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Chapter

Designing Interactive and Immersive Multimodal Installations for People with Disability

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Abstract

We developed an end-to-end co-creative methodology for designing interactive and immersive multisensory virtual reality experiences with a particular focus on people with disability. Our method draws on what is called "design thinking" to provide a backbone to our approach. This embraces three stages, an empathic first stage, followed by an ideation phase, during which the thematic context is elaborated, and then an iterative exploration phase during which the initial concept is refined and the implementation is achieved. Furthermore, the "cognitive design" methodology developed by one of us led us to an approach incorporating all sensory modalities, not just the audio and visual modalities (that is, it includes odor, tactile, taste and proprioceptive stimuli), in order to deliver an experience that fully enhances the user's sense of embodiment, and also led us to place the user's experience at the heart of the installation. Users participate in the design process through co-design protocols. We showcase the application of this methodology in a detailed way for the construction of an interactive and immersive VR installation for people with disabilities.

Keywords: immersive interactive installations, disability, design thinking, participatory design, virtual reality

1. Introduction

The best way to find yourself is to lose yourself in the service of others (Gandhi)

For years, researchers, scientists, and artists have worked with similar aims: to create, innovate, and share knowledge across diverse fields [1]. Sometimes, these innovators are classified into one of two categories: either as finders or makers [2]. Both of these are equally creative. Finders focus on their energy and creativity on understanding phenomena to increase the stock of knowledge about these, making quicker decisions to establish or confirm facts, and thereby solving new or existing problems. Meanwhile, makers or creators bring forth their own ideas and conceptual knowledge, to create and design for others [3]. Both could be understood as oriented toward what Heidegger called *Dasein* [4], that is, *Being* understood in relationship with others while the self remains alone and aware of our mortality. Within

such a framework, both finders and makers equitably care about how to make the world a better place for themselves and others. Aspects of this Heideggerian concept of "Being" were embraced later by Deleuze, who translated this in terms of creativity, and considered Being as *unlimited creativity where creation depends on the one creating* [5]. Design encompasses a set of methods and tools for carrying out such a program.

Design is an exploratory process [6] that often starts with abstract ideas that gradually grow into more definite specifications through iterative cycles that adjust the solution [7] to the desired application context. An ongoing cognitive process, designing is like thinking: it is an ubiquitous activity of human creation, regularly triggered through the problem-solving process [3]. Design embraces a crucial skill set for understanding and responding to the needs of others, especially in the constantly changing world in which we live. One way to approach design is called Design thinking [8]. Design thinking offers an efficient way for researchers, scientists, and artists to innovate productively for others in a context of rapid change [9]. It offers a frame for understanding how designers undertake human-centric problem-solving for creating objects, services, or systems, as well as offering a hands-on methodology [10].

Building upon participatory, human-centered action research, the design thinking process may be viewed as occurring over three distinct phases: (1) *empathy*, in which an empathic understanding of the needs to be addressed is obtained from users, (2) *ideation*, during which ideas are generated [11], and finally, (3) *experimentation*, where methods are developed and tested to implement the ideas. During each of these phases, designers engage in different cognitive activities including thinking, preparing, and assimilating new knowledge [12].

Design thinking as a practice has drawn attention across different fields including engineering [13], business science [10], and education [14]. The approach has also been used in disability studies and the development of human-computer interaction (HCI) for people with impairments [15]. Design thinking has been shown to offer a high degree of flexibility for these applications. Indeed, designing for people with impairments is challenging, as they often require a range of special adaptations using highly personalized equipment—one size does not fit all. Generally, teams working in this area must arrange for design assistance from appropriate experts, for example, with training in ergonomics or biomechanics, as well as people with disabilities themselves, in order to develop an understanding of the factors that affect the participation of people with disabilities [16]. To address these issues, universal design principles [17] have been adopted for designing both natural and urban spaces to ensure their accessibility and safety.

Interactive and immersive digital installations are a relatively recent artistic innovation [18]. The range of installations that have been developed is already large, however, and they are not always well reported in the literature, making it difficult to get a handle on the breadth and diversity of productions. Some general distinctions include primarily immersive audio installations [19, 20], immersive storytelling installations [21, 22], somatosensory and movement-based embodied installations [23, 24], and immersive digital culture installations [25–27]. With regard to issues of accessibility for these installations, however, the written record is meager, and what evidence there is suggests accessibility is an issue. Accessibility is defined in the dictionary as "the quality of being available when needed". However, even today, minority groups such as people with impairments, or the elderly, can find themselves excluded in many, even most, contexts. This exclusion is usually the result of a poorly organized environment and/or disabling interactions [16], that is, it is a result of the designers' lack of understanding of the dynamic interaction between environment and personal factors. In order to overcome this problem,

designers must step out of conventional ideas, and learn to experience the world through their own vulnerability in empathic resonance with people with disabilities.

Designing for all goes beyond ensuring accessibility, it also requires that the installations explicitly include representations of disability, to motivate people with impairments to participate. Furthermore, people with impairments need to take part in the design process to be fully engaged [28]. Also, one of us developed a cognitive design protocol in earlier work [1] for developing assistive technologies for people with disabilities. Cognitive design draws upon knowledge of human cognition in order to design technologies with a broader basis of application. Hence, for example, Yaagoubi et al. [1] presented a tool to assist people with visual deficits to orient themselves in space, drawing on the hierarchical organization of spatial information in our cognitive representations of geographical space. The approach, which we called cognitive design, consists of matching data organization methods and technical requirements to cognitive principles, and is quite general. In principle, it could also be applied to installation design. We drew on these ideas to situate the design process for our interactive and immersive installation development work, as we shall detail below.

A quick note about terminology: we use the expressions "people with impairments" and "people with disabilities" interchangeably, although in fact there is a difference between the two. Impairments are understood to be the functional limitations associated with persons, while disabilities are understood to be the result of a maladapted environment, which renders impairments disabling [16].

In this chapter, we present our end-to-end co-creative design methodology for the development of interactive and immersive multisensory virtual reality experiences, with a particular focus on designing installations for people with disability. We also showcase the application of this methodology in a detailed way via the "رحلة - réhla (Odyssey)" project.

2. The process of co-designing an immersive and interactive installation

To design a user-centered, immersive, and interactive installation that addresses the needs and interests of people with impairments, we adopted an end-to-end co-creative design methodology, inspired by the design thinking process. The proposed methodology is composed of three phases: (1) empathy, (2) ideation, and (3) experimentation. Each of these phases is detailed below.

2.1 Empathy

The idea of empathy was introduced by Lipps in 1867 [29], and originally referred to the process of projecting oneself into a perceived object or person so that a sense of identification occurs. Later, however, the term has been used in a variety of ways. Bachrach [30] proposed a general definition as follows, although not everyone agrees: "the concept of empathy... refers to the ability of one person to experientially 'know' what another is experiencing at any given moment, from the latter's frame of reference and through the latter's eyes." This definition covers the essential idea for this discussion, the idea of "feeling oneself into" [29] another person's experience of the world. To achieve this, designers must set aside their own knowledge and needs, and focus on first understanding how others interact with the environment. This goes beyond, therefore, the idea of "needs assessment" that typically forms the first stage of an engineering project [31]. The success of this first stage of the design thinking process depends on integrating all the relevant elements in the problem-solving process.

In the context of designing for people with disabilities, additional elements also need to be taken into consideration to ensure that the solution serves people of all ages, personal abilities, pathologies, and sizes [32]. Designers are called upon to apply universal design principles [17] to create buildings, products, services, or environments that are accessible for all people. Virtual as well as physical environments require design assistance to develop a deeper understanding of user interactions, as well as changes required to both policies and procedures [33]. Ensuring access to virtual environments goes beyond making them accessible [34]. Indeed, immersive and interactive installations need to reflect users' experiences, as well as their interests and personas. The concepts incorporated into the design need to be based on an explicit understanding of people with disabilities, and in particular address their needs in terms of risk and safety management [33]. In a more paradoxical way, it is about supporting both designer and user visions to the best advantage of all. To ensure this, designers must involve users in the complete process. Perceiving another's vision implies putting oneself into someone else's place, allowing oneself to be vulnerable while gathering, assimilating, and processing the experience.

Participatory design (PD) is one of many cooperative design approaches that have been successfully applied to the development of human-computer interaction environments (HCI) for people with impairments [15] . The very essence of this approach is about engaging neglected users in the design process to inspire more systematic changes in social organization [35], while at the same time empowering participants [36]. Our proposed methodology combines both design thinking and participatory design in each of its phases. The roles of both the users and the designers are redefined, to create fairness and a proportionate benefit for both [37].

رحلة - "réhla" is an Arab word for travel or journey. The choice of this name was not an arbitrary one. Indeed, to implement "رحلة - réhla (Odyssey)," the design team engaged in a lengthy, sometimes chaotic yet exciting journey. This began when we first investigated the problem of designing immersive installations for people with impairments. A personal, yet shared interest among members of the research team, this was fueled in part by our realization of the extent to which people with disabilities face risk on a daily basis [28]. For some, it was also the continuation of research that had been carried out over a number of years, whereas for others, it was about ethical principles and generating new forms of societal value. Furthermore, involving the participants in the design process showed us that rendering these installations accessible for people with disabilities involved a sharing of visions.

2.1.1 The first design concept: Vertigo

To the best of our knowledge, very little research has been applied directly to the problem of designing immersive and interactive installations for people with disabilities, due in part to the complexity of making these accessible yet safe for all. In early 2017, we developed the concept of *Vertigo*. This was to be an installation that placed participants into uncommon situations such as floating and defying gravity. It was a continuation of earlier work on developing embodied experiences in virtual environments, that is, experiences that would enhance consciousness of body states. Participants would be placed on, for example, a robot-supported platform over a virtual, bird's eye display of the city of Quebec. This would provide a multi-sensory experience that offered for some participants an adrenalin-loaded moment, while others might experience calm floating. Nonetheless, we were aware that such an innovative and ambitious concept could not be achieved without involving participants in its design. To overcome our own lack of knowledge about what elements should be incorporated, we set out to conduct a qualitative study to examine

the perception of risk and the decision-making process involved in accommodating such risk among people with disabilities [28]. The results of this qualitative study are briefly summarized in the subsection below.

2.1.2 The qualitative study

In the summer of 2017, we began recruiting and interviewing a broad range of people with disabilities. In semi-structured interviews, participants aged between 30 and 59 years answered questions about: (a) Safety and risk management; (b) Loss of control; and (c) Experiences of Vertigo. All sessions were audio recorded and then transcribed verbatim, analyzed, and coded. The results of this qualitative study [28] demonstrated that people with disabilities experience risk on a daily basis and deal with it in different ways depending on their functional limitations, personal factors, past experience, and other factors. Regardless of their particular functional limitations, they all found creative ways to manage the risk of injury in order to carry out their lives. In fact, the study showed that managing risk is composed of four stages [28]:

- assessment phase;

- adoption of a structured decision-making strategy;

- adapting decisions actually taken due to unexpected events; and

- managing the sometimes intense feelings elicited by challenges.

The identification of the four stages of the risk management process provided the basis for how we planned to organize the installations. Moreover, almost all the interviewed participants agreed that the *Vertigo* concept did not represent a substantive change from their high risk daily routine and therefore expressed little interest in experiencing it. Based on these findings, it became obvious that in order to engage these participants, we needed to offer them something more adapted to their actual experience of the world. Instead of seeking out experiences of risk, they were drawn to experiences of calm and safety, experiences that promoted relaxation and well-being.

2.2 Ideation

The qualitative research study provided us with a strong basis from which we could explore such a concept. People with disabilities clearly asked for a safe relaxing space in which environmental and emotional barriers had been reduced. They also pointed out the importance of being able to explore usually inaccessible locations such as natural environments. Raising awareness among the general public about accessibility issues was also important for them [28].

Given all these facts, we determined to rethink our concept. We decided to take some time away from the creation process, to step back and reflect on the results of the qualitative study and on the participants' real needs. After a hiatus of about 2 months, the main designer A. Arfaoui proposed the رحلة -réhla (Odyssey) installation concept.

Fully aware of the importance of involving people with impairments in the design process, we set out to invite the same participants that we had first met as part of the qualitative research [28] to provide feedback on the new concept. We decided to trace four main aspects in relation to the concept and further discuss these with the group:

- revisiting the definition of accessibility;

- how to create an experience of relaxation and well-being;

- how to include in appropriate and effective ways issues of safety; and

- how to use the installation to raise public awareness concerning accessibility to natural environments.

2.2.1 Focus group

As we started planning the focus group, it was necessary to carefully think about sampling (who should be invited to participate) as well as how to achieve full participation and equal access for people with disabilities. For this, we formed two groups: (1) participants with a broad range of impairments and (2) researchers and experts. For the first group, we invited back many of the same group that had already participated in the qualitative research, hoping to ensure continuity in the co-creative process. The second group included researchers working in targeted research areas related to disability studies, accessibility, and virtual environments. During the co-creation session (focus group), both groups were equally active and played significant roles in conducting the session. The session was divided into two parts: in the first part, the concept of the proposed installation was presented and critiqued, while in the second part, we discussed modes of evaluation and looked for improvements.

2.2.2 The second design concept: رحلة - réhla (Odyssey)

2.2.2.1 Presenting the concept for the installation

The installation as conceived, proposed a journey to one of two natural environments within which participants were invited to relax. The installation was inspired by the often moving testimonies gathered from the qualitative study participants, as well as childhood experiences of the main designer, A. Arfaoui, who chose to introduce the participants to the Sidi Bou Said beach in northern Tunisia, where she grew up. For the second environment, a fictional site inspired by Quebec's Nordic forest was chosen. Both destinations are usually inaccessible for people with disabilities. Moreover, they may also, paradoxically, create experiences which can be simultaneously happy and sad. This is the result of the vulnerability that may arise when we are relaxed, or when we are alone or surrounded by silence. Participants in the qualitative study remarked on this aspect of experiences of relaxation.

In the context of the رحلة - réhla (Odyssey) installation, participants would be invited into a dedicated white-chamber, would don a 3D virtual reality helmet, and then let themselves relax while interacting with a multisensory environment, including sight, hearing, touch, and smell. Each of the different elements included should contribute to transporting participants to either site, evoking the designer's vision, while finding ways to make the experience their own. Furthermore, the installation should accommodate as many people as possible, regardless of whether they live with a disability or not. Once installed in the environment, the participant would also be given the opportunity to modify the experience, varying colors, and sounds, in order to further personalize the experience, and enhance enjoyment.

To present the concept, a 6-minute video recording was prepared and shown to the Focus group participants, in which reference was made to both the Odyssey concept and the two natural sites. A PowerPoint presentation detailed the different

stages of the proposed installation and its main features. Since a visually impaired participant was present, we created a model to represent the chamber hosting the installation and showcased certain elements used in the environment. The model provided, in addition, tangible benefits to other members of the co-creation session. Indeed, through touch and feel, our blind participant was able to understand the proposed environment, and the model provided a visual configuration to the sighted participants as well. We also presented noise and olfactory samples, which contributed to increasing the participants' engagement and underlined the diversity of the proposed installation stimuli.

2.2.2.2 Enriching the concept

Once we finished presenting the concept, the participants were ready to give us their perspectives on what they thought about the proposed installation. Some were excited and looked forward to being a part of the planning, implementation, and experimentation, while others were skeptical and began identifying problems or making suggestions for improvements, particularly with respect to safety issues, viewed as essential if relaxation was to be achieved.

The first point raised was in relation to the accessibility issue. Indeed, participants were eager to go back and redefine it, to help us understand what we would need in order to create an accessible experience for all. It was quickly realized that our definition of accessibility, which focused on the physical and environmental aspects of the installation, did not fully reflect the understanding of people with disability. Indeed, from the perspective of the members of our group 1, one cannot talk about accessibility without also addressing issues of safety. This is a direct result of the fact that people with disability experience high degrees of risk in everything they undertake, as revealed by our qualitative study. Hence, a definition of accessibility that does not acknowledge issues of safety makes no sense. Furthermore, for environments to be accessible to people with disability, they must incorporate a representation of disability within the environment. Without such a representation, they always feel excluded. Examples of what is meant by this are the presence of accessible ramps or ways, podo-tactile tiles, or other indications that accessibility issues have been addressed when the environment was developed.

In the proposed installation concept, we took into consideration these concerns, offering participants a range of choices, and included them in the decision-making process for developing the installation. Nonetheless, participants still found both environments to be lacking explicit disability representation. It was suggested that we add more indications of accessibility such as wheelchair ramps or a wooden path to support their access to both 3D environments.

They also pointed out that there are other barriers than purely physical ones that need to be addressed, including social attitudes such as prejudice. Participants from both groups agreed that dealing with risk remained personal, and varied from one person to another. The memories of past experiences strongly influenced the assessment of risk. To address this issue, it was suggested that we provide the choice to stay or leave the experience at any moment, thereby ensuring their control over events as they unfolded. They also wanted a more active role during the experience. They viewed the personalization of colors and sounds as useful, but insufficient. They wanted greater control over the choice of scene elements, over their position within the white-chamber, and over the duration of the experience. Based on these remarks, we decided to redesign the white-chamber and its elements to be easily dismantled and replaced in accordance with the choices made by the participant. All these issues led us to become more fully aware of how to accommodate the

needs of people with impairments, and underlined the importance of having included them in the design process.

2.3 Experimentation: the رحلة - réhla (Odyssey) installation

Even though the installation concept was by this time both highly specific and validated by people with disability, we still needed to gather comments and suggestions during the experimentation and implementation phase. To implement رحلة - réhla (Odyssey), meetings took place on a weekly basis with both the researchers and expert team members, and one or two people with disabilities, to work out the development and construction timelines. We examined closely every detail and selected appropriate elements to meet the requirements. With the development of the virtual environment being more demanding, this work was begun months before engaging in the physical construction of the white-room, which was further constrained by the fact that we would have access to the physical space only for a limited period of time.

2.3.1 Prototyping the virtual environment

Creating an immersive and interactive installation involves designing 3D environments to which users would be given access via a virtual reality interface (3D helmet). For the رحلة - réhla (Odyssey) installation, initial ideas were developed using sketches as well as a physical mock-up of both places. A specialist in 3D virtual design was hired (J. Proulx-Guimond). The beach site (**Figures 1** and **2**) was created using maps of the Sidi Bou Said beach, and also drawing on A. Arfaoui's memories, concerning, for example, the color of the water, of the sand, the birds present or even rare regional plant species. These were supplemented by recent photos taken *in situ*. Naturally, accessibility found its way into the design through the creation of a wooden walkway and platform (**Figure 3**) among other elements. Furthermore, access was offered to the site at two different times of the day (morning and late evening). A beach offers a different kind of relaxation during the evening (**Figure 4**) than during the day. To these were, of course added, sounds of the waves and birds, as detailed elsewhere (**Figure 5**).

For the Nordic forest, we drew our inspiration from an aerial photograph of a cabin on the edge of a lake, but modified the scene to create landscape elements to enrich the experience. These included a ravine with a stream, a waterfall, and mountains as well as boreal forest. The idea was to offer a relaxing yet inaccessible environment that people with impairments cannot easily visit. For this, a cabin was placed near the top of a cliff (**Figures 6** and **7**). A wooden walkway and platform, similar to that developed for the beach site, were also introduced. Again, an evening

Figure 1.
The Sidi Bou Said beach as depicted virtually, looking west.

Figure 2.
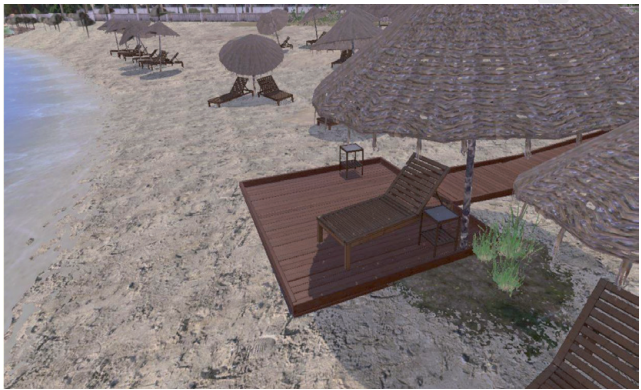*The virtual model of the Sidi Bou Said beach, looking east.*

Figure 3.
The wooden walkway and platform within the shade of its parasol. The walkway extends from the road, across several hundred meters to this location near the waterline.

Figure 4.
The virtual model of the Sidi Bou Said beach at night, looking west.

(sunset) time of day was also modeled (**Figures 8** and **9**). The sound of the water-fall, the wind, and a variety of bird songs were also provided. At any time of the day, the Nordic forest inspires absolute relaxation and well-being.

The two virtual sites took 5 months to develop, half time. It was decided to slow the development by paying the developer to work half time, since we were still working out diverse design issues. We needed breathing room to fine-tune the design specs as the work proceeded.

Once the 3D visual environments had been developed, these were supplemented with appropriate sounds, smells, and tactile elements. A partnership with an olfactory Tunisian company, *La maison des senteurs*, was organized, which provided appropriate scents for both environments. These scents were presented to the Focus

Figure 5.
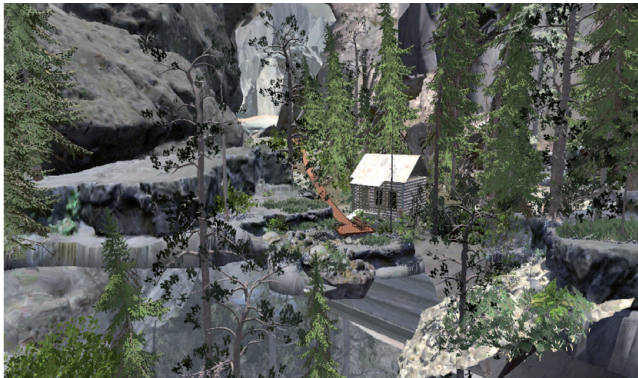*The virtual model of the Sidi Bou Said beach at night, looking east.*

Figure 6.
The Nordic forest site, showing the cabin, rock faces, waterfall, walkway and wooden platform.

Figure 7.
The view from the wooden platform, located in front of the cabin, during the day.

Figure 8.
A view of the walkway and cabin at sunset.

Group, in order to validate their choice. The visual experience was also supplemented with sounds. For the beach scene, we included the sounds of the waves and children's voices, as well as the cries of gulls. For the forest scene, bird songs were introduced, the sound of the waterfall, and the sound of the wind. In addition, music was offered for both experiences. Given the fact that music choice tends to be highly personal, we consulted a music expert to help with this aspect (Jocelyne Kiss). All sounds and music were offered to participants as choices that could be added or suppressed (and volume adjusted) as they wished.

رحلة - réhla (Odyssey) offered a multisensory immersive and interactive experience based upon a wide range of different stimuli. Once the overall experience had been designed, we focused attention on the interactive elements. To do so, we

Figure 9.
The view from the platform at sunset.

Figure 10.
The cabin-like structure inside the white-room, shown with a person lying down in the lawn chair and wearing the 3D helmet.

Figure 11.
The flower box, with forest plants and soil.

Figure 12.
The sandbox, which, in addition to sand, also contained shells, pebbles and algae.

Figure 13.
The scent diffuser.

co-designed with our participants a white-chamber where participants could perceive and engage with the experience in a safe manner. Obviously, the white-chamber had to include assistive technology accommodations, as well as create a suitably relaxing atmosphere for people with impairments. Having an expert architect among our team members (Morales) facilitated our design efforts in this regard. We first decided to build a one room chamber simulating the cabin (**Figure 10**), inside of which was placed a comfortable, inclinable lawn chair so that participants could lie down and truly relax. In addition, a sandbox and a flower box were offered to provide participants with tactile textures for each virtual site (**Figures 11** and **12**). To dispense scents and thereby generate a fragrant environment, we used a scent diffuser to provide the participant with a distinctive olfactive journey for each site (**Figure 13**). Participants were given the option to remove any of these elements, or to use their wheelchair instead of the lawn chair if they wished.

The white-room itself was constructed over 2 weeks in the final period before launching the installation.

3. Experiencing the رحلة - réhla (Odyssey) installation

To test the complete installation, each member of the design team went through it first to generate feedback before inviting participants with disabilities to try it. By the end of this internal testing phase, we developed a clearer understanding of how invited participants might behave, think, and feel when interacting with the installation. This, however, was insufficient to determine whether the installation truly succeeded in creating a relaxing, safe, and accessible installation while at the same time raising public awareness of issues of disability and accessibility.

Wearing a 3D helmet has been known to cause eye fatigue, which was one concern. We were also still unsure how much time to allocate to the experience as a whole. Before opening the installation open to the public at large, we invited one participant with disability (whom we will call "P" to keep his or her identity secret) who was present from the very beginning of the project, to inaugurate the installation and help us make final adjustments. "P" was asked to undergo the experience for almost an hour. Upon arrival, and for 15 minutes, "P" was welcomed by A. Arfaoui, who provided explanatory context, presented the installation, and explained its features. Thereafter, "P" was asked to sign a document of consent before transferring to the lawn chair in the white-room. For the next 30 minutes, "P" was able to explore and mostly to relax, wearing the 3D helmet, managing to navigate between the different locations while interacting with the multisensory installation. The 1 hour session ended with a discussion during which answers were sought to a series of questions concerning: (1) accessibility, (2) relaxation and well-being, (3) safety, and (4) raising public awareness.

According to P's experience of رحلة - réhla (Odyssey), the installation exceeded expectations. "P" had been unaware of the power of a virtual multisensory environment and had been skeptical that the installation would provide both an immersive experience and yet also allow relaxation. "P" confirmed being able to relax once a feeling of safety was achieved, and found it indeed possible to enjoy the journey while interacting with the installation. When we asked "P" about accessibility, there was a suggestion that we add more representation at both sites. For example, "P" noticed that we did not have any restrooms specially designed for persons with disabilities which made it harder to relax. "P" also considered that 30 minutes was enough for participants to let their guard down and enjoy the experience.

Based on these first results, we started recruiting, first, people with a broad range of disabilities, and, secondly, members of the general public (students and researchers not involved in the project, invited guests, etc.). We divided participants into two groups: (1) subjects and (2) guests. Subjects were primarily people with impairments who were given an extensive questionnaire and a follow-up interview, whereas guests were primarily members of the public and were given a shorter questionnaire.

3.1 Data collection and analysis

Once the participants finished exploring the installation, they were asked to participate in a follow-up interview where they were answered a short questionnaire. The interview was subdivided into four sections:

1. the concept of the installation;

2. the degree of relaxation achieved during the experience;

3. the multisensorial aspects of the experience; and

4. the installation as an awareness-raising tool.

The principal questions addressed in the first section were:

- How easy was it to experience the installation?

- How accessible was the installation?

- Which sites did you prefer the most (beach or forest)?

- What do you think about being able to actively interact with the installation (e.g., changing colors, sounds and decor)?

For the second section:

- What helped you the most to relax?

- Did you feel safe during the experience?

- How representative was the experience?

- Did you notice accessibility representations at both sites and what do you think about that?

- What do you think about the concept of the installation (visiting two inaccessible natural sites)?

The third section addressed:

- What did you think about the visual, auditory, tactile and olfactory stimuli? Did you enjoy them? Did you think their presence enhanced the experience?

The final section, concerned with raising awareness, asked the following:

- Do you consider the رحلة - réhla (Odyssey) installation to be effective as an awareness-raising tool?

- If so, how was it effective? If not, why not?

All the interviews were audio recorded and then transcribed verbatim. To facilitate analysis, the transcripts were systematically coded [38], then analyzed, and finally sorted and categorized. The main results will be detailed below.

3.2 Results

3.2.1 The رحلة - réhla (Odyssey) concept

For most of the participants, this was their first experience of a fully immersive, virtual environment. All the participants from both groups agreed that after putting on the 3D helmet they needed a little time to adjust and understand the interactive environment, but soon after they were able to relax more and start exploring the potentialities of the installation.

> *I have never experienced any virtual experience before […] It can seem overwhelming at first, but once you get used to it, it kind of worked well for me.*
>
> *(Man: Spinal cord injury; free translation)*

The 3D helmet was not comfortable for all participants. Several experienced significant difficulties in adapting to it. In the middle of the experience, some experienced mild symptoms of headache and eye fatigue, while others found the

3D helmet straps were too tight. The majority of participants, however, made no complaints at all.

The helmet was too tight, and even heavy [...] Am I the first one to complain about it?

(Man: Congenital limb deformation; free translation)

For years I suffered from migraines, and I was scared and hesitant to put a 3D helmet on [...] I honestly didn't even feel it on my head. It is not heavy at all.

(Woman: Spinal cord injury; free translation)

When we asked the participants who visited either site to comment about ease of use, they all agreed that despite the fact that the installation uses a virtual environment, and advanced technology, it remained easy to use and was adapted to their needs.

The user interface only displays relevant information. the user is guided in a straightforward manner and transparently through all the steps [...] I didn't need to ask any question to learn how to change the colors or sounds.

(Man: Congenital limb deformation; free translation)

Before starting the experience, you took time explaining the installation and how to interact with it, and that made a big difference [...] Being unfamiliar with virtual reality, my experience may be different. I first had to look around to figure out how to change the colors and interact with the installation, but once I found the menu, it became easy to play with sounds and change colors.

(Woman: Spinal cord injury; free translation)

رحلة - réhla (Odyssey)'s concept is based on taking the participants to two natural environments, to relax and enjoy themselves. Both environments, whether beach or forest are usually inaccessible. All participants without exception responded positively to the concept.

I have never been on a beach, [...] I once tried to go to the beach at Beauport Bay with my friends, only to find out that it's not accessible [...] Putting on the 3D helmet and traveling across the world to find myself on a beach is at the same time overwhelming and exciting [...] Thank you for this opportunity.

(Woman: spinal paralysis; free translation)

I'm currently living with the help of financial assistance programs. I hardly manage to support myself, traveling and relaxing is not something that I can't afford [...] Now I know that everything is possible with virtual reality.

(Man: Congenital limb deformation; free translation)

When we asked the participants to choose between the two environments and determine which one they preferred, the response was close to an even split between beach (56%) and forest (44%). Most participants are living in Quebec, where

forest covers almost one third of the province. Participants were more familiar with greenery and forests than with beaches and sun destinations.

> *I grew up in the Saguenay–Lac-Saint-Jean region, playing with my friends in the forest near to my parents' home, but I have never been to the beach, especially one in Tunisia. [...] It is quite unlikely that I will get another opportunity to visit one, so I tried to spend as much time as I could there.*
>
> *(Man: Hearing impairments; free translation)*
>
> *I have always wanted to travel and go to a sun destination, but I never thought of visiting Tunisia. I'm so excited to go there especially because it's free and also accessible.*
>
> *(Man: spinal paralysis; free translation)*
>
> *Water scares me [...] When I was younger I almost drowned. I couldn't enjoy the beach, but I loved being on the top of the cliff overlooking the whole valley, in the forest.*
>
> *(Man: From the guest group; free translation)*

When evoking accessibility during the interviews, many participants noticed how we had included accommodations for assistive technology in our design. Some considered access to all public spaces to be a vested right, while others appreciated our efforts in this regard.

> *When I first got to the room, I noticed all the elements you put into your design to ensure my accessibility such as the wheelchair ramp and the wooden path. I really appreciated the attention and your support.*
>
> *(Woman: spinal paralysis; free translation)*
>
> *Being able to access public spaces or areas should be available for all, I should not have to think about that. [...]*
>
> *(Woman: From the guest group; free translation)*

The participants associated the accessibility with the fact that the experience was multisensorial.

> *During the experience, I managed to get deeply involved with the installation, it was accessible through the images, the sounds, even the odours and touching the sand.*
>
> *(Woman: From the guest group; free translation)*

All the participants from the subject group agreed that the visual and auditory stimuli had played an important role in the experience.

> *The quality of the images and how realistic both sites were, allowed me to access it all mentally as well as physically. I somehow felt immersed, completely present on the beach in Tunisia, the sounds of the waves and the moisture's odor took me there.*
>
> *(Woman: Spinal cord injury; free translation)*

3.2.2 Relaxation and well-being

When we asked the participants about how relaxed they were during the experience, their answers varied greatly. Indeed, more than half agreed that relaxation and well-being differ from person to person. Most, however, noted that in addition to feeling safe and secure, the presence of many accessibility elements allowed them to let go and relax.

> *From the moment I got to the room, I knew that I could trust you and your experience, […] All the safety arrangements and the assistive technology accommodations helped me to relax.*
>
> *(Man: Congenital limb deformation; free translation)*

However, a small percentage of participants could not make up their minds whether they felt truly relaxed.

> *I somehow don't know how to feel about this experience. For sure I felt good and relaxed […] Virtual experiences are new for me, maybe that's why I can't make up my mind.*
>
> *(Woman: From the guest group; free translation)*

The participants confirmed that spending time in natural environments often helps them relax. At the same time, they felt the need to remind us that often these spaces are inaccessible for them. Almost all the participants from the subjects group agreed that being able to relax in spaces such as a beach or forest was only possible because of the accessibility elements that we had integrated into the design.

> *There is no doubt that every time I need to clear my mind, l go to the park near my home[…] It is almost impossible for me to relax with my wheelchair since I am constantly trying to make sure not to get hurt. In this experience, I did not need to do that, […] I only had to put on the 3D helmet to find myself in your country of origin by the seaside*
>
> *(Woman: spinal paralysis; free translation)*

For the participants trying virtual reality for the first time, they attached special importance to the technology, thereby confirming that VR made the whole experience exciting and raised their level of interest.

> *I always wanted to try a VR experience […] Experiencing it for the first time with you was so exciting, […] I know that you wanted me to relax, I couldn't do it at first. I wanted to discover everything. Once I did, though, I was able to relax and I enjoyed the moment travelling between the beach and the forest*
>
> *(Man: Congenital limb deformation; free translation)*

Being able to personalize and customize the installation was positively perceived among all the participants from both groups. In fact, almost all of them agreed that having the opportunity to express their taste in colors, sounds, or even in choosing different physical elements within the white-room gave them a sense of control which helped them lower their guard and enjoy the present moment.

> *Involving me in the making of the experience through changing the colors made me feel more in control [...] Since my accident I learned to control my things to ensure my safety. During this experience even without being able to fully control every aspect, simply changing the colors and the sounds boosted my self-confidence and helped me to relax.*

> *(Man: Stroke; free translation)*

3.2.3 Multisensorial experience

When we presented the رحلة - réhla (Odyssey) concept to the participants, we made a point of mentioning that the experience focused on body sensations and interactions which involve several sensory modalities. This was done so as to accommodate the broadest range of participants and also to enrich and enhance their experience. All participants from both groups agreed that the installation offered different stimuli which helped them during the experience.

> *I enjoyed every aspect of the installation from the high quality images to the sounds of the birds and waves, everything was perfect. I couldn't stop exploring [...] But what made the difference was the pleasing scents that kept triggering positive memories and elevating my mood.*

When we discussed the multisensory aspects of the experience with the participants, they described how they felt about being able to experience the installation through their senses. Some of them qualified themselves as visually oriented, while others as a scent-oriented.

> *I'm too sensitive to smells and scents [...] I travelled to your home country, Tunisia, through all those pleasant smells and odors*

> *(Man: From the guest group; free translation)*

> *I enjoyed every moment of the experience, but my favorite was the beach at night. Those images took my breath away and I felt like I was present there with you and through your old memories*

> *(Man: Congenital limb deformation; free translation)*

Some participants enjoyed relaxing with the birds, waves, and even the waterfall sounds. They managed to let themselves go and start thinking about the experience as an opportunity to travel away from their daily lives.

> *For a moment I forgot where I was [...] I even chose to close my eyes and only enjoy the sounds and the odors, that made such a difference, I felt secure and relaxed [...]*

> *(Woman: Spinal cord injury; free translation)*

3.2.4 Awareness-raising tool

Although رحلة - réhla (Odyssey) was conceived with the primary purpose of offering participants an immersive and interactive journey promoting relaxation and well-being while exploring two natural environments (beach and forest), we also wanted to use the installation as a tool for raising public awareness about the

issue of accessibility among people with impairments. Against all expectations, the participants from the guest group almost did not notice our efforts.

> *[…]If you had not asked me about it, I would not have noticed. I was having such a good time that I didn't pay any attention.*
>
> *(Woman: From the guest group; free translation)*
>
> *I did notice the safety arrangements and the assistive technology accommodations and I thought that it is important to have all these elements in the experience since it is designed for all, but I did not understand that you were trying to raise aware-ness about the issue of accessibility*
>
> *(Man: From the guest group; free translation)*

On the other hand, participants from the subjects group highlighted the efforts made to address the issue through our design, and even advised us to adopt a more proactive approach. It is true we dealt less directly with the accessibility issues than we could have. Participants from the subjects group encouraged us to address the issue more directly to showcase the social and environmental barriers and also to reflect the reality of their life as it unfolds day to day.

> *I understand that the primary purpose of رحلة - réhla (Odyssey) was to offer relaxing spaces, but if you want to raise awareness about the issue of accessibility you need to address it in a more direct manner, […] Intent to shock and disturb often helps.*
>
> *(Woman: spinal paralysis; free translation)*
>
> *I get what you were trying to do, […] but I'm not sure that the general public is aware of how much natural environments are inaccessible for us.*
>
> *(Man: Stroke; free translation)*

From the guest group, only a few participants confirmed that from the begin-ning of the experience they became more sensitive to the accessibility issue for people with disability. Almost all of them were shocked when we mentioned that among the 25 participants with impairments who had taken part in the experience, few had ever been able to physically go to a beach.

> *To be honest I never paid attention to the accessibility issue, maybe because I never considered that going to the beach was challenging even for people using wheel-chairs, I think that I need to open my eyes […]*
>
> *(Man: From the guest group; free translation)*

4. Discussion and conclusion

In summary, our work consisted of developing a methodology for designing interactive and immersive installations that harness virtual reality experiences, with a particular focus on designing for people with disability. This complex project was, ultimately, a considerable success, and we learned a great deal about preparing

and implementing such an installation. We framed the design process in terms of "design thinking," an approach that has found favor across a broad range of disciplines and applications for more than three decades. The three stages invoked, which we called "empathy," "ideation," and "experimentation," are widely associated with this design approach although sometimes slightly different labels are used. The empathy stage encouraged us to go beyond the "needs assessment" process typically used as a first step in engineering design, to examine the day-to-day lives of people with disability, particularly, in the study presented here, focused on risk taking. This led to a major restructuring of the proposed project, and emphasized the ever-present need to involve people with disability in all aspects of the design process. Our early efforts orienting the design were also informed by the Cognitive Design methodology developed by members of the team earlier, and led us in particular toward an installation design that would call on as many sensory modalities as possible, to enhance the experience and also provide a sensory experience that would be interesting to anyone, regardless of the nature of their functional limitations. The importance of this early design choice was heralded by many participants during the evaluation stage. Another important issue raised by this work was the idea that definitions of accessibility need to address issues of safety and also social issues, and not be only confined to the physical, or informational environment as is often the case.

Beyond the process of designing the installation, there were also many lessons concerning the content of the experience that was presented to participants. Hence, we drew on universal design principles to determine, for example, the width of the walkways and the configuration of the platforms (for example, ensuring adequate room to turn a wheelchair, etc.). The need to include specific representations of accommodations for disability in the virtual environments was also emphasized both during the design phase, and also in the remarks made by participants after having experienced the installation. Although we incorporated some of these representations, it was clear from the post experience assessment that we could have done more, especially to heighten the use of the installation for raising awareness among a broader public concerning issues of accessibility.

Another feature of the design process we adopted was to integrate the personal vision of the main designer with additional elements, memories, and remarks culled from the experiences of people with disabilities who were consulted throughout the development. This made for a highly evocative experience, characterized indeed by a certain poetry of visual expression, which also was remarked upon by participants in the postexperience assessment. The realism of the 3D environment was also remarked upon and appreciated by participants.

It is also worth noting that the post-installation interviews highlighted the ways in which the installation inspired or even, in some cases, changed the perceptions of people with impairments, concerning what might be possible for them in the future. More could be done both with the development of installations like رحلة - *réhla (Odyssey)* that may have similar transformative effects, and also with longer term assessment to determine whether such effects are sustained in time.

Finally, it is worth noting that the costs for developing the installation were modest, amounting to no more than 12 K$ Canadian for both the virtual and physical components of the environment, not counting the student stipend.

Although for the purposes of this research we developed a particular installation that addressed the interests and needs of people with disabilities, we believe that the lessons learned, as presented in this chapter, could serve other virtual reality design projects, especially in the context of serving the population of people with impairments, but also whenever there is a focus on designing for everyone (i.e., universal design).

Acknowledgements

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