

Incorporating Virtual Reality with Experiential Somaesthetics in an Embodied Interaction Course

Cumhur Erkut and Sofia Dahl

Abstract: *Engagement with virtual reality (VR) through movement is becoming increasingly important. Therefore, VR developers should improve their bodily skills and learn how to use movement as design material. To do so, first-person accounts of the development and experience are necessary. Since these qualities are well addressed in experiential somaesthetics, we explore the education space in VR, with attention to the first-person experiences, movement data, and code. We present an approach for teaching and designing VR-based embodied interaction and describe simple projects implemented by the participants. The evaluation of projects indicates that the concepts, practices, and perspectives of embodied interaction were attained in VR. Our reflections contribute to the literature on movement-based interaction education in VR, and its evaluation and validation by first-person accounts, in addition to the data and program code produced.*

Keywords: *embodied interaction, design theory, movement qualities.*

1. Introduction

This article focuses on teaching fundamentals of movement-based interaction in virtual reality (VR) to media technology students, by combining specific activities informed by experiential somaesthetics, including movement exercises and theoretical research material, with technological practices such as motion capture and coding. While the digital technologies of movement are increasingly specialized, the value of somaesthetics is appreciated in designing the complex and effective feedback loops between technology and humans.¹ As an interdisciplinary project grounded in philosophy and aesthetics, the potential of somaesthetics in the education of human-computer interaction (HCI) and interaction design is explained in detail by Bardzell, in his commentary to Shusterman's Somaesthetics entry in the HCI Encyclopedia.² According to Bardzell, design professionals need to have the following skills:

1 Höök et al., "Somaesthetic Appreciation Design."

2 Shusterman. "Somaesthetics," *Encyclopedia of Human-Computer Interaction*.

1. a cultivated ability to read sociocultural signs and trends;
2. a creative and reasoned ability to explore alternative futures;
3. a verbal ability to articulate these activities;
4. a receptiveness to alternative framings and a willingness to explore highly variable alternative directions; and above all
5. a personal identity or coherence that holds all of these moving parts together through a given process.

Shusterman discusses some of these skills in the context of somaesthetics education,³ and suggests that experiential somaesthetics can provide:

1. pre-warning for feeling and emotions, with impact on learning effort;
2. better control of movements, hence our actions; and
3. more positive attitudes and conduct, since education can be considered as reorganizing or retraining habits of feeling and movement and habits of conduct to which feeling and movement contribute.

Shusterman asks,⁴ “In what manner of framework could practical somaesthetics be most effectively introduced into the school curriculum at the various levels of primary, secondary, and college education? What reforms of curriculum, institutions, and attitudes would be needed to introduce such embodied education?” In this paper, we try to provide an answer to these questions with a case study in media technology curriculum, as an embodied education (as in the quote) of VR.

Somaesthetics has been previously applied to media technology for body/media relationship,⁵ with frequent references to VR. Specifically, the diversity of media forms and the importance of interactivity, as well as the moral, social, and aesthetics problems of the body representation in VR are still very important. The call for experiential somaesthetics⁶ encourages people to “transfer their concern from the external shape and attractiveness of the body to improving the qualitative feeling of its lived experience and functioning.” Here, we describe and reflect upon our educational activity of such experiential skills directed at developers of media technology.

2. Background and State of the Art

The recent affordability of headsets and content distribution channels have made VR an interesting educational opportunity. Takala and his colleagues provide a good overview of the academic curriculum of VR during the last three decades.⁷ High-quality textbooks, such as *The VR Book*,⁸ and MOOCs, such as the popular five-course VR specialization created by Gillies and Pan at Coursera,⁹ provide learning opportunities for large audiences. All these channels agree on the uniqueness of the bodily VR experience, consider embodiment as one of the illusions

3 Shusterman, “Somaesthetics and Education: Exploring the Terrain.”

4 Ibid.

5 Shusterman, “Somaesthetics and the Body/Media Issue.”

6 Ibid., p. 45.

7 Takala et al., “Empowering Students.”

8 Jerald, *The VR Book*.

9 <https://www.coursera.org/specializations/virtual-reality>

that make up this experience,¹⁰ and derive interaction design guidelines.^{11,12} The illusions in VR are defined as erroneous or misinterpreted perceptions of sensory information that provide direct response to synthetic stimuli, indicating a positive experience of VR. The embodiment illusion (or virtual body ownership) and the illusion of presence (the experience of *being there*) are considered the most prominent illusions in VR. Presence is composed of the place illusion and the plausibility illusion.¹³ There are also illusions and distortions occurring on behalf of virtually stationary and moving users. While there is much research on the representational and the experiential aspects of illusions, the first-person accounts of developing and experiencing virtual reality, so ubiquitous in early VR,¹⁴ are not common in the current scientific literature.¹⁵

Shusterman has previously addressed¹⁶ this issue of a media technology challenge to embodiment mainly by arguing two points: “First, no technological invention of virtual reality will negate the body’s centrality as the focus of affective, perceptual experience through which we experience and engage the world. Second, that cultivating better skills of body consciousness can provide us with enhanced powers of concentration to help us overcome problems of distraction and stress caused by the new media’s superabundance of information and stimulation.” Soma-based interaction design,¹⁷ in a similar vein, recognizes VR as one of the emerging technologies that will have an effect on our lived experience. Depending on its design, it will encourage certain movements, experiences, practices, and awareness of our bodies—while not encouraging others. This, in turn, will affect how we work, play, and communicate in VR. This is why we need to cultivate our understanding of what it means to be a sensing, feeling, and moving body, shaping and being shaped by our lifeworld.¹⁸

The skills that we see as useful for VR developers in terms of embodied interaction include:

- understanding and describing movement as a sociodigital design material in real and virtual worlds,
- developing the bodily skills needed for technological development,
- understanding what movement qualities are and how they can be extracted from movement tracking data, and
- applying these methods and techniques to real-world scenarios, e.g., games, robots, installations, and for the present paper, in VR.

We consider this list as a practical and thematic rendering of Shusterman’s list for media technology, to address the last and the most important item in Bardzell’s list: a personal identity or coherence.

How can this need be incorporated in learning and practicing VR, with attention to soma-based, embodied interaction with a strong first-person perspective? Our aim was to inform

10 Slater, “Place Illusion and Plausibility.”

11 Gillies, *What Is Movement Interaction in Virtual Reality For?*

12 Jerald, *The VR Book*.

13 Slater, “Place Illusion and Plausibility.”

14 Lanier, “The Sound of One Hand.”

15 Serafin et al., *Virtual Reality and the Senses*.

16 Shusterman. “Somaesthetics,” *Encyclopedia of Human-Computer Interaction*.

17 Höök et al., “Embracing First Person Perspectives.”

18 Ibid.

our students in using movement as design material and obtain first-person experiences of felt qualities of movement, both in virtual and real worlds. By “qualities,” we refer to the sensation of how (e.g., lightly, smoothly, jerkily) an action is performed, rather than the action itself (e.g., reaching, grasping).¹⁹ These qualities can be described through the first-, second-, and third-person perspectives²⁰ and sensed through proprioception, in addition to vision and hearing.

Our study on the educational space of embodied interaction in VR included the general overview of VR education by Takala and his colleagues,²¹ textbooks,²² and MOOCs, e.g., Gillies and Pan’s Coursera specialization. Although they are very useful learning resources for the technical side of VR, none of these resources have the vivid first-person accounts of developing and experiencing virtual reality, in line with previous descriptions.²³

Our ongoing embodied interaction course was designed for first-year master’s students at Aalborg University specializing in sound and music computing, games, interaction, or computer graphics. In 2016, two students proposed a project that combines the Leap Motion hand-tracking sensor with VR, using the Orion SDK and Oculus Rift and focusing on a drawing application. When this mini-project was integrated with a larger one (which was eventually published),²⁴ we expected to recruit more students interested in VR. Indeed, the following years have seen an increase in students interested in applying embodied interaction in VR, with five students in 2017 and more than ten students in 2018 (accounting for about half of the class) interested in VR. To meet this demand we performed some rearrangements and changes in the course. The following section will describe in more detail the general outline of the course and the changes implemented.

3. Our Approach: Methods and Interventions

General Course Outline

Our master’s-level elective course in media technology requires our students to learn the theory of embodied interaction, together with the use of basic computer vision, creative coding, embodied agents, multi-agent systems, AI engines, and wearables and VR basics. Many of these subtopics were inherited from a curriculum focusing on robotics and embodied conversational agents. Although the curriculum and study plan are the same as the original course²⁵ (taught also in a different location), we have gradually changed our approach to these subtopics through a lens focused on soma-based design.²⁶

As specified in the course description, the successful student must have knowledge about standard methods and techniques in embodied interaction; be able to understand and describe movement as a design material; be able to understand the bodily skills needed for technological development, decision making, steering, and path finding; and be able to understand what movement qualities are and how they are extracted from movement tracking data.

19 Fehr and Erkut, “Indirection Between Movement and Sound.”

20 Hornecker, Marshall, and Hurtienne, “Locating Theories of Embodiment.”

21 Takala et al., “Empowering Students.”

22 Jerald, *The VR Book*.

23 Davies, “OSMOSE.” Lanier, “The Sound of One Hand.”

24 Gerry, “Paint with Me.”

25 See <https://moduler.aau.dk/course/2019-2020/MSNMEDM2145>.

26 Höök, *Designing with the Body*.

The course consists of ten sessions, either half or full days, in combination with a project (worth 2 ECTS, or two-fifths of the course effort) that students hand in together with a brief paper for the oral examination in June. The students prepare for the first lecture by watching a video prepared by the Universidad de Zaragoza ([The embodied mind](https://vimeo.com/107691239) at <https://vimeo.com/107691239>) and select their background research literature from the proceedings of the ACM Movement and Computing (MOCO) Workshop (<http://moco.ircam.fr/>). We believe that every graduate course could be linked to a particular scientific community, and for our course the best candidate is MOCO.

Our general approach is to build the knowledge and skills around theory, technology, and movement. In the theoretical part we introduce students to concepts from interaction design, AI, philosophy, and psychology. We engage the students in learning activities on how the different perspectives aid and affect the design process and outcomes, how our bodies affect perception and action, and how developers/designers use their bodily skills in their craft.

The technological part is focused on tools for implementation and analysis (including motion capture and various toolboxes for VR development and movement analysis). For the movement part we engage the students in different kinds of movement exercises to make them perceive and reflect on the first-person experience of movement. This movement material includes some practical exercises from a previous collaboration with contemporary dance choreographers,²⁷ which were adopted from Loke's movement exercises,²⁸ such as playing with everyday movements, e.g., in the act of walking.

Within the general course outline, we typically devote some sessions to workshops on movement, for instance by exploring and analyzing movement with motion capture systems. With respect to technological and analytical tools the students also get a brief introduction to *Laban Movement Analysis (LMA)* and specifically Laban's theory on *effort*.²⁹ Although developed for dance, LMA provides a conceptual framework for describing the quality of movement in a way that can be systematically used to analyze and understand a range of activities. Briefly, Laban proposed to describe the effort of a movement as how it evolves in terms of time (quick-sustained), space (direct-indirect), flow (free-bound), and weight (light-strong), and this systematic way to describe movement quality has been used for dance as well as music and human computer interactions.³⁰

Specific interventions in 2017

In comparison with earlier versions of the course, we specifically implemented the following main changes during 2017:

1. **Short, frequently occurring movement tasks.** Rather than the previous two-day movement workshop, we implemented short exercises into the sessions. Examples of such movement exercises are walking through wide or narrow door openings, or the change of viewing perspectives by standing on a desk or crouching under it. In the 2018 edition of the course, we have further experimented with the Finnish health-fitness program ASAHI.³¹

27 Erkut and Rajala-Erkut, "Beyond Command & Control."

28 Loke and Robertson, "Moving and Making Strange."

29 Höök, *Designing with the Body*, Chapter 6.

30 Ibid.

31 <http://www.asahinordic.com/en/front>

2. Introduction to soma-based design and first-person perspectives, by reading Höök et al.³² Specifically, we present the students with two partly opposing viewpoints, contrasting soma-based design with a more utilitarian view of HCI as problem solving³³ and highlighting the necessity for first-person experiences. Through a debate, the students are challenged to argue for one or the other approach.

3. No set programming environments. Rather than introducing and giving exercises to solve in a particular programming environment, we let students choose freely what to use for implementation and concentrate on giving them a solid base for performing choices that make sense in terms of using movement as design material. However, those who develop VR applications univocally chose Unity3D³⁴ as their programming environment.

4. One-day practical workshop together with students at the Danish National School of Performing Arts. In 2017, this proved a very fruitful collaboration, not only because of the specific exercises (presented below) but also due to the feedback and perspectives the students offered each other. Our students also practiced trusting their autobiographical,³⁵ first-person experiences in developing their mini-projects. In 2018, we had a graduate student from the Danish National School of Performing Arts following the course and preparing occasional choreography for our participants. In addition, we have conducted practical motion capture workshops in a workshop setting.

Details of joint workshop (strengthening the first-person experience)

On March 23, 2017 the whole class visited the Danish National School of Performing Arts, which offers an international graduate program in contemporary dance, for a full-day workshop. The title of the workshop was “Making Sense of Technology for Performing Arts,” and its learning objectives stated that participants should be able to:

- discuss the use of technology subjectively and objectively, regardless of their discipline;
- evaluate the use of technology from existing artworks;
- make appropriate technological choices for their artistic/technological projects; and
- collaborate with participants outside their discipline to create an artistic idea/sketch/task involving HCI.

The participants, who were equally distributed from the Danish National School of Performing Arts and our students, gathered in the studio, and during a short greeting and introduction the performing arts students were briefly informed about the course and the projects of our students. After a short warm-up session, all students engaged in movement exercises proposed by the performing arts students. All exercises related to the experience of

32 Höök et al., “Somaesthetic Appreciation Design.”

33 Oulasvirta and Hornbæk, “HCI Research as Problem-Solving.”

34 <https://unity3d.com>

35 Höök, “Transferring Qualities from Horseback Riding to Design.”

movement qualities such as body limbs moving in straight lines as opposed to curves. Another exercise mapped the movement effort and viscosity of the imaginary matter to the width and length of the dance studio, respectively, and instructed the participants to experiment with different trajectories. After a break, our students presented their project ideas in more detail in a “speed dating” exercise. Here the two groups of students formed two concentric circles where the students in the inner circle quickly explained the main idea of their project to the students in the outer circle, which was rotated every five minutes. This exercise, which is used in soma-based interaction design,³⁶ allowed the students to refine and sharpen their own idea by repeating it. After this, students from the two institutions paired up and “body-stormed” about the project ideas. That is, the students acted out the movements and how the interaction could work out. With adequate reflection, discussion, body-storming, and resting, the explorations continued for the entire day. The session ended by setting a date for the performance students’ visit to the media technology venue to experience and try out the mini-projects.

4. Outcomes: Self-reports and Evaluation

The VR-related mini-projects submitted by students as part of their examination are outlined in this section, resembling *annotated portfolios*.³⁷ The structure of our presentation is as follows: we first describe the projects in their creators’ own words (in italics), then reflect briefly on the perspective and movement qualities in relation to experiential somaesthetics. Specific to the VR projects, we requested the students to reflect upon the three important illusions in VR, as introduced in the Background section of this paper, namely the place, plausibility, and embodiment illusions.³⁸ They all showed good understanding of these illusions, both in their reports and presentations.

Projects 1 and 4 were individual projects, whereas P#2 and P#3 were completed by groups of two students. All projects except P#3 were tried out by one of the authors in a lab setting, wearing an Head-mounted Display (HMD) and headphones, and project source codes were also examined. P#3 required the fixture of a wearable prototype, which was time consuming; therefore one of the students presented the interaction, and the evaluators watched the virtual environment from a big screen.

Until 2017, the grading basis was pass or fail; a project that addressed most elements of the course learning objectives and ran in real time was evaluated as passing. Therefore, all projects below had a passing grade. Starting in Spring 2018, the course has been evaluated on a 7-scale grade, and we currently assess to what degree the learning objectives were met.

P#1: TaijiJian VR

In this project, a virtual experience was created, in order to explore the possibilities of an embodied cognition and interaction approach of sound effects synthesis in real time, responsive to the virtual body of the user and his movement. The experience consists of a Taijijian simulator, a Tai-chi modality with a Chinese Jian sword. The HTC Vive system was used for the visual display and movement tracking, processing the data collected in real time in both Unity 5 and Max 7, including 3D binaural sound rendering.

In the real world, the presence and movement of human bodies and objects make changes in the

³⁶ Höök, *Designing with the Body*.

³⁷ Gaver and Bowers, “Annotated Portfolios.”

³⁸ Slater, “Place Illusion and Plausibility.”

sound environment that surrounds them and how it is perceived. Therefore, to improve the illusion of presence in virtual reality experiences, it is interesting to investigate and develop new techniques and frameworks for creating sound design systems responsive to the presence and movement of the user's body and virtual objects. Furthermore, these systems should be compatible with 3D sound rendering methods to give them spatial meaning from the user's perspective.

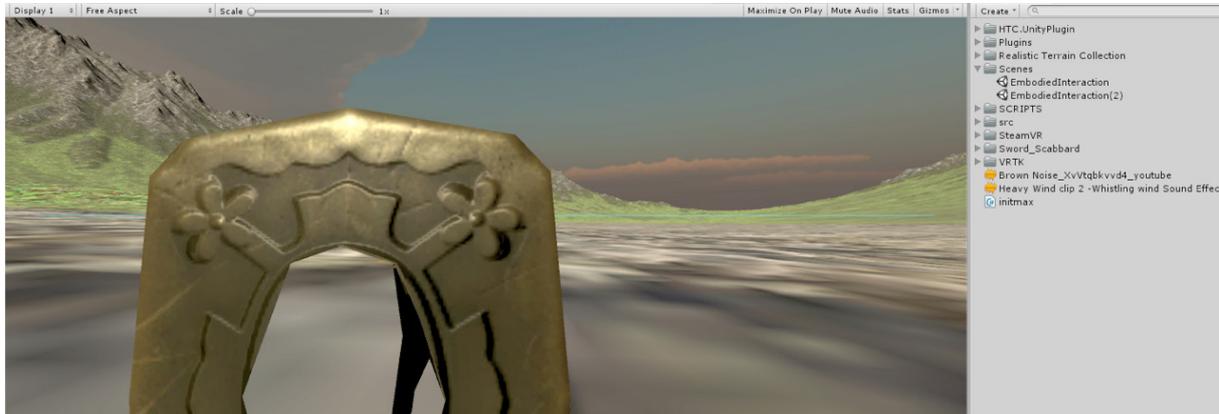


Figure 1: Top: Taichi Jian beginning scene. Bottom: Entering the cave and holding the torch. Pay attention to the animal paintings on the walls.

Evaluation of TaijiJian VR

The slow, completive movements of Tai-chi practice (Figure 1, top) offered a useful premise to discuss the movement qualities, and the meditative nature of the audio/visual environment (mountain view and subtle wind) sparked high expectations in evaluation. The report, however, was written in third-person perspective and explained mapping of the sounds and their relation to presence in VR (not the movement) from a cognitive point of view. While the project focus was on the functional outcome, the student demonstrated several subtle, nuanced movement qualities in the use of the sword. However, the first author's trial needed exaggerated movements to make the sword sounds audible, and this negatively affected the soma-based experience.

P#2: Cave Exploration—Rock Paintings

This project focused on the design of a virtual reality experience of ancient rock and cave art. It relies on embodied interaction to relive a virtual ancient cave. The interaction design invites the user to navigate and explore a virtual cave by interacting with a virtual fire torch. Based on the user's movements in the virtual cave, synchronized sonic and light events are triggered. The interaction design utilizes the Oculus Rift CV1 and the Oculus constellation system to track a user in the physical world and transfer the movements of the user into the virtual environment. The Oculus touch controllers are used to substitute for the user's hands in the virtual environment. The programs are used to develop the virtual reality, likewise the mapping of fire particles to the virtual fire torch and the triggering of events.

The embodied interaction design was informed by movement-based game guidelines:³⁹ we focused on a specific movement guideline from the category of “movement requires special feedback” as a framework for designing the movement feedback ... The category “celebrate movement articulation” encompasses the choice of giving feedback to the user's movement quality moment by moment. Importantly, it is not merely a question of if and when, but especially how the movement is performed.⁴⁰ The fire particles are rendered with the Unity particle system. The dynamics of the system are influenced by properties of birth and properties of lifetime. The speed of the user's movement is directly reflected in the emission and spread of the fire particles from the virtual fire torch. Slow movements produce a trail of spread fire particles leading to attention on the surroundings. Fast movement produces a narrow flame with no trail of fire particles.

Inside the cave is a hidden history; the revelation of this depends on how much a user invests herself in VR, meaning moving away from the starting center point and exploring the space. The user can trigger four events that provide enhancement of the symbolic cave paintings in the form of soundscapes and light effects. To incorporate a gradually unfolding of the cave paintings, a user must discover the cave to trigger the sonic events paired with the visuals of the paintings. Four soundscapes are mapped into four areas in the cave that are paired to the four cave walls. The soundscapes provide more vivid descriptions of the cave paintings in terms of sound effects, e.g., wild animal sounds paired to the related cave painting. Four spotlights in distinct colors turn on with the related sonic event.

Evaluation of Cave Exploration—Rock Paintings

This project creatively utilized many guidelines coherently in a high-quality production. It described some of the development and implementation choices in first-person perspective. The code contained four iterations of the concepts, all of which were calibrated by the designers'

39 Isbister and Mueller, “Guidelines for the Design of Movement-Based Games.”

40 Ibid.

own movements and explorations. Both the report and the presentation had frequent references of movement qualities. Especially in the presentation, Laban dimensions (see Section 3) were used to describe the movement qualities. The visual and auditory elements were very skillfully constructed, and the narrative was engaging and captivating. Rock Paintings was the highest-quality production we have evaluated in several iterations of the course.

P#3: Arm Constraint—Pseudo-Haptics

The ability to modify and reshape the physics of a virtual reality creates countless opportunities, yet not all controllers allow for suitable human interaction. This project investigated an alternative approach to the bubble technique⁴¹ in a virtual environment using pseudo-haptic feedback. The method exploited physical affordances of stretching an elastic band to represent the imaginary tension one would feel when extending the arm to boundaries that are physically impossible (see Figure 2).

Our initial focus was to investigate the acceleration of hand motion while reaching out and grabbing an object. We assumed that a quick acceleration of your arm would be the most promising way to eject some grabbing device in a virtual space.

This assumption was considered from a third-person perspective,⁴² by discussing the imaginative movement of grabbing an object out of reach. Yet after actually performing the movement ourselves, it was discovered that a quick stretching motion not only felt unnatural to do but also decreased how well you aimed toward the object. When reaching for objects in the real world, a much slower and fluent movement is performed than first anticipated. This might be caused by having to use multiple motor skills and visual cues, in order to maintain a certain precision needed to grab objects. We have to judge the distance to the object, control the speed of our arm and other body parts such as torso rotation, and determine when and how to grasp the object with the hand. We are naturally good at this within our reaching limits, as we know exactly where our limbs are in relation to our body. However, when you are able to reach beyond this limit it becomes an unfamiliar motion that may cause some cognitive confusion. As can be seen (Figure 3), the apparatus allows for two states: one in which the elastic cable is loose, resembling normal reach within the VR environment (left), and the other having high tension, resembling reaching beyond normal reach (right).

The virtual hand (Vh) follows several measurements depending on the distance between the shoulder point and the real hand (Rh), and the chosen threshold of the rubber band (Figure 3). If users have their Rh stretched further than the rubber hand threshold, the Vh will move in the direction of a vector represented by the shoulder and hand joint (VSH). The speed of the Vh is determined by how large the magnitude of VSH is compared to the rubber hand threshold. If users have their Rh stretched less than the threshold, the Vh will move toward the Rh, where the speed is determined by the duration of the state added to a bias. When the user's hand and the Vh are positioned at the same location, the Vh will completely follow the Rh.

Evaluation of Arm Constraint

The students have completed a VR engineering project with little resemblance to experiential somaesthetics, including the movement qualities and first-person experiences. Yet they have solved a practical HCI problem⁴³ and contributed to a state-of-the-art VR interaction. Fortunately, during their demonstration they referred to Laban dimensions and explained how the wearable

41 Dominjon et al., "The 'Bubble' Technique."

42 Loke and Robertson, "Moving and Making Strange."

43 Oulasvirta and Hornbæk, "HCI Research as Problem-Solving."

apparatus changed the movement qualities in typical reaching tasks.



Figure 2: Wearable apparatus



Figure 3: Left: The two states of the wearable apparatus. Right: The states in a virtual environment.

P#4: MoCap with Rokoko Smartsuit

This project was a special assignment to learn how to use a recently acquired Rokoko Smartsuit⁴⁴ to capture subtle movements in a practical somaesthetics workshop. While the project focus was on the functional outcome, the student tried to apply the embodied design ideation framework of Wilde and her colleagues⁴⁵ to the observations he made on the wearer of the suit, and on his behavior when observing the avatar on screen (see Figure 4). We outline his account as an example of the third-person perspective.

By wearing the suit and viewing one's movements as an avatar on screen, the user is disrupted in his or her habitual behavior. This destabilizes the user's understanding of how his or her bodily movements look from a different perspective and changes the proprioceptive perception of one's limbs. A natural curiosity emerges to see how well the avatar responds to one's own movements, as it acts like the user but looks different. This embodies the potential for exploring possibilities of real-time motion capture technology.

Evaluation of MoCap with Rokoko Smartsuit

By being present at a two-day practical somaesthetics workshop, the participant gained a lot

44 <https://www.rokoko.com/en>

45 Wilde, Vallgård, and Tomico, "Embodied Design Ideation Methods."

of first-person perspective in movement and interaction design. The special nature of the assignment did not allow for reflection on these, yet the student provided examples of some movement qualities from the recorded videos and motion capture data. Based on his work, in the current (Spring 2018) edition of the course, we used the Rokoko Smartsuit extensively in our movement and computing exercises.



Figure 4: MoCap with Rokoko Smartsuit. The actual situation (left), the Smartsuit Studio representation (middle), and the virtual on Unity (right).

5. Discussion

The course activities briefly outlined above—movement exercises; theoretical research material; and practical motion capture, coding, and designing embodied interaction—constitute our approach to make students well equipped for being good designers of movement-based interactions, also in VR.

The mini-projects submitted by the students demonstrate their knowledge of three important illusions in VR, namely the place, plausibility, and embodiment illusions, the last being extended toward human-centered embodied interaction. Students were able to discuss perspectives of movement⁴⁶ and quality in terms of Laban effort,⁴⁷ and in our opinion, developed “a personal identity or coherence that holds all of these moving parts together through a given process,” with reference to Bardzwell’s list in the introduction. These projects were made available to the new students in Spring 2018 for inspection, try-outs, and reflection from a first-person perspective.

Taijijian VR proved the technical possibility of using VRTK for different headsets and desktop prototyping. This is important since the increasing number of VR projects put pressure on our labs, in terms of logistics. It also proved the potential of interactive, procedural sound generation in tandem with VR interaction. While it focuses on instrumental interaction with a sword—a popular controller for fast-paced and adrenaline-driven VR games—the project provides an alternative framing for slow, contemplative movement and paves the way for experiential somaesthetics. *Taijijian VR* also challenges the design guideline that auditory feedback may be distracting for somaesthetics appreciation⁴⁸ and proves that skillfully designed interactive sound can, on the contrary, strengthen the action–perception loop.

Cave Exploration VR integrated many guidelines from VR, games design, narratives, and embodied interaction into a high-quality application. It provided an example of what we want to achieve in embodied VR interaction. It will be a running demo in our lab and a case study for future editions of the course.

⁴⁶ Loke and Robertson, “Moving and Making Strange.”

⁴⁷ Maranan et al., “Designing for Movement.” See also Section 3.

⁴⁸ Höök et al., “Somaesthetic Appreciation Design.”

Arm Constraint proved a useful practice for us to understand the engineering side of multimodal interaction in VR. The passive device prototype has a potential to be actuated with haptics. The project has obvious references to the body, embodiment, and familiarity/unfamiliarity with the movement and its cognitive effects (*However, when you are able to reach beyond this limit it becomes an unfamiliar motion that may cause some cognitive confusion*). Yet bringing these closer to the enacted first-person view of interaction will require iterations.

MoCap with Rokoko Smartsuit became a standard part of our course in Spring 2018, and together with somatic exercises it had the most profound impact on the student projects since then. Based on this implementation, some participants in the Spring 2018 edition could put a transparent sphere around a moving body, indicating its immediate reach, or visualize the traces of the arm movements in an assignment after the first class. We are currently researching and developing this aspect for the 2019 edition.

6. Conclusions and Future Work

We have presented an approach for incorporating VR elements in teaching embodied interaction. The activities are conducted to guide the participants toward the felt qualities of movement, in real and virtual worlds. We have reflected upon the structure, activities, outcomes, and recent changes in the current phase. We have identified two factors that have the most impact on student projects: somatic exercises and hands-on work with motion capture including the data produced. We recommend the somatic exercises to any program that enters into new design areas. Höök discusses five techniques⁴⁹ for further training somaesthetic skills: 1) focusing on change and interest, 2) disrupting the habitual, 3) Laban movement analysis, 4) autoethnographies, and 5) engaging with other somaesthetic connoisseurs. We continuously experiment with new tools, techniques, and guidelines to design for and through movement qualities, and we hope to contribute to this list, as well as to interaction design, VR, and programming education in general. Likewise, motion capture training is very valuable for VR, and we hope to work with more advanced tools and techniques in the future.⁵⁰

Before we could work with the tools and exercises, we had heavy theory on the history of HCI and VR, as well as embodied cognition and enaction. In addition, some projects spent a lot of time trying to solve emerging technical problems. We address these as follows: By showing and not telling, we introduce the current students to the field by the previous years' projects, our evaluations, the program code from a private repository, and inviting the students who had good projects or solutions to technical problems. As tutors, we provide our examples on the Unity 3D game engine, but the students are free to choose their platforms to work on their projects.

Our future courses in embodied interaction will include less theory and a more substantial experiential component. The participants will evaluate their designs in terms of an account of the intellectual, emotional, and physical characteristics felt by themselves in the making of the application, and an account of the felt experiences of those who tried their applications. The first-person perspective would then cover all aspects of movement and computing, acknowledging the realities and idiosyncrasies of the development process as it evolves. Data and program code could be molded into our design as personal design material to be felt and subjectively experienced—unlike the movement interfaces, games, and virtual and augmented reality

⁴⁹ Höök, *Designing with the Body*.

⁵⁰ We look forward to integrating the Virtual Production workflow in the course 2019 onwards: <https://www.rokoko.com/en/explore/blog/virtual-production>

applications of today, where they are hidden in software/hardware abstraction layers.

We have introduced the elements of practical somaesthetics at the end of the second-cycle graduate education. While this might be considered late, we aimed for full understanding and mastery of third-person design and evaluation methods before encouraging the student to trust his or her soma from a first-person, experiential point of view. We have aimed for “a personal identity or coherence that holds all of these moving parts together” that would inform our graduates during the onset of their professional career (Bardzell’s commentary to Shusterman’s Somaesthetics in the HCI Encyclopaedia).⁵¹

Our effort was not without challenges. We now comprehend what Shusterman⁵² means when he asks “What reforms of curriculum, institutions, and attitudes would be needed to introduce such embodied education?” From curriculum design through practical logistics about the movement space, equipment, cameras, MoCap, etc., all the way to examination, there were lots of issues that needed solutions when extending a college-level learning activity beyond the classroom. However, with a correct attitude from the students and staff about the importance of experiential somaesthetics in designing for VR, our solutions worked for our initial effort, and they can be excelled in the future. As for curriculum reforms, we are introducing our positive experiences to earlier semesters, e.g., to second-year BSc students, as a flipped class, so that they experientially learn somatic practices at our university.

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