level of interaction/engagement.
- how many (different) people it attracts.
- “visitors tend to focus on the kinds of media that they are familiar with instead of getting exposed to unfamiliar ones”.
- hands-on exhibits are liked by all age groups.
- mixed media installations/exhibitions can reach diverse user groups and arise interest in new topics.
- hand-on exhibits with the possible bodily interaction mainly attracts children.
- successful exhibits provide either a challenge to the user or allow creative confrontation with a new topic.
- users do not mind that their interaction with an exhibit is displayed to other visitors.
- exhibitions are not always used in the intended way/result in the outcome the designers have planned. Still, users tend to create a satisfying outcome and want to find the correct way to handle an installation.
- the number of people interacting with an exhibition depends on the physical set-up and the available space.
- the “success” of an interactive installations depends not only on the technical set-up, but also on the content and the appeal of a topic.
- Allowing and motivating group interaction.
Appendix H - Universal Design Analysis

**Equitable use: The design is useful and marketable to people with diverse abilities**
The museum of Performing Art Stockholm offers different tools for visitors with impaired visitors. According to Lars Annersten, exhibition manager, the museum offers many interactive installations for hearing impaired visitors, especially in the dance, theatre and puppetry areas, as well as the possibility to test acoustic instruments, like harp or amadinda. Those instruments create clear vibrations when played.
The museum is equipped with light-integrated fire alarms in the public spaces and offices. And for concerts and programs, equipment for hearing aid is available.

Soundforest was designed to be musical instrument that motivates exploring music making alone or with other people regardless of any impairment.

**Flexibility in use: The design accommodates a wide range of individual preferences and abilities**
The installation offers the possibility to be used alone or within a group of visitors. There are no restrictions for wheelchair users or visitors with walking aids. There is no option to sit down and enjoy the installation in a resting condition. Benches can be found outside the space. There is no integrated audio-guide to the installation nor an introduction for blind or visually-impaired visitors. This can cause confusion.

**Simple and Intuitive: Use of the design is easy to understand, regardless of the user’s experience, knowledge, language skills, or current concentration level**
The strings are easy to spot and touch. The immediate acoustic and visual response helps to understand the installation. Several questions remain: What kind of interaction triggers which result? Does the position of contact matter? [10]

**Perceptible information: The design communicates necessary information effectively to the user, regardless of ambient conditions or the user’s sensory abilities.**
A sign gives basic information. However, it does not explain how to use the installation. It is not possible for blind visitors to get information about the installation.

**Tolerance for error: The design minimizes hazards and the adverse consequences of accidental or unintended actions.** There is no “wrong” way to use the installation. Response is created almost no matter what way of interacting with the string is chosen.

**Low physical effort: The design can be used efficiently and comfortably, and with a minimum of fatigue.**
The installation is easily accessible through ramps and wide, open entrances. The strings are approachable and quite visible.

**Size and Space for approach and use: The design provides appropriate size and space for approach, reach, manipulation, and use, regardless of the user’s body size, posture, or mobility.**
The room is large enough to move around easily in wheelchairs, for instance, and to get to know the installation. It could be helpful to offer foldable chairs or other seating options to prolong the time spent in the installation space.
The canopy during the first testing in the Lighting Lab at KTH. The individual pages are fixed with adhesive tape onto cardboard. Some shadows are already visible.

Different colored canopy lighting during the first testing: This effect could for example be used for future sound compositions and to create different atmospheres.