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Chapter 7
Embodied and Sonic Interactions in Virtual Environments: Tactics and Exemplars

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Abstract As the next generation of active video games (AVG) and virtual reality (VR) systems enter people's lives, designers may wrongly aim for an experience decoupled from bodies. However, both AVG and VR clearly afford opportunities to bring experiences, technologies, and users' physical and experiential bodies together, and to study and teach these open-ended relationships of enaction and meaning-making in the framework of embodied interaction. Without such a framework, an aesthetic pleasure, lasting satisfaction, and enjoyment would be impossible to achieve in designing sonic interactions in virtual environments (SIVE). In this chapter, we introduce this framework and focus on design exemplars that come from a soma design ideation workshop and balance rehabilitation. Within the field of physiotherapy, developing new conceptual interventions, with a more patient-centered approach, is still scarce but has huge potential for overcoming some of the challenges facing health care. We indicate how the tactics such as making space, subtle guidance, defamiliarization, and intimate correspondence have informed the exemplars, both in the workshop and also in our ongoing physiotherapy case. Implications for these tactics and design strategies for our design, as well as for general practitioners of SIVE are outlined.

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7.1 Introduction

> I felt that there was an opportunity to create a new design discipline, dedicated to creating imaginative and attractive solutions in a virtual world, where one could design behaviors, animations, and sounds as well as shapes. This would be the equivalent of industrial design but in software rather than three-dimensional objects. Like industrial design, the discipline would start from the needs and desires of the people who use a product or service, and strive to create designs that would give aesthetic pleasure as well as lasting satisfaction and enjoyment [17].

Thus spoke the IDEO founder Bill Moggridge in his book Designing Interactions (2007), on inventing the term "interaction design". The field Sonic Interaction Design was initially concerned with the aesthetic pleasure, lasting satisfaction, and enjoyment [24], but more recently the research focus in sonic interaction in virtual environments (SIVE) has shifted towards the sound spatialization tools and techniques. We posit that uniting sound and movement can bring back the desired qualities of sonic interaction to SIVE.

When we reviewed the interaction styles and metaphors in the past SIVE papers [24], we noticed how movement was mentioned as an integral part of sonic interaction, and we identified three broad categories of sonic interaction in those papers (1) object-focused, (2) direct mapping, and (3) movement-focused [10]. Twenty-six papers mentioned the term '*movement*' in the SIVE corpus (119 times total). Yet, no paper in the corpus gave a processual account on how these sound-movement interactions are actually designed. In other words, the coupling between movement and sound is treated as a black-box in SIVE papers, and the design dimensions such as aesthetic pleasure, lasting satisfaction, and enjoyment are not considered.

This is why we propose the general approach and particular elements of soma design for designing interaction in virtual environments. Soma design is a design process where designers aim for an improved sensory appreciation through their lived, sentient, subjective, purposive bodies—both improving their own design skills and sensitivities, but also aiming to deliver designs to end-users [12, 27]. Soma design aims to provide aesthetic pleasure, a lasting satisfaction, and enjoyment to a wide range of users, also in virtual environments. This aim pertains to the hardest living conditions, including but not limited to, aging, frailty, and physical pain.

This chapter focuses on encounters between soma design and movement-focused sonic interaction. By providing selected soma design concepts, design exemplars, and tactics, we hope to better articulate the need for movement-sound-interaction relations. To do this, we focus on the subtlest manifestation of these relations: the act of balance. We start with five soma design concepts we find most related to balance, and review three soma design exemplars using these concepts. We then put our considerations into an ongoing physiotherapy case study, which is being conducted in collaboration with an outpatient rehabilitation center in Frederiksberg, Denmark. We finally outline the implications of soma design in our next design phase, as well as on sonic interaction design practitioners in general. The structure of this chapter follows this narrative.

7.2 Soma Design

Philosophically, soma design is based on Shusterman's project somaesthetics, which is defined as the "critical, meliorative study of the experience and use of one's body as a locus of sensory-aesthetic appreciation (aesthesis) and creative self-fashioning" [25]. Somaesthetics has been adapted as a theoretical foundation for explaining the aesthetic experience of interaction early on, but Höök has *translated* also the practical aspects of somaesthetics into the design disciplines [12, 27].

In 2017, the last author of the current chapter organized a soma design workshop with the leading proponents of the approach, design professionals, and about a dozen researches. Our focus was the movement, sound, and light design on an actual bridge, connecting two buildings in our campus.[1] We have learned how to pay close attention to our bodies and first-person experiences while walking forwards and backwards, dancing, and crawling on the bridge (see Fig. 7.1), as well as during collective movement and reflective sessions. We also noted how this pragmatic approach differs from more cognitively rooted approaches in sound design [18] by putting movement in the forefront, and keeping the attention on the entire body or its parts at all times. In the following, we iterate the reflections towards experiential virtual environments, by visualizing the concepts in Fig. 7.2, as a seed for future multisensory world-making sessions in extended realities.

The **Inscription Bridge** considers how people use different parts of their bodies dominantly while leaving traces on the bridge. The traces will be initiated by light and spatialized ambient sound, but will be "carved" on the bridge by its curvature, and body parts. The curvature is,

> felt with your balance, how it changes your walking up or down. Which part of the body (people) use will change the experience, in a different way every time.

Smoothed carving and particle rolling sounds could complete the act of inscription.

The rationale of the second concept, **Bridge to Heaven** was to make people more aware of their surrounding outside of the bridge. In order to build such an awareness, the designers decided to create a dangerous zone at the bridge width, and envisioned to remove the side walls in a virtual environment. They wanted people to feel the danger and tension while passing through an open bridge without any fence. In designers' words

> "An everyday zone and then enter the danger zone as we call it Heaven." "Totally open bridge no fence nothing . . .. In order to be safe, you have to be aware of the surrounding!" "Tension and relief and tension. . ."

This design concept replaces an interior soundscape with an exterior one, and sonifies the danger zone with buzzing, supernatural, electric-like warning sounds. At the Heaven side, there will be a localized, granulated, and evolving major-seventh chord played by strings and a harp.

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[1] See http://soma-rhythms-2017.weebly.com.

Fig. 7.1 Soma workshop process

Fig. 7.2 Soma workshop outcomes. **a** Inscription bridge (left), **b** Bridge to Heaven (middle), and **c** Awe and wonder bridge (right)

The third concept, the **Awe and Wonder Bridge** concentrated on the ceiling. This is a design concept that will be sensible only if people slow down and explore the bridge. They will experience a night sky full of stars on the ceiling, and use it as a canvas to create their own painting. In designers' words:

> "We decided to put the emphasis on the ceiling because not to disturb people who don't want to get involved like people who just walk there, drink coffee..." "If you just walk slowly and then stop, that might be a start. Because the ceiling is your canvas, you are an artist, and you friends are artists as well..." "You move, you participate as you slow down... You create your painting!"

This concept clearly took inspiration from Petros Vrellis' interactive rendering of Van Gogh's painting *Starry Night*[2] and affords a similar, granular soundscape with localized, high-pitch star tines.

We hope the workshop process and ideation outcomes provide insight into the soma design space, and its relevance for sonic interactions in virtual environments. More recently, in a series of investigations, Plant *et al.* used soma design in tandem with critical incident technique for ideation and interactive machine learning for computation [22]. Sensory misalignment in virtual environments has informed the work of Tennent and colleagues [28]. At the same time, the teaching space of soma design has been more widely disseminated [29, 30], and applied to VR [7]. We are now able to try out and exchange soma design practices in wide range of domains [10], including virtual and augmented realities. Therefore we are in a good position to extend the multimodal listening design framework introduced in [26] towards bodily interaction through soma design.

A brief description of some characteristics encompassed by soma design can be outlined as follows: *subtle guidance* (directing focus and attention, for example towards a part of the body, without grabbing attention), *making space* (slowing down time, disrupting habitual routines and literal secluded areas), *intimate correspondence* (synchronized feedback loops) and *articulate experience* (provide opportunities to articulate the felt bodily experience). An important grounding in these methodologies is the concept of perspectives. Also, the act of defamiliarization shapes these characteristics. Defamiliarization, also known as estrangement [31] is a tactic to unbalance an established relationship between a movement, interaction, or sound (e.g., acousmatic listening) for generating novel design ideas [14].

7.2.1 Defamiliarization: Making Strange

A key aspect of the design approach outlined in [14], and elaborated further in [31] is the concept of "Making Strange". It aims to change certain aspects of a familiar activity until automated behavior acquired through habitual practice or experience (ingrained somatic habits) is broken, and a reflection on the inner processes is initiated within our bodies. The phases of defamiliarization may be grouped into four discrete

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[2] http://artof01.com/vrellis/works/starry_night.html.

steps [31]: *disrupt*, *destabilize*, *emerge*, and *embody*. In our bridge workshop, we have defamiliarized our everyday experience of passing the bridge by dancing and crawling on it, for example.

Postural stability, also more popularly referred to as balance, could be another example for making strange. It is something we all do every day when walking, running, sitting, and standing. To really understand what is involved in our balancing habits, we need to *disrupt* them. But engaging in arbitrary disruption might not destabilize the core of what we are searching for. Since we usually do not get sonic feedback from our balancing activities (except maybe from external auditory stimuli such as a creaking floor, or audible sounds from our joints in acute conditions), sound may provide the disruption needed. Within physiotherapy, both static and dynamic balance exercises, are often embedded in many therapy programs specifically targeting elderly, since postural instability generally increases with age [21]. The imbalance may be caused by an inability to integrate somatosensory, vestibular, or visual information [20]. Ideally, the participants will take on and understand what a sonification of balance might entail, through a first person intellectual, visceral, and somatic engagement. For an exemplar on balance and its relation to soma design and sensory misalignment in virtual reality using vibratory haptics, please see [28].

7.2.2 Perspectives

Soma design distinguishes between three perspective modes, namely the first, second, and third-person perspectives [12, 27]. The third-person perspective conceptualizes an observatory approach to design, encompassing routine methods in interaction design such as observing, interviewing, and user testing. The second person is important in user-centered or participatory design. Soma design puts forth the case of designing from a first-person perspective instead.

The first-person approach is represented by the designer actively engaging her physical body with the artifact under consideration during every part of the design process. In other words, this perspective evolves around *being* the user and attempting to experience what they will inevitably experience. Participatory design approaches are not neglected in this scenario. Höök argues that in order to make a meaningful design artifact, the designer has to take an active part in the participation aspect, not merely rely on observations. This creates a stronger coupling between the intended design idea (mental map) and how it is perceived by its end-users.

A related concept was also used in [14], distinguishing between the mover, observer, and machine perspectives. The mover perspective is very similar to the first-person perspective. It ensures that designers generate first-hand experiences about the activity being developed, which remain closely linked to the felt, lived experience of the potential user. The observer represents the idea of subjective evaluation through inspection of data, for example, video analysis or motion capture. The observer perspective is a loop meant to improve the desired movement through performance and subsequent inspection. Any application that uses movement as the primary source of interaction must process and make sense of the inputs. Hence, this perspective is about mapping movement captured or recorded by some sensing technologies into meaningful representations and/or feedback for the observer and mover. The machines currently only capture movement with considerable loss, in space, time, or range. Understanding these limitations is crucial in human-computer interaction.[3] Loke and colleagues provide convincing examples of how these three perspectives can be combined in design holistically [14].

7.3 Soma Design Exemplars for Balance

7.3.1 Balance Rehabilitation

The ability to maintain balance is fundamental for an individual's capabilities to move and function independently. Since postural instability declines with age, it puts older adults at an increased risk of falling, which can result in severe injuries. Therefore, balance training is often a well-integrated part of rehabilitation programs to improve balance and self-efficacy in activities of daily living (ADL) [20]. According to [2] balance loss usually occurs in a situation where attention is diverted; therefore, many interventions seek to embed physical activities that increase body awareness and kinesthetic awareness, including but not limited to dance-based training, aerobic, and tai chi, to increase balance and reduce falls [13]. However, the training has to be repeated procedurally to promote motor learning, causing many patients to lose interest and motivation [4]. Both AVG and VR systems have been deployed to increase enjoyment and exercise adherence. Most often such systems rely on visual, audio-visual, and/or vibrotactile feedback. However, balance deficiencies are compensated by both visual or podal dependences, and (static) balance rehabilitation often includes exercises that utilize both visual cues (open eyes) and without (closed eyes) [15]. In fact, previous research suggests that balance therapy using visual deprivation is more effective than when using vision as well, which indicates that vision can become a compensatory coping strategy for balance deficiencies [3]. Yet, augmented systems rarely rely solely on auditory feedback, meaning that such systems likely delimit the user from training other sensory-motor modalities which are critical to postural stability [5]. For this reason, it is highly necessary to explore how SIVE, focused on auditory feedback only during closed-eyes balance tasks, can be used to support balance training.

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[3] Readers interested in the machine perspective are referred to the MOCO provocation at https://provocations.online/whatescapescomputation/.

7.3.2 SWAY

SWAY is a prototype that seeks to encourage exploration of postural stance and stability through somaesthetic experiences [1]. On a high level, SWAY conceptualizes a dedicated space. Users within this space are tracked (observed) by a Kinect depth camera, which serves as the only means of capturing interactions with the system. From the pose (skeleton) acquired through the Kinect software, the authors extract an estimate of the center of mass (COM) relative to a fixed origin. Fluctuations of the COM in the XZ-axes are used to control two feedback mechanisms. The first element is a mechanical plate resembling a square bowl, which contains a set of marbles. This element is, within the SWAY space, placed in front of the user. The element delivers both visual and aural feedback. Micro-movements (fluctuations in the COM) tilt the plate, which in turn makes the marbles move. In the words of the authors *"...audio feedback from the marbles on the wooden platform, creates a soothing soundscape that could be compared to the sound of rolling waves"* [1, p. 471]. The second element is a wooden platform placed at the user's feet. Two loudspeakers underneath the plate propagate vibrations through the material, serving as a haptic feedback. The amplitude of the vibration signal is panned across the two speakers depending on the current offset of the COM. As a result of the combined modalities experienced through these elements, SWAY embraces many of the somaesthetic appreciation design concepts [11]. Its innate physicality relates it to *making space*. The quality of *subtle guidance* towards posture is achieved through the soundscape arising from the rolling marbles and the haptic vibrations. SWAY especially seeks to embrace the quality of *intimate correspondence*, with the feedback serving as an amplifying mirror of the bodily micro-movements.

7.3.3 Snap-Snap T-Shirt

Snap-Snap is a wearable garment embedded with a matrix of magnets spread out at even intervals across the back [16]. Through rich haptic feedback, Snap-Snap gives information about the posture of the back. Intended for people suffering from repetitive strain injury, Snap-Snap seeks to create acute awareness of posture through playful and somaesthetic experience. The design process of Snap-Snap is an exemplar of utilizing the different perspectives as laid out by soma design. Working primarily from a first-person perspective, the designer molds the intentions of the garment to fit the perceptions of the co-designer. The co-designer, in turn, provides feedback on their reflections and felt experiences during a three-stage design process. In addition, it serves as a good example of the mover-observer perspectives. Switching between the designer being the mover, then becoming the observer during trials by the co-designer, and vice versa. The result of this design process is that Snap-Snap became an excellent example both in terms of using the *subtle guidance* and *intimate correspondence* qualities of soma design. The strength of the haptic feedback was gradually corrected over the course of the design process, to provide just enough attention towards current posture of the back. The close coupling between muscle contraction/movement in the back and the haptic vibrations unifies in a feedback loop. The final design of Snap-Snap can be linked to the “Making Strange” principle as well. The final placements of the magnets within the garment require its user to move in uncustomary ways to activate the haptic feedback around certain parts of the back. This, in effect, was observed to cause the wearer to move more.

7.3.4 Slow Floor

Another prototype closely related to balance and estrangement is slowing down walking significantly, as done for example in Butoh dancing, and providing sonic feedback on the quality of the micro-movements [8, 9]. The authors collected phenomenological accounts of participants walking in relationship to the feedback provided by auditory displays. A program of case studies working directly with 13 movers from dance and somatic practices in “slow walking” evaluations combined with pilot design interventions in exhibition contexts informed the iterative and reflective cycles in this research. These case studies reveal themes around the first person felt qualities, the variant and exploratory nature of movement, and the rhythmic patterning that all result from the pressure-mediated auditory display. The final case study derives morphologies and features of micro-movement efforts as variant or invariant to movement intention, thus exploring the felt, first-person perspective in relation to high-level pressure data resolution.

7.4 Work in Progress: Balance Rehabilitation

Given the outline of the design strategy and three design exemplars, we will briefly explain how this relates to sonic interaction in virtual environments. A movement-based interaction consists of finely nuanced coordination between cognitive effort and bodily function, and does not entirely concentrate on the objects in the environment, but on the body itself. In that state, sound could be strategically used to maintain attention. Therefore, we kept the idea and the sound model of a rolling ball [23], but removed its tangible interface. Next, we provide a case study on how we tackle this nuanced movement-based sonic interaction in balance rehabilitation.

We made two visits to a Frederiksberg outpatient rehabilitation center and conducted semi-structured interviews with the primary contact therapists. These interviews helped us to determine the target group and their needs. Sessions at the rehab center in this context consist of a heterogeneous group of people of varying ages and diagnoses. Unique sessions for treatment of certain illnesses are available. However, the therapists would use a classification of their patient teams as those being “bad” and those being “good”. The bad teams are patients who are severely physically indisposed. The good teams are those who are recovering from minor inhibitions. Independent of unique illness, age, and severity of physical inhibition, therapists would reuse certain exercise programs and schemes.

In addition to interviews, ethnographic observations were also carried out over three physical therapy sessions at the outpatient center. These observations served two purposes: **(1)** gather further insight on the potential target group, and **(2)** generate an understanding of everyday sessions to determine which type of technological intervention best fit into daily routines. During these observations, informal interviews were also carried out with both the present therapist and her patients. When asked whether the therapist could see herself using a technological artifact during her sessions, she was generally positive. She expressed that such a thing could be weaved into her program, or in some cases replace another exercise. However, she pointed out that if the technology was too difficult to handle (e.g., too complicated to understand or too unpractical to maneuver) she would be hesitant to use it.

A couple of the patients were asked to reflect on their exercises. One patient explained, that his view towards an exercise was dependent on the challenge it presented. He explained that it was a self-reinforcing effect, whether he enjoyed it or not. If the exercise was too difficult or too exhausting, he would gradually come to dislike it. A group of patients explained that it was largely dependent on their mood on the given day, and what they perceived themselves to be able to do physically.

7.4.1 System Architecture

Based on these observations, a virtual prototype based on SWAY was constructed, see Fig. 7.3. The primary software running the prototype is a macOS program developed in Unity3D using the C# programming language. The program development has been realized through object-oriented programming (OOP) principles and has been constructed in a modular fashion. The complete architecture can be divided into five distinct areas:

1. **Audio Module**: The audio module taps into Unity's built-in audio pipeline. It contains the main classes that handle all audio processing.
2. **OSCulator application**: An OSCulator application is responsible for communicating with a Wii Balance Board (WBB) through a connected Bluetooth port. Sensor data from the board is parsed and further broadcast through open sound control (OSC).
3. **Balance Board Module**: The WBB module is in charge of receiving the OSC messages from OSCulator, and interpreting sensor data from the board. It also contains the main classes handling physics and game logic.
4. **Interaction Module**: The interaction module is the bridge between the WBB module and the audio module. It interprets user actions from the WBB module and supplies excitation signals to the audio module.

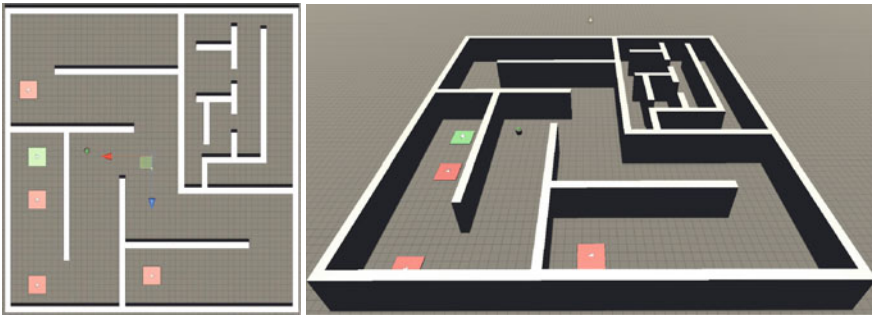

Fig. 7.3 Perspectives of the virtual environment (which is invisible to the users) developed on unity

5. **Python Web App**: The Python web app is a simple WebAPI that is in charge of heavy-duty matrix operations.

Consider the following scenario. A rehabilitation patient steps onto the WBB, puts on a pair of headphones, and closes his/her eyes. By distributing weight across its four sensors, the **WBB module** controls a 3D object in a virtual environment invisible to the user, see e.g., Fig. 7.3. A physics simulation in turn makes the object move, and its kinematic properties are used to generate excitation signals which are used by the **audio module** to generate feedback to the patient. While this auditory feedback is generated by physical model of a rolling ball, and therefore inherently object-focused, can we turn the attention back to the body and movement by employing soma design elements?

7.4.2 Soma Design Elements

The design of the prototype can so far be brought together by describing how the different aspects relate to creating somaesthethic experiences. Let us break down how the different elements of the experience correspond to certain qualities of soma design:

- ***Making Space*** has been approached by several design elements. The prototype is meant to be experienced with eyes closed. This should, in theory, force the sensory system to weight the vestibular and somatosensory systems higher [12]. By placing oneself on the WBB combined with the closing of eyes, transfers your mind and body into a dedicated *space*, both mentally and physically. The interspersed moment of standstill slows the down time and provides an opportunity for reflection.
- ***Intimate Correspondence*** has been approached through the feedback loops arising due to the mapping strategy. This is connected to the aural feedback, which is provided by an invisible object controlled by physics. Properties of physics such as

inertia extend the movement of the virtual object when attempting to do standstill, which in turn extends the aural feedback. This evokes a correctional movement in the mover, which results in a feedback loop until a total standstill is achieved.

- ***Subtle Guidance*** is achieved design of the aural feedback. The audio is a result of a feedback chain starting from the mover, moving through the machine, and the effects of a physics system controlling a virtual object. Hence, there is an argument for making the audio be physically inspired as well. Recall the SWAY project [1], which created a rich soundscape through marbles rolling on a wooden platform. Drawing on this inspiration, investigations on the audio design were aimed towards real-time synthesis of rolling and bouncing objects. This has been established by modal synthesis, as is customary in sound source modeling (see Chap. 2 for guidance on this topic). The other components of SIVE, namely (1) sound propagation modeling and (2) sound receiver modeling [24] remain to be implemented in our prototype.

7.4.3 Initial Observations

To evaluate the sound-source modeling of prototype, a small study was conducted. The participants we designed with consisted of four patients (*mean age* = *71, SD* = *8*); three males and one female. Three of the four patients were recovering from chemotherapy and one was having general balance issues. Three of the patients had never used technology in a rehabilitation context, while one had used it 4–5 times. To gather further insight on the felt bodily experiences, the first author encouraged participants to "think aloud" (as per the think-aloud method, e.g. [19]), or to "articulate experience" (e.g. [11]).

7.4.4 Test Procedure

The test was conducted on April 14, 2021 at the outpatient rehabilitation center in Frederiksberg, Denmark, during an actual therapy session. The prototype was allowed to take the place of an exercise, and be incorporated in a routine therapy session (see Fig. 7.4). Before commencing the test, the participants read, understood and signed a consent form. The whole evaluation procedure took approximately one hour. Each participant was allotted 15 min, whereas approximately 10 min were spent trying the prototype and another 5 min to filling in the rating scales. Before trying the prototype, each participant was informed about the general purpose of the test. They were asked to equip the headphones and step onto the balance board. The board was placed behind a chair which the participant could use for support (see Fig. 7.4). From this point, the application would be run, and the participant was told to close his or her eyes and just explore the space available by distributing weight across the balance board. During this time, they were encouraged to report on their general

Fig. 7.4 Test setup at the rehabilitation center

thoughts. After a while, or if the tester recognized that the participant was stuck, they were allowed to open their eyes and try the application with visual feedback from the otherwise "invisible" virtual environment. After having tried the prototype, they were asked to fill out the evaluation surveys.

7.4.5 Observations

The first participant (male, age 80) was hesitant to try the prototype at the outset. After he was convinced to try it by the present therapist, he struggled to understand the concept. While observing the virtual interface, the author noticed that he was unable to get the virtual object moving at all, which in turn resulted in little to no feedback. During the whole 10 min, even when allowed visual stimuli, he was unable to navigate around. Admittedly, he was frail and had a hard time even standing up without frontal support. Hence, he could not create enough force for pressure sensors in the WBB to recognize his attempts.

The second participant (male, age 74) did better. Even though he was similarly in need of support, he managed to navigate around the virtual environment with his eyes closed, hence producing a feedback. When visual stimuli was allowed, he was able to complete several obstacles and manage to score a point.

The third participant (male, age 58) simply did not comprehend the interaction. When asked to elaborate, he explained that he could not perceive what the goal was. Again, similar to participant one, he was a bit hesitant to give into the experience, and declined to have his eyes closed. He could maneuver around fine, but chose to use the support anyways.

The fourth and final participant (female, age 74) was surprisingly positive. Of the four participants, she was the most able and/or agile, but still chose to use the provided support. She was able to navigate around using only sound, and even managed to explore an obstacle, which unfortunately she could not escape. After allowing her visual stimuli, she considerably improved, both in terms of game progression and participation factor. Struggling from existing balance problems, she was used to doing various rehabilitation exercises, and explained that she had a hard time pushing herself to maintain them. She explained, in contrast, that she could see herself using the prototype often. However, she expressed that she really did not care about any of the aural elements and that they did not affect her in any way. However, just using the primitive interface to the virtual environment, she could keep going for a long time.

These observations indicate that we need to work harder to design meaningful soma-based physical rehabilitation experiences. We also need to complete the entire sound design chain, as well as incorporate other modalities. In addition, opening yourself towards somaesthetic experiences and bodily reflections requires a certain internal will to do so. Similar notions were observed in SWAY, whose users had a hard time reflecting on their felt experiences. As such, one would agree with [12], that creating designs which quietly cater towards enabling such reflection is rather hard to achieve.

7.5 Conclusions and Future Work

This chapter highlighted three themes of soma design that can be useful for designing sonic interaction in virtual environments: Making space, intimate correspondence, and subtle guidance. These elements should be trained by the designers first, then introduced to users. The first ideation workshop describes how they are trained by the designers, and the therapy case study illustrates how they are introduced to the users.

- **Making Space**: Allow your users to be on a dedicated physical or virtual *space,* slow down time, and facilitate inner sensorial tuning and reflection.
- **Intimate Correspondence:** Facilitate and embrace the feedback loops.
- **Subtle Guidance:** Externalize attention subtly, and try to keep it on movement as much as possible.

Perspectives and defamiliarization should frame all these elements. We invite sound designers to try soma-based approaches and reflect on their design sessions regularly and actively. One way of doing this is using body maps before and after the design sessions. We regret this was not the case in the case studies reported here, but we will include them in the future.

Body maps are simple sketches of body contour, used to recognize, visualize, and reflect on all three elements of soma design outlined above. Besides its ubiquitous use in soma design, body mapping currently informs research projects with populations marginalized by disability, mental health status, and other vulnerable identities [6], enabling diverse technologies such as wearables, virtual reality, and web-based technologies. The approach can also have a significant impact on sound design, from externalization of sound sources to participatory sense-making in dynamic soundscapes. We plan to implement the three bridges of the ideation workshop in VR, together with the body maps and soma sound design principles.

Finally, the therapeutic applications of soma-based sound design should be further developed. While somaesthetics has rich relation to therapeutic movement correction through defamiliarization, soma design is yet to embrace this direction with technological interventions. We hope to contribute to this line of research by re-implementing the ideas and soma-based methods in exemplars such as the Slow Floor and using body maps as a reflection tool in our own research.

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