California Institute of the Arts

Designing Virtual Environs

for

Synesthetic Experience

and

Expression

by

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Abstract

Virtual reality as a genre of artistic expression lacks a significant catalog of academic study in regard to its design, form, functionality, and practice. Therefore, the goal of my academic work over the last two years was to document the development and progression of my virtual reality thesis project, entitled *Pollock*. Its design is based around the concept of "deep play," a term describing truly immersive experiences. At the project's end, it became clear to me that the differences between real and virtual worlds are still vast and more research and development focusing on the advancement of virtual reality needs to invent new technologies that better simulate stimuli of non-visual modalities.

Acknowledgments

The completion of this thesis would not have been possible without my companion and sidekick, Rose Arscott, who took care of me when I couldn't take care of myself. A special thanks also needs to be extended to Owen Vallis, my graduate mentor, whose guidance, wisdom, insight, and patience was instrumental in my graduate work.

Contents

List of Figures

Chapter 1

Introduction

1.1 The Origin Story

The fantasy of traveling to other worlds or discovering other planes of existence is obviously not a new one. Though the exact point of inception for hominid imaginative faculties is debatable (Mithen 49), it is conceivable that some of our earliest ancestral predecessors found themselves wondering and daydreaming about places far beyond their feet. It is even posited that some other species in the animal kingdom, such as chimpanzees, possess the basic mechanisms for imagination and display them through such activities as tool-making and language comprehension (Mithen 31-35).

Yet, for most of human history, many of these fantastical planes of pretend have remained bounded to the extents of our mind. Art and technology have afforded us an ever-evolving means of expression to transport ourselves to other fictional realities. It is argued that the extension of human thought through external world objects via tool-making was the critical factor in the interconnection of different cognitive processes in early human brains, thus allowing for more abstracted, creative contemplation. However, the totality of our *actual* reality is so all-encompassing that full immersion, one of complete transcendence, is difficult to achieve through artificial means. We can be engrossed, completely lost in a work of art, yet that experience is still bounded by the confines of the art's chosen medium of expression. However, new technological advances in virtual reality are now providing us the ability to take us even closer to these once imagined places.

Yet, having the technology is not the same as using the technology, and it is fair to say that the development of any emerging art form requires the efforts of artists who, through their own experimentations, begin to define the modes, aesthetics, and actions that future artists reference in their own work. It is from this realization that my thesis was born. Over the last two years, I have been exploring the development and design of immersive virtual experiences through the development of my own virtual reality experience. It is my hope that my work can, in some small way, help to inspire more artistic work in this burgeoning field, further bridging the gap between the imagined and the real.

1.2 Virtual Reality and the Modern Age

Now in section 0, the idea was presented that achieving full, unobstructed immersion in a work of art is challenging. For example, one may find oneself in a movie theater watching the newest sci-fi adventure film. On the screen, a wacky, ragtag group of dysfunctional heroes is trailblazing through space at warp speed. Visually, we see blue and white streaks of seemingly infinite light on the screen. Yet, these images are limited to a confined space. Moreover, the parallax that gives objects three-dimensional depth is absent from the two-dimensional image on-screen (for the sake of this thought experiment, this is not a 3D film). What if one looks away from the screen? Naturally, they'll no longer be in the midst of warping through space-time; rather they'll be reminded of their current theatrical surroundings.

Sonically, we hear the buzzing and whirring of the ship's engines as it traverses the universe at blistering speed. The audio will be coming out of multiple speakers, but it's likely that the imaging and depth of the scene is scattered or smeared and lacks complete coverage along all perceivable axes. This is because the audio coverage is likely confined to a limited amount of speakers, most likely aligned along one horizontal axis.

Let's take it one step further. Our team of zany explorer's have jumped out of warp speed and landed on an exotic locale covered in lush jungle landscapes, teeming with wildlife. The audio and visuals, again, help tell the story, be it one with a forced perspective. However, what about the other sensory modalities that color our consciousness? Are they being stimulated? Better yet, are they being stimulated in direct correlation to what is being perceived or felt? In this kind of setting, the answer is, for all intents and purposes, no. In the context of what's occurring on-screen, there are no scents to smell; there are no tastes to savor; there are no tactile cues indicative of what is happening from scene-to-scene.

This example illustrates what is so exciting about virtual reality. Though still in its infancy, the affordability and practicality of the medium's requisite technologies is allowing more people to create works of art that can potentially possess a dimensionality never before seen in any artistic discipline. Alas, since virtual reality is still in its nascent upswing, there isn't currently a substantive lexicon of commercial or artistic projects to help solidify the considerations, requirements, and language for designing in this new art form. As I have mentioned, it is for these reasons that I am cataloguing and reflecting on the development of my virtual reality thesis project, entitled *Pollock*. *Pollock* is an Oculus Rift-based, virtual reality experience wherein a single user becomes a painting robot in a colorless world. By painting his world, the user creates a generative sonic/tactile composition that is timbrally and spatially linked to the user's unique choices within the space.

At the outset of my graduate studies, much of my research was spent towards uncovering the complexities of human perception. A significant amount of my research was specifically directed towards understanding the evolutionary history of human imagination, a topic I thought would help elucidate why humans are so drawn to existing in worlds of fantasy. Moreover, it was an attempt to understand why I was so drawn to this kind of artistic work. Fortunately, this research actually revealed much more. These revelations profoundly blurred my conceptions of what reality truly is and it is *here*, at this intersection of history and creativity that Chapter 2 begins. By Chapter 2's end, it is firmly established that humans are primed to create and exist in virtual realities and that *play* is a byproduct of these adaptations. Furthermore, the concept of immersion through *deep play* is discussed, which becomes very important to the development of my deep play model. This model becomes the theoretical framework upon which my thesis project is built.

Chapter 3 focuses primarily on the design of this project, clearly outlining applied approaches and methods. Also highlighted are certain technological advancements like the Oculus Rift virtual reality headset (see Figure 1). Though these technologies that have been the catalyst for a significant amount of my explorations within the field, there are many other tools and resources (both tangible and intangible) to consider as a means to achieve real creative gains in immersivity. Chapter 4 recaps the successes and failures of my thesis project and sums up my thoughts about the process of virtual world building, which I hope will spark further interest in virtual reality within the fields of art and entertainment.

Figure 1. Oculus Rift headset in use

Chapter 2
Research

In this chapter, we first take a look at various theories on the origins of human creativity and its ties with our own perceptions of reality. This then evolves into a discussion on the process of making art specifically for entertainment purposes through analysis of its development in human societies over the last few centuries, introducing us to the very important concept of deep play and the theoretical model I have developed as a framework towards the creation of deep play experiences. We then proceed to examine the histories of different mediums *within* the world of audiovisual/multimodal art as a means to provide context as to how they influenced my design work showcased in chapter 3.

2.1 The Vagaries of Creativity

As previously mentioned, the extension of human thought through external world objects allowed the human mind to fuse novel neural connections across different parts of the brain. It's at this point in human history that the mechanisms for artistic expression began to take shape, leading to a proliferation of never before seen cultural activity most evident in the archaeological record starting around 30,000 years ago (Kaufman et al. 293). Evolutionary theorists seem to be divided on how creative imagination, the mental ability to think beyond what is actually experienced in our daily lives, developed. Some think that this ability was epiphenomenal, meaning that "natural selection shaped human motives to maximize inclusive fitness within a hunter-gatherer ecology […] creative imagination, whenever it appeared in human evolution was just added on as a byproduct of the cognitive/behavioral mechanisms that solved practical problems" (Carrol 51-52).

In other words, it was a secondary ability brought about by a primary adaptation to some sustained, multi-generational environmental pressure, or a random offshoot of an evolutionary reaction. In *How the Mind Works*, Steven Pinker holds that most forms of art "reflect only the human capacity to exploit evolved mechanisms for producing pleasure […] detached from all practical value with respect to survival and reproduction […] equivalent to the pleasure derived from masturbation" (Pinker 524-543).

Figure 2. This scratched plaque and other artifacts discovered in South African caves date back to 120,000 years ago and are some of the first art pieces seen in the archaeological record

However, there is another faction of theorists who see creative imagination as a primary adaptation to the rapid expansion of human intelligence. Edward O. Wilson holds that this newfound "high intelligence" gave way to a behavioral flexibility unseen before in the animal kingdom that is, in part, regulated by the arts, in the sense that they "form an imaginative interface between complex mental structures, genetically transmitted behavioral dispositions, and behavior" (Carrol 52-53). Terrence further expounds upon this notion, stating that "we tell stories about our real experiences and invent stories about imagined ones, and we even make use of these stories to organize our lives […] in a real sense, we live our lives in this shared virtual world" (Deacon 22).

In other words, our reality, with all of its symbols and systems of understanding, only exists in our collective human minds and is not an absolute quality of the universe. Our human experience is inherently ***virtual***, in the sense that our conceptual framework of understanding reality is, even at its most primal, an abstraction of a universe that has no fundamental definitions (at least in the human sense of the word). The fact that creative imagination is undoubtedly a human universal that manifests in all developing children and is able to be created and perceived by all members of the species further validates this theory. This concept is well reflected in these words by the neuroscientist Beau Lotto: "The brain didn't actually evolve to see the world the way it is [...] instead the brain evolved to see the world in the way that was useful to see it in the past and how we see it is by continually redefining normality" [1]

In another video on the topic of the nature of creativity, Beau Lotto explains, "perception is fundamental to everything the brain does, from what we know, from what we think or believe." [2] He goes on to further state that the human brain defines its reality in two very interconnected ways. First, it finds patterns in the world. These patterns "are inherently meaningless… there's nothing inherently valuable in these relationships that we discover in the world." [3] Then, it immediately ascribes meaning to these patterns. So, in other words, "we never see the world as it is, we never see the information that falls onto our eyes, because that would be meaningless. We never even, in fact, see pattern. What we see is the meaning of pattern and that meaning is inherently grounded in our history." [4]

These theories and perspectives are relevant to the virtual reality design process because, ultimately, the main purpose of these works is to replicate the kinds of stimuli that allow us to create our everyday, *virtual* worlds. Understanding how our plastic minds generate perception is critical to creating works that feel real. So, if one is able to succeed in establishing a well-defined sensory vocabulary within a virtual environment, hopefully one can redefine what reality is, allowing for the kind of user interaction, integration, and transcendence that people like myself are working to achieve through immersive environments.

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[1] www.ted.com/talks/beau_lotto_optical_illusions_show_how_we_see?language=en 09/25/14
[2] https://www.youtube.com/watch?v=1Rtw6HoLHkM 09/25/14
[3] https://www.youtube.com/watch?v=1Rtw6HoLHkM 09/25/14
[4] https://www.youtube.com/watch?v=1Rtw6HoLHkM 09/25/14

2.2 That's Entertainment

From a high-level, theoretical standpoint, entertainment as an *art form* is devoid of the kind of academic study characteristic of other art disciplines, due in part to its ambiguity in intent. From an art world perspective, entertainment is that which is "not formally perfect, accomplished, or innovative, not emotionally deep, with nothing interesting to say about the world," a sentiment reflective of an academic culture that justifies and distinguishes itself by its self-appropriated significance (Dyer 1). Another definition is much less imaginative: "entertainment is whatever individuals find entertaining" (Dyer 2). The reasons for this lack of definitive agreement on what entertainment is can be attributed to the fact that it "is by now so thoroughly woven into the fabric of our existence that […] it is difficult to understand, and even to talk about" (Stromberg 104).

Peter Stromberg, anthropologist and writer of the book *Caught in Play: How Entertainment Works on You*, argues that entertainment is a form of "play," an activity that is (as defined by anthropologist Robert Caillois in Figure 3):

1. **Free:** in which playing is not obligatory; if it were, it would at once lose its attractive and joyous quality as diversion;
2. **Separate:** circumscribed within limits of space and time, defined and fixed in advance;
3. **Uncertain:** the course of which cannot be determined, nor the result attained beforehand, and some latitude for innovations being left to the player's initiative;
4. **Unproductive:** creating neither goods, nor wealth, nor new elements of any kind; and, except for the exchange of property among the players, ending in a situation identical to that prevailing at the beginning of the game;
5. **Governed by rules:** under conventions that suspend ordinary laws, and for the moment establish new legislation, which alone counts;
6. **Make-believe:** accompanied by a special awareness of a second reality or of a free unreality, as against real life.

Figure 3. Definition of play as featured in Roger Caillois' *The Definition of Play, The classification of Games*

Given this definition, Stromberg summarizes entertainment as "playful activity undertaken for its own sake, in pursuit of pleasure that diverts the player from the day-to day" (Stromberg 171).

The level of arousal a work of entertainment instills in its audience has been theorized as a product of three attributes: novelty, uncertainty or dissonance, and complexity (Hicks 288). "Based on an individual's assessment of these attributes, interaction with an object or situation is either avoided or sought out." (Hicks 288). Diane Ackerman, the acclaimed essayist and naturalist, holds that play can become *deep play* when this state of arousal "reaches an ecstatic level of engagement," resulting in a playground space "which we push ourselves to our limits, within which we are challenged and lose ourselves in the process of exploration, novelty, and the discovery of new, unfamiliar potentials for play" (Hicks 288). In essence, this is the level of immersivity that virtual reality experiences are aiming to achieve. Therefore, any and all virtual experiences are attempting to create spaces of deep play, which means that understanding how deep play manifests is the most significant aspect in virtual reality design.

All definitions and theories aside, as an artist, one has to decide who the intended audience is for his/her work, which means that it's reliant upon appealing to said audience's expectations. Though my graduate work has been fueled by scientific knowledge and technological innovation, the result was a series of projects whose primary objectives were to entertain, culminating in my largest and final project, *Pollock*. Much like the aforementioned topics of human perception and creative imagination, understanding the evolutionary history and science behind works of entertainment has been crucial to the development of my artistic design process, greatly influencing the direction of my graduate work. So, how has entertainment evolved in western society? What are the important features of successful works of entertainment? How do these abstractions from reality *shape* our reality?

2.3 A Romantic Split

Entertainment can be seen as a form of art, though often art and entertainment are classified as their own distinct entities. These distinctions arose out of nearly a millennia of stratified social systems whose cultures, in most respects, were defined by the whims of the bourgeoisie elite.

This can be seen even in late 18th- early 19th century America. "Prior to mass-produced entertainment, American culture, like European culture, had been the special preserve of the wealthy, the educated, the refined—this country's own aristocrats […] they assumed the responsibility for determining what qualified as good […] as in Europe, the American elite's idea of culture was a rather narrowly defined notion of art" (Gabler 14-15). Things characterized as "fun" or "sensational" were maligned by the social aristocrats of the day and deemed as works of entertainment. The notion of "fun" in the way people think of it today may actually be a relatively new concept in human history according to the philosopher and historian Johan Huzinga. Huzinga found that "the word 'fun' was of recent origin and that no other language had an exact equivalent to the English meaning, leading him to speculate that fun was neither readily understood nor fully accepted until the twentieth century" (Gabler 20). From a modern perspective, to reduce all entertainment as curated "fun" is myopic. However, these sentiments acknowledge that, historically, fun and entertainment are conspicuously linked.

Probably the most significant reason for this aversion to entertainment and its eventual proliferation is that it foreshadowed a shift in cultural thinking. "[Entertainment] deposed the rational and enthroned the sensational and in so doing deposed the intellectual minority and enthroned the unrefined majority" (Gabler 21). This revolution in human thought was indicative of what became known as the Romantic era. Typified by its fondness for sentimentality, this primarily artistic movement put emphasis on the feelings of *wonder* that art can inspire in its observers as opposed to intellectual pursuits. It's during this era that artistic works of entertainment, in all its forms, was able to proliferate. Ultimately, the aims of Romantic work were to "produce absorption in the beholder" by "creating an alternative symbolic universe in which the subject may momentarily dwell," as can be seen in the Caspar David Friedrich's painting *Wanderer Above the Sea Frog* (Stromberg 634). This "absorption" is obviously another manifestation of the concept of deep play, illustrating the intrinsic connection between entertainment and the concept of deep play. Entertainment tries to induce states of play, which means creating successful works of entertainment is, in one sense, a product of how "deep" a level of play is achieved. In other words, the more entertaining something is, the deeper the play.

Figure 4. Caspar David Friedrich's *Wanderer Above the Sea Frog*, 1818

Stromberg spends much of his novel, *Caught in Play: How Entertainment Works on You*, discussing a phenomenon he calls *romantic realism*, which is defined by fictional, seemingly utopian realities where the world depicted is familiar to our day-to-day reality, yet is, at the same time different, possessing a contrived perfection "that are constructed in such a way as to accentuate what their creators take to be significant" (Stromberg 380). Romantic realism is very much an element of entertainment today and exists, quite glaringly, in numerous aspects of Western society, from Facebook profiles to advertising to political campaigns.

> "We observe a world which looks a lot like our own world but is somehow better. For example, we are familiar with the concept of friends gathering to eat at a restaurant, but a TV ad depicting such an event is likely to feature spectacular looking people eating spectacular looking food and having more fun than us mortals ever get to have" [5]

5

Our goals and desires are very much fueled by these culturally-constructed romantic realities we consume and desire for *ourselves*. All of these examples are evolutionary outgrowths that trace their roots back to the Romantic era. It is, arguably, the origin point for many of the social precepts governing the construction of our modern day realities. Virtual reality can be seen as a more immersive extension of romantic realism, as it allows for the actual integration of the user(s) in a fictional reality.

2.4 Mirror, Mirror in the Brain

Now that we have established an understanding of what entertainment is as a type of artistic expression, I would like to focus some attention on the effects of entertainment on those experiencing it. There are competing theories as to what happens when humans immerse themselves in a state of deep play. One of the theories that I find most compelling is called simulation theory. Simulation theory is predicated on a set of visuomotor neurons called mirror neurons. These neurons were first discovered in the premotor cortex of macaque monkeys. Researchers found that "these neurons respond both when a particular action is performed by the recorded monkey and when the same action, performed by another individual, is observed" (Gallese et al., 493). It is hypothesized that these neurons allow "all normal humans [to] develop the capacity to represent mental states in others" (Gallese et al., 495). Simulation theory posits that humans use these mechanisms to inhabit the mental states of other people. In other words, "we can tell what others are doing because in observing an agent carrying out an action our nervous system is activating some of the same pathways we would use in carrying out the action ourselves" (Stromberg 317).

Gallese et al. explain this through a hypothetical chess match. "To predict White's next move in a chess match, [simulation theory] suggests that you try to simulate White's thought processes and arrive at a decision which you then attribute to him. First you create in yourself *pretend* desires, preferences, and beliefs of the sort you take White to have. […] These pretend preferences and beliefs are fed into your own decision-making mechanism, which outputs a (pretend) decision. Instead of acting on that decision, it is taken 'off-line' and used to predict

White's decision" (Gallese et al., 499) Figure 5 acts as a visual representation of this process.

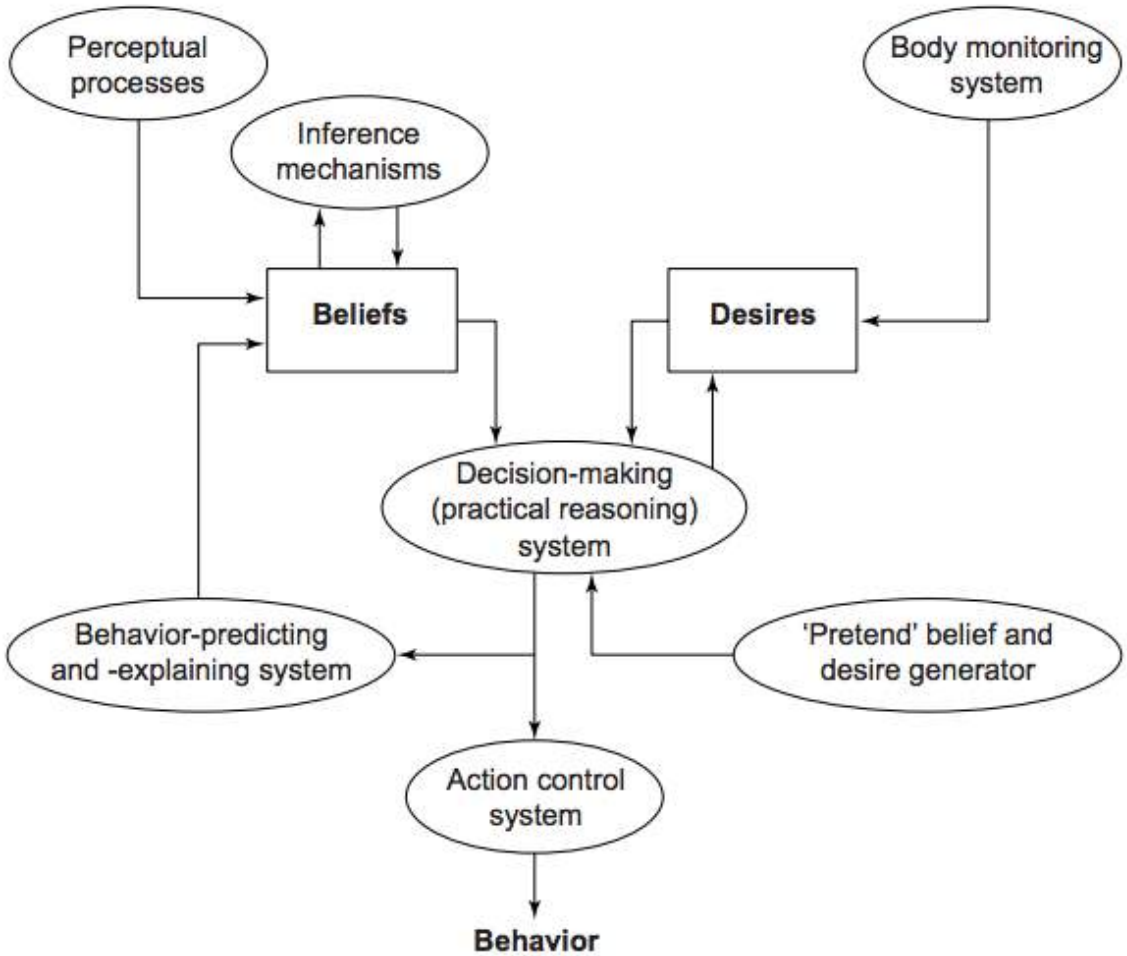

Figure 5. The Simulation Decision-making Process

Simulation theory is presented as a means to explain how "humans can be socialized into an enormously complex way of life that was not their own making" (Stromberg, 252). Our capacity to imagine ourselves as other people allows us to take the clearest markers of human culture, tools and language, and infer their purposes in order to utilize and refine them. This kind of imaginative projection is what allows for deep play. "When a child adopts a role, when a role player adopts a character, or when a fiction reader identifies with a protagonist, it is not difficult for the players to adopt the imaginary perspective and experience the world as does the fictional being" (Stromberg 284).

There is another aspect to deep play that simulation theory accounts for: absorption. Humans can significantly focus their attention toward a given subject, so much so that other concurrent, unrelated stimuli or perspectives cease to exist. Stromberg provides an excellent explanation of this through the lens of a spectator at a sporting event.

> "A feedback loop develops among attentional narrowing, entrainment, and emotional affects: as the experience becomes more emotionally compelling, attention is focused ever more closely on the situation one is becoming absorbed in, and as a result attention is diverted from the everyday world. If one is, say, a spectator at a sporting event, one may be galvanized, along with other spectators, by a dramatic game. As people become focused on this common interest, they may begin to imitate one another's shouts and movements, with the result that the crowd becomes even more cooperatively focused on the game. A common emotional mood may come to dominate, inflating the importance of the game, which thereby becomes an even more compelling situation in which to invest one's attention. In such a situation, the person can be powerfully pulled away from the day-to-day world and into a situation in which something external seems to be guiding the self. *Ultimately, this can manifest itself as a form of ecstasy, a self-transformative experience, a standing outside of the self*" (Stromberg, 461).

I have italicized the last sentence of this excerpt because it describes exactly what I am trying to achieve in my own work: the creation of transformative, immersive experiences. So, it is at this point that I would like to discuss the theoretical framework that guided the overall design of *Pollock* (graphically represented in Figure 6).

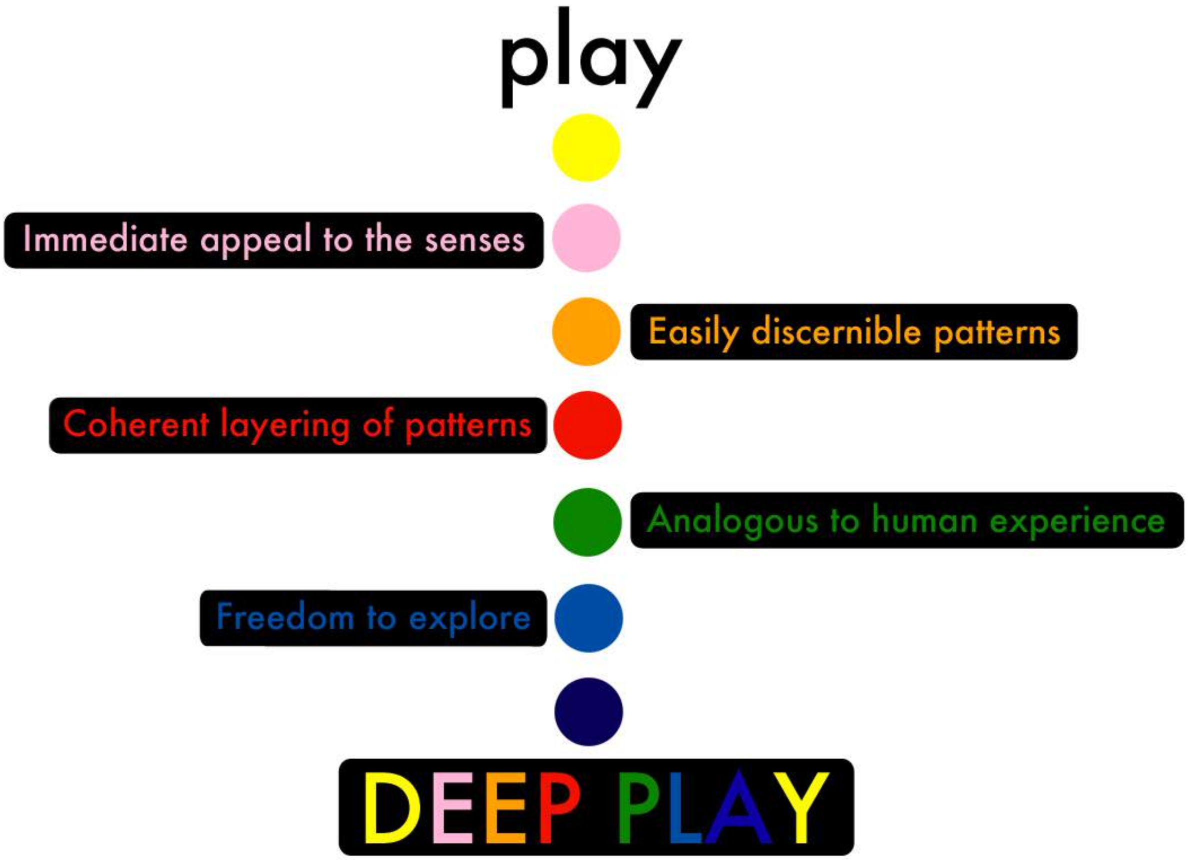

Figure 6. Deep Play Activation Model

What this graphic above represents is a design model developed through my research that establishes a logical roadmap for the transformation of a play environment through deep play activation. According to this model, there are five essential components to deep play experiences. They are:

Immediate Appeal to the Senses: The neural pathways devoted to visual processing greatly outweigh those used in processing other sensory modalities, as "nearly the entire caudal half of the cerebral cortex is dedicated to processing visual information."
[1]

[1] http://neuroscience.uth.tmc.edu/s2/chapter15.html 12/28/16

However, it is the multimodal integration of different sensory stimuli that manifests our reality, which is why it is so critical that any play environment has multiple streams of various sensory elements. These stimuli act as the entry point towards deep play. If a play experience delays, poorly develops, or completely neglects the activation of these senses, it creates a barrier to user entry.

Easily Discernible Patterns: Since our realities are a product of our brain's recognition of distinguished sensory patterns, the deep play experience is dependent upon the sequencing of patterned arrays of stimuli. Ideally, these patterns coalesce into a discernible, intuitive language that one's brain can quickly engage, laying the foundation for understanding and progression within the "play" reality. Without patterns, the human brain lacks the ability to ascertain meaning.

Coherent Layering of Patterns: In order for play to persist, the play experience has to offer different threads of multimodal stimulus. These "patterns of patterns" form new multisensory patterns by modifying the timing and arrangement of basic sensory elements, creating a sense of complexity that can elicit increased player engagement, further one's sense of immersion, and prolong interest. This step is so crucial because humans process their world multimodally, which means that much of the end user's experience is heavily defined by design choices made at this stage.

Analogous to Human Experience: As discussed in section 2.1, our respective realities are defined by our unique life histories, shaping our personal systems of pattern recognition that frame our present. Furthermore, we are constantly simulating the perceptions of people we interact with throughout our daily lives. Thus, in play environments, the ways in which one interacts with other play agents (whether they are other persons or tangible/intangible objects) has to be related to general modes of human behavior. Otherwise, intentional sensory patterns lose their significance, consequently affecting one's emotional response.

Freedom to Explore: There are various types of human freedoms, some defined by physical laws of nature, our respective cultural histories, and biological makeup. The scope of these freedoms is constantly in a state of flux as humans continue to advance technologically or become more self-aware of the universal human condition. The play environment inherently modifies these freedoms in order to establish the constructs of player experience. Deep play experiences are made possible through the establishment of clear boundaries that allow for varying degrees of player agency and expression, yet still provide a seemingly infinite amount of possible actions. This final guideline addresses the importance of developing a type of play that eliminates situational boredom, a kind of boredom defined by a lack of contrast and a feeling of constraint (Rogge 289). Boredom is the antithesis of deep play. A play environment that continually offers an infinite amount of new outcomes is essential for deep play.

Now that we have introduced a model for deep play activation, I'd like to shift the discussion towards the histories of the art/entertainment mediums that my work has been either influenced by or is defined as being in order to provide context and establish precedent for my own virtual reality project.

2.5 La Réalité Virtuelle

The creation of virtual reality, as a concept, cannot be accurately determined through the historical record. However, the term itself can be traced back to the French playwright Antonin Artaud, who, in his 1938 book entitled *The Theatre and its Double*, used the term "la réalité virtuelle" to describe his notion of theatre and how it should be understood. For decades, the term virtual reality was synonymously linked to technology and the hardware used to create it. However, in 1993, computer scientist Jonathan Steuer defined virtual reality through the notion of telepresence, which is "the sense of being in an environment […] by means of a communication medium" (Steuer, 7). So, virtual reality is "a real or simulated environment in which a perceiver experiences telepresence" (Steuer 8). This definition's breadth of scope allows for the inclusion of a multitude of works that do not necessarily adhere to the accepted practices of the current virtual reality community.

The actual practice of creating a sense of immersion through artistic means can be seen in the archaeological record as early as the 2nd century B.C. during the late Roman Republic in wall paintings "painted in the second style of Pompeii […] that include not only mimetic but illusionary elements" (Grau, 25). Through different visual techniques, a wall painting in this style make "the room appear larger that its actual size and draw the visitor's gaze into the painting, blurring distinctions between real space and image space […] this creates and illusion of being in the picture" (Grau, 25). One of the most famous of these is the Great Frieze in the Villa dei Mesteri at Pompeii (seen in Figure 7).

Figure 7. The Great Frieze in the Villa dei Misteri at Pompeii (60 B.C.)

One of the earliest examples of this kind of illusionary art in the occidental, post-antiquity world is the *Chambre du Cerf* (Chamber of the Stag). The Chamber du Cerf, located at the Palais des Papes in Avignon, France, was used as Pope Clement VI's study and living room. The room is completely painted with imagery, as the "the entire wall space is covered with a lush dark forest landscape with only a thin strip of azure blue sky above the treetops" (Grau, 33). The wall paintings completely surround the observer and almost occupy his/her entire field of vision. "Certain figures are even enhances by thee-dimensional modeling of hands and faces" (Grau, 34). Given the totality of its visual elements, the Chambre du Cerf "can be classified as a space of illusion because of the effect created by its 360-degree design, and most important, the fact that there are no framing elements, neither painted nor architectonic" (Grau, 33).

The Renaissance, amongst other groundbreaking cultural advances, brought about the development of linear perspective, the representation of an image as seen by the eye. Leonardo Da Vinci used the analogy that "a picture is a window that opens onto another, different reality" (Grau, 37). What perspective allowed for is a shift from art deriving its significance from symbolic representation to a more objective evaluation of the image itself. "Perception replaced the system of symbolic reference from which medieval painting derived its meaning. Without knowledge of the basic text of this art, the Bible, reception did not function. Perspective now provided this art with the additional option of objective representation, as it might appear to the eye and, like virtual reality today, it tended in the direction of deception or, rather, related to it a greater or lesser extent" (Grau, 37).

This change in perspective (pun intended) is very much tied to the introduction of 360-degree, panoramic murals attributed to Italian artists such as Baldassare Peruzzi. Peruzzi is considered to be the "first to succeed in bringing together individual walls of the views to form a spatial unity" (Grau, 39). Peruzzi's *Sala delle Prospettive* is a prime example of this kind of work (Figure 7).

Figure 8. Baldassare Peruzzi's *Sala delle Prospettive* (1516)

The Sala delle Prospettive fluidly combines real architectural features with painted ones, such that an attempt at demarcating where the boundaries between real and painted lie becomes challenging. An example of this can be seen in its marble floor, as the "pattern of the real marble floor continues, painted, in the illusion space […] ceilings, walls, and floor—the entire room is subject to the principle of illusion" (Grau 39). These "spaces of illusion" flourished during the 15th century, eventually finding their way up to the ceiling, as illustrated in Andrea Mantegna's

Oculus in the Camera degli Sposi, the first work of its kind. These ceiling paintings became a fixture of the Baroque era, a prime example being Andrea Pozzo's The Nave of Sant'Ignazio in Rome (Figure 9). These murals act both as progenitors and indicators of the oncoming acceleration of interest in immersive art seen in the following centuries.

Figure 9. The Nave of Sant'Ignazio (1694)

At around this same time (1655-1680), Dutch painters began to make perspective boxes. These were rectangular boxes lined with perspective paintings of either house or church interiors. A peephole at the end of the box allowed users to view the scene. The paintings themselves, viewed under unrestricted conditions, seem distorted, however, when looked through their respective box's peephole, the viewer's forced perspective transforms the painting into an impressive illusionary effect. What's significant about these devices is that they "stand at the beginning of a line of development […] where the illusionistic effect results from bringing the images up very close to the eyes of the observer" (Grau, 52). In essence, they mark the beginning of the production of simulated reality devices that continues on today with modern day head-mounted displays.

At the beginning of the 19^{th} century, panoramas became the first immersive art installations to gain immense popularity with the general public. First patented in 1787 by English painter Robert Barker, the panorama is a product of the application of linear perspective rules to a circular canvas, allowing artists to paint 360-degree views of any landscape. When these panoramic images were positioned in a proper cylindrical building and viewed from a central, elevated position, they appeared as undistorted, accurate representations of their original source material. A viewer would see the painted landscape encircling around them in the same manner as its corresponding real landscape, with no viewing angle ever providing a discontinuity with the overall scene. William Uricchio, a comparative media studies scholar at MIT, writes that "re-reading Barker's [patent] from a contemporary perspective, we might today say that he was about as close as anyone in the late 18^{th} century could get to describing virtual reality and the goal of creating a state of immersion for the viewer" (Uricchio, 1).

As its form took shape, panoramas began to incorporate other sensory stimuli into their presentation. "The other senses were addressed through the haptic element of *faux terrain*, sound effects, artificial wind, and smoke […] to increase, or at least maintain, illusion by moving towards forms that addressed all the senses" (Grau 70). The first panoramic rotunda was designed and built by Robert Barker, opening in 1793 at Leicester Square, London and their popularity lasted for the remainder of the 19^{th} century.

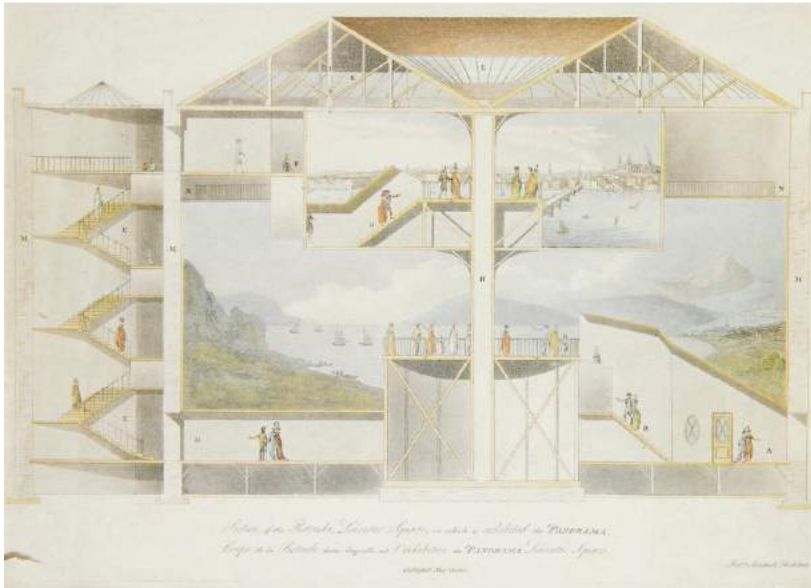

Figure 10. Cross-section of Robert Barker's panorama rotunda at Leicester Square

In 1830, Sir Charles Wheatstone invented the stereoscope (Figure 12), the first man-made device to produce three-dimensional images. The knowledge that human depth perception was a product of our eyes slightly different viewing angles of the world has been hypothesized since Grecian times, but Wheatstone's invention was the first to actually prove this theory. It was composed of two mirrors angled at 45-degrees with each being centered over one eye. By reflecting two slightly different perspectives of the same image to each eye, the reflected image was perceived as a three-dimensional object. The public did not see Wheatstone's stereoscope and other scientific findings until 1838. Around this time, William Fox Talbot had made great advances in the burgeoning field of photography by discovering that real life images could be captured on silver-chloride paper. The daguerreotype, a kind of photograph captured on silver-plated copper, was another photographic process that came into prominence during this era and was eventually the first photographic medium used for stereoscopic photography, a kind of photography that captures two slightly varying angles of the same image. When viewed with a stereoscope, the two photographed images merge to form a three-dimensional image. These experiments in stereoscopy were crucial in the development of immersive, three-dimensional vision systems.

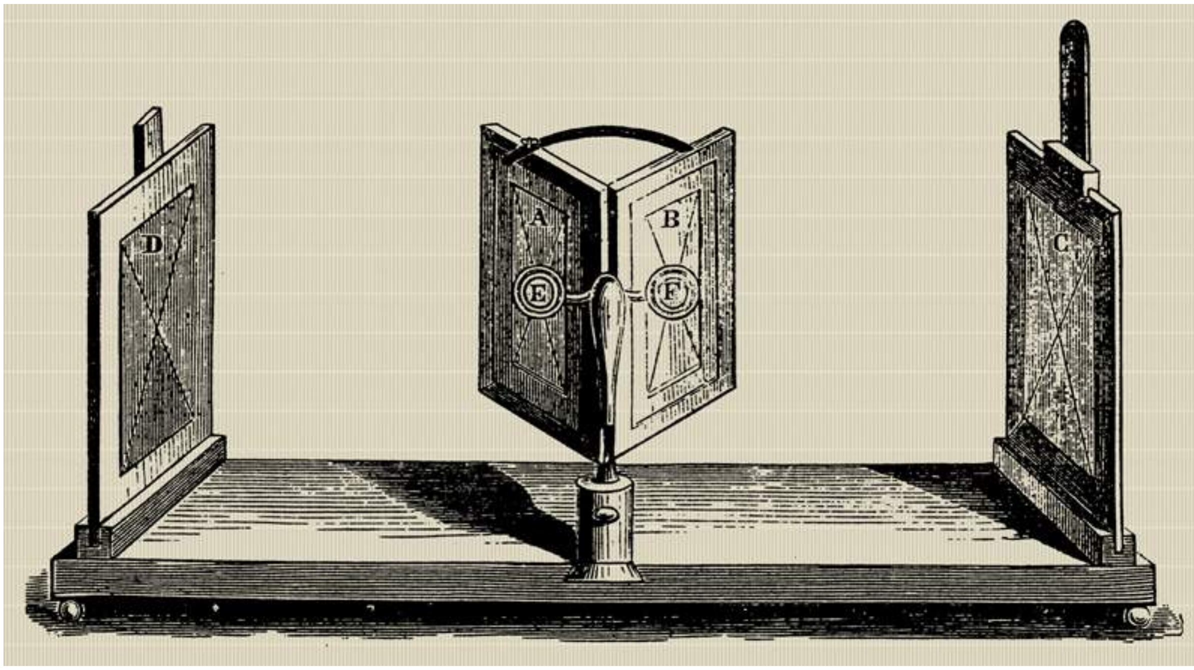

Figure 11. Illustration of Wheatstone's stereoscope

What followed after Wheatstone's discovery is a sort of "arms race" in stereoscopic vision. Many researchers and inventor contributed to perfecting this new art form, making it affordable for a wide audience. Around 1870, manufacturers were building stereoscopic viewing cabinets that displayed a sequence of three-dimensional images with each image corresponding to the progression of an over-arching narrative. As one can infer, the mechanisms for the invention of cinematic film or "moving pictures" were, at this point in time, developing exponentially.

2.6 A.V. Assurgency

With the dawn of the 18^{th} century came new developments in the realm of audiovisual art that fostered new types of simulated experience via other sensory means. One of the first audiovisual works to successfully bridge auditory and visual modalities is Louis Bertrand Castel's optical harpsichord. Castel, a French Jesuit priest, invented this "color organ" in 1735 as a means to explore the vibrational relationships between sound and light. He envisioned that this musical instrument would pave the way for "a whole new form of art […] a music of colours" (Franssen, 19). The optical harpsichord "adopted Newton's correspondence between spectrum colors and the musical scale" and "would illuminate the 144 different colored papers as the keyboard was operated" (Conrad, 1). Other color organs were made over the next couple centuries, most notably Thomas Wilfred's *Clavilux*, which produced geometric shapes that were rear-projected onto a screen. The performer's selection of different notes would affect the light intensity and fluctuations of a system of prisms behind the projection screen, thus affecting the overall visual display. This real-time manipulation of projected visual elements through user input as well as the syncing of these same manipulations to auditory phenomena can be seen as precursors to some of the core mechanics of video games and virtual reality.

Figure 12. Castel's ocular harpsichord by Charles Germain de Saint Aubin

The discovery of electricity and the birth of electronics in the twentieth century brought forth seemingly unimaginable technological innovations. Film had superseded panoramas in popularity, becoming the "new mass media for images" (Grau, 147). Accounts of the first public showings of film "read like a blend of legends, anecdotes, and sensational journalism" (Grau, 151). Case in point, the initial audiences of French film *L'arrivée d'un train en gare de La Ciotat*

(1897), a fifty-second film depicting a train arriving and leaving a train station, purportedly "reacted to the approaching train […] with screams of panic, by running away, and, according to many contemporary sources, by fainting" (Grau, 151). The *Teleview* was the first 3D film projection system in the United States. Introduced in 1921, the programming for teleview-equipped theatres included several short films, a live projection of shadow imagery, and the feature film M.A.R.S. Finally, in 1926, the Vitaphone sound system was patented by Warner Bros., allowing for synchronous, automated playback of both film and sound, a major milestone in the evolution of audiovisual art.

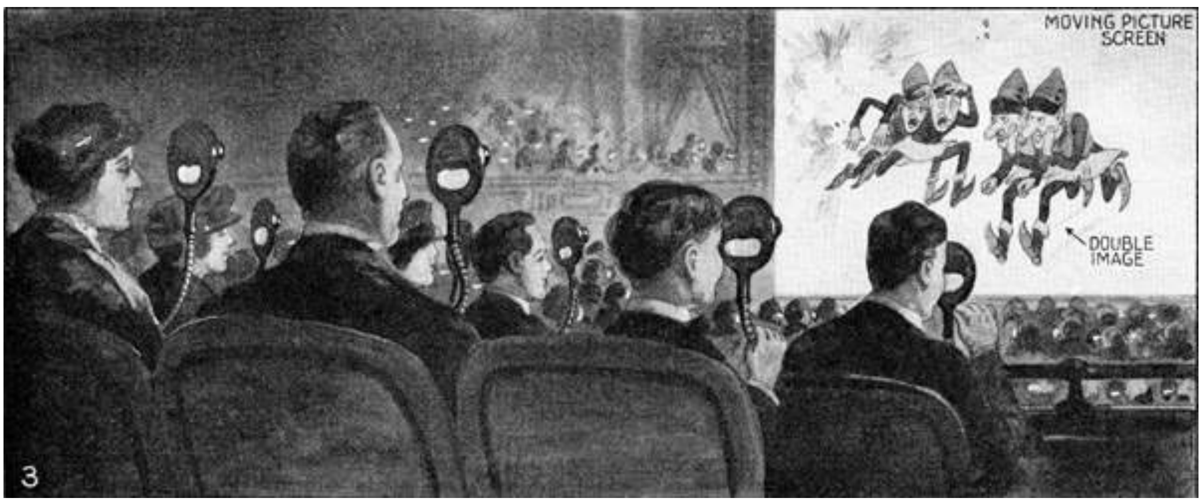

Figure 13. Advertisement of Teleview System (1922)

After the end of WWII, another audiovisual art form took shape, merging the moving two-dimensional imagery popularized by film with autonomous user interactivity. This medium, now referred to as video games, acts as a sort of transitional audiovisual species between film and virtual reality. The *Cathode Ray Tube Amusement Device* is considered by many to be the world's first playable video game, though the accuracy of this claim is still debated, since its graphics/game logic did not involve any computers of any kind. Invented in 1947, the entire game was built upon a World War II radar system that used a cathode ray tube, an oscillator, and control knobs to allow the user the ability to redirect light rays ("missiles" in the context of the game) on the screen to hit specified targets (Rabin 4).

Other historians cite 1962's *Spacewar!* as the first, true video game. Building the game on DEC's

PDP-1 microcomputer, *Spacewar!* is a two-player video game in which player's attempt to destroy each other's spaceship (Rabin 5). To increase the game's difficulty, a large star at the center of the space field constantly exerts a gravitational force on each spaceship. If a spaceship is pulled into the star for too long, the spaceship explodes. A hyper speed option allows player to jump to a random portion of the screen as an evasive maneuver. However, if the player uses this function to often, their spaceship will explode. Unfortunately, this virtual explosion could not be heard, as sound did not become a feature of video games until the release of the arcade game *Computer Space* in 1971—itself an updated version of *Space War* (Collins 8).

Figure 14. *Spacewar!* battle

In the same year, a sector of the audiovisual medium began to evolve into something else entirely—virtual simulation, Mortan Heilig's Sensorama Simulator became one of the first virtual simulation devices to incorporate three-dimensional imagery. "In addition to 3D CinemaScope images and stereophonic sound, the audience in the Sensorama were subjected to vibrations and smells simulated by chemicals" to simulate a 10-minute long motorcycle ride through New York City (Grau 158). These machines (seen in Figure 14) were featured primarily at amusement parks in California throughout the rest of the 1960's.

Soon after, in 1968, the first virtually reality head mounted display system, called the *Sword of*

Damocles by its inventor Ivan Sutherland, was created at MIT's Lincoln Laboratory. The graphics were simple wireframe rooms generated by a computer. The head-mount display was very large and heavy. As a result, it had to be suspended from the ceiling. A user's head movement was tracked, which allowed visual imagery to be adjusted in real-time given the user's viewpoint, a true first in the field of virtual reality. Some maintain that this system was also the first use of augmented reality, as there was a translucent element to the headset, which allowed the visual within the headset to be overlaid on top of the existing space in the laboratory.

Figure 15. Sensorama Simulator

Nolan Bushnell and Ted Dabney founded Atari (the company behind the 2600) in 1972. The company, from its outset, was determined to make games like *Spacewar!*, whose entire operating system cost around $40,000, more affordable. Because of their ingenuity in hardware design, they were eventually able to achieve this goal (Kent 66-80). Atari soon became one of the emerging powers in the burgeoning Silicon Valley tech industry. Bushnell founded Atari's research and development group in 1974. It's at this think tank that computer scientists Thomas

Zimmerman and Jaron Lanier met. This duo would eventually form the firm VPL Research, a company who made a large impact on the advancement of virtual reality throughout the 1980's (Heffernan 1). It's at this point that the developmental histories of virtual reality and video games become intertwined.

At VPL, Zimmerman and Lanier refined the data glove, a wearable piece of technology invented by Zimmerman in 1981. The glove, now one of the most common features of the majority of virtual reality experiences, was "a highly specialized sensor, which registers and transmits the position of the fingers, thus enabling movement and navigation in a virtual space," allowing the user the ability to interact with the computer-generated environment (Grau, 167). VPL became the first company to develop virtual reality and the data glove for commercial applications.

Meanwhile, after a successful run during the late 1970's, Atari's fortunes drastically changed during the early 1980's, culminating with crash of the video game market in 1983. Ultimately, the market had become saturated with video games from Atari and other competitors. More importantly, these games were of low quality, as developers were prematurely rushing games out to market. As a result, demand plummeted and video games were, for a brief time, seen as a passing fad (Kent 182). Due to executive level mismanagement, Atari never fully regained its market share, especially as a result of the arrival of a brand new console released by Nintendo in the fall of 1985 in North America (Kent 183).

The 1980's brought about a surge in virtual reality driven projects, due in part to the increased affordability of high-performance computers as well as the eventual rebirth of the video game market during the same decade. Companies like aforementioned VPL, Autodesk, and Sense8 rapidly formed, in the hopes of creating the digital, three-dimensional spaces of the future. The English use of the term "virtual reality," coined by Jaron Lanier in 1989, caught the public's interest, finally giving a name to the efforts and research of those in this emerging technological field. The manufacture of even higher-performance computers in the 1990's, like the Silicon Graphics workstation, made it "possible to depict naturalistic three-dimensional bodies with up to 500,000 polygons [as well as perform] real-time operations," allowing for more complex user interactions within the virtual environment (Grau, 174). Research institutions devoted solely to virtual reality development were soon founded, like Carnegie Mellon's University's SIMLAB, who created projects like 1996's *Virtual Ancient Egypt*, where multiple users could move and interact within a simulated ancient temple.

Figure 16. The Power Glove

This surge of interest in virtual reality also had an effect on the video game industry, as consumer products developed for home consoles began to experiment with virtual reality technologies. The first of these experiments was the Power Glove, a peripheral, data glove accessory meant for use with the Nintendo Entertainment System. Born out of Zimmerman and Lanier's initial failed attempts of making a glove for the console, the Power Glove was released in 1989 by Mattel as a replacement controller device for select video games. The Power Glove was equipped with an ultrasonic speaker that emitted short bursts of a 40 kHz tone that was then received by a receiver unit that would then triangulate the position of the glove based off of the spectral and magnitude qualities of the waveform. Bend sensors installed in the fingers could roughly track whether certain fingers were bent or not. These sensors formed a digital sign language that allowed users to interact with the virtual environment they were seeing on the television screen. Due its imprecise controls and overall difficulty in use, the power glove failed to attract much of an audience. However, it has garnered a postmortem legacy, one that has inspired others, including myself, to revisit its potential application.

Though various teams had developed stereoscopic head-mounted displays throughout the second half of the 20th century, it wasn't until the release of Nintendo's *Virtual Boy* in 1995 that a product of this kind was made available to the public at large. Nintendo developed the Virtual Boy as a means to allow users the ability to play video games with simulated stereoscopic depth. Released in 1995, the Virtual Boy was a huge financial failure for the company. The *Virtual Boy* proved to be very unpopular with the public, as all the visuals generated by the headset were red and the unit itself, being fixed atop a stationary stand, forced the user to experience the gameplay from one static perspective. These failures in integrating virtual reality into consumer markets stymied the development of these technologies within the video game industry for nearly two decades.

Figure 17. Nintendo's Virtual Boy

It wasn't until 2012, with the release of the Oculus Rift head-mounted display (Figure 1), did virtual reality, once again, became feasible for a widespread, public audience[7]. Given the advances in display types, computer graphics, and motion sensing as well as the overall affordability of all the requisite hardware, the Oculus Rift has seemingly kick-started a new virtual reality movement. Many tech and video game companies like Sony and Valve are now

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[7] http://www.nytimes.com/2014/11/16/magazine/virtual-reality-fails-its-way-to-success.html 12/30/15

developing their own head-mount displays for eventual consumer release Artists, designers, and technologists like myself are now on the digital edge of this new frontier, and, hopefully our efforts will help further the case for virtual exploration in the 21st century.

2.7 Takeaways from the Past…

From this historical perspective, one can hopefully see that the progression from Roman frescoes to virtual reality is defined by advances in the recreation and pairing of sensory modalities with one another. This assertion may seem obvious, however much of the efforts in regard to virtual reality have been consumed, up until recently, with the development of three-dimensional visuals. Moreover, rarely do virtual reality projects try to appeal to all five of the human senses, especially in considered, synesthetic relationships. In contrast, *Pollock* was a first attempt at creating a more detailed, multimodal experience that equally leveraged all possible sensory modalities through systematic patterning (as outlined in the "Deep Play" model) of sensory stimuli. The next chapter goes in to further detail about the design principles that shaped *Pollock*'s development.

Chapter 3

Design

In this chapter, I start by providing so much needed context as to what my thesis project actually is. I then move forward by recounting how my first technical/creative design efforts were informed by my research, efforts which led me to adopt a synesthetic design approach. The subsections therein after explain how the synesthetic design process informed how my thesis project adhered to the various stages of the deep play model.

3.1 In the Beginning…

Pollock was conceived during a seemingly inconsequential conversation between my roommates and I during my first year of graduate study. I had been watching videos of Jackson Pollock painting earlier in the day and was captivated by the visceral power of his strokes. His art-making process felt so *active* and *alive*. I shared with them what I had watched and we started to talk about the idea of having a "Pollock-like" art experience without actually having to do it (in the sense that you could paint in this way without having to use real paint)? Furthermore, what if one's painting could be tied to some kind generative composition, a sort of sonic extension of one's artistic creation. The discussion veered towards how one would develop this idea virtually, which serendipitously became the catalyst for my thesis work over the past two years.

This lightning rod of inspiration came at the most opportune time. I started to explore different virtual mediums, as I originally had no thoughts towards developing a virtual reality-based experience. Virtual reality as a concept seemed a bit too impractical and, more importantly, expensive. Nonetheless, a fleeting whim led to some research into the state of virtual reality in our present day. Fortunately, this research coincided with the debut of the Oculus Rift on

Kickstarter[8] , the popular crowd-funding website. After looking in to this new piece of hardware, it soon became clear that this technology could very well reignite a sorely undeveloped medium. I immediately purchased one, deciding that I would base my virtual experience around it.

It then became imperative that I quickly figure out the scope of the project. Creatively, I had to figure out what this experience was going to be. What I eventually settled on was that the user would assume the role of Pollock (see Figure 29), a paint-blasting robot whose painting creates a corresponding sonic/tactile composition. Users would move around this black-and-white world charging and releasing paint blasts from Pollock's arm blaster. The sonic textures generated by these blasts of paint would be synesthetically related to its color and spatialized by its end position so that the overall amplitude and positioning of these textures would change dynamically in relation to Pollock's position. This audio would be sent to both the user's headphones and haptic vest, so that this unique, user-generated composition was both heard as well as *felt*.

My prior technical experience had never involved anything video game-related. The Oculus Rift offers support for integration with the Unity game engine, so I chose to develop my project, at this point called *Pollock*, within this game development environment. Adam Watkins' book *Creating Games with Unity and Maya: How to Develop Fun and Marketable 3D Games* was instrumental in familiarizing me with the standard game development workflow as well as teaching me how to use Autodesk Maya[9] and Unity[10] to facilitate this process.

Maya is a 3D animation and modeling software used in a wide variety of applications. All of the visual assets developed for *Pollock* were created in Maya. Maya allows three-dimensional objects (like a character) to be "rigged" in order to replicate complex motions, an essential step in animating process. Once these assets were complete, they were imported into Unity. In Unity, scripts (chunks of code) were applied to these assets so certain actions or events were triggered based on user input.

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[8] https://www.kickstarter.com/projects/1523379957/oculus-rift-step-into-the-game 9/02/13
[9] http://www.autodesk.com/products/maya/overview-dts?s_tnt=69290:1:0 9/14/15
[10] https://unity3d.com/unity 9/14/15

Based off of my historical research and my development of the deep play model, I soon found myself heavily researching the science of human sensing with an emphasis on our perceptions of beauty. From my perspective, it was important that users received Pollock's sensory language and the resulting virtual world constructed from it favorably, so much of the patterning in design was based around this pursuit of beauty (however, subjective the concept of beauty may be).

I first discovered that our discernment of beauty is a very quick process. We are primed to rapidly discern the perceivable characteristics of an environment. That remains true even for more subjective elements, as "it takes less than a second to distinguish an images beauty" (Chaternee 139). The process of experiencing beauty has been attributable to activation in the "orbitofrontal cortex, the anterior insula, the anterior cingulated, and the ventral medial prefrontal cortex" (Chaternee 139). But, it is important to note that these processes evolved within the human species as a *byproduct* of the hostile conditions of the Pleistocene era, a time period that began about 1.8 million years ago and lasted until 11,700 years *ago*. Therefore, the human brain's propensity for art is "cobbled together from bits and pieces of the brain that are used to do other things" (Chaternee, 139).

What this means is that, though the process of art can be abstracted or intellectualized, our perception of it is fast and reliant upon base inputs from multiple sensory modalities. This notion extends to reality. In fact, it not only extends to reality—it *is* reality. "We are, by virtue of perception, constantly confronted with perceptual objects as models of the reality, but not directly with the physical objects behind them" (Haverkamp, 118). Moreover, it's the combination of these inputs that generates our perceptions. "Perceiving and imaging an object in a conscious states is the basis of human cognitive activity […] this never occurs with the participation of only one modality" (Haverkamp, 55). These layers of sensory information form the language of reality. Thus, in order to make effective works of art, especially ones that try to imitate life, one has to be deft at sculpting sensory perception.

So, I turned to Michael Haverkamp's *Synesthetic Design: Handbook for a Multi-Sensory Approach* for guidance in understanding the art of sensory-based design. *Synesthetic design* is the "conscious design of objects with respect to connections between the modalities […] that results in a pleasant, harmonious overall appearance while coinciding with the particular functions desired"

(Haverkamp, 14). *Pollock* became immensely influenced by this design approach. Every sensory asset created for this virtual environment was constructed from an overarching theme of synesthetics, making *Pollock* as much an exploration of synesthetic design as it is virtual reality. By choosing to design my thesis project in this manner, I also firmly established and reinforced a patterning system, something that is essential to the framework of the Deep Play model. The next subsections further highlight how the design process was foundational built on top of this model.

3.2 Immediate Appeal to the Senses

Though the visual perception of three-dimensionality is fundamental to virtual reality in order to truly make someone feel as though they have been transported to another, distinct reality, the other, non-visual senses have to also be stimulated in a similarly convincing way as was discussed in the latter half of Chapter 2. By designing through the senses, one is constructing from the building blocks of perception, creating an entryway to transmit information in an accessible, instinctive manner. The synesthetic design process' is concerned with "maintaining a delicate balance of the signals going to the senses, so that only the essential information is processed at any given moment" (Haverkamp 51). So, from the standpoint of synesthetics, one has to not only appeal to the senses, but ultimately find a combination of modalities that effectively transmit the overarching goal of the design. In order to achieve this, one must "ascertain which sensory stimuli and perceptual characteristics best transmit information and which perceptions should be avoided" (Haverkamp 37).

In the case of *Pollock*, I did extensive research in sensory-activating technologies. Given their impracticality, those pertaining to the sense of taste and smell were unfortunately excluded (it is my hope that technical advances in the future allow for these kinds of features). First, in the case of visuals, the Oculus Rift head-mount display was used to provide complete, 360-degree visuals with three-dimensional depth. Head tracking is made possible via an inertial measurement unit and an infrared camera.

In terms of sound, many different kinds of spatial audio techniques were researched in order to find the best practical way to immerse users in a rich sonic environment. Stereophonic sound, the most ubiquitous form of sound reproduction, lacks the dimensionality offered by other sound reproduction techniques. Initially, the *Pollock* user experience was intended to be completely unbounded, in the sense that the user would be able to explore the virtual environment by moving around a real, physical space. Given this initial design, wavefield synthesis and ambisonics were considered. Wavefield synthesis is a "spatial sound field reproduction technique that utilizes a high number of loudspeakers to create a virtual auditory scene over a large listening area" (Spors et al. 1). Due to cost and lack of space, this technique was deemed infeasible given these constraints. Ambisonics was, for a time, considered the optimal choice for *Pollock's* spatial audio system. Ambisonics utilizes circular or spherical loudspeaker arrangements to spatialize sound sources (Kronlachner 1). One can record audio with an ambisonic microphone, allowing for the capture of a sonic event from a 360-degree perspective. Ambisonics requires less speakers than wavefield synthesis and can work within custom speaker configurations. However, the venue for the final version of *Pollock* would, amongst other things, not be able to properly accommodate non-headphone based audio reproduction systems, so ambisonics was also eventually dropped as a possibility.

In terms of headphone-based spatial audio techniques, binaural audio is the only real option, Binaural audio aims to recreate the spatiality of an audio event by relying on the location/depth cues that humans rely on to distinguish the source of sonic material. Like ambisonics, one can record audio with a binaural microphone. A binaural microphone attempts to recreate the human experience of hearing by embedding two microphones within the ears of a full-sized "dummy" head. The inevitable issues with binaural microphones is due to the fact that humans have different-shaped heads and ears, which means every individual has a unique neural processing network that establishes the location of sound-generating objects. So, even though a binaural recording may appear to have impressive spatial aspects to most users, the actual imaging will most likely be inconsistent with the actual audio event it is attempting to recreate.

Since *Pollock* was developed in the Unity game engine, I was able to leverage its impressive audio playback engine, allowing for real-time panning of audio in relation to the position of characters within a game environment. Furthermore, a third-party company, Two Big Ears, has released a third-party plug-in built for the Unity game environment called 3Dception[11] that "extends

[11] http://twobigears.com 4/11/15

Unity's audio functionality to include full 3D positional audio and environmental modeling" . In short, 3Dception provides for real-time binaural audio playback, allowing for the simulation of the position and elevation of sound sources. 3Dception also models the reverberations of real spaces given a specified size and material composition. So, after all this research, I chose to use Unity 3D's built-in audio engine with 3Dception's extended functionality. Bose noise-cancelling headphones were chosen to provide for even more auditory isolation while within the virtual environment.

Touch is another obvious sensory modality that shapes our perceptions and interactions. The ability to touch an object or pick it up and use it for a self-designated purpose is essential for a species like ours whose evolutionary history has been shaped so much by tool-making and environmental manipulation. Touch "informs us about object properties, such as texture, softness and viscosity, and provides dynamic feedback on our interactions with physical environments around us" (Israr et al. 2). I soon began to research all as much as I could on all of the current haptic technologies.

Simulating touch is very difficult. The human epidermis is a very complex organ. The actual physiological mechanisms of touch are a product of "mechanoreceptors embedded at various depths in the skin, some of which are sensitive to deformation ('slow adapting receptors' for static touch) and others sensitive to vibrations arising from movement ('fast adapting receptors' for dynamic touch)" (Skedung et al). Differences in static stimuli can be detected down to 0.2 mm and as little as 10 microns for dynamic stimuli, which illustrates how discerning are skin truly is. Dynamically simulating different materials and textures has yet to be completely realized as "current tactile technologies can produce only a small fraction of the infinite variety of tactile sensations" (Israr et al. 2). Progress is being made with such novel applications like vibro-tactile actuator arrays, which simulate haptic movements across a two-dimensional plane.

Tactile transducers are electromechanical devices that work in the same way speakers do, vibrating any medium it's attached to when supplied with an alternating voltage. These transducers allow for the simulation of certain types of touch, as there are various sensory cells embedded in the skin that […] are sensitive to frequencies "within the range of 50 to 200 Hz [while] frequencies up to 1000 Hz may be perceived during exposure of vibration upon hands and arms" (Haverkamp 82). Because of their practicality, I made the decision to somehow use these kinds of transducers, as were the best possible way to infuse haptics into the *Pollock* in-game experience. Initially, the most obvious use case for them was within the game controller users would wear to interact with the virtual world. But, the exact design of this controller had yet to be determined.

These thoughts led to a more focused effort towards determine the nature of the user's controls. Because of my want to replicate the visceral nature of Jackson Pollock's artistic process, I felt that some kind of gesture-based controls were important in shaping the overall experience. What that meant is that user movement/gesture tracking would now be a requirement. Inertial measurement units are electronic devices that can determine the acceleration and orientation of any object or surface they are attached to. They are comprised of a combination of accelerometers, gyroscopes, and sometimes magnetometers. Certain tracking systems are reliant on these inertial measurement units to track the orientation of limbs and joints in space. Others rely on ultrasound, like the aforementioned Nintendo Power Glove.

Tracking individual finger movement is much more difficult a process, which is why data gloves are so commonly used in virtual environments. A modern data glove of particular note is a product Imogen Heap's continually evolving data glove project[12]. In 2010, Imogen Heap brought together an eclectic group of designers and engineers to develop a data glove for live musical performance. Their current glove features an inertial measurement unit that transmits data over WiFi via OSC messages. It also has bend sensors for finger tracking, buttons for mode switching, haptic feedback, and LED's for visual feedback. Her glove project became an incredible resource for my work and provided me with an abundance of invaluable information for the development of my own data glove.

Optical motion capture systems use retroflective materials or light emitting diodes placed around a full body suit. Specialized cameras capture where these sources of light are in space. Computer algorithms triangulate where these individual light sources are in three-dimensional space to create a complete skeletal mapping of the user wearing the suit. Other methods exist that require much less equipment, making it so that users have to wear nothing at all in order to be tracked.

[12] http://www.imogenheap.co.uk/thegloves/ 3/16/14

The Microsoft Kinect is a sophisticated infrared camera/sensor that is able to track multiple users without the use of on-body tracking sensors, making user movement much less restrictive and obtrusive. The Kinect emits an infrared point cloud composed of thousands of small infrared dots. A sensor inside the Kinect figures out how human bodies in front of the camera distort the position of these infrared dots, making them seem closer or farther away given their position. The latest development version of the Oculus Rift utilizes infrared light emitting diodes installed on the front of the head mount display in conjunction with an infrared camera/sensor as well as an inertial measurement unit to track user head movement.

With these technologies in mind, I developed my initial hybrid approach to user-specific tracking and touch-sensing. My first attempt was based around retrofitting the original Nintendo Power Glove with modern sensing capabilities, taking many cues from Imogen Heap's glove project. Before choosing bend sensors for this glove, I spent a lot of time researching bend sensor technology. Most bend sensors on the market get data by measuring changes in resistance created by the deformation caused when the sensor is bent. The prevailing notion was that the data from these sensors did not offer replicable, reliable data over long periods of time. I discovered a new kind of bend sensor being applied to the field of biomedical science for the accurate recording of muscle movement. These sensors use dielectric elastomers that can stretch and deform, producing variations in capacitance. Manufactured by the New Zealand's StretchSense[13], I was able to secure four of these sensors for my glove.

[13] http://stretchsense.com/ 3/16/14

Figure 18. The First Data Glove Prototype

Though this first attempt at a data glove served fruitful for other applications, it became clear that it was too restrictive for use in my thesis project. I went back to the drawing board and came up with a completely original design.

Figure 19. Second Controller Prototype

Figure 15 shows images of this new controller prototype. By reassessing the needs of the project, I practically eliminated most of the glove aspects of the controller. I realized that the only user actions I needed to monitor was whether the hands were open or closed, so I designed a mechanism that wraps around the user's hand and sits comfortably in the palm. It then detects these two possible states through a touch capacitive sensor. To simulate Pollock's charging and releasing of paint blasts, tactile transducers were added to a mechanism that sits on top of the user's forearm. This controller was able to transmit data as well as receive audio wirelessly via Bluetooth. An additional wireless controller was added to the user control system to allow for movement within the virtual environment as well as the ability to switch between paint colors. This controller is held in the opposite hand of the "paint blast" controller and features an analog stick and two trigger buttons.

Other haptic elements utilized were the KOR-FX Gaming Vest[14] and a Guitammer Buttkicker[15] were both utilized. The KOR-FX Gaming Vest is outfitted with two tactile transducers that vibrate the user's chest. The Buttkicker can reproduce infrasonic sound and is typically installed underneath seats. Both these devices were used to simulate Pollock's movement within the space, provide sonic low-frequency feedback of the user generated composition, and enhance the visual effects of user actions.

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[14] http://korfx.com/

[15] http://www.thebuttkicker.com/

Figure 20. Guitammer Buttkicker and KOR-FX Gaming Vest

By definitively establishing the sensory palette of a play experience, one can firmly set the sensory patterns from which the other stages of the deep play model are defined by.

3.3 Easily Discernible Patterns

As discussed in earlier sections "the mind evolved to continually redefine normality, to find—indeed to create—the relationships in the sensory image that matter, and to imbue those relationships with value, which we then see" [16]. What this means is that our senses are constantly receiving complex, sensory patterns that we interpret through our genetic and cultural histories. The ways in which we interpret these patterns have proven to be evolutionarily advantageous to the survival of our species. All of human perception is built upon this "extraction of patterns" (Haverkamp 132).

From the standpoint of human visual processing, phosphenes act as the smallest units of information that our brains see. When light hits our retina, these phosphenes are generated and arranged in certain patterns, called endogenous image patterns. Haverkamp notes that the "perception of endogenous image patterns evidently provides information pertaining to the basic forms of perception implemented into the visual system, which are required to construct complex visual pictures but which generally do not enter into the consciousness as forms themselves. Knowledge as to these building blocks is thus valuable in choosing the appropriate,

[16] http://www.lottolab.org/programmes-article_humanperception.asp

elementary forms of design" (Haverkamp 378).

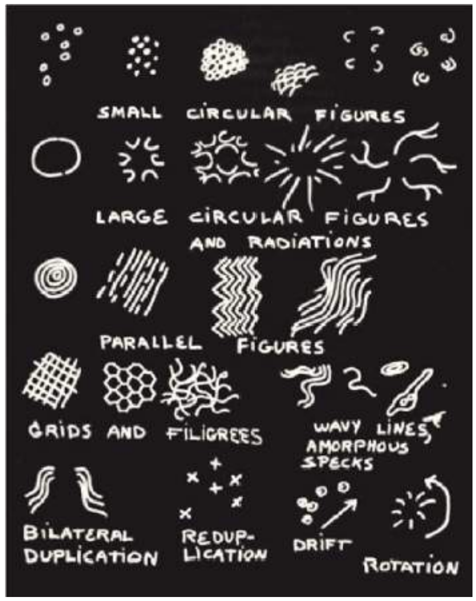


Figure 21. Varieties of Endogenous Image Patterns

Our appreciation of art is, as mentioned in the previous section, reliant upon how quickly we can receive and process it. "Aesthetic appreciation is partly grounded in the viewer's information processing and that cognitive fluency is an intrinsic source of the hedonic value of art" (Leder et al. 63). It's these facts that have informed the visual style of how paint and other objects are represented within *Pollock*. For example, instead of trying to represent paint as realistically as possible, I chose to model its form after small circular endogenous image patterns as a means to provide for a more easily processed visual stimulus. Figure 18. Illustrates what paint blast splatters look like within the game environment.

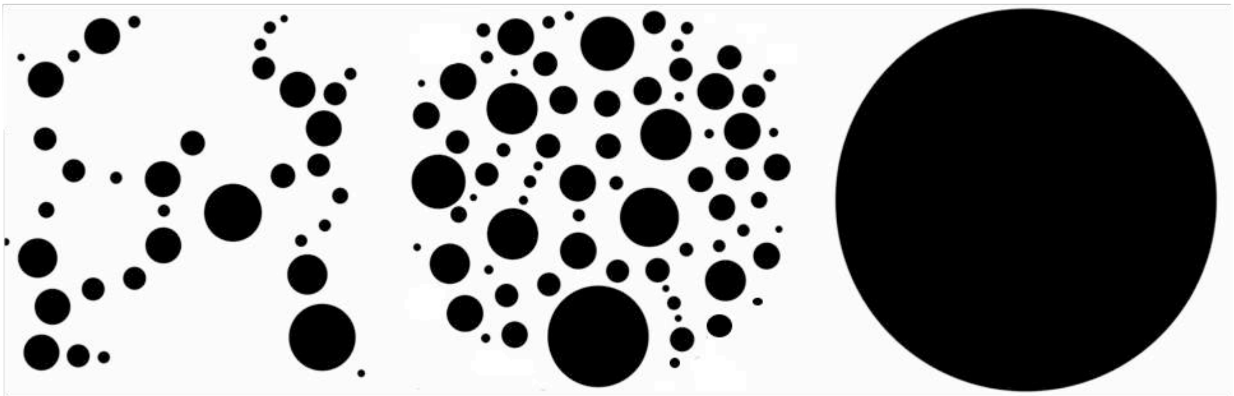


Figure 22. ***Pollock*** **Paint Splatters**

It has been posited that geometrical primitives called geons are the elementary shapes recognized by the brain (Leder et al. 55). In another attempt to create a more aesthetically fluent environment for the user's visual processing system, the entirety of the Pollock environment is inspired by these simple shapes, with similar shapes grouped into clusters, forming a cohesive layering of geon-based patterns all across the virtual environment.

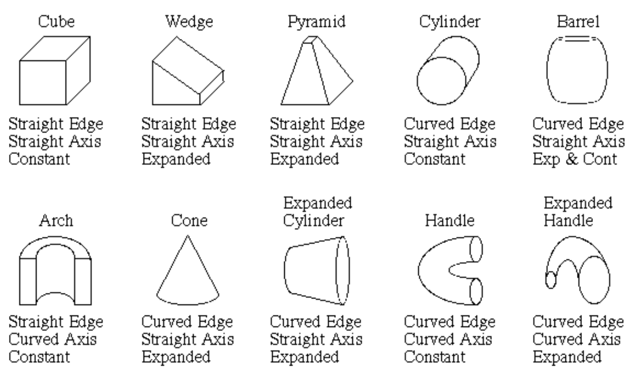


Figure 23. Examples of Geons

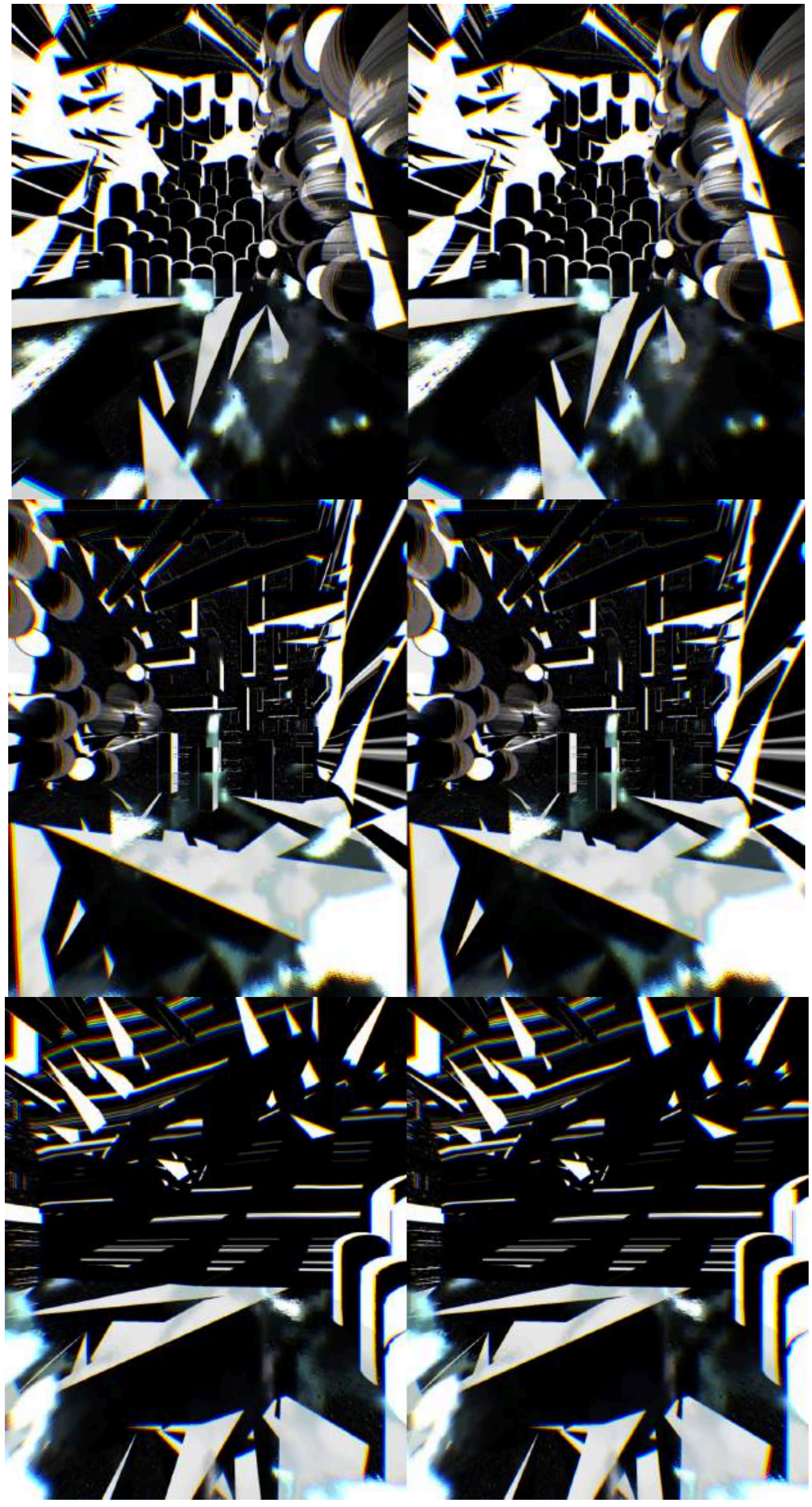
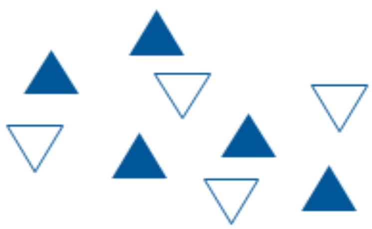


Figure 24. Pollock Game World from Different Perspectives

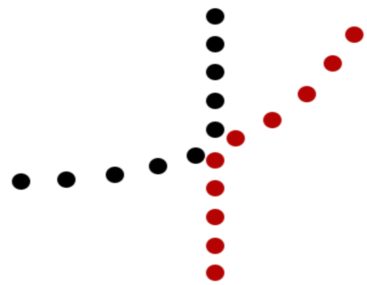
The ways in which these clusters were arranged applied many of the Gestalt laws of grouping. These principles are an offshoot of a larger psychological framework known as Gestalt psychology, which tries to understand the human faculties to acquire and maintain meaningful relationships in a stochastic, chaotic world. Figure 21 Succinctly highlights the most common grouping laws used for pattern creation within the *Pollock* game environment. Again, this was another tool utilized to provide for rapid user visual processing.

Homogeneity/Similarity



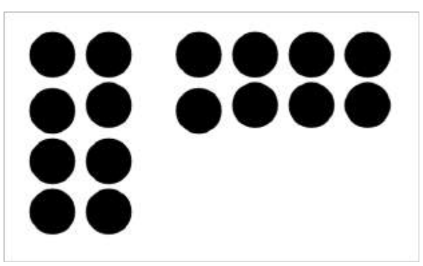
Similar structures are consolidated

Common Fate



Congruent behavior leads to grouping

Proximity



Neighboring structures are consolidated

Pragnanz

Reality is reduced to its simplest form

Figure 25. Most Common Gestalt Laws of Grouping

Ultimately, "perception must process a variety of data with very great efficiency […] it focuses on establishing simplified models of presenting the environment and objects by virtue of less complex characteristics, which suffice to evaluate the objects perceived" (Haverkamp 93). The brain seeks out sensory patterns of all kinds to piece together a logical, understandable reality. The brain does not do this by summing all received sensory input. Rather, it filters this sensory data to manifest a reality that is consistent with one's current perspective. By appealing to our senses through concerted, perceivable patterns, one is allowing for the creation of reality as humans experience it. They our world-building language that is essential to the fruition of deep play environments. Though the focus in this section has been towards the sense of sight, these patterns are not exclusive to vision. We'll discuss how these other sensory patterns play a role in fostering deep play in the next section.

3.4 Coherent Layering of Patterns

Our sensory modalities don't exist in a vaccuum. They are always concurrently stimulated by other sensory patterns. Think of any object, be it a book or a favorite food. Whatever thing you are currently thinking about has a visual component, a sound, a smell, and a taste. Certain senses may hold more significance in your own personal understanding of this object; however, every object possesses some kind of characteristic applicable to all other senses. Perception is, in part, a product of the conglomeration of all the distinguishable objects within the bounds of one's sensory limits. These physical objects that exist externally to our being become perceptual objects after our brain processes and organizes their sensory characteristics. These cognitive representations of physical objects act as models whose properties can then be assessed and compared with our own experiences. In other words, "perceptual objects represent the perceived reality in the consciousness" and "are fundamentally of a multisensory nature" (Haverkamp 94).

What is also important to note is that "even the stimulation of only one modality with unknown stimuli directly leads to the construction of hypothetical, multisensory perceptual objects" (Haverkamp 94). For example, the sound of an ambulance triggers the cognition of a perceptual object that is defined by more than just a sound. So, as a result, the design process has to be multisensory in nature, for everything is just that—multisensory. This is where synesthetic design comes in. "An important basis of synesthetic design, therefore, consists of determining the patterns which are significant with respect to the connections between the sensory modalities and which are essential in contributing to the creation of multisensory perceptual objects" (Haverkamp 132).

This is exactly what company brand's do. Think of McDonald's, a restaurant chain, and you're likely to hear its jingle play in your head. Haverkamp explains that "by communicating through more than one sensory channel, the symbolism gains meaning and is endowed with emotional content" (Haverkamp 44). This is a principle that *Pollock* and other experiences, immersive or not, are built upon. It's the unique combination of sensory modalities that elicits human emotion. It's also important to note that "a conveyance of data via several sensory channels increases the capacity of processing and minimizes the risk of errors," so multisensory design is essential in crafting any product or experience that is intuitive and readily understood (Haverkamp 370).

The most obvious way that *Pollock* applies this cross-modal approach is the way in which color is tied to sound. Users have the ability to select between seven different color choices that have corresponding musical sounds. The user's painting of the game environment triggers the playback of these sounds. Much research was done in hopes of discovering any innate connections between light and sound, but the only relationship that seemed to appear, at least from a human qualitative standpoint, is that perceived color brightness could have some correlations between high and low frequency sounds. Haverkamp writes, "generally speaking, a color scale describing auditory phenomena is particularly well-received when it is characterized by continually increasing or decreasing brightness" (Haverkamp 387). It's with this in mind that I chose Pollock's color options, which descend in order from a very bright shade of yellow to a very dark shade of blue. Their respective "sound" varied in the same manner, with highest frequency content mapped to this "Pollock Yellow" and the lowest frequency content being mapped to "Pollock Dark Blue."

From there, however, the actually timbre/harmonic content of each individual sound was chosen based off of my own subjective judgment as to what the color should sound like. But, the decision was more complex than that. "A large body of empirical research now shows that the atmosphere of an environment can play an important roles in determining which foods and drinks we choose to purchase, and how much we enjoy them" (Bacci et al. 211) Furthermore, what studies have shown is that other sensory stimuli can adversely affect one's valence of a concurring sensory stimulus. Beerends and Caluwe (2002) did a study examining how the perceived quality of the individual elements (image and sound) of an audiovisual happening can affect one's respective perceptions of these components. They found that "if the image quality is high, the audio signal is also regarded as being of high value – and vice versa" (Haverkamp 165). So, regardless of what characteristics define a hypothetical object in and of itself, "the environment of an object is a determining factor in the perception of the properties of an object" (Haverkamp 245).

Pollock has always been an experience that I wanted to be both whimsical and, yet, at the same time meditative, which is why the game environment is set in a remote local deep in space. I find that the night sky or darkness in general tend to elicit reflective thought. Therefore, the user-generated composition should be in concert with these emotional evocations. I find Major 7^{th} chords to be contemplative, yet slightly nostalgic, so I constructed things sonically so that the combination of all seven colors' unique sound textures results in the formation of a C major 7^{th} chord, spanning multiple octaves. The sustain of each sound loops infinitely as an ambient drone, which also lends itself towards establishing a meditative state within the user. Finally, in terms of the relationship between the user-generated composition and the somewhat complex visual composition of the game environment, "it is advisable to contrast complex music with simple images; however, if the music is structured in a simple manner, the visual stimuli could be more complex (Haverkamp 168). So, the choice of making the sonic elements ambient in nature supports the more complex visuals of the game environment.

Figure 26. In-game Color Combinations

In relation to this combination of different modalities "new perceptual qualities arise which none of the participating channels can generate for itself" (Haverkamp 335). So, in the case of *Pollock's* sights and sounds, their overall effects can only be determined when they are married together within the experience, because the resulting perception is cognitively a singular multi-sensory object. But, there are even additional considerations, since the user-generated composition is not only heard, but it is also felt. The audio signal that plays back in the user's headphones is also concurrently sent to the KOR-FX Game Vest, so that the sound is tactile, further coloring one's perception of the experience.

There are intersensory attributes that allow for the analogous definition of different modalities, them being intensity, brightness, volume, density, and roughness. Knowing this, cross-modal correlations can be more easily linked or analyzed. Earlier in the section, a connection between modalities was achieved by relating the brightness of color to the "brightness" of a sound. Volume is also correlated between the three modalities. A specific instance of a color will appear greater in the user's visual field as they approach it directly, which will also trigger an increase of that color's respective sound volume, so that the user will hear it more as well as feel it more. Density is also linked between the senses in a similar way. As can be seen in Figure 22, numerous splattering of different colors in a particular section will result with a correspondingly dense sonic/tactile experience.

Figure 27. More In-Game Screenshots

So, synesthetic design is concerned more so with the combination of sensory modalities than the individual modalities themselves, or, to quote the famous Gestalt psychologist Kurt Koffka, "The whole is other than the sum of its parts" (Wong 863). Therefore, the design process has to go further than just establishing various sensory patterns. It has to then interweave these patterns to create a multisensory design that accomplishes the desired purpose of the end product or experience. This multisensory design is ideally reflective of the designer's intended reception from the user. How the intended audience is actually going to receive it cannot be fully known during the design process. If the design choices are, in fact, understandable and engaging, then a deep play environment is achievable. If they are not, then the design has to be redone. This step in the deep play model is so crucial because it determines so much of the initial user reactions to the play environment, and, if the results are unsatisfactory, further user participation is profoundly inhibited.

3.5 Analogous to Human Experience

As a multisensory design continues to develop, it is important to always verify that the perceptual objects manifested by cross-modal patterning are tied to human experience. Once perceptual objects are constructed within the mind, the object recognition process begins. "During the object recognition process, objects are recognized when the representation built from perceptual processing matches a representation stored in memory" (Leder et al. 55). Humans can only know themselves through past experience, so the patterns and the layering of different sensory patterns need to make sense from our shared cultural histories, or at least those of the intended audience.

This is why making work for a large public audience of varying demographics is so difficult. Finding the base, shared streams of experience between people from different walks of life will always be the ultimate challenge for works of popular art. Prototypes are an average of many examples of the same category. "People prefer prototypes of different kinds because they are typical of a category" and "are processed more easily and liked (Chatterbee 40). This harkens back to previously mentioned concepts of streamlining stimulus patterns for easier neural processing. This is why much of the design of *Pollock* was meant to go beyond cultural experience and, instead build upon universal, neural perceptions. However, there may be universals that exist somewhere in-between low-level perceptual processes and culture.

In 2005, Vilayanur Rachamandran repeated an experiment in which test subjects (American college undergraduates and Tamil speakers in India) were given the words "kiki" and "bouba" and were asked to assign these words to the two different images seen in Figure 24. The results showed "an extraordinarily clear tendency to refer to the sharp, jagged form 'kiki' and to designate the circular form to 'bouba'," supporting the findings of the original experiment performed in 1929 (Haverkamp 233). Similar studies suggest that curvature is "associated with emotional valence such that curved objects are positive while sharp-angled objects are negative" (Leder et al. 56). Things like symmetry and high contrast have also been found to be preferred amongst test subjects from various cultures. What these studies suggest is that some human behaviors may exist outside the bounds of culture. Certain elements of *Pollock's* visual design are reflective of these findings, from the use of circular endogenous image patterns as the model for how paint is represented within the game world to the environment's symmetrical, black-and-white aesthetic.

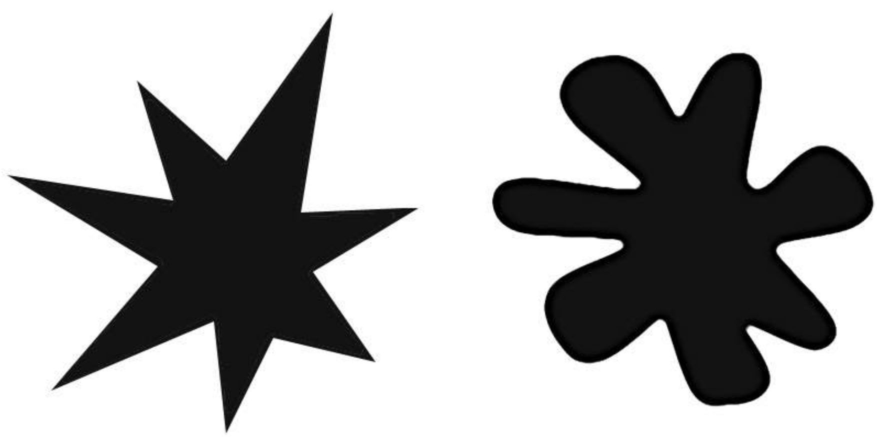


Figure 28. The Kiki/Bouba Experiment Images

This concept of analogous human behaviors also extends to how interaction within the game environment works. All of the tactile transducers were added to make virtual actions within *Pollock* feel real, one of the ultimate drawbacks of most virtual reality experiences is that the physicality of one's being is lost in translation to the virtual environment. So, when Pollock fire's his paint cannon, the user feels it; any time Pollock moves around, the user feels its. Moreover, I decided to make a custom game controller for the user's arm because I felt it was the most analogous way of simulating the processes that would actually occur if one had a paint cannon for an arm. Modern console controllers, though well-designed for those who habitually play video games, can act as a barrier to user-engagement within a virtual world, as most of them lack motion gesture controls analogous to the actions performed by one's avatar character.

It is at this step in the deep play model that more concrete associations with actual human experience take shape, and because the steps prior establish a strong sensory framework one can feel assured that these associations will be expressed in a way that is accessible and intuitive. After this step, the core mechanics of the intended experience are in place. The next step establishes the bounds of these mechanics and how much agency in expression is afforded to the user.

3.6 Freedom to Explore

"Simultaneously, scenes need to be somewhat complex. Complexity is the richness and number of elements in a scene. Without complexity, a scene is boring and unlikely to promise much in the way of food and water […] mystery tantalizes us with the possibility of interesting discoveries if we only dared to explore" (Chatterbee 50).

This excerpt is commenting on why complexity in real or simulated landscapes is appealing to human beings. What *I* would like to posit is that complexity is a byproduct of the amalgamation of *simple* forms. Furthermore, it is when these simple forms are combined in meaningful ways that the resulting complexity is accessible, as it offers a certain depth of experience that entices further exploration. And, that's what the deep play model aims to do: utilizing the building blocks of reality to redefine what reality *is* through the careful juxtaposition of basic sensory patterns. This sense of infinite exploration is absolutely fundamental to the deep play experience, as it indicates a sense of investment in the outcomes of a play event.

Play and deep play are just two ends of a spectrum and the design of a play experience determines where on this continuum the experience falls. Freedom to explore does not imply a lack of structure or rules. Many different play experiences are engaging as a result of their underlying bounds. The sense of freedom in a play environment comes partly from possessing the understanding of what rules govern the experience. Another important facet is that there are no barriers to entering the play environment. This is another aspect that the deep play model accounts for, which is why there is such an emphasis on the immediacy and fluency of sensory stimuli. So, *Pollock* conceptually is a very simple game experience: you hear and feel what you paint. You are essentially in a confined space. However, the choices you make, their resultant effect, and how you choose to express yourself within the game environment are infinite, which allows for the sense of freedom that truly makes any deep play environment. Without this agency, there is not enough stimulus to sustain any sense of immersion.

Really, this last step of the deep play model acts more as a verification of the successes and failures of the finished design as opposed to generating more content that produces this "freedom to explore." Moreover, its execution is extremely dependent on the multisensory design in question, so the only hard-and-fast rule is that the rules and logic governing the experience allow for expressive, "predictably-random" behavior. What I mean by predictably random behavior is that the actions of or actions done to the user can be reasonably hypothesized and readjusted for yet, at the same time, are not deterministic. For example, I can shoot a basketball from the same position fifty times, yet I cannot fully guarantee the outcome of every shot. In the next and final chapter, I'll share some anecdotal thoughts from participants who actually experienced *Pollock* as well as reflect on my entire project as a whole.

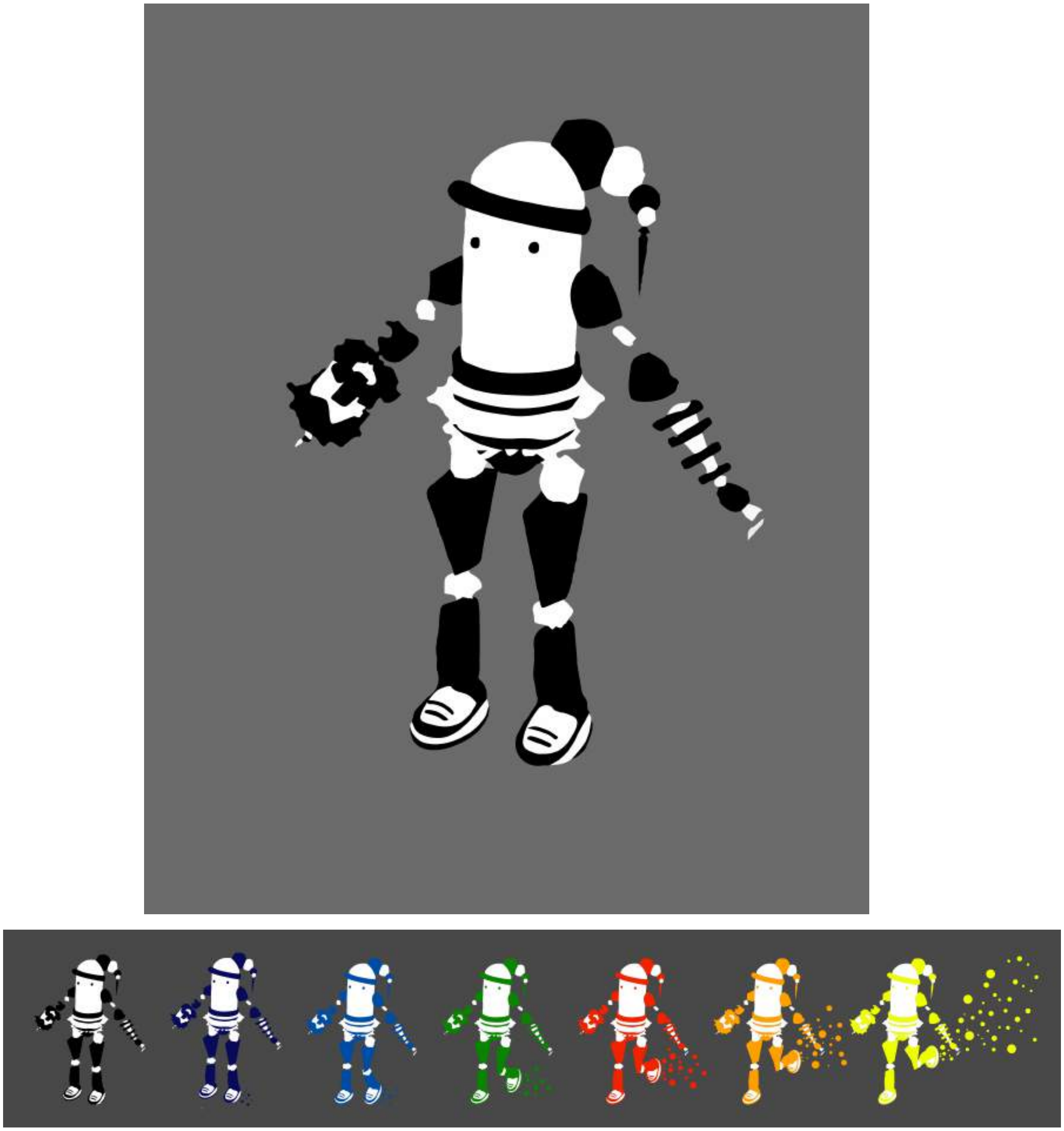


Figure 29. Pollock

Chapter 4
Conclusion

4.1 In the End…

The final version of *Pollock* debuted at the 2015 Digital Arts Expo at the California Institute of the Arts. Random participants typically stayed in the game environment for roughly five minutes. In order to gauge the effectiveness of my final design, video interviews were conducted with each participant immediately after leaving the game environment. I felt that a questionnaire might lead participants to some bias, in the sense that it would result in the kinds of answers that would validate my deep play model yet lack the kind of impartiality required for an academic research. Much of the questioning performed in the video interview was open-ended, where the user was essentially asked to describe their experience.

Here are some selected participant quotes:

"It blew my mind... I was in a whole different world. You're just completely immersed in it. I can't even like wipe this grin off of my face. I'm stuck in it."

"Amazing! Oh my god. That's like my happy place. I wanted to be there all day, but my friends are making me leave. It just put me in this place...."

"I really enjoyed that, it felt... authentic. Like I was really transported to a different reality"

"I feel very inside this world and it's very abstract... but I don't care. I was totally lost. I felt like I was living in that world."

"I've never experienced anything like that. It's like you start to lose your own sense in space. It was all around you."

"Even though I was in a digital world it felt totally real. Even though I couldn't touch, I had this sensation of the air in the space, the sounds in the space... It was one of the most incredible things I've experienced and I did it looking through a pair of goggles. It was really breathtaking."

Looking back on *Pollock's* debut, I feel that the reactions to the project were extremely positive and, at the very least, indicative of the strengths of the deep play model. What I found interesting is that the many users tended to stay relatively in the same position for much of the experience, painting just a single wall (see Figure 29). I think this is partially due to the lack of instruction in how to control Pollock, an oversight that was not properly accounted for in the structuring of the experience. There were no trends of note, though I think this more reflective of the participants' lack of prolonged periods of time within the game environment, a decision I made in order to cycle through as many different people as possible through the experience.

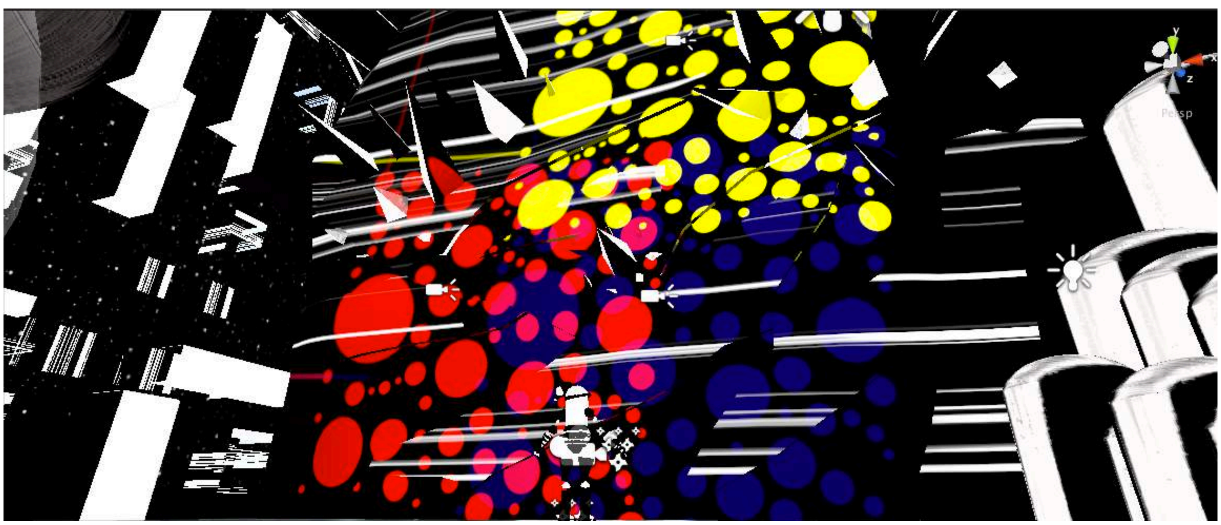


Figure 30. User-generated art From Digital Arts Expo

Figure 30 illustrates the hardware setup within the space. There were no participants who felt that the user controls were awkward or unresponsive. What is also worth noting is that participants tended to describe the experience as a collective whole as opposed to referring to individual elements of the design, indicating how much the multisensory event is processed as a single unit of stimulus.

Figure 31. Participants at Digital Arts Expo

4.2 Final Thoughts

Even though I am very proud of how much I was able to accomplish through my thesis project, this is really just the beginning of what I imagine will eventually be a much more advanced technology in ten years. I think these advancements would be best served towards developing all non-audiovisual stimulatory technology so that the sensory resolution of virtual environments in the future can be as rich and expressive as what you see and hear. Even just the addition of simple haptics to my thesis project added so much more immersivity to the experience. Without these kinds of development, virtual reality will continue to be more reflective of the video game experience than as an art form in and of itself.

In regard to the proposed deep play model, I think my results are promising for future research, however many more applied iterations of this model are necessary in order to validate its effectiveness. It is my hope that my research can act as a possible starting point for the next generation of virtual reality experiences to come.

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