TRANSCENDING PERCEPTION:

AN EXPLORATION INTO VIRTUAL, MIXED, AND EXPANDED REALITY

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Abstract

As interest in Virtual Reality (VR) grows, there is a need to critically engage with it, to explore the possibilities created by it, and to understand the technology and content required for its success. VR is considered in terms of its purpose and function rather than being fixed to any particular technology. To keep pace with the rapid progression of this field, VR is explored with a vision towards its future.

VR is a communication medium that connects more directly to the senses than any prior media, mediating perception almost directly. VR requires that the user's unavoidable connection to reality be acknowledged while simultaneously expanding upon that reality. Through a stronger connection with the virtual, VR can expand the domain of natural experience as the virtual becomes more directly integrated in reality.

The proliferation of virtual technology has produced a shift towards the body as framer of information. VR attempts to remove the frame entirely, connecting directly with the viewer's senses. VR is intrinsically participative and public installations are inherently social. Their combination into public VR translates a technology that might otherwise be private and disconnected into a site of participative social production.

Following a practice-based research and design method informed by the arts and engineering, the limitations and requirements of VR production are confronted. New interfaces are developed and concepts for the application of VR established through an open, continuously iterative process. This exploration culminates in the exhibition of the technology, concepts, and theory encountered through a public VR installation that encourages social interaction and play and provides an opportunity to experience and understand the potential of VR.

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Dedication

This work is dedicated to my Mom and Dad who inspired me to live life to its fullest, to embrace life's challenges, and to find joy in everything I do. This achievement is only possible thanks to their unending love and support.

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Nomenclature

AR = Augmented Reality

AV = Augmented Virtuality

CAD = Computer Aided Design

CNC = Computer Numerical Control

DAW = Digital Audio Workstation

FOV = Field-of-View

IR = Infrared

LAN = Local Area Network

MR = Mixed Reality

UDP = User Datagram Protocol

VR = Virtual Reality

Chapter 1 / INTRODUCTION

Virtual reality is a medium that has the potential to engage all of the senses, and in doing so, could be instrumental in building a sense of expanded reality. Until recently, the technology necessary for the satisfactory production of Virtual Reality (VR) was lacking—the visual aspect alone demands rendering complex imagery at frame rates and resolutions that are just now becoming feasible; however, as suggested by Hall and Takahashi of the World Economic Forum,[1] we are now amidst a technological revolution in which we have already been given the ability to engage with the virtual in ways previously unimagined.

With VR technology gaining momentum the main problem is now content. Much of the content produced for VR is limited by being modeled after familiar media such as television and video games. Most current examples prioritize vision over the other senses, and in doing so, misalign the other senses, preventing the user's full engagement with the virtual by reducing their sense of presence. While failing to acknowledge the user's unavoidable connection to reality, there is also the problem that the content often insufficiently expands upon that reality, lacking the justification to put on the VR headset. These problems threaten the viability of this emerging medium, and could result in its failure, stagnation, or abomination into a manipulative tool of commercial enterprise with the capacity to connect more directly to the senses than ever before.

1. Stephen Hall and Ryo Takahashi, "Augmented and virtual reality: the promise and peril of immersive technologies," *World Economic Forum .org*, accessed February 4, 2018, https://www.weforum.org/agenda/2017/09/augmented-and-virtual-reality-will-change-how-we-create-and-consume-and-bring-new-risks/.

To overcome these problems and ensure its successful contribution to society as an active, participative medium, I have critically engaged with VR technology through an interdisciplinary Master of Fine Arts informed by Computer Science and Creative Technologies. Combining my engineering background and creative practice I have explored creating both for, and in VR. By creating immersive works centered around the participant and their experience I am developing technology, methods, and content needed for VR. The technology is developed with a focus on creative generation, producing both artwork and the tools for further artistic production. The experiences offer the participant the opportunity to explore and learn about themselves, and to escape the boundaries of reality and self-imposed social conventions. Participants gain insight into the power of the technology and are given a voice in contributing to its development through this awareness.

Throughout this paper the terms "virtuality" and "the virtual" appear repeatedly—as further detailed in section 2.2, these terms are meant in a Deleuzian sense to encompass all things virtual: that which is perceived but not actual. Here the true potential of VR is considered in the context of the imagined future that will result from the continued development and improvement of VR technology and content. As VR researchers Philippe Fuchs and Pascal Guitton state, the definition of virtual reality must not be limited to the device used to interact with it or centered around any particular technology, as these approaches oversimplify the complexity of VR.[2] Instead virtual reality is defined more broadly, in terms of its purpose and theoretical function.

2. Philippe Fuchs and Pascal Guitton, "Introduction to Virtual Reality," *Virtual Reality: Concepts and Technologies*, (Boca Raton, FL: CRC Press, 2011), 5.

According to Fuchs, “the purpose of virtual reality is to make possible a sensorimotor and cognitive activity for a person (or persons) in a digitally created artificial world, which can be imaginary, symbolic, or a simulation of certain aspects of the real world.” [3] In defining the theoretical function of VR, Fuchs and Guitton state, "virtual reality will help [humankind] to come out of the physical reality to virtually change time, place and (or) the type of interaction: interaction with an environment simulating the reality or interaction with an imaginary or symbolic world.”[4] These definitions do not limit VR to the headsets currently gaining commercial traction such as the Oculus Rift or HTC Vive, but rather treat these devices as but one technology seeking to accomplish the purpose and function of VR as defined above. These definitions also avoid restricting VR to the domain of the visual. According to theorist Mark B. N. Hansen, “the tendency to privilege vision has the effect of restricting what can be perceived… to what can be apprehended visually.” [5] As will be discussed in chapter 2, perception is produced through a combination of interdependent senses, meaning that VR must engage much more than vision to enable interaction on the same level as with the real world.

My motivations for exploring VR and producing technology and artwork for it stem from the extraordinary capability of emerging VR technology to contribute to social and technological development, as well as the danger for that capability to be lost or abused. Previously the virtual was only accessible to the general public via two-

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3. Phillipe Fuchs, *Les interfaces des la réalité virtuelle*, (Les Presses de l’Ecole des Mines de Paris, 1996), cited in Philippe Fuchs and Pascal Guitton, “Introduction to Virtual Reality,” *Virtual Reality: Concepts and Technologies*, (Boca Raton, FL: CRC Press, 2011), 6.

4. Fuchs and Guitton, “Introduction to Virtual Reality,” 7.

5. Mark B. N. Hansen, *New Philosophy for New Media*, (Cambridge, Mass.: MIT Press, 2004), 162.

dimensional screens, which formed a boundary between the viewer and the content; however, as will be discussed in chapter 3, VR removes this conventional boundary entirely. The capacity of this technology to produce believable experiences by manipulating our senses is what makes it so powerful, and potentially dangerous. As theorist Marshall McLuhan stated, "once we have surrendered our senses and nervous systems to the private manipulation of those who would try to benefit from taking a lease on our eyes and ears and nerves, we don't really have any rights left."[6] In response, neuroethicists Michael Madary and Thomas K. Metzinger have sought to establish a code of ethics for VR practices through their concern for the effects this under-researched technology could have on its users.[7]

This might be taken to suggest that VR is a Pandora's Box that would be best left alone, and that artists should avoid contributing to technology that could be manipulated by the corporate entertainment industry; however, the opposite is true: for those aware of these ethical considerations to abandon this medium is to leave it to those who would take advantage of it. Instead, society is best served by pioneering this technology collectively, becoming experts in its operation and fully understanding it so that its power cannot be leveraged by a privileged few. As McLuhan suggests, "the future of modern society and the stability of its inner life depend in large part on the maintenance of an equilibrium between the strength of the techniques of communication and the capacity of the individual's own reaction."[8] I critically

6. Marshall McLuhan, *Understanding Media: The Extensions of Man*, (New York: McGraw-Hill, 1964), 75.

7. Michael Madary and Thomas K. Metzinger, "Real Virtuality: A Code of Ethical Conduct. Recommendations for Good Scientific Practice and the Consumers of VR-Technology," *Frontiers in Robotics and AI* 3 (2016), DOI: 10.3389/frobt.2016.00003.

8. McLuhan, *Understanding Media*, 22.

engage with VR design and practice to provide insight and information into its function, and to enable others to engage with the technology so they are equipped to fully understand and utilize it.

Virtual reality has the potential to reshape society. By making the virtual more accessible, VR promises to expand reality, to include in the physical world virtual data that was previously only accessible via two-dimensional screens. Perhaps most revolutionary is that the virtual can now be integrated into reality without the need to physically construct it, allowing digital electronics to produce complex virtual objects and spaces that appear to contradict the physical laws of nature.

While this vision of the future is encouraging, the technology needs considerable development to achieve this. Contributing to that technological development is a motivating factor for my engagement with VR, and my work takes this contribution seriously, with the creative production of new technology forming a central role. While VR technology is still in its infancy, according to a survey by Perkins Cole LLP, another major issue is the lack of content.[9] Although I have had a few exceptional experiences in VR, most have been uninspiring, motivating me to find what contributes to a successful VR experience, and what prevents it.

McLuhan states that, "the artist is indispensable in the shaping and analysis and understanding of the life of forms, and structures created by electric technology."[10] Artists need to take control in directing VR to its fullest realization; however, to do so they will require the help of engineers and computer scientists. This interdisciplinary

9. Perkins Cole LLP, *2016 Augmented and Virtual Reality Survey Report*, (Perkins Cole LLP, 2016), 7, accessed November 26, 2016, https://dpntax5jbd3l.cloudfront.net/images/content/1/5/v2/158662/2016-VR-AR-Survey.pdf.

10. McLuhan, *Understanding Media*, 71.

collaboration necessitates moving beyond the rigid boundaries that conventionally separate these disciplines, requiring artists who are familiar with technology and computer scientists who understand artistic theories, methods, and motivations. This is true not only of VR, but of all new media art. As curators Beryl Graham and Sarah Cook claim, "new media art has an interdisciplinary nature. It works across art and technology and across all the associations of newness inherent in both fields."[11] I am driven to build on this interdisciplinarity through my own understanding of the practices involved and to facilitate collaboration between others.

I also aim to encourage individuals to cross social boundaries: bringing new visitors into the gallery and encouraging artists to contribute to technological development. I aim to provide opportunities to break free from norms that restrict social communication, for individuals to rediscover their creativity, to play and improvise, and to bring joy to themselves and others.

This critical engagement paper begins with the theoretical foundations of my work, discussing the critical concepts of perception, reality, and virtuality in chapter 2. In chapter 3, I position my work in the context of participatory art, and the potential of VR to produce virtual public spaces of communal creativity. Chapter 4 progresses along with my experimentation, describing the methodologies employed in developing contributions to the technical and theoretical aspects of VR. In chapter 5, I describe the installation, which serves as a culmination and exhibition of the technology and ideas developed over the course of my Master of Fine Arts and discuss the outcomes of producing this work. Finally, conclusions are presented in chapter 6.

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11. Beryl Graham and Sarah Cook, *Rethinking Curating: Art After New Media*, (Cambridge, Mass.: MIT Press, 2010), 29.

Chapter 2 / THEORETICAL CONTEXT

2.1. Communication and Media

In *Understanding Media: Extensions of Man*, McLuhan defines all media as the extensions of senses.[12] Artist Roy Ascott further solidifies this claim and links media to the human experience, stating, "human communication has never been… beyond mediation… the constraints and limited range of our biological systems of perception, and the ordering experience by our languages, involve us in a continual process of constructing our world."[13]

Mathematician Warren Weaver in his introduction to Claude Shannon's *The Mathematical Theory of Communication* states that, "communication… in a very broad sense [includes] all of the procedures by which one mind may affect another."[14] The technical nature of communication, the capacity of a medium to reliably transmit messages with no regard to their meaning, has been established since Shannon's revolutionary theory was first published. Semantic communication, however, is not as simple. Meaning is not transmitted in communication, but rather is constructed through the interpretation of information through encoding and decoding. In "Encoding, Decoding" cultural theorist Stuart Hall states:

> Since there is no necessary correspondence between encoding and decoding, the former can attempt to 'pre-fer' but cannot prescribe or guarantee the latter, which has its own conditions of existence. Unless

12. McLuhan, *Understanding Media*, 23.

13. Roy Ascott, "Telenoia," *Telematic Embrace: Visionary Theories of Art, Technology, and Consciousness*, ed. Edward A. Shanken, (Berkeley: University of California Press, 2003), 268.

14. Warren Weaver, "Recent Contributions to the Mathematical Theory of Communication," in *The Mathematical Theory of Communication*, C.E. Shannon and W. Weaver, (Urbana: University of Illinois Press, 1964), 3.

> they are wildly aberrant, encoding will have the effect of constructing some of the limits and parameters within which decodings will operate… Nevertheless, this 'correspondence' is not given but constructed."[15]

The source can do its best to invoke a particular meaning, but despite its efforts, the way in which the receiver decodes the message is outside of its control, and thus, communication is asymmetrical, even if only slightly. In addition, the possible interpretation and use of the communicated message is complicated by the semiotic paradigm. According to theorist John Storey, "the theorists of poststructuralism suggest that… signifiers do not produce signifieds, they produce more signifiers. Meaning as a result is a very unstable thing."[16] The meaning of a message is shaped by the individual's unique history of experiences, evoking a range of possible interpretations and effects.

The field of interaction design and human-computer communication has acknowledged this in the concept of the user experience. According to designer Jesse James Garrett "every product that is used by someone creates a user experience."[17] From McLuhan's definition, as extensions of humanity, products are communication media. Through what psychologist Marc Hassenzahl calls an Aesthetic of Experience,[18] the design of the product transmits an affective experience. According to Preece, Rogers, and Sharp, "one cannot design a user experience, only design *for* a user

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15. Stuart Hall, "Encoding, Decoding," in *The Cultural Studies Reader,* 2nd ed., ed. Simon During, (New York: Routledge, 1999), 515.

16. John Storey, *Cultural Theory and Popular Culture: An Introduction,* 5th ed., (Harlow, England: Pearson Longman, 2009), 126.

17. Jesse James Garrett, *The Elements of User Experience: User-Centered Design for the Web and Beyond,* 2nd ed., (Berkeley, CA: Newriders, 2011), 10.

18. Marc Hassenzahl, "User Experience and Experience Design," *The Encyclopedia of Human-Computer Interaction*, 2nd ed., ed. M. Soegaard and R. F. Dam, (N.P.: The Interaction Design Foundation, 2013), accessed January 22, 2018, https://www.interaction-design.org/literature/book/the-encyclopedia-of-human-computer-interaction-2nd-ed/user-experience-and-experience-design.

experience."[19] Thus, user experience design seeks to *pre-fer* a particular experience, aware that a particular experience cannot be *prescribed*.

In my work I utilize this principle of experience design to acknowledge the asymmetry of any semantic or experiential communication. I focus on presenting the viewer or user with tools with which they might engage in a desired experience, following a model of communication described by art historian Edward Shanken: "Brecht's theory of two-way communication envisioned a less centralized and hierarchical network of communication, such that all points in the system were actively involved in the production of meaning."[20] This is especially important in VR where active participation invokes various experiences unique to each participant.

New media theorists Jay David Bolter and Richard Grusin state that, "virtual reality operates most often under the logic of transparency… the immediacy of virtual reality comes from the illusion of three-dimensional immersion and from the capacity for interaction."[21] Immediacy being the characteristic of a medium which "make[s] the viewer forget the presence of the medium."[22] Upon putting on the headset, the VR technology disappears in order to obtain a sense of immersion. It connects as directly as possible to the perceptual apparatus, seeking immediacy on the level of the retina or eardrum. VR therefore demands active participation: lending the body to passive

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19. Jenny Preece, Yvonne Rogers, and Helen Sharp, *Interaction Design: Beyond Human—Computer Interaction*, (Chichester, West Sussex: John Wiley & Sons, 2015), 12, emphasis added.

20. Edward Shanken, "From Cybernetics to Telematics," in *Telematic Embrace: Visionary Theories of Art, Technology, and Consciousness*, ed. Edward A. Shanken, (Berkeley: University of California Press, 2003), 55.

21. Jay David Bolter and Richard Grusin, *Remediation: Understanding New Media* (Cambridge, Massachusetts: The MIT Press, 1999), 162.

22. Bolter and Grusin, *Remediation*, 272.

mediation numbs the affected senses like an anesthetic, a feature that Hoffman et al. have shown to be effective enough to be used for supplementary pain relief during the treatment of burn wounds. [23]

2.2. Perception and Reality

In *Matter and Memory*, philosopher Henri Bergson states, "it is true that an image may *be* without *being perceived*; it may be present without being represented; and the distance between these two terms, presence and representation, seems just to measure the interval between matter itself and our conscious perception of matter."[24] Reality extends beyond what is perceived—from the senses the mind infers a subjective interpretation of that physical reality.

Psychologist Donald D. Hoffman claims, "the perceptual systems with which we have been endowed by natural selection are a species-specific interface that allows us to interact adaptively and successfully with objective reality, while remaining blissfully ignorant of the complexity of that objective reality."[25] Not only is what is perceived different from reality, but evolution drives divergence between reality and perception, rather than convergence. He suggests that perception is the optimization of the senses,

23. Hunter. G. Hoffman et al., "Virtual Reality as an Adjunctive Non-Pharmacologic Analgesic for Acute Burn Pain During Medical Procedures," *Annals of Behavioral Medicine*, 41, no. 2, (2011): 183-91, DOI: 10.1007/s12160-010-9248-7.

24. Henri Bergson, *Matter and Memory*, tr. Nancy M. Paul and W. Scott Palmer (London: George Allen & Unwin, 1911), 27, emphasis in original.

25. Donald D. Hoffman, "The Interface Theory of Perception," *Current Directions in Psychological Science* 25, no. 3 (2016): 158, accessed November 30, 2016, DOI: 10.1177/0963721416639702.

delivering what information is necessary to survival and eliminating any that might slow cognition and delay decision making.[26]

Bergson also indicates that perceptions are determined by their functional use: "we can conceive that their mere presence is equivalent to the suppression of those parts of objects in which their functions find no interest. They allow to pass through them, so to speak, those external influences which are indifferent to them; the others isolated, become "perceptions" by their very isolation."[27] Bergson is pointing to another important fact about perception, that reality is only understandable because the senses eliminate that without "functional value." By eliminating much of the complexity, it is simplified to the extent that it might be understood.

This view of reality as more than perception can also be seen in the writing of Florian Rötzer, who states, "today, seeing the world is no longer understood as a process of copying but of modelling, a rendering based on data. A person does not see the world out there, she only sees the model created by the brain and projected outwards."[28] Furthermore, as Hansen suggests, perception relies on all of the senses: "human perception takes place in a rich and evolving field to which bodily modalities of tactility, proprioception, memory and duration—what I am calling affectivity—make an irreducible and constitutive contribution."[29]

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26. Donald D. Hoffman, "The Interface Theory of Perception," 158.

27. Bergson, *Matter and Memory*, 28–29.

28. Florian Rötzer, "re:Photograph," in *Photography after Photography: Memory and Representation in the Digital Age*, ed. H. v. Amelunxen et al. (Amsterdam: G+B Arts, 1996), 17–18, cited in Mark B. N. Hansen, *New Philosophy for New Media*, (Cambridge, Mass.: MIT Press, 2004), 106.

29. Hansen, *New Philosophy for New Media*, 5.

The imperfection of perception can lead to illusions and misunderstanding, but it also enables humans to perceive things that would otherwise be impossible. Were perceptions a direct measure of physical reality, there would be no way of expanding upon it as these illusions would be eliminated; however, the space between perception and reality gives access to the limitless expanse of the virtual. As Hansen claims, "it is precisely this "hallucinatory" dimension… that explains the capacity for the VR interface to couple our bodies with (almost) any arbitrary space, and not just spaces that are contiguous with the physical space we happen to occupy."[30]

The virtual is a difficult concept to define, but one that is nonetheless familiar. One everyday example of the virtual is the mirror. As philosopher Michael Foucault states, "in the mirror, I see myself there where I am not, in an unreal, virtual space that opens up behind the surface." [31] In this way, the mirror defines the virtual, the image within the mirror both existing upon a real surface, but not *actually* existing as it is perceived. Another way the virtual can be understood is in terms of memory. Referring to Bergson's *Matter and Memory*, philosopher Keith Ansell-Pearson states, "It is in terms of the difference between matter and memory that we can best appreciate the "sense" of the virtual." [32] Like the image in the mirror, memory exists in reality, stored in physical neurons and synapses, but the objects of those memories, as they are perceived, are not materially present. According to philosopher Gilles Deleuze, "the possible is the

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30. Hansen, *New Philosophy for New Media*, 41.

31. Michel Foucault, "Of Other Spaces: Utopias and Heterotopias," *Architecture/movement/continuité*, October, 1983, tr. Jay Miskowiec, accessed January 20, 2017, http://web.mit.edu/allanmc/www/foucault1.pdru, 4.

32. Keith Ansell-Pearson, "The Reality of the Virtual: Bergson and Deleuze," *MLN* 120, no. 5, (2005): 1114.

opposite of the real… the virtual is opposed to the actual. The possible has no reality (although it may have an actuality); conversely, the virtual is not actual, but *as such possesses a reality*."[33] Proceeding with this concept it becomes easy to see the virtual, which already exists within the world. In paintings, the actual object whether real or not, is virtualized in the pigments. Within digital media, it is virtualized as the state and flow of electrons.

According to Graham and Cook, "art has long been concerned not just with geographic space, but with abstract space—its creation and exhibition—and by extension with the question of materiality. For new media art, these concerns go even farther into the realms of the virtual."[34] Throughout its history, art has connected us to the virtual through various media.

While many paintings depict real spaces, objects, and people, those depictions are not actually there, instead existing as virtual surrogates. The combination of pigments on a two-dimensional canvas would be nothing more than that, but the perceptual system allows for more to be seen, to interpret even the simplest shapes into something as complex as an identifiable individual or location. Upon this, in the virtual space of the painting, the artist is able to produce images that could not ordinarily exist.

Paintings enable a glimpse into the virtual but are limited to a static portrayal that occupies only a single sense. The expansion of technology over the past century has provided an overwhelming number of new ways to access the virtual more directly.

33. Gilles Deleuze, *Bergsonism*, tr. Hugh Tomlinson and Barbara Habberjam, (New York: Zone Books, [1966] 1991), 96.

34. Graham and Cook, *Rethinking Curating*, 6.

Film and video allow for access to a temporal virtual space, which engages vision and hearing. Though this media may capture its images from reality, it is stored and transmitted in a way that relies completely on the perceptual system's ability to access the virtual. As computer science researchers James Davis, Yi-Hsuan Hsieh, and Hung-Chi Lee observe, "the light output of modern displays may at no point of time actually resemble a natural scene. Instead, the codes rely on the fact that at a high enough frame rate human perception integrates the incoming light, such that an image and its negative in rapid succession are perceived as a grey field."[35] Were it not for persistence of vision and motion, a television would appear blank or as a collection of unrelated images, and were there no gap between perception and reality, it would be impossible to perceive an entire cityscape through the frame of the television. While allowing a closer connection with the virtual, the linear, one-directional nature of these media prevents the viewer from affecting this virtual image in the way they might affect reality.

The sounds generated by a speaker also access the virtual. While sounds are carried by physical waves, they can cause virtual objects to be perceived that are not actually present. A complex 3-dimensional virtual space can be represented to the ears, and objects constructed throughout an empty room. Janet Cardiff's *Forty Part Motet*, is an example of an installation that accesses the virtual. The 40 speakers placed around the room play 40 separate channels of audio, each representing an individual vocalist.[36] The viewer not only hears their voices but can also feel the presence of each individual vocalist, embodied in each speaker. Experiencing this piece in person with closed eyes,

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35. James Davis, Yi-Hsuan Hsieh, and Hung-Chi Lee, "Humans Perceive Flicker Artifacts at 500 Hz," *Scientific Reports* 5 (2015), DOI: 10.1038/srep07861.

36. Janett Cardiff, *The Forty Part Motet*, 2001, installation, Tate Modern, London.

and standing in front of a speaker, I felt an intimate connection to a human being, not just the sound emanating from the speaker.

With the advent of computation and cyberspace came the ultimate realization of the virtual. Ascott states:

> Within these separate realities, the status of the "real" in the phenomenology of the artwork also changes. Virtual space, virtual image, virtual reality—these are categories of experience that can be shared through telematic networks, allowing for movement through "cyberspace" and engagement with the virtual presence of others who are in their corporeal materiality at a distance, physically inaccessible or otherwise remote.[37]

The technologies of the digital age have allowed for the generation of vast swaths of virtual space and information. Digital media allow for the storage, access and computation of information in a virtual state. While the information is stored and transmitted by the real states and flows of electrons, it is again of a virtual nature, which can only be accessed through perception. The electrons themselves are not imbued with meaning, but must be coerced through systems that translate them into a perceptible state. The images produced on the screen still require decoding through visual perception to become meaningful.

More important still is that computation has established a causal relation between the virtual and real. The virtual is no longer stored in a linear, predefined form, but in one that is modifiable, fluid and always changing, continuously altered through its connection to reality. This interactive connection between virtual and actual reality has brought the two closer together than ever before; however, until recently this space continued to be accessed through imagery on a fixed two-dimensional window. To

37. Ascott, "Is There Love in the Telematic Embrace?" *Telematic Embrace*, 243.

further engage with the virtual, it needs to occupy three-dimensional space, at least perceptually. According to theorist and philosopher Brian Massumi, stereopsis is more than just a visual sense:

> Depth perception is a habit of movement. When we see one object at a distance behind another, what we are seeing is in a very real sense our own body's potential to move between the objects or to touch them in succession… We are using our eyes as proprioceptors and feelers… Vision envelops proprioception and tactility… Seeing is never separate from other sense modalities. It is by nature synesthetic and synesthesia is by nature kinesthetic.[38]

The 3D vision produced by a VR headset is a first step towards engaging the other senses and finally being able to enter virtual space. Stepping into the virtual—the frame, which has until now always separated the virtual from the surrounding reality, is lost. As the virtual gains access to the whole of the perceptual system it loses its identity and becomes indistinguishable from reality, becoming part of perceived reality.

2.3. From Virtual Reality to Expanded Reality

The concept of virtual reality has a long history. Stereoscopic 3D imagery has existed since the stereoscope was invented by Charles Wheatstone in 1838.[39] Ivan Sutherland and Bob Sproull are credited with creating the first virtual and augmented reality headset in 1968, before those terms were even coined.[40] Known as the Sword

38. Brian Massumi, "Sensing the Virtual, Building the Insensible," in Architectural Design 68, cited in Mark B. N. Hansen, *New Philosophy for New Media*, (Cambridge, Mass.: MIT Press, 2004),109.

39. Charles Wheatstone, "Contributions to the Physiology of Vision. Part the First. On some remarkable, and hitherto unobserved, Phenomena of Binocular Vision," *stereoscopy.com,* accessed November 26, 2016, http://www.stereoscopy.com/library/wheatstone-paper1838.html.

40. The Computer History Museum, "The Diversity of Output Devices," *Revolution: The First 2000 Years of Computing*, accessed January 20, 2018, http://www.computerhistory.org/revolution/input-output/14/356.

of Damocles due to its large support structure, it projected simple computer-generated wireframe imagery.[41]

VR was under considerable development in the 1980s, with Jaron Lanier and VPL Research developing many devices that are currently seeing a resurgence, including wearable headsets, gloves, and body suits.[42] Perhaps the most famous example of VR's past was in 1995, when the Nintendo Virtual Boy was released and pulled from shelves within a year.[43] Researchers Matt Zachara and Jose P. Zagal list numerous faults with the system, including poor marketing, a very low resolution monochromatic display, discomfort from hunching over the fixed system, eye strain, and simulator sickness that contributed to its downfall.[44] While often referred to as a VR display, the lack of head tracking and restricted body position essentially makes this nothing more than stereoscopic display. This discrepancy between technology, and the common imagination of what VR should be, prevented any real development until recently.

These early VR systems are primitive compared with recent consumer VR systems including the HTC Vive and Oculus Rift. As VR researchers Philippe Fuchs and Pascal Guitton claim, "virtual reality has been possible only recently, thanks to a significant increase in the intrinsic power of computers, especially the possibility of

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41. The Computer History Museum, "The Diversity of Output Devices."

42. Ann Lasko-Harvill et al. "FROM DataGlove TO DataSuit," in *Digest of Papers, Compcon Spring '88 Thirty-Third IEEE Computer Society International Conference*, San Francisco, CA, (1988), DOI: 10.1109/CMPCON.1988.4925.

43. Matt Zachara and Jose P. Zagal, "Challenges for Success in Stereo Gaming: A Virtual Boy Case Study," in *Proceedings of the International Conference on Advances in Computer Enterntainment Technology*, Athens, Greece, 2001, 101.

44. Zachara and Zagal, "A Virtual Boy Case Study," 102–104.

creating computer-generated images in real time and enabling a real-time interaction between the user and the virtual world."[45] This, combined with significantly reduced costs has made the prospect of widely available VR a reality. The continued miniaturization of electronics towards exhausting the limits of Moore's Law[46] perpetuates the proliferation of such low-cost, widely available technology.

There are two main aspects that need to be resolved to ensure the successful adoption of VR by society: VR must acknowledge the physicality of the user's body, and VR must expand upon reality. According to Ascott, "Virtual reality has as its interface the total body."[47] This implies that virtual reality engages all of the senses; however, as Hansen suggests, "the vast majority of VR systems… work with an impoverished conception of experience as above all (or exclusively) visual. By endowing the user with VR goggles and helmet, VR systems deploy vision as the privileged sense endowed with the task of mapping the human sensory apparatus onto new dataspaces."[48]

VR is absolutely dependent on proprioception, an extended concept of kinesthesia. According to Fuchs et al., the proprioceptive senses allow for an awareness of the body's position and movement as well as the forces on the muscles.[49] Convergence, the sense that gives the stereoscopic imagery in a VR headset depth, is

45. Philippe Fuchs and Pascal Guitton, "Introduction to Virtual Reality," *Virtual Reality: Concepts and Technologies*, (Boca Raton, FL: CRC Press, 2011), 3.

46. Chris A. Mack, "Fifty Years of Moore's Law," *IEEE Transactions on Semiconductor Manufacturing,* 24, no. 2, (2011): 206–207.

47. Ascott, "Telenoia," *Telematic Embrace*, 270.

48. Hansen, *New Philosophy for New Media*, 162.

49. Philippe Fuchs, Moustapha Hafez, Mohamed Benali Koudja, and Jean-Paul Papin, "Human Senses," *Virtual Reality: Concepts and Technologies*, (Boca Raton, FL: CRC Press, 2011), 76.

a combination of visual and proprioceptive cues. According to Fuchs et al., the position of the orbital muscles around the eye along with the disparity of images detected by the retina provide information on the distance of an object.[50] The movement and orientation of the head and body are another example; VR is able to succeed by reaching a correlation between proprioception and vision.

This interconnectedness of the senses is of utmost importance in VR. As Fuchs states, "the senses do not function independently of one another… All the sensory stimuli together give a coherent perception of the world. We must not understand the perception as a passive phenomenon… Human perception is active and this must not be forgotten while understanding a subject immersed and interacting in a virtual environment." [51] A possible consequence of ignoring this is simulator sickness which, according to simulation researcher Eugenia M. Kolasinski, produces symptoms including: "general discomfort, apathy, drowsiness, headache, disorientation, fatigue, pallor, sweating, stomach awareness, nausea, and vomiting."[52] In defining one of the possible causes of simulator sickness, Kolasinski states, "cue conflict occurs when there is a disparity between senses or within a sense. The two primary conflicts thought to be the root of simulator sickness occur between the visual and vestibular senses."[53] Even when it doesn't lead to simulator sickness, a discrepancy between the position of, for example, a hand between the visual and proprioceptive senses it is easily detected. The

50. Fuchs, Hafez, Koudja, and Papin, "Human Senses," *Virtual Reality*, 57–63.

51. Philippe Fuchs, "Theoretical and pragmatic approach to virtual reality," *Virtual Reality: Concepts and Technologies*, (Boca Raton, FL: CRC Press, 2011), 12.

52. Eugenia M. Kolasinski, "Simulator sickness in virtual environments," Technical Report 1027, (ARTI-TR-1027), (Alexandria, VA: Army Research Institute for the Behavioral and Social Sciences, 1995), 4.

53. Kolasinski, "Simulator sickness in virtual environments," 7.

tactile sensations also coordinate with vision and proprioception—when an external object is touched, the position, among other characteristics, of that object is established by the integration of touch, proprioception, and vision. To satisfy the interconnectedness of the senses a move away from VR's fixation on the virtual and visual is needed, towards a mode of interaction that acknowledges the physical and better engages with the whole body.

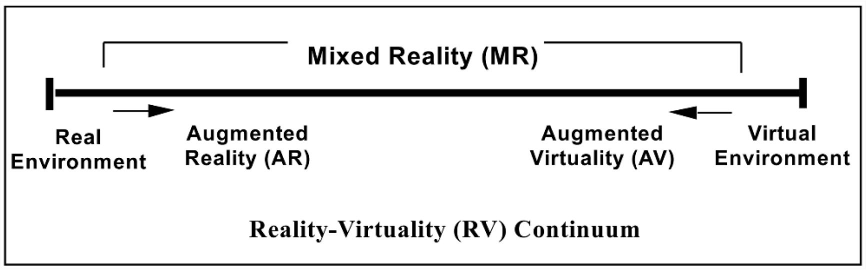

Figure 1. Milgram and Kishino's Reality-Virtuality Continuum.[54]
Reproduced with permission of Paul Milgram and SPIE.

Engineering and interaction researchers Paul Milgram and Herman Colquhoun Jr define Mixed Reality (MR) as the full spectrum of virtual experiences, from augmented to virtual reality.[55] The Reality-Virtuality Continuum, shown in Figure 1, positions Virtual and Augmented Reality (AR) along a Reality-Virtuality Continuum that extends from a purely real environment to a purely virtual one.[56] While Augmented Reality is a real environment enhanced with virtual objects, Augmented Virtuality is a virtual environment enhanced with real objects. Any experience involving the virtual exists

54. Paul Milgram, Haruo Takemura, Akira Utsumi, Fumio Kishino. " Augmented Reality: a Class of Displays on the Reality-Virtuality Continuum." SPIE 2351, Telemanipulator and Telepresence Technologies, (1995). DOI: 10.1117/12.197321.

55. Paul Milgram and Herman Colquhoun Jr., "A Taxonomy of Real and Virtual World Display Integration," *Mixed Reality: Merging Real and Virtual Worlds*, ed. Yuichi Ohta and Hideyuki Tamura, (Secaucus, NJ: Springer-Verlag New York, 1999), 9.

56. Milgram, Paul and Fumio Kishino. "A Taxonomy of Mixed Reality Visual Displays." *IEICE Transactions on Information Systems E77D*, no. 12 (1994): 1321–1329. Accessed April 5, 2017, http://etclab.mie.utoronto.ca/people/paul_dir/IEICE94/ieice.html.

somewhere along this continuum, and for the real and virtual to interact, must in some form be considered Mixed Reality (MR). As a result, the physical interface and the virtual environment must, to some perceptible extent, follow the rules of physical reality to which they remain partially bound.

Currently most technology exists at the furthest extents of this spectrum; however, industry leaders such as Microsoft see augmented and virtual reality technology progressing towards a more homogenous mixture of real and virtual, where the distinction between the two becomes lost.[57]

Researchers Misha Sra and Chris Schmandt suggest that seeing and interacting with real objects improves presence in VR.[58] Using commercially available products they were able to create a more immersive environment for the HTC Vive by scanning the room with a Google Tango device and tracking object and user locations with a Microsoft Kinect. In addition, cognitive psychologist Hunter G. Hoffman found that physical objects can enhance the realism of the virtual environment by making the virtual objects and surrounding environment feel more real.[59] These experiments seek to augment the virtual world with reality, making them forms of Augmented Virtuality. The user's body is ultimately trapped in the real environment regardless of what is presented to their eyes, and by enriching the virtual environment with real objects, it is

57. Microsoft, "Mixed Reality," *Windows Dev Center*, accessed December 17, 2017, https://developer.microsoft.com/en-us/windows/mixed-reality/mixed_reality.

58. Misha Sra and Chris Schmandt. "Bringing Real Objects, Spaces, Actions, and Interactions into Social VR." *2016 IEEE Third VR International Workshop on Collaborative Virtual Environments (3DCVE)*, March 20, 2016. DOI: 10.1109/3DCVE.2016.7563561.

59. Hunter G. Hoffman, "Physically Touching Virtual Objects Using Tactile Augmentation Enhances the Realism of Virtual Environments," *IEEE 1998 Virtual Reality Annual International Symposium* (1998): 59–63. DOI: 10.1109/VRAIS.1998.658423.

made to align with the expectation of the user. As literary critic N. Katherine Hayles writes, “we can see hear, feel and interact with virtual worlds only because we are embodied.”[60] By acknowledging the mixture of real and virtual, the connection to the virtual can be strengthened, giving a stronger sense of presence in the virtual environment.

While acknowledging the reality of the user, any AR, VR or MR experience must also expand upon reality in some way. To justify surrendering the senses to the virtual, the virtual must offer something in return. At the very least it should change something about the real environment. It might superimpose imagery onto the real world, as is the case with AR, producing a virtual object that could not otherwise exist, or bringing an inert object to life. It might alter perspective: transporting someone to a view from across the room, or across the globe. Similarly, it could transport the user across time, allowing for the experience and re-experience of events that have already occurred, or that have only been imagined. It may also allow altered perception, displaying ordinarily invisible ultraviolet and infrared wavelengths or producing synesthesia by transposing sound into the visual domain or vice-versa. Entire worlds can be created. The imagined worlds typically bound to the pages of a book could become virtually real. As with a book, the creation of the world might be a cooperative process between the artist who creates the world, and the viewer who might shape it. VR will enable imagination to become reality, and media theorist Gene Youngblood’s observation that “an increasing number of the inhabitants of this planet live virtually in another world”[61] will become

60. N. Katherine Hayles, “Embodied Virtuality: Or How to Put Bodies Back into the Picture,” *Immersed in Technology: Art and Virtual Environments*, ed. Mary Anne Moser and Douglas MacLeod, (Cambridge Mass.: MIT Press, 1996), 1.

61. Gene Youngblood, *Expanded Cinema*, (New York: P. Dutton & Co. Inc., 1970), 47.

ever-more true. These other worlds, however, through their realization, become a part of our reality, expanding reality itself. According to researcher Myeung-Sook Yoh:

> Virtual reality, by providing new experiences that cannot happen in a physical environment, expands its domain of natural experience, and enhances the quality of the experience by integrating the limited sensory experiences previously restricted by physical rules. If our notion of the world is formed through experience, then the introduction of virtual reality implies the expansion of the world and the appearance of a new reality.[62]

While the virtual is only accessible through the perceptual systems, it affects personal experiences, society, and culture the same as any actual thing. Deleuze states, "The virtual… does not have to be realized, but rather actualized; and the rules of actualization are not those of resemblance and limitation, but those of difference or divergence and of creation."[63] The virtual belongs to reality just the same as the actual, and through actualization, virtual reality can affect and become actual reality. Yoh defines VR as more than a medium, "a new emergent mode of reality in its own right, that comes together with actual reality to construct an extended world of human experience."[64]

62. Myeung-Sook Yoh, "The Reality of Virtual Reality," in *Proceedings of the Seventh International Conference on Virtual Systems and Multimedia*, Berkeley, CA, (2001): 4, DOI: 10.1109/VSMM.2001.969726.

63. Deleuze, *Bergsonism*, 96.

64. Myeung-Sook Yoh, "The Reality of Virtual Reality," 8.

Chapter 3 / SOCIAL CONTEXT

3.1. The Body as Framer

Art critic and curator Nicolas Bourriaud states, "unlike an object that is closed in on itself by the intervention of a style and a signature, present-day art shows that form only exists in the encounter and in the dynamic relationship enjoyed by an artistic proposition with other formations, artistic or otherwise." [65]

Ascott states that "while traditionally focused on the appearance of things and their representation, art is now concerned with processes of interaction, transformation, and emergence."[66] Technology has produced this shift in the focus of art, from objects to people, and from ideas to experiences. According to Hansen, "with the flexibility brought by digitization, there occurs a displacement of the framing function of medial interfaces back onto the body from which they themselves originally sprang."[67] Art Historian Ina Blom suggests that, "[this is] the general condition under which art after 1989 produces and engages with technology."[68] The body as framer is reinforced by the ambiguity of digital information in the absence of contextualization and decoding. In *New Philosophy for New Media*, Hansen states:

> The reality encoded in a digital database can just as easily be rendered as a sound file, static image, video clip, or immersive, interactive world, not to mention any number of forms that do not correlate so neatly with our sensory capacities… Simply put, as media lose their material specificity,

65. Nicolas Bourraud, *Relational Aesthetics*, (Dijon: Les Presses du reél, 2002), 21.

66. Ascott, "Technoetic Aesthetics," *Telematic Embrace*, 375.

67. Hansen, *New Philosophy for New Media*, 22.

68. Ina Blom, "Inhabiting the Technosphere: Art and Technology beyond Technical Invention," In *Contemporary Art: 1989 to the Present*, eds. Alexander Dumbadze and Suzanne Hudson, (West Sussex UK: John Wiley & Sons, 2013), 149.

> the body takes on a more prominent function as a selective processor of information. [69]

This statement directly contradicts a common misconception that technology erodes humanness and destroys the importance of the individual. Instead the disappearance of material specificity gives the human body a larger role, as a Bergsonian "center of indetermination" where meaning is formed through a creative process of selecting the relevant information amid a flux of data.[70]

VR takes full advantage of the flexibility brought by digitization, removing the physical frame of the medium entirely, and uniting the body with the virtual. While VR currently requires a screen, and that screen itself is framed in the device, the way in which it is used destroys the frame in a conventional sense. The frame itself does not exist within the reality of the device as it is no more a boundary of the projected world than the pupil. The user of the device becomes fully connected with the experience and exists within its frame.

The importance of body as framer is further emphasized by recent artworks which are not derived from a determinate set of features associated with an existing technology, but which instead rely on complex technological relations. The complexity of technology requires building layer upon layer of abstraction. As Hunter D. Hoffman states, "if you had to know the details of the transistors, voltages, magnetic fields, and megabytes of system and application software, you would never finish your

69. Hansen, *New Philosophy for New Media*, 22.

70. Hansen, *New Philosophy for New Media*, 5.

presentation in time."[71] It is only through abstraction that this complexity is reduced to a comprehensible state. The user is solely concerned with using the software itself and sees only the interface. Meanwhile the programmer who wrote the software thinks in terms of another abstraction, the code in which the application is written, and this code is an abstraction of the electronics through which the code operates.

This abstraction and integration of endless technologies further reinforces the body's relevance as framer of information. Ina Blom states that, "[the body is] a nodal point in a web of technologies and constructions that operate at a number of different levels."[72] VR exists at the intersection, of numerous technologies that form the interface through which the viewer interacts. The body is the node through which various technologies become consolidated, framed and interpreted as VR. All of which destroys the material significance in the absence of framing by the viewer.

The body's role as framer of information gives the participant a pivotal role in the artwork. The viewer is no longer seeking understanding of something external to themselves but is instead acting as the medium through which the work is actualized. The artwork is not centered around the artist, medium, or technology, but around the viewer, or rather participant. The artist's role then is to decide the nature of that participation and to define the environment in which it will take place.

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71. Donald D. Hoffman, "The Interface Theory of Perception," *Current Directions in Psychological Science* 25, no. 3 (2016): 158, accessed November 30, 2016, DOI: 10.1177/0963721416639702.

72. Blom, "Inhabiting the Technosphere," 157.

3.2. Participation and Interactivity

Participation gives the audience agency, allowing for a direct and responsive connection with the piece as well as with other people sharing in the experience. Graham and Cook state that "participation implies that the participant can have some kind of input… not just getting reactions, but also changing the artwork's content. There is a range of levels of participation… artistic participation can mean just showing up (or logging in) or having real creative input."[73] Participants are given the power to contribute to shaping the artwork not only personally, but socially. They also have the option not to participate, or to participate in a way and to a level that they feel comfortable with. Ascott states:

> …The artist, the artifact and the spectator are all involved in a more behavioural context… [T]hese factors… draw the spectator into active participation in the act of creation; to extend him, via the artifact, the opportunity to become involved in creative behaviour on all levels of experience—physical, emotional, and conceptual. A feedback loop is established, so that the evolution of the artwork is governed by the intimate involvement of the spectator.[74]

According to Shanken, "[Roy Ascott] celebrates telematic art as a 'site of interaction and negotiation for meaning' that heralds a 'sunrise of uncertainty… a joyous dance of meaning… [and suggests] a paradigm shift in our worldview, a redescription of reality'"[75] The artwork becomes a site of negotiation between participants where the act of creating and interpreting is shared communally.

73. Graham and Cook, *Rethinking Curating*, 113.

74. Ascott, "Telenoia," 110–11.

75. Shanken, "From Cybernetics to Telematics," 75.

With interactive art, the artist is more of a curator or facilitator among the collaborating participants, setting a framework for their interaction through the artwork and acting as a host for this interaction as suggested by Graham and Cook.[76] As the conventional order of the space is eliminated, participative artworks require their own simple, effective, and enforceable rules, but only to the extent which the artist desires control. Graham and Cook claim, "even with the simplest levels of navigation and choice, then the question must be asked of the audience's motivation for doing this or that and whether the experience… is rewarding."[77] Through carefully constructed rules, the artist can decide the level of engagement and social interaction required and might decide to promote collaboration or antagonism. While the rules of any such participative work are necessarily limited, the restrictive nature of these rules can promote results beyond that expected by the artist. Graham and Cook state, "the limited nature of programmed interaction can serve to host the much wider range of human interaction."[78] Graham and Cook claim that, "one of the most exciting characteristics of the behaviour of group interaction is that it is largely outside of the artist's or curator's control." [79]

Despite efforts of the artist to control the interaction, the rules of a participative work inevitably provoke their own subversion. As artist and designer Mary Flanagan states, "players will consistently explore what is permissible and what pushes at that boundary between rules and expectations, and a player's own agency, within any given

76. Graham and Cook, *Rethinking Curating*, 124.

77. Graham and Cook, *Rethinking Curating*, 128.

78. Graham and Cook, *Rethinking Curating*, 130.

79. Graham and Cook, *Rethinking Curating*, 181.

play environment—no matter how structured that play is."[80] While this might seem to lead to chaos, Graham and Cook suggest that in cases such as Rafael Lozano-Hemmer's *Body Movies* there is a self-regulating aspect to social participation, and "that trust should be placed in the participants to deal with the dynamics in ways appropriate to their own culture."[81]

Participatory works must be designed as such, with real intentionality in the mechanisms that will inspire interaction with the artwork and between individuals. Graham and Cook state, "the audience might choose not to use the artwork if the interaction has not been carefully considered."[82] According to Graham and Cook, "Lozano-Hemmer's solution is to make works that are intended to be enhanced best by group interaction; many people can interact with the artwork at a time, and the artwork encourages interaction between people."[83]

Rafael Lozano-Hemmer's artwork is an exceptional example of participatory art. I am inspired by his large scale interactive light-shows that have been displayed around the world. The intense beams emitted from searchlights can be seen from up to 15km away, making the spectacle visible to an entire city and inviting onlookers to come to the epicenter to see what it is all about. Each installation features a unique method of control. Some are controlled by voice, such as *Voz Alta,* which responds to the

80. Mary Flanagan, *Critical Play: Radical Game Design*, (Cambridge, Mass.: MIT Press, 2009), 13.

81. Graham and Cook, *Rethinking Curating*, 119.

82. Graham and Cook, *Rethinking Curating*, 128.

83. Graham and Cook, *Rethinking Curating*, 130.

amplitude of an open megaphone, while others such as *Articulated Intersect* enable direct manipulation via giant levers.[84]

Pulse Corniche, shown in Figure 2, is perhaps the most interesting, projecting the individual's heart beat into the brightness of the light. The mystery of the spectacle draws viewers in and encourages participation, for which they are rewarded by the intimacy of displaying something so personal to the entire city. The encounter with the piece makes the viewer aware of the human source of the light, and the next time they look up they will see not just pulsing lights, but the life and energy of another human displayed across the sky.

Figure 2. Rafael Lozano-Hemmer, *Pulse Corniche*, Abu Dhabi, UAE, 2015. Commission for Guggenheim Abu Dhabi. Image courtesy of the artist under Creative Commons Attribution Noncommercial-Share Alike 3.0 Spain License.

84. Rafael Lozano-Hemmer, "Projects," *Lozano-Hemmer*, accessed January 21, 2018, http://www.lozano-hemmer.com/projects.php.

Daily Tous les Jours is a Montreal based design studio led by Mouna Andraos and Melissa Mongiat that produces large scale interactive installations that inspire play and creativity. They transform public spaces into performative social playgrounds for adults and children alike. Their works *21 Balançoires* and *The Swings* invite participants to work together in producing music simply by swinging together.[85] The success of these participatory works is rooted in their application of a simple rule: the periodicity of a pendulum. The swings will naturally move in time with each other, keeping a natural rhythm through their oscillation. Of course, participants have some control over the system, and can disturb this rhythmic pattern to alter the melody. Every swing plays a different note, giving each contributor equal responsibility in the production of a shared improvisational score.[86]

Figure 3. Daily Tous Les Jours, *The Swings,* Detroit, Michigan, 2016.
Photograph by Jay Fenech. Reprinted with permission from Daily Tous Les Jours.

85. Daily Tous Les Jours, "Work," accessed January 21, 2018, http://www.dailytouslesjours.com/work/.

86. Daily Tous Les Jours, "Work."

According to Claire Bishop, participatory art is driven by one or more of the following agendas:

Activation: to empower the spectator with agency, creating an active subject. [87]

Authorship: to cede some or all control to the participant, producing a more democratic result that may benefit from unpredictability. [88]

Community: "a restoration of the social bond through a collective elaboration of meaning."[89]

According Bourriaud, "depending on the degree of participation required of the onlooker by the artist, along with the nature of the works and the models of sociability proposed and represented, an exhibition will give rise to a specific "arena for exchange"."[90] Participation gives the participant agency to contribute to the work (or not) while the authorship of that participation is shared jointly among participants. The artwork becomes a catalyst for social reform through encouraging the formation of relationships, and the exchange of emotions and ideas. These relationships may be temporary, or they may yield lasting connections, but either way the participants leave transformed not only by the artwork, but by the collective thoughts of all who were present. According to Bourriaud, "the contemporary art exhibition… creates free arenas, and time spans, whose rhythm contrasts with those structuring everyday life, and it

87. Claire Bishop, "Introduction//Viewers as Producers," *Participation,* ed. Claire Bishop (Cambridge, Mass.: The MIT Press, 2006), 12.

88. Bishop, "Introduction//Viewers as Producers," 12.

89. Bishop, "Introduction//Viewers as Producers," 12.

90. Nicolas Bourraud, *Relational Aesthetics*, (Dijon: Les Presses du reél, 2002), 17.

encourages an inter-human commerce that differs from those "communication zones" that are imposed on us."[91]

3.3. Public Virtual Reality

Participation is an essential element in any public VR installation. As mentioned previously, VR's almost direct mediation of the perceptual systems demands active participation, and the public nature of an installation transforms this participation into a social one. Participants must accept the risk of putting on a headset that blocks their view and become an impromptu performer among an unfamiliar audience. As such, the installation needs to provide some sense of transparency, of progressive engagement that makes the participant feel safe and allows them to participate at their level of comfort. The Farshou Foundation's exhibition of VR artwork including Paul McCarthey's *C.S.S.C. Coach Stage Coach* and Christian Lemmerz *La Apparizione* attempt to evade this by sequestering each participant in a semi-private cubicle, blocking each off from the other and preventing any potential for socialization.[92] This implementation is a particularly frightening vision of a possible dystopian future where individuals are separated by VR technology rather than united by it. Furthermore, it raises the question: what is the purpose of a public VR exhibition that segregates its audience into private booths? According to Boris Groys, the social aspect of participation is an essential aspect in digital art:

91. Nicolas Bourraud, *Relational Aesthetics*, (Dijon: Les Presses du reél, 2002), 16.

92. Faurschou Foundation, "Faurschou Foundation Beijing - 10 years," Posted August 25, 2017, http://www.faurschou.com/beijing/virtual-reality-art/faurschuo-foundation-beijing-10-years/.

> A computer installation stages a social event and is bestowed in turn with a political dimension… it facilitates an encounter between diverse individuals who become aware of the communal presence of their bodies in space… It is here, in the real space of social communication that the cooling of the virtual can take place—a process that, if you will, counteracts the dissolution of real space into virtuality…[93]

A much more inspiring example of social participation in VR is *Invisible Walls*, an installation at Vienna Design Week 2016. This installation was an experiment in co-presence in virtual reality wherein a "player" wearing a VR headset, is placed in the same room as spectators. For technical and safety reasons, the player is positioned behind an invisible wall in one half of the room but can see sculptural avatars of spectators who are tracked by laser range-finders in the other half of the room. The player and spectators can still see each other and communicate vocally. While the invisible boundary prevents the player and spectator from ever touching each other, this visionary experiment in co-presence in VR has proven the technical feasibility of implementing a participative, social VR installation.[94]

Indeed, *Invisible Walls* produces an interesting dichotomy between the spectators and the player, with the player positioned as a performer on a stage, subject to the unseen gaze of the audience; however, the player is aware of their vulnerable position and engages anyway. The audience is simultaneously present and absent in the virtual space. Their sculptural avatars are a comfort to the player, allowing them a basic awareness of the spectators' presence, while their simplification to a geometric

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93. Boris Groys, "A Genealogy of Participatory Art," *The Art of Participation: 1950 to Now*, (New York: Thames & Hudson, 2008), 31.

94. Michael Lankes, Jürgen Hagler, Georgi Kostov, and Jeremiah Diephuis, "Invisible Walls: Co-Presence in a Co-located Augmented Virtuality Installation," in *CHI PLAY 2017*, Amsterdam, Netherlands, 2017, 553–560. DOI: 10.1145/3116595.311660.

apparition removes much of the pressure that might otherwise be felt by the player. The player can interact with their environment and can affect spectators' avatars through gestures, allowing for interaction between the audience and player at a distance, and producing a game-like experience where the spectators control their position and the player controls the spectators' appearance.[95]

Another experiment in participatory VR is SoundThimble. While it is just a technical demonstration, the concept is nonetheless applicable to VR installations. There is no conventional VR apparatus involved in SoundThimble; instead, a user tracked with motion capture equipment explores the invisible virtual space searching for the unseen SoundThimble using sonification.[96] Upon reaching a threshold distance the sonification changes to indicate the user's proximity, and the user can grab the SoundThimble. With it in hand, the user can now create sound through varied expressive movements or can drop the SoundThimble and begin searching for another.[97] The participant is able to retain their connection to the real space, and in theory multiple participants could collaborate in the same space, competing to find the next SoundThimble, or collaborating to produce music with this interesting spatial instrument.

The expansive rooms of art galleries are the ideal space for these participative social experiences in VR. The public space invites anyone to enter within and become

95. University of Applied Sciences Upper Austria, "Invisible Walls," *Playful Interactive Environments*, accessed January 21, 2018, http://pie.fh-hagenberg.at/projects/invisible-walls/.

96. Grigore Burloiu, Ştefan Damian, Bogdan Golumbeanu, and Valentin Mihai, "Structured interaction in the SoundThimble real-time gesture sonification framework," In *Proceedings of Audio Mostly* '17, London, UK, 2017, DOI: 10.1145/3123514.3123543.

97. Burloiu et al., "SoundThimble."

part of the experience, and the expansive rooms enlarge the extents of the virtual space available. However, according to artist Caroline S. Langill and curator Lizzie Muller, "It is widely acknowledged that media art has, for over 30 years, been displayed in a kind of parallel exhibitionary universe to "mainstream" contemporary art."[98] Often these artworks are instead displayed at technical conferences such as SIGGRAPH, and while these provide an open space for new ideas, the strong technical focus causes art to take a back seat to technological progress. Langill and Muller contend that, "on the one hand it has led to a robust and supportive community of practice, but not necessarily to greater understanding or recognition – either at the level of the general public, or in terms of a sophisticated, broad and integrative critical discussion."[99]

By bringing VR into the gallery, there is the potential to generate many positive effects. The year-round and widely distributed nature of art galleries makes them ideal locations to connect with the public. Participative VR experiences such as those described have a strong potential to bring new visitors into the gallery, providing them with transformative experiences and exposing them to a space they might have previously avoided. Thus, locating VR experiences in art galleries has the potential to act as an agent of change, bringing together art and technology, while creating public awareness and action. At the same time, the gallery is transformed into a communal creative space, where social norms can be broken and rewritten through collective performance.

98. Caroline S. Langill and Lizzie Muller, "Curating Lively Objects: Post-disciplinary Affordances for Media Art Exhibition," in *Curating the Digital: Space for Art and Interaction*, eds. David England, Tecla Schiphorst, and Nick Bryan-Kinns, (Switzerland: Springer, 2016), 33.

99. Langill and Muller, "Curating Lively Objects," 34.

Chapter 4 / METHODOLOGY

According to Blom, "a rich subfield of recent artistic practices is devoted to intensive research and development in the realm of digital technology, spurring collaborative networks between artists, scientists, engineers and theorists."[100] Through my work I seek to make myself a node between disciplines, facilitating collaboration as a specialist in interdisciplinarity.

My research follows a practice based mixed-methodology approach: creating possibilities through artistic methods and rationalizing results through an engineering approach. Art theorist Barbara Bolt states that the generative potential of artistic research is in its repetition with difference.[101] I follow an art-as-research methodology that "does things in the world" rather than "describing the world," with emphasis on the force and effect of the work.[102] This allows for the generation of ideas by what artist Graeme Sullivan calls "looking beyond what is known,"[103] while the products of the creative practice document the results in an embodied form.

The force and effect of my work is not only through its display in the gallery, but also through the development of ideas, methods, and technologies discovered through the iterative production of the work. With a focus on experimentation, documentation,

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100. Blom, "Inhabiting the Technosphere," 153.

101. Barbara Bolt, "Artistic Research: A Performative Paradigm?" *Parse Journal, Issue #3 Repetitions and Reneges* (2016): 132.

102. Bolt, "Artistic Research: A Performative Paradigm?" 140.

103. Graeme Sullivan, "Making Space: The Purpose and Place of Practice-led Research," *Practice-Led Research, Research-Led Practice in the Creative Arts*, eds. Hazel Smith and Roger T. Dean (Edinburgh: Edinburgh University Press, 2009), 62.

and dissemination, the work does much more in the world than would otherwise be possible.

As claimed by Graham and Cook, "new media art engages any medium necessary for its realization. The overarching impression of new media is that it is deeply hybrid in approach, method, content, and form. This quality aligns new media art with our post-postmodern time or postmedium condition."[104] I work with whatever tools and methods are necessary for the realization of the work. I conceptualize with charcoal, with cardboard mockups, and using VR tools including Google Tilt Brush. I produce designs using Computer Aided Design (CAD) and modelling software. I transform the designs into reality using 3D printing, Computer Numerical Control (CNC) machining, and fabrication. I bring life to these physical objects using microprocessors such as the Arduino and a variety of customized electronics. I use programming languages including C++, C#, Unity, and PureData to create the programs that enable interactivity in my work. The breadth of my practice prevents restriction in the products I create and certainly fits within Graham and Cook's claim regarding new media art.

4.1. Creative Design Process

Engineering researchers Howard, Culley, and Dekonick state that, "Creativity is an integral and essential part of the engineering design process." [105] Despite this, their review comparing engineering design process models to creative process models

104. Graham and Cook, *Rethinking Curating*, 34.

105. T. J. Howard, S. J. Culley, and E. Dekoninck, "Describing the Creative Design Process by the Integration of Engineering Design and Cognitive Psychology Literature," *Design Studies* 29 (2008): 164, DOI: 10.1016/j.destud.2008.01.001.

demonstrates that engineering process models poorly represent creative processes.[106] They tend to be deterministic and restrictive and fail to align with human creative processes. This linearity limits them to incremental improvements and translates a creative process into an optimization problem. While problem-solving requires creative thinking, it produces a pre-determined result defined by the problem statement. The interaction design process is similar to engineering design processes but applied in a more iterative manner. According to Preece and Sharp, the interaction design process follows an iterative approach through a repeating cycle of (1) Establishing Requirements, (2) Designing Alternatives, (3) Prototyping, and (4) Evaluating.[107] Iterating opens the process to evolution, but the results are still highly constrained, as the iteration is limited, and the cycle is still a problem-solving one rather than a creative one. Perhaps the process needs to be rethought: instead of iteratively creative thinking to solving an overarching problem, the creative process can be divided into small problem-solving tasks, incrementally proceeding forward towards an ever evolving ideal.

The experimental design methodology I have followed during my studies is informed by engineering and interaction design models, but reverses the importance of creativity and problem-solving and works in a continuous, open-ended cycle rather than one with a finite destination. Borrowing the more generalized creative process terms from Howard, Culley, and Dekonick: Establishing Requirements and Evaluation

106. Howard, Culley, and Dekoninck, "Describing the Creative Design Process," 164.
107. Preece, Rogers, and Sharp, *Interaction Design*, 330.

are folded into one "Analysis" stage, followed by a "Conceptual Design" phase, and then an "Embodiment" or prototyping phase.[108]

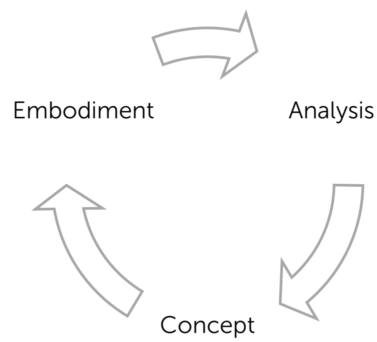

Figure 4. Continuously Iterative Design Process.

This continuously iterative design process, shown in Figure 4, follows a less rigid structure, with cycles varying in duration and intensity. The process can be started or stopped at any time, when the desired result is achieved, or when the creative process needs a new direction. It is continuously informed by external knowledge, not just at the initial requirements phase. The analysis of results simultaneously sets the stage for the next cycle's goal. Dissemination or resolution can occur at any time. For example, the analysis of one cycle could result in a conference paper while the embodiment of another produces an exhibition or demonstration. Throughout the process, problem-solving is applied to accomplish short term goals and to fulfill creative desires. Throughout my research I have cycled through this process, building iteration upon iteration, each time with a new direction, sometimes in a matter of days, other times over months. The flexibility of this process allowed me to quickly integrate inspiration, translating what might appear as coincidences into opportunities that shaped the progress of the system.

108. Howard, Culley, and Dekoninck, "Describing the Creative Design Process," 164.

4.2. Maker Culture, Developer Community, and Accessible APIs

My work would not be possible without the recent explosion of shared knowledge through maker culture, the developer community, and easily accessible Application Programming Interfaces (APIs) and Software Development Kits (SDKs). As suggested by Lev Manovich, "the most sophisticated forms of conceptual innovation may be linked to the development of Web 2.0 itself—namely, the new creative software tools… designed by individuals and small collectives as well as large companies such as Google."[109]

The products of large companies provide much of the foundation for the work. The Unity game engine facilitates content creation through its editor, and open and shared development through its asset store and simple packaging and integration system. APIs and SDKs facilitate the implementation of advanced systems and hardware including the HTC Vive, Leap Motion hand tracker, Kinect sensor, and efficient VR rendering via NVIDIA VRWorks. The availability of these tools benefits both the companies producing them and the creators using them, funding their development through hardware sales while enabling creators to produce unencumbered.

Add to this the sharing of programs among a community of developers that allow creators to build upon each other's work, and the production of advanced systems becomes feasible. Through open source and shared software, the conventional sense of authorship becomes blurred as each author integrates numerous sources into their own work and subsequently contributes to the work of others. According to Roy Ascott, "[A]rt itself becomes, not a discrete set of entities, but rather

109. Lev Manovich, "Art After Web 2.0," *The Art of Participation: 1950 to Now*, (New York: Thames & Hudson, 2008), 78.

a web of relationships between ideas and images in constant flux, to which no single authorship is attributable, and whose meanings depend on the active participation of whoever enters the network."[110] By building upon the work of others, I contribute back to the community, sharing the results online through GitHub, through academic conferences, and through exhibition in the gallery: existing as a node within the web of shared knowledge.

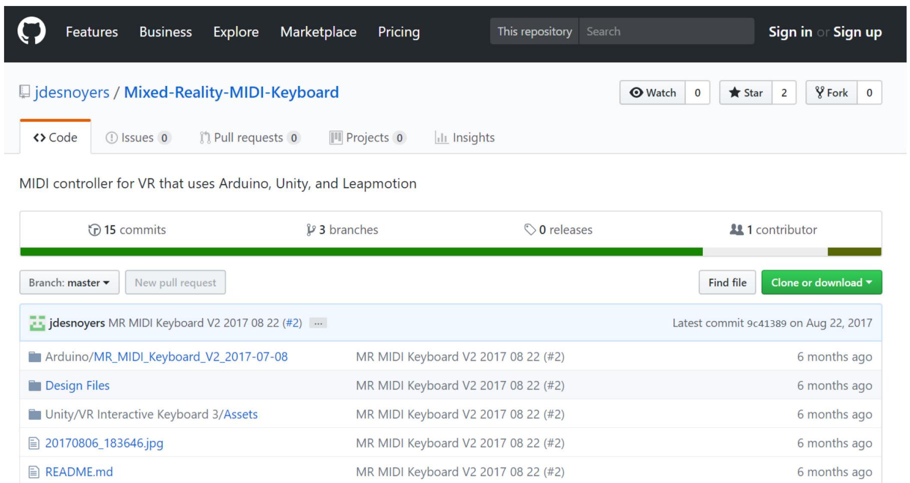

Figure 5. Code made publicly available through GitHub.

4.3. Experiments in Satisfying the Senses

Over the course of my Master of Fine Arts, I developed a number of experimental works, each building upon the last. I began with little experience using VR and no experience creating for VR and had limited access to the hardware required. Beginning with a Samsung Gear VR, my experimentation evolved from simple stereoscopic imagery to complex systems that integrate several devices to generate embodied

110. Ascott, "Art and Telematics," *Telematic Embrace*, 199.

experiences. This journey allowed me to learn several aspects of VR development and to gain a thorough understanding of this technology.

I followed the continuously iterative design process described previously, focusing on what Bolt describes as "repetition with difference." [111] I began each cycle with a flexible proposal, sometimes a concept defined by a sentence, other times a proposal document several pages long. These proposals identified a motivating concept as a vector for departure but were written with the expectation that by the time I arrived at the end, the product of the work was likely to have evolved along with the discoveries made in the process. Upon completing each iteration, I set off in a new direction, guided by the results.

I began with a simple experiment in stereoscopic imagery, meant to compare the effect of VR to a two-dimensional image. Starting with a sketch of the *Winged Victory of Samothrace*, I produced a digital image that I then processed both for print and for VR, shown in Figure 6. I produced a depth map that was used to create lens blur, and to displace the left and right images generating a stereoscopic illusion of depth in a 360-degree 3D image for the Samsung Gear VR. I printed a large scale 66" x 44" print and compared the two. Both featured the figure positioned and scaled to match a life-size person. The VR version resulted in a significantly greater sense of presence, with the stereopsis bringing my sketch into three-dimensional form. I felt as though I should be able to reach out and touch the now sculptural form. As Masumi claims, the stereopsis produces a kinesthetic sense, I could *feel* the image, and it was

111. Bolt, "Artistic Research," 132.

as if I could enter that space.[112] This, however, produced a division between what I should be able to feel and what I actually could: although I could look around at the spherical, 3D image, I was trapped in a single point in the virtual space. The desire to enter the space conflicted with the static nature of the image, and it was immediately clear that VR demanded participation.

Figure 6. John Desnoyers-Stewart, *Fiery Victory of Samothrace*, 2016.
Graphite on Paper, Digital. 360° stereoscopic VR image and 66" x 44" Print.

112. Massumi, "Sensing the Virtual, Building the Insensible," cited in Hansen, *New Philosophy for New Media*, 109.

In developing participative experiments, I realized the importance of VR expanding beyond the limits of reality, so I produced works that played with physical and social rules such as gravity and expected behaviour within a gallery setting. One of these pieces, *Subconscious of Movement* was inspired by Cornelia Parker's *Subconscious of a Monument*, a piece that fills a room with chunks of clay from beneath the Tower of Pisa suspended in the air. The fragile clay almost floats in the air, yet forms a solid barrier preventing entry into the room. The inaccessibility of the gallery space is confronted in Subconscious of Movement, where the user is presented with stark white walls and didactic text of the gallery. Through the freedom of the virtual space, users are inspired to experiment with the conventional social rules of the space. In addition, the user has control over the physical rules governing the virtual gallery—they can turn gravity on and off, make the air thick like syrup, and cause the shapes in the space to gravitate towards each other as shown in Figure 7. The room, which would have ordinarily been impenetrable, is shaped by the user's presence. Given control over the space and enabled to affect change within it, they can choose to stand amidst the beautiful chaos as the disturbed cubes flow about the space, or they can produce a sculptural work by careful manipulation of the physical rules that govern the objects.

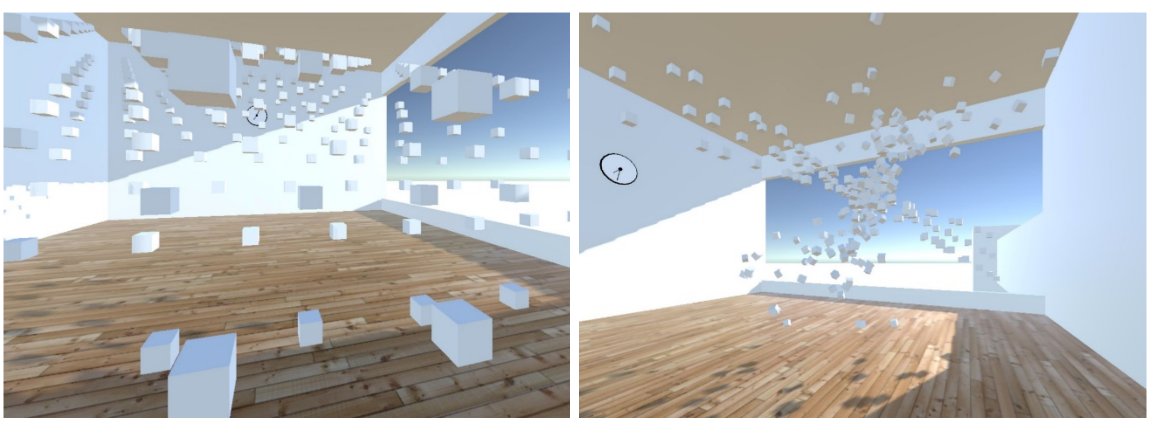

Figure 7. John Desnoyers-Stewart, *The Subconscious of Movement*, 2017.
Virtual Reality (Unity/C# for Samsung Gear VR).
Left: Undisturbed cubes. Right: Cubes sculpted into a form by the controlling physical rules.

4.4. Augmented Virtuality: The Mixed Reality MIDI Keyboard

At this point I was fortunate enough to begin working with an HTC Vive and could begin to bring the user into an open space rather than confining them to a chair. With the rapid development of VR, I realized I needed to work in a futuristic context. Working with the tools I have, I imagine what the end result's application might look like as the technology progresses. This allows me to make a significant and lasting contribution that could apply not only now, but to future generations of VR technology, and in addition has the potential to shape the future of the technology itself.

The Mixed Reality MIDI Keyboard shown in Figure 8 was developed as an exploration of augmented virtuality. It began as an experiment in aligning a real, dynamic object in virtual space, enhancing presence through a tactile interaction, similar to the work of H. G. Hoffman and Sra and Schmandt, but implemented using the interface of a dynamic interactive object: a keyboard. [113]

Figure 8. The Mixed Reality MIDI Keyboard.

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113. Sra and Schmandt. "Bringing Real Objects, Spaces, Actions, and Interactions into Social VR."; Hunter G. Hoffman, "Physically Touching Virtual Objects."

The MR MIDI Keyboard uses VR technologies to form a seamless mixed reality interface for playing music in a virtual setting. By using an HTC Vive, a Vive Tracker, a Leap Motion controller, and a specialized MIDI keyboard, the location of the keyboard, the user, and their hands can be synchronized between the real and virtual environments. The Unity game engine is used as the central hub of the system, integrating the various inputs, and providing the engine for simulating the virtual environment. The HTC Vive, which is the primary hardware component, locates the user's head and provides the visual output from Unity. The Leap Motion controller is used for hand tracking, enabling the user to see their hands in VR and delivering a stronger sense of presence. The MR MIDI Keyboard itself is the physical input device on which the mixed reality interface is based.

Figure 9. The Mixed Reality MIDI Keyboard in VR.
(left: overview of virtual interfaces, right: closeup of interaction)

Designing for mixed reality also requires a unique approach to design methodology, as both real and virtual objects must be designed simultaneously and made to align with minimal redundancy. In order to rapidly develop devices, such as the MR MIDI Keyboard, a detailed design was first produced for the physical production, while a simplified virtual version was created as a secondary branch, facilitating any subsequent changes to both the physical and virtual designs. This process ensured that the physical and virtual keyboards align with minimal effort.

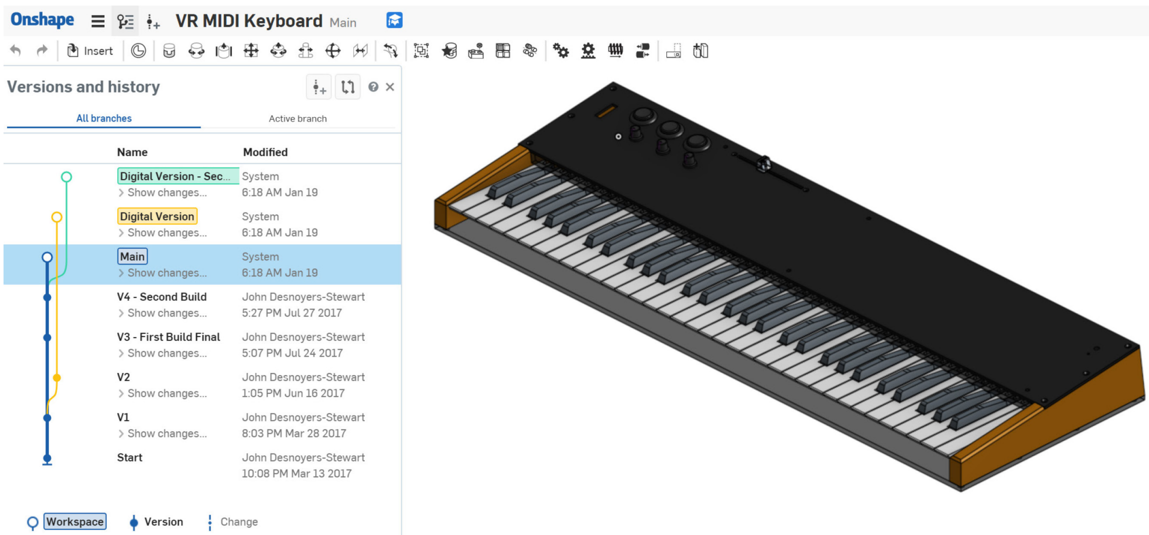

Figure 10. The Branched Version Control used in CAD.

The virtual interface for the MR MIDI Keyboard, shown in Figure 9, is centered around a virtual keyboard. Not only is the user able to use the physical keyboard's controls, but also every surface of the keyboard is augmented with virtual controls. The surface of the physical keyboard is made into a virtual touch screen covered in buttons, sliders and switches. In addition, volumetric 3D interfaces surround the keyboard, allowing for novel methods of input. Every control, whether real or virtual, is further enhanced with visual feedback that allows for greater precision and awareness without having to look away to a screen or panel. Each interface is made to be flexible and modular so that the keyboard can be tailored to the needs of the user and circumstances.

The interfaces developed offer functional and immersive control in a virtual reality environment. While some mimic ordinary real interfaces, they do so without the need for expensive, fixed sensors. They offer significantly improved flexibility compared to their real counterparts, and often improved functionality. The tactile feedback offered by the surface of the keyboard greatly improves the feel and immersion over purely virtual systems. The system was carefully designed with a clear distinction between virtual and real objects, to ensure the user is aware of whether to expect a real or virtual object.

Several other interfaces build upon this expanded sense of immersion to take full advantage of the virtual environment. While these controls are suspended in empty space and do not enjoy the same tactility, the real and mixed controls that share the same environment give the user the sense that they belong to reality. With this added presence the user is more capable of successfully engaging with the interface and is more likely to do so for longer periods of time. Some situations still justify the use of real sensors, as in the case with the keyboard keys. They provide a synchronized, dynamic surface that continuously confirms the user's sense of presence, retaining their connection to the virtual environment.

A user study was conducted to substantiate these claims and has been submitted for publication in the Springer Lecture Notes in Computer Science. The study found that the keyboard significantly improved the users' experience and sense of immersion, with 63% of participants rating the experience as "much better" than previous experiences and all of the participants agreeing that they felt more immersed than in other VR experiences.[114] The study also found that the accurate alignment and differentiation of real and virtual objects were some of the most significant aspects

114. John Desnoyers-Stewart, David Gerhard, and Megan Smith, "Augmenting Virtuality with a Synchronized Dynamic Musical Interface: A User Evaluation of a Mixed Reality MIDI Keyboard," Forthcoming in *Music Technology with Swing*, *CMMR 2017*, Lecture Notes in Computer Science, (2018).

reported by users, and as such needed considerable attention in future developments.[115]

4.5. Expanding Reality: Surreal Instruments

Building on concepts developed for the MR MIDI Keyboard, two virtual instruments were developed using natural user interfaces based on particle simulation. According to Seagao, Holland and Mulholland, "While the range of tools and techniques available to the musician for the design and editing of sound is very large, usability in modern synthesizers is generally poor."[116] They claim that with most existing software synthesizers, the user is required to translate qualitative task language such as colour and texture to quantitative core language such as cutoff frequency and resonance. The migration of synthesis from hardware to software has freed up designers from the constraints of hardware synthesis; however, digital synthesizers continue to emulate the interfaces of their predecessors.[117]

These digital synthesis interfaces restrict the capacity of the computer to extend the musician's capacity to create, and undoubtedly have a material impact on the resulting sounds produced. To resolve this, I sought to develop divergent interfaces constructed from familiar metaphors based around fluids such as water. These metaphors are more familiar not only to musicians, but to all humans, as there is a learned understanding from numerous daily encounters with water such as using an

115. Desnoyers-Stewart, Gerhard, and Smith, "Augmenting Virtuality with a Synchronized Dynamic Musical Interface.

116. Allan Seagao, Simon Holland, and Paul Mulholland. "A Critical Analysis of Synthesizer User Interfaces for timbre," Technical Report, (Milton Keynes, UK: The Open University, 2004).

117. Seagao, Holland, and Mulholland. "A Critical Analysis of Synthesizer User Interfaces for timbre."

umbrella to shield from the rain or splashing water in a pool. The underlying complexity of fluids produces numerous parameters to control a complex system, while their apparent simplicity guides the user's interaction and provides predictable results with familiar visual feedback. Furthermore, these metaphors are highly extensible, able to be altered in many ways to control or expand upon the interactions possible. The designs produced are meant to be enjoyable to play from the first interaction. They simultaneously facilitate learning, encouraging beginners to experiment, while also challenging experienced musicians to maintain cognitive stimulation and interest.

One of the designs, shown in Figure 11, centered around a rain interaction metaphor. Rain droplets emitted from a small cloud generate sounds upon impact with the user's hands, the floor, and an umbrella. The user collaborates with the chaos of the rain, taking various levels of control. They can either let the rain take over on their outstretched arms or pick out individual notes in a melody, with the timing of the notes generated through the random interval between raindrops.

Figure 11. Interacting with the hands in Rain Interface Prototype.
(left: screenshot, right: image of user interacting)

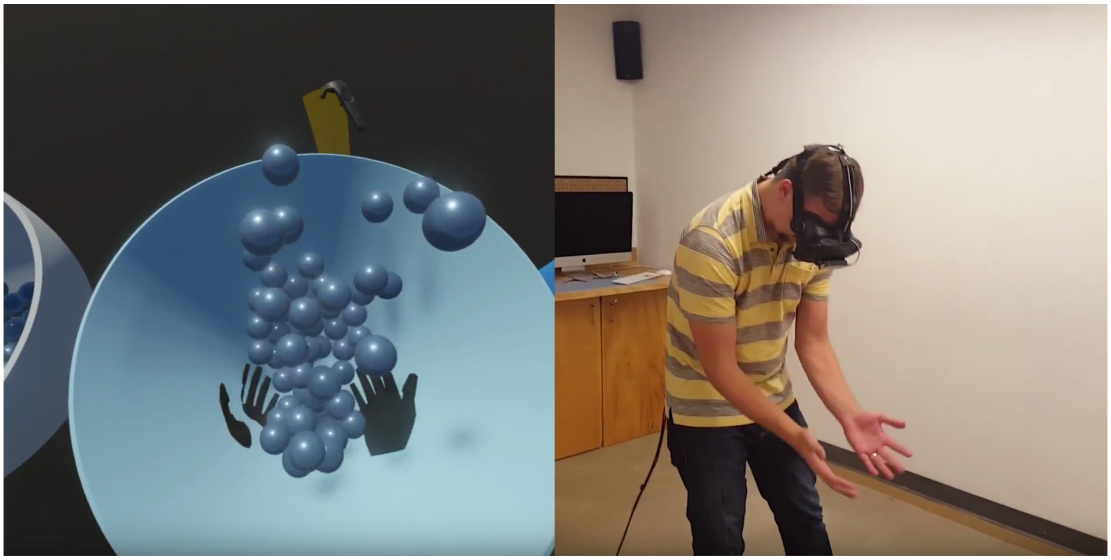

Figure 12. Using the hands to splash marbles in Basin Interface Prototype.
(left: screenshot, right: image of user interacting)

The other interface, shown in Figure 12, uses three basins of various shapes, each connected to a different synthesizer. The user has a virtual pitcher in their hand and can generate marbles that simulate the characteristics of water. By pouring the marbles into the various basins they gain control over each synthesizer. Different actions such as stirring or swishing the marbles around in the basins allow the user to modulate the sound produced, creating a sort of pad-like instrument.

These two new interfaces were initially created without sound, with a focus on using virtual fluids as an interactive medium, but as they were developed into instruments the sound they produced was inherent to their form. Architect Frank Lloyd Wright once said: "Form follows function—that has been misunderstood. Form and function should be one, joined in a spiritual union."[118] Neither form nor function takes priority over the other, instead, they are inherent to one-another—changing either will affect the other, and as such they must be considered simultaneously. While each of

118. The Solomon R. Guggenheim Foundation, "Form Follows Function," *Guggenheim.org*, accessed November 4, 2017, https://www.guggenheim.org/arts-curriculum/topic/form-follows-function.

the interfaces were designed to be intentionally different and divergent, the stark contrast in the sounds produced and the ways in which users interacted with them suggested that the sound produced will always have characteristics of the interface imbued upon it. No matter how customizable the parameters are or how they are mapped, the interface defines the quality of the sound produced: the interface's form and function are one. The sounds produced in current electronic music are inherent to the tools used to produce them, reinforcing the need to explore technologies such as virtual reality to find new modes of interacting with the digital that go beyond conventional button and knob-based interfaces.

The sounds of these instruments were created using PureData, a visual programing language. They produced interesting results that were intuitive and dynamic. They can be seen as providing a new form of gestural interaction, wherein the gestures are not directly mapped to parameters, but instead the simulated results of their interaction are mapped. This affords natural gestures that provide direct feedback via the VR system. In addition, the disparity between what the user and an observer could see produced an interesting result: the user began to make expressive gestures coherent with their performance without realizing it. While the user perceived interacting with an object, the observer saw only the resulting movement.

On demonstrating my work to two colleagues, I had the opportunity to see the fluid interfaces used alongside the MR MIDI Keyboard when they both began to play. For the first time both instruments were performed simultaneously in the same space, and, although neither of them was a musician, once immersed in VR they began to improvise together. As they riffed off of each other, they gained confidence and their energy built to the point where one began to sing and the other began to dance. The magic of this impromptu performance inspired the installation for my master's exhibition.

Chapter 5 / INSTALLATION

The results of the research conducted over my studies have informed an interactive virtual reality installation at the Fifth Parallel Gallery at the University of Regina. This two-week installation transforms the gallery into a space for performative expression open to all who enter. The goal of this installation is to remind participants that they are creative, expressive individuals: to use VR to place them in what psychologists Csikszentmihalyi, Abhamdeh and Nakamura call a flow state[119] and enable them to have extraordinary experiences.

According to performance theorist Richard Schener: “Playing, not ‘the world of working in daily life,’ is the ground, the matrix, birthing all experiences exfoliating multiple realities… being is playing and ‘working daily life’ is just one reality cookie-cut, or netted, out of playing. Working daily life… can appear to be ‘the archetype of our experience’ only as the result of careful netting.”[120] This VR installation gives participants an opportunity to escape their “working daily life” and to spend a moment engaging with the play at the root of their being.

The physical space of the gallery is left mostly empty, giving ample room for participants to interact with the piece. The system consists of the Mixed Reality MIDI Keyboard, an HTC Vive VR headset equipped with leap motion hand tracker, a VR ready PC, two projectors, and a Kinect sensor. The VR experience is built in the Unity Game

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119. Mihaly Csikszentmihalyi, Sami Abuhamdeh, and Jeanne Nakamura, “Flow,” *Flow and the Foundations of Positive Psychology*, (Dordrecht, Netherlands: Springer, 2014). 279–238. DOI: 10.1007/978-94-017-9088-8_15.

120. Richard Schener, “Playing,” *The Improvisation Studies Reader: Spontaneous Acts*, eds. Rebecca Caines and Ajay Heble, (New York: Routledge, 2015), 387

Engine and the keyboard controls the sound of an instrument in the Bitwig Digital Audio Workstation (DAW). Each instrument controls a PureData-based synthesizer and the resulting sound is played over speakers throughout the space. The system diagram is shown below in Figure 13.

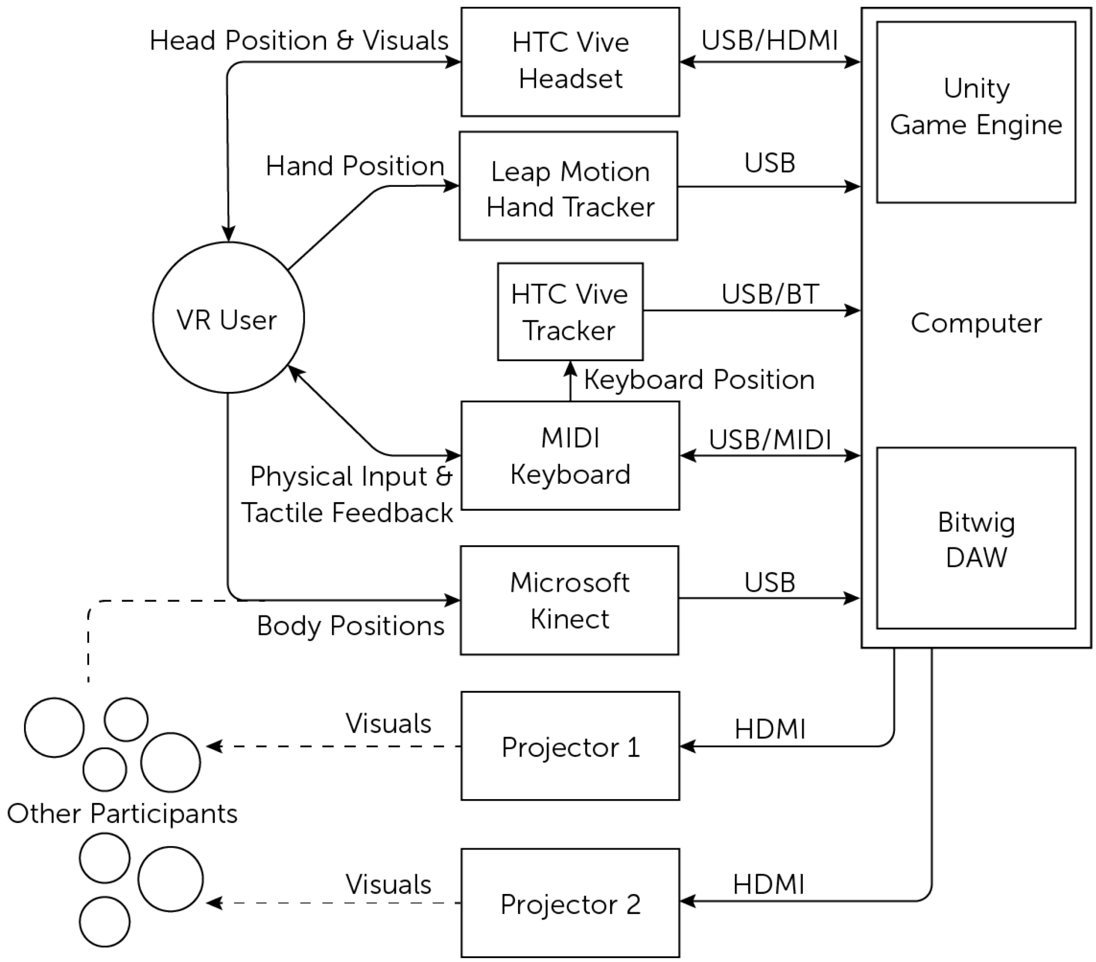

Figure 13. Installation System Diagram.

The Mixed Reality MIDI Keyboard stands at the center of the space. Above the keyboard a VR headset is suspended from the ceiling, counterbalanced to allow for engagement throughout much of the space and a safe return to its neutral position. Spotlights shine on the keyboard and headset exaggerating their presence as the focal point of the space. Two projections are filled with imagery which responds to the participants' actions through a Kinect sensor. From outside the gallery space, onlookers see the keyboard, a glimpse of the projection and participants moving about the space, enticing them to enter the gallery and join the interaction. The installation layout is shown below in Figure 14.

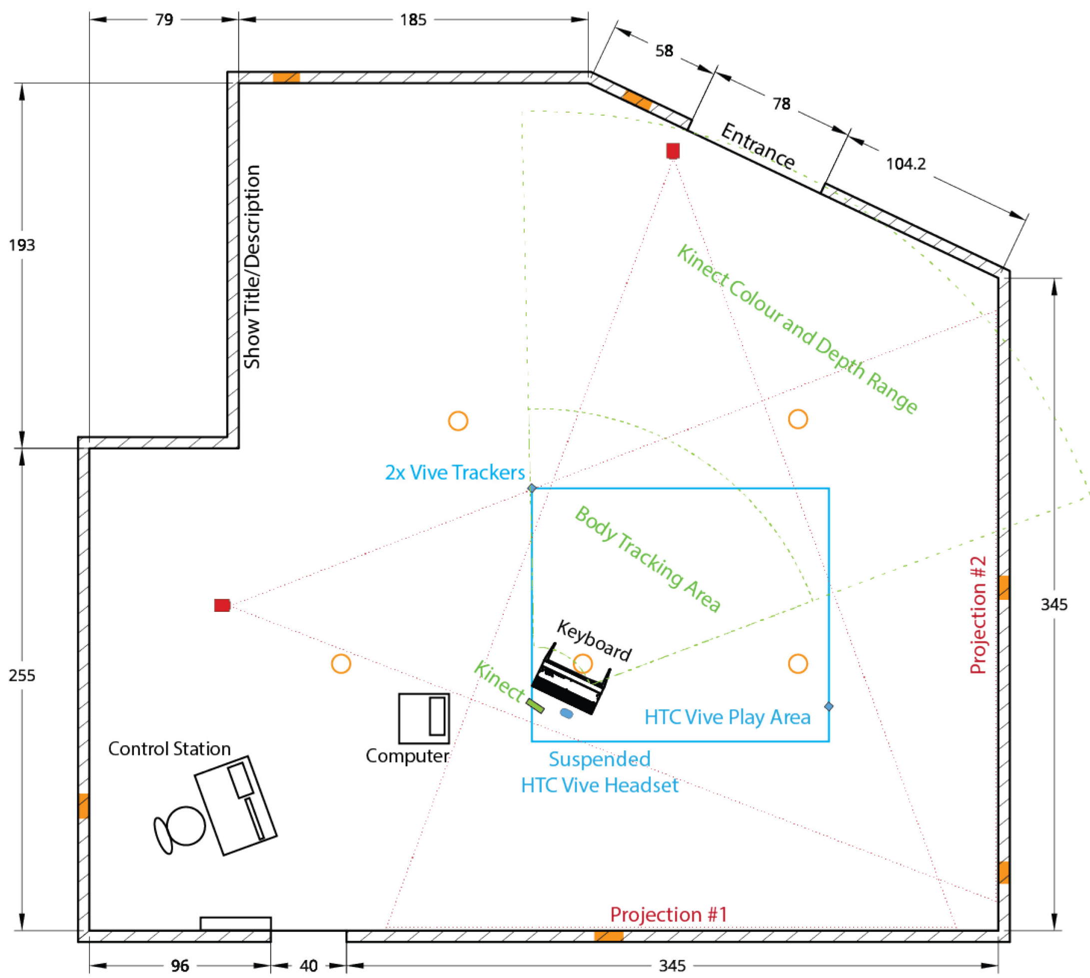

Figure 14. Installation Layout.

The space welcomes both the timid and the confident, amateur and professional, and will enable people to participate at their level of comfort. To accomplish this, participants are able to interact with the virtual on various levels. Upon entering the space, they find their presence detected by a Kinect infrared tracker, and that simply by moving through the space they can have a direct effect on the sound and projections. This will encourage further exploration of the space and eventual engagement with the VR system. According to Flanagan, "play occurs only when players feel comfortable."[121] However, as Schener states, "security is needed at the outset of play more than later on. Once play is underway, risk, danger, and insecurity are part of playing's thrill."[122] While the keyboard may be intimidating, participants will be eager to try touching something in VR. The sound and resulting visualization are designed to reward their brave steps into a new experience and encourage further interaction. The keyboard will also provide a familiar interface for experienced musicians to perform.

Across from the keyboard, the VR headset provides access to virtual instruments designed to encourage flowing, dance-like movement. While the participant may feel they are simply playing a game or instrument, they will in-fact have been guided into dancing. According to Merce Cunningham, "dancing is a lively human activity which by its very nature is part of all of us."[123] As participants become immersed in the activity, their movements will feel natural and will encourage further performative exploration. Merce Cunningham aptly describes the joy of dance that will be instilled upon the participant: "our ecstasy in dance comes from the possible gift of freedom, the exhilarating moment that this exposing of the bare energy can give us. What is meant is not license, but freedom, that is, a complete awareness of the world and at the same time a detachment from it."[124] The participants' complete awareness of the virtual space

121. Flanagan, *Critical Play: Radical Game Design*, 261.

122. Schener, "Playing," 386–387.

123. Merce Cunningham, "The Impermanent Art," *The Improvisation Studies Reader: Spontaneous Acts*, eds. Rebecca Caines and Ajay Heble, (New York: Routledge, 2015), 168.

124. Cunningham, "The Impermanent Art," 166.

will allow their body to detach from the confines of self-enforced social boundaries. The channeled attention to the task combined with the shift in the balance between perceived challenges and perceived skills, and the clear and immediate feedback promote entering a flow state as suggested by Csikszentmihalyi, Abuhamdeh, and Nakamura.[125]

The Kinect tracker allows those not wearing the headset to also be brought into the virtual space. Their representations are simplified, similar to the abstractions in *Invisible Walls*, allowing the VR user an awareness of others' presence in the space. It also enables interaction and contribution by those not wearing the headset. The projections will function as a virtual mirror, displaying a reflection of the virtual space seen from within the headset.

Because this technology is expensive, and the software still in development, it will require my continual presence to monitor the system, troubleshoot any technical issues, and ensure participants can engage with the piece. I will spend my time in the space acting as a host and engaging with participants, and occasionally playing the instruments myself. When a timid, but curious participant enters the space I will make it my objective to perform with them before they leave the gallery.

In addition, I am currently recruiting local musicians to participate. I will organize impromptu workshops and performances throughout the week depending on others' interest. The workshops, led by volunteers, including myself, consist of discussions about VR, or improvisation, or playing an instrument, transforming the space into one

125. Mihaly Csikszentmihalyi, Sami Abuhamdeh, and Jeanne Nakamura, "Flow," *Flow and the Foundations of Positive Psychology*, (Dordrecht, Netherlands: Springer, 2014). 232. DOI: 10.1007/978-94-017-9088-8_15.

where ideas are generated and exchanged. Performances could include both the virtual instruments, and others brought into the space, and they may be scheduled or completely sporadic.

5.1. Outcomes

This installation is an experiment, a venture into the unknown. I aim to have this installation give participants exposure not only to the realm of VR, but to what might be possible with VR. It is meant to give those who attend a transformative opportunity, that will inspire thought and creativity while forming new social bonds and rethinking the purpose of the art gallery. As theorist Margaret Morse states, "Virtual landscapes can also figure as liminal realms of transformation, outside of the world of social limits and constraints… not entirely imaginary nor entirely real, animate but neither living nor dead, a subjective realm wherein events happen in effect, but not actually."[126]

Further to this installation, the technical and theoretical aspects have been and will continue to be shared broadly. They are freely disseminated to the community that contributed to making this work possible. Through presentations, written papers, and resources published online, the work is shared, and allowed to become part of something greater. The source code and designs are shared on GitHub,[127] made available for anyone interested in building them into their own work. Aspects of this work have been presented at conferences around the world, including Audio Mostly in

126. Margaret Morse, *Virtualities: Television, Media Art, and Cyberculture*, (Bloomington: Indiana University Press, 1998), 185.

127. Source code and designs available on GitHub https://github.com/jdesnoyers.

London, [128] CMMR in Matosinhos, Portugal,[129] and the Role/Play Symposium at the National Academy of Science in Washington, DC. Papers have been submitted to the Journal of the Audio Engineering Society and Springer Lecture Notes in Computer Science.

5.2. Future Work

I intend to continue to research VR and creative methods through a PhD in Interdisciplinary Studies. Building on the research conducted to date, I will ask if mixed reality can allow for the development of more expressive artistic interfaces, and if these interfaces can be developed following a more creative, human-centric methodology than conventional engineering and design practices. The research will critically investigate the potential of mixed reality to enable creativity, the constraints of current design processes, and the creativity that can be realized by examining and redefining the design process from a human-centric, creative practice perspective.

This research will contribute the development of further expressive interfaces and the documentation of design through creative processes. This project provides evidence that art is a fundamental element of innovation with equal importance to engineering. It will inform continued development of the University of Regina Creative Technologies program, fostering further collaboration between the Arts and Engineering.

128. John Desnoyers-Stewart, David Gerhard, and Megan Smith, “Mixed Reality MIDI Keyboard Demonstration,” in Proceedings of Audio Mostly 2017, London, UK, August 23–26, 2017, DOI: 10.1145/3123514.3123560.

129. John Desnoyers-Stewart, David Gerhard, and Megan Smith, "Mixed Reality MIDI Keyboard," in *Proceedings of the 13th International Symposium on CMMR*, Porto, Portugal, 2017, 376–386, http://cmmr2017.inesctec.pt/wp-content/uploads/2017/09/38_CMMR_2017_paper_25.pdf.

Chapter 6 / CONCLUSION

Virtual Reality will provide new modes of creative expression not yet imagined, and through the development of new instruments and tools, artists will be enabled to create in a world capable of expanding reality beyond the normal physical limits. The rapidly developing medium of VR will allow for new forms of communication between artist and viewer through immersive, participatory experiences that satisfy all the senses rather than any one in particular.

VR is a medium that is capable of enabling new modes of communication in which entire experiences are shared between artist and viewer. In addition, VR engages the senses and requires active participation to engage with the virtual. As with actual reality, the virtual is accessible only through the perceptual systems. It is not opposed to reality but instead a part of it and forms a creative space that is outside of the limitations of actual reality yet one which contributes to reality. The virtual has long been sought through various means including painting and film, but VR promises to provide a closer connection than ever before. VR has only become feasible recently thanks to rapidly progressing technology; however, it is still in its infancy. By improving VR's connection with reality, the connection with the virtual is simultaneously enhanced, strengthening its effect on reality.

Technology has produced a shift in focus from objects to people and established the viewer's significance as a selective processor of information. VR removes the frame entirely, reinforcing the importance of the body as framer of information and giving the viewer a pivotal role in the artwork. Participatory art follows this model and is centered around the viewer, ceding control in favor of unpredictability, giving the audience agency in the production and interpretation of the artwork, and creating spaces for socialization and collaboration. The artwork takes on the role of a catalyst for social interaction and collaboration with the artist's role transformed into that of a host. While the artist maintains some level of authority over the artwork through the creation of its framework and rules, the participants may subvert these rules and act outside of the expectations of the artist, creating unexpected results. Although the hierarchy between artist and viewer is not eliminated, it is certainly altered. VR is a medium of active participation, and in a public setting such as a gallery, it is inherently social in nature. This contradicts the private and sequestered nature of current VR headset technology and opens up the possibilities of active social participation.

Through my research I have contributed to the development of this expanded reality. I have developed methods for integrating the real and virtual to improve presence and allow a closer connection to the virtual. The Mixed Reality MIDI Keyboard provides the user with an improved sense of presence through tactile interaction with an object simultaneously present in virtual and real space. With this improved presence, the MR MIDI Keyboard brings both the inert surfaces of the keyboard and the space around it to life with virtual interfaces and the augmentation of real interfaces.

I have also produced new forms of interaction that break free of the limitations of conventional metaphors and take advantage of the virtual. The interfaces developed for VR are not restricted to the boundaries of conventional human-computer interaction, but instead are designed specifically for the immersive nature of VR. Instead of using conventional metaphors based on other interactive systems, I sought to establish new ones which rely on more universally familiar concepts such as catching raindrops and stirring a liquid. These interfaces not only afford new methods for control, but also the ability to control numerous parameters simultaneously. Building on these interfaces I have developed new expressive instruments that encourage movement rather than restricting it and have developed methods for participative and transparent electronic music performance.

In addition to my contributions to the technical and theoretical development of VR, through my installation, I have generated a space that exemplifies VR's capacity to promote active participation and encourage social activity. I have encouraged creativity and self-expression by creating a space that is simultaneously real and virtual, public and private, producing a communal experience that affects each individual directly. I have exposed many to the potential of VR and have hopefully inspired others to create in it.

I have shared the knowledge I have developed in order to inspire others to do the same and to create a thorough understanding of VR. In creating a space for play, expression, and social engagement I have contributed to the future of VR that I hope for. One in which virtual reality is not used to escape reality, but to expand it: a future in which we are able to transcend perception.

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