The User, The Space and Everything Else in Between: Designing Context-Driven Interactive Spaces through Direct-User Inputs

By

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Abstract

In this thesis, I present my research project *Air + Water*. *Air + Water* is an interactive installation system that detects breath pressure and changes its visualization by detecting the number of users in its space. This project was developed within an exploratory-research design process. It aimed to establish clearer understanding of the user's input within an interactive installation system through its overall design and visual feedback. The design process used a mixed-method approach, leveraging research through design and user-centered design methodologies along with interaction design methods presented in literature. Building upon related works and existing design frameworks, the idea of a contextualized interactive system came into formation. Through a usability study, *Air + Water* was evaluated, with and without its context-aware features. This was to see if it was capable of bridging its context-driven design choices to the user's understanding of the system. The contributions from this research could provide designers in related HCI and interaction design fields to consider these types of design choices when working with direct-user inputs.

Keywords: Context, Context-Aware Systems, Direct-User Inputs, Installations, Interaction design, Interactive, Smart-spaces, Visualized Displays.

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Definitions

Here are the following definitions I have gathered and applied throughout my research on this thesis's subject matter:

CONTEXT
"Context is any information that can be used to characterize the situation of an entity. An entity is a person place or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves" (Dey, A.K., et al., 2000, p.4-5).

CONTEXT-AWARE
"A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task" (Dey, A. K., et al as sourced in Perera et al., 2014, p.7).

DIRECT-USER INPUT
Physiological characteristics and traits that come directly from a living thing such as touch, smell, breath, pulse, taste, movement etc., and is translated into data. (Definition provided by my own understanding based from Mignonneau and Sommer, 2005 and Sra et al., 2014, p.1).

INTERACTION
"An occasion when two or more people or things communicate with or react to each other" (Cambridge Dictionary).

INTERACTIVITY
"The involvement of users in exchange of information with computers and the degree to which this happens" (Cambridge Dictionary).

INTERACTIVE INSTALLATION SPACE
"Interactive art is audience led, allowing viewers to interact with and become a part of an artwork through activities such as walking, writing, sitting or playing" (interactiveart.tv, 2019).

INTERNET OF THINGS
"Things have identities and virtual personalities operating in smart spaces using intelligent interfaces to connect and communicate within social, environment, and user contexts" (T. Lu and W. Neng as source in Perera et al., 2014, p.7).

SMART SPACES
"A highly integrated computing and sensory environment that effectively reasons about the user physical and context of the space to transparently act on human desires" (Luipana et al.,2009, p.522).

UBIQUITOUS-COMPUTATIONAL DEVICES
"Devices such as sensors that are placed in the space. These devices collect and track numerical data in real-time" (Definition provided by my own understanding from Lupianna et al.2009 and Perera et al. 2014).

Chapter 1: Introduction

1.1 Experiences as a Participant and as a Designer

The first time I had experienced an interactive art installation was when I attended an exhibition show at the Arta Gallery in Toronto's Distillery District. I was exposed to many forms of artistic expression in the form of machines, video installations, games and sculpture. Each of them had their own charm and narrative approaches that I could experience by interacting with a button-controlled interface. In return, I would receive some form of output that drove a narrative further. Some installations required no input as I could just watch and listen as a viewer. These installations were fun and interesting but what really caught my eye was an installation I would never forget. It was unique unlike any other. The installation was an empty space behind a black curtain. I walked into it. I noticed little colored-projected circles following me. Specifically, they were following the position of my arms and legs. I took another step and noticed sound. I raised my right arm and noticed a different pitch of the same sound. It was not until I started to move was when I realized what was happening. I was making sounds with my body through this installation and I started to make the connections between what I was seeing, hearing and doing. I was not just experiencing an interactive installation space. I was the installation space.

The piece was *Play On (2013)* by Karen Cochrane and Olivia Kolakowski. It was exhibited at META 2013, Ryerson University's new media end-of-the year show for the fourth years' undergraduate thesis projects. I was a second-year undergraduate student at the time and would not be able to understand just how important that piece meant to me or how it made me feel until I attended the following end-of-the year new media show in 2014.

Ryerson's META 2014 show was a wide-opening shock and a completely different experience from the year prior. Without any guidance, the projects presented at the show were overwhelmingly difficult to interact with. It would be almost impossible to understand anything what was happening despite the crowds. I recall one piece that looked like a dock as a place to sit as I saw other attendees sitting on it. Turns out, the dock was not meant to be sat on according to the artist. Other pieces were hard to understand in its entirety while a few were able to get their artist statements across. Overall, the entire experience was confusing and difficult to process. I had failed to gain any important information that would make most of my encounters and interactions through these installations more engaging.

I was not alone in feeling this way. The following days after the show resulted in a meeting between the faculty and my cohort in what went wrong and what us future fourth year students could improve on for our graduating show in 2015. I could not help but reflect on the many missed opportunities of engagement each of these installations presented. What could have possibly been the difference between the two that made the previous show such a success and this one such a complex disaster?

The answer is a lot more complicated than it seems. I had been judging an experience based off my expectations of strong interactivity and user-engagement. Those expectations that were met at the 2013 show were not met at the 2014 show. In most of these cases, I would find myself trying to associate my input or participation within an interactive installation system and have learned many things by doing this constant bridging of thought. As a participant, I had been inspired and encouraged to think about the participant and their experience of the work as well as their significant participation within the space and what makes the interaction the way it is with their input. As a designer, I wanted to learn and understand how effectively the participant's input would be perceived through the installations I designed. As I continued to research other interactive installation works, design methods and frameworks, I started to look into interaction design, tangible design, virtual reality (VR) design and its use in spatial ability training practices within a human computer interaction (HCI) discipline. I had worked with virtual-reality and hybrid-tangible systems to test its effects on spatial ability training for four years as a research assistant before pursuing a MDes and undergoing my own research in user-interaction design.

The research team I had worked with, known as T.A.S.C (Tangibles for Augmenting Spatial Cognition), published a paper called "TASC: Combining Virtual Reality with Tangible and Embodied Interactions to Support Spatial Cognition". It focused on using tangible-embodied interactions within a virtually reality (VR) environment to help improve spatially cognitive abilities. VR was capable of immersing users into virtual environments through a headset (Chang et al., 2017, p.5). The T.A.S.C system dealt with a spatial ability known as perspective-taking. Perspective-taking was the ability to mentally represent a viewpoint that differed from the viewers own perception (Change et al.,2017, p.3). There was not a lot of virtual reality and tangible design implementations that made use of perspective-taking or any other spatial abilities at the time (Chang et al., 2017. p.3), so I was designing a hybrid system at a relatively new peak of research.

After working with VR technologies and building interactive hybrid systems with them for several years, I came to realize that their use made designing interactive and immersive scenarios more complex. Their use did not seem to be needed to ease interactivity with physical tools and virtual displays. The use of the Leap Motion that mapped hand movements as users interacted with tangible objects in the T.A.S.C game, made the experience feel and look un-natural. To me, virtual reality mainly severed the user from the physical environment completely, fabricating a new environment, while also suspending and re-mapping a lot of the user's senses and awareness of the body. This led me to reflect on what kinds of interaction designs I wanted to do moving forward, recalling the works I have seen and experienced during the META shows at Ryerson prior. It felt worth looking into designing around this human-to-computer relationship through other approaches such as the use of sensors and visual displays that were not only complimentary to the user's direct inputs and actions but also mapped its feedback.

1.1.1 Personal Reflections

What I had learned in my search for easier interaction in these virtual and computerized systems was the user and their involvement. This involvement had usually dwindled down to the user's expectations, their thoughts, their understanding, learning and purpose. The interactive installation systems I wanted to design after my experiences as a research assistant became less about the tool or project and more about the user. I had realized how important it was that the user understood how significant their input was and its use within the context of an installation space. The aim to achieve simpler and intuitive interactions within these spaces became something I held in high regard in any interactive space that dealt with the use of sensors, what they gathered in their environment, how they did it and why.

This thesis aims to explore and inspire the design approach that implements the use of user inputs, their qualities and the process required to translate and visualize them in a meaningful and intuitive way that is easy for users to engage with. Meaningful engagement to me, is the captured visual representation of the user's participation within the installation in relation to their actions and direct-user input.

This thesis does not aim to use prototypes to prove or strengthen user engagement in the context of interactive installation spaces as opposed to existing methods and works. In *Air + Water,* I use breath pressure and explore context-aware features to affect the visualization of the installation that all fit under the context of the user input. My experiences as both a participant and as a designer have driven me to this point to explore simpler interactive methods that can be engaging and complimentary to a user's input. *Play On (2013)* was unique because it directly created a connection with the use of my body, a very personal source of input directly stemmed from my own being. If this source of input could be used in other expressive forms of digital media, imagine how interconnected and significantly intimate these virtual and physical spaces can make users feel.

1.2 Rationale and Research Question

Interactive installation spaces have opened my design practice to new opportunities. With the use of sensors and the utilization of their data, interfaces, visual outputs and the overall design of a system can become aligned with the context of a direct-user input. The aim to achieve simpler and intuitive interactions within these spaces became something I held in high regard in any interactive space that dealt with the use of ubiquitous computing. Ubiquitous computing is a paradigm that utilizes the use of disappearing computers and context-aware applications. "...*disappearing computers*, where computational power is not provided in a manner such as by a traditional computer; and *context-aware* applications; that understand and react to their environment appropriately" (Lupiana et al., 2009, p.516). Using sensors to capture raw data and translate the data into a visual component became a unique strategy worth exploring further in making stronger connections between the user and the interactive installation space.

Traditional modes of input such as buttons, keyboards and controllers could only do so much in exploiting user input until the use and deployment of sensors (Lupiana et al., 2009, p.518). Starting with the user, I wanted to design around their input and encourage interactions through the installation's design that were relevant to that input. Beyond the use of traditional forms of input and stepping away from game controllers, creating customisable interfaces that focused on the input directly could potentially inspire new forms of user-interaction and provide positive yet meaningful experiences for the user's participation.

Ever since my experience at Ryerson's META 2013 end-of-the year show, I have always been interested in how a part of a person can metaphorically be incorporated into an interactive installation space. My research focuses on the use of information from sensor data, cues and context to visually display and retrieve the user input in the best way possible. I have attempted to use design choices that I know could compliment well into the feedback loop of the system as well as possible user's expectations. This was an extremely difficult task mainly because designers could never expect what the user would experience, act or feel when producing these designs. They could only iterate and test until the final outcome met the required goals that the creators had hoped for. The kinds of inputs I had interest in working with ranged from the use of the senses to behavioral actions we humans already acquire and are familiar with to gather information: touch, smell, hearing, speaking, seeing, tasting, reacting. Sra et al., referred to these as directly controlled forms of psychological input (Sra et al., 2018, p.1). I will refer to them as direct-user inputs for clarity. The use of these types of inputs can potentially help obtain a strong interactive connection between the user, the environment or the object they are interacting with due to their close relativity to a person and life. I also feel that these types of inputs can lessen the cognitive process of understanding why a reaction happened the way it did based off the user's action.

Therefore, it was important that this thesis formulated a question that addressed the necessary steps needed to further investigate the use of user inputs, their visual reflective counterparts and the process of actions needed to arrive at the final output.

How can user inputs such as touch and breath be applied to design effective visual feedback in a meaningful way, that is shared with and amongst participants using a contextually-aware smart-environment?

Within the context of creating interactive installation systems that worked with their respected user inputs, the main research question had generated a set of sub-questions that have aided me in my understanding of my research goals:

1. *How can I strengthen the connection between users in smart spaces and the information in smart spaces using affordances (E.g., recognition of tools or items), context-aware tools and visualized displays?*

2. *In what ways can I use context-aware design methods and tools to visually interpret user input (such as touch and breath) that could encourage interactions or improve the shared relationship with the users and the space?*

3. *How can I evaluate a user's experiences within an interactive installation system that fully expresses the user's engagement in a meaningful way for both the user and the space?*

1.3 Chapter Summary

This chapter covered my experiences of interactive installation spaces, designing hybrid-interactive systems and presented my reasons of why I wanted to work with direct-user inputs through sensors and visualized displays. Chapter 2 presents background literature as I focus on the evolving relationship between humans, environments and objects. I later, discuss the definitions of interaction and interactivity as their nature and treatment evolve within our relationship with computerized systems. Later subsections focus on context and context-aware systems with the introduction to smart-spaces and their use of context from their direct-user inputs. Other related works that focus on unique utilizations of user input will derive from interactive installation work examples, how their applied uses are outputted and visually perceived. These works will be critiqued on their design and input choices for learning purposes. Methodology and methods are explored in chapter 3 and their significant influence is weighted on my exploratory design process in chapter 4. Chapter 5 covers *Air + Water's* usability study where I evaluate the system and user experiences with the system. Chapter 6 concludes with a summary of what I have derived from this research and outlines future work for possible uses of context-aware features for *Air + Water*. These lessons could illuminate the affordances of the user-input further for more meaningful experiences for future work.

Chapter 2: Background

This chapter focuses on the evolution of the user interface and how user engagement has invited new forms of interaction beyond the desktop, mouse and keyboard. User interfaces have become more intimate and apparent to us as well as the systems we part take in. With the use of less obtrusive, ubiquitous technologies such as sensors, interaction design has become more attuned with presenting characteristics and attributes of human life through customized tools and visualized displays. The following sections look at the relationship between us, our objects and our environments. Later, the terms interactivity and interaction are defined to better examine this evolving shift in interaction and feedback. These foundational points will eventually begin to tie into the idea of interaction and interactivity and how interaction can further evolve into more seamless, natural and intuitive forms of user-engagement using digital counterparts and computerized systems.

2.1 The Human, Object and Environmental Relationship

When we think of computers, we think of them as tools to get things done for us effectively and efficiently. Heidegger's *Basic Writings from Being and Time to The Task of Thinking* discussed the ideas of *Dasein*, which derived at the idea of Being. Not having awareness of only just this self-being, but the being of other things in the universe. "…*Dasein* is the open space where beings reveal themselves in sundry ways, coming out of concealment into their 'truth' (aletheia) and withdrawing again into obscurity" (Farrell and Heidegger, 1967, p.20).

This brings into focus some ontological ideas about humans and their relational part in the use of objects, tools and their environment from the beginning. *Dasein* is this space of silent interactions and relations yet to be revealed to us through awareness.

> "*Dasein* is the kind of Being that has *logos*-not to be understood derivatively as reason or speech but to be thought as the power to gather and preserve things that are manifest in their Being. This gathering happens already in a fundamental yet unobtrusive way in our everyday dealings, for example, in our use of tools. When we lift a hammer or drive a car we are before we know it enmeshed in a series of meaningful relationships with things" (Farrell et al., 1967, p.19).

In Graham Harman's *Heidegger Explained*, where Harman analyzes the earlier writings of Heidegger himself, Harman explains the themes of time and awareness. He brings most of his attention to Heidegger's idea of *broken tools*, his *ready at present* and *present at hand* situations, as well as the space and timing of these events. "Every entity we encounter gains its ultimate meaning for us from our own being. If we find water at a desert oasis, we do not just describe the water in terms of visible qualities, but feel a sense of thrill at the opportunity to quench our thirst" (Harman, 2007, p.64). The relational context of humans' part in the existence of our own awareness and the awareness of objects, tools and environments improved my understanding of the relationship. His insights had strong relations to the idea of being and the existential applications to interaction and engagement. The ideas of *Dasein* have inspired my thoughts of networked information, relative uses of applied information and the use of relative inputs, outputs and their connections.

The ontological perspective of the human, object and environmental relationship from the works of Heidegger lead me to understand this ongoing and evolving relationship with our present interfaces as they, our roles and their purposes continued to change. Ian Bogost mentioned this relational connection to human beings in his book "Alien Phenomenology, or

What's It Like to be a Thing" with his philosophical views on object-oriented ontology. "OOO puts *things* at the centre of being. We humans are elements, but not the sole elements, of philosophical interest" (Bogost, 2012, p.6). Bogost's statements on OOO highlight that the things we interact with are not hierarchical, meaning we are not above or below any other thing, but are all along the same plain. "OOO steers a path between the two, drawing attention to things at all scales (from atoms to alpacas, bits to blinis) and pondering their nature and relations with one another as much with ourselves" (Bogost, 2012, p.6). This kind of relation made me feel that we were all interconnected to things in simpler ways that applied to simply just being and being aware. Our construct of obtaining information and applying it to our expected outcomes from our actions have always aligned with awareness and satisfying our needs. In my opinion, when those outcomes do not align, we notice the mismatch and our experiences are not as enjoyable. However, our push for these pleasant and successful interactions seem to have been heading towards becoming more and more aligned with our needs and goals. Johnathan Grudin's article, *The Computer Reaches Out: The Historical Continuity of Interface Design,* looks at the evolution of the user interface that took end-users the furthest away from the hardware side of the computer to the graphical desktop interface that users now engage with on a daily basis (Grudin, 1990). He predicted that we will be in a situation where we will be in grouped interactions with our interfaces, which has already come to light in most social and work situations today. "Since most work occurs in a social context, computers will support it more successfully if they implicitly or explicitly incorporate social and organizational knowledge" (Grudin, 1990, p.264). James Bridle, the author of *The Dark Age: Technology and the End of the Future*, had discussed how reliant we have become with our technology even to the extremes of relying on them for information and executing that information. He also mentioned how we are capable of blindly trusting our GPS systems to being shielded from seeing underneath the black box of a user interface and understanding what happens under its cloak (Bridle, 2018, p. 40).

We have also applied this blind reliance and trust of technology into our workspaces. Kim Vicente, the author of the "Human Factor: Revolutionizing the Way We Live with Technology", illustrates how we work within tight units to get things done and sometimes at the expense of our own well-being due to the circumstances of the system itself. If one cog in the machine is not working the way it should, then it is only a matter of time before things start to fall apart and have catastrophic outcomes (Vicente, 2003, p.18). This applies to our perception of information and what to do with how it is offered to us. These authors have provided an insight of where we are, how we incorporate such systems in our lives, how we perceive and utilize the information we expect to help guide us and, in some ways, understand ourselves a bit better.

Designers, artists and researchers have aimed to make computerized interactive systems attuned to our behaviours, actions and needs and produce aligned outcomes to express output in some form. I explain this more in depth in the related works section and the following methodology chapter. One of Bogost's chapters he acknowledges Alan Turing and his contributions to the developing communications of the computer through the *Turing test*. This test is generally used to see whether users can decipher if they are speaking to a person or a computer based on the responses from the users' statements or questions (Bogost, 2012, p.14). As this test started in the 1950's moving forward and the ideas of Grudin and Bridle happened much later, it was evident that this relationship between the user and the computer had been evolving to become much more intimate with our engagement as interaction design methods continued to change to achieve this. The computer started to become more than an extension of our personal selves, it was the beginning of a new kind of language forming between us and the computer that we have yet to interpret through design.

This evolution became precedent in how we interact with interfaces and perceive feedback. It has bridged a range of opportunities that allowed the re-integration of existing technologies for new purposes, ideas and systems. The following sections focus on the distinct definitions of interaction and interactivity and how these terms have been applied within the context of interactive installation works that focus on user engagement and user input uses within related works. These definitions are meant to help justify their use and potential advances within computerized interactive systems and user input mechanics.

2.2 Defining Interaction and Interactivity

Interaction and Interactivity have been commonly used to explain the course of actions that take place when coming into contact with another entity object. They have helped us communicate and recall information so we can then later apply such information in order to receive an expected outcome. However, these two terms have not only been constantly evolving in the way we understand each other but also heavily involved in how we understand ourselves through computers, machines and digitized systems. Therefore, it is important that we have a clear definition of the two to better understand how interactivity and interaction have continued to change and increase in significance with the evolving user's engagement of the computer.

According to Cambridge Dictionary, interaction can be defined as "An occasion when two or more people or things communicate with or react to each other" (Cambridge Dictionary). Interactivity on the other hand is defined as "…the involvement of users in exchange of information with computers and the degree to which this happens" (Cambridge Dictionary). With these two definitions, it is safe to assume that interaction is in fact the exchange of actions and reactions that form some sort of communication. The definition of interactivity however focuses more on what is happening and how the exchanges of actions and reactions are relevant to the feedback of the computerized system. It focuses on the user's reaction to their actions and what take-ways or interpretations they received through satisfying forms of feedback. As interactivity has changed with the user interface, so has our perceived expectations of what the computer outputs into the world based on that input. Authors Yuping Liu and L.J Shrum from the article *"What is Interactivity and is it Always Such a Good Thing? Implications of Definition, Person and Situation or the Influence of Interactivity on Advertising Effectiveness"* formulated their own definition of Interactivity through a three-way model that applied to advertising methods:

> "The degree to which two or more communication parties can act on each other, on the communication medium, and on the messages and the degree to which such influences are synchronized…we specify three dimensions of interactivity: active control, two-way communication and synchronicity (Liu and Shrum, 2002, p.54)."

In their definition, the authors account the cognitive process, rate and understanding of events that happen at a certain level that give interactivity an opportunity to strengthen and actively be improved on. That is why the level of interactivity is always different at many complex stances and situations. Interactivity is always improving for the better benefit of the user. However, it is also improving for the better understanding of the interactions and environments these interactions take place in. As long as there are designs continuing to challenge and change what could be improved, our understanding of interactivity will and can construct more fluid and synchronized forms of communication and feedback from here.

The terms interactive installation and smart space respectfully are different in their own right. An Interactive installation is audience led, allowing viewers to interact with and become a part of an artwork through activities such as waking, writing, sitting or playing (interactive-art.tv, 2019). Dennis Lupiana defines a smart space as “A highly integrated computing and sensory environment that effectively reasons about the physical and user context of the space to transparently act on human desires” (Lupiana et al., 2009, p.522). He also explains later that the use of integration, context and transparency all result in the existence of related information that contribute in the existence of a smart space. My understanding of a smart space lied in its ability to act as a linguistic system of actions that the user could understand and observe how actions and feedback co-related to the space. Therefore, within the parameters of interactive installation, the schematics are similar to a smart space in which it follows the same construct but through the lens of an exhibition. This is where the opportunity of expressing information comes in. The user’s cues to act prompt them to feel less doubtful or confused and perform the appropriate actions while also contributing to the nature of the installation piece. Through such interactive installation pieces, this level of interactivity has shifted into more intimate forms of communication with the existence of interactive installation works and smart spaces.

2.3 Context-Aware Design Frameworks for Ubiquitous and Interactive Smart Spaces

Researchers and designers have relied on context-design related frameworks to either understand a form of design, implement its use more effectively or learn from its previous applied uses for better future design. Context-aware design frameworks have been utilized within scopes such as the internet of things (IoT), interaction design and HCI research. In this section, a couple of case studies that implemented their own use of context, input and feedback will be presented. The resulting research had prompted my critical thoughts on context and inspired me to formulate my own concept of a contextualized installation system. I later apply this concept towards earlier to later prototyping stages with touch and breath inputs. The designs were created through the user-inputs own contexts. Designing around these inputs required cues of information and to understand such given information, it was necessary to understand the importance of their context.

2.3.1 Looking at Context and Context-Aware Systems

Context is a significant factor within interaction design that designers should consider when designing for user engagement. Authors Anind K. Dey and Gregory D. Abowd provided their definitions of context and context-awareness.

> "Context is any information that can be used to characterize the situation of an entity. An entity is a person, place or object that is considered relevant to the interaction between a user and an application, including the user and application themselves" (Dey and Abowd, 2000, p. 4).

Context-awareness is the use of context to provide relevant information and/or services to the user, where relevancy depended on the user's task (Dey and Abowd, 2000, p. 7). In their article "Context Aware Computing for The Internet of Things: A Survey" Charith Perera et al. investigated contextual-aware design methods and techniques within the scope of the internet of things (IoT) while also discussing context-based definitions. These terms have also been applied in smart-space examples that explored the co-related actions and feedback within an interactive space in Lupiana's "Defining Smart Space in the Context of Ubiquitous Computing" article. One of their examples, *MavHome* described a smart home that could predict its users' needs based on movement and practiced actions done previously (Lupiana et al., 2009. p.520). Another example *EasyMeeting,* was a smart meeting environment that used the context of a meeting to better understand the types of information it received and delegated its actions and behaviours accordingly "By meeting context Chen et al. mean meeting related events such as identity of participants, speakers, the start of the time of the meeting, slide presentation and other related tasks" (Lupiana et al., 2009, p.520). Contextually-aware systems such as *MavHome and EasyMeeting* introduced new forms of utilizing beneficial needs to the user, that expressively acted on the user's input simply by gaining informational cues of its surroundings. I later apply this contextual-aware feature into *Air + Water's* system of understanding the context of its own surroundings in hopes to add better context to the user's participation in engaging with its utilization of breath input. Information from users and translated information through the system's modalities could be communicated within the right context to potentially better foster and express new learning opportunities and experiences within interactive installation works. Understanding different kinds of context could also help plan what kinds of interactions could not only take place but work well with previous actions and feedback. There were two types of context I came across in my readings that caught my attention: explicit context and implicit context. Explicit is a more direct approach to obtaining a certain outcome such as interacting with a button or a graphical user interface (GUI) while implicit is implied or not directly expressed or noticed forms of communication (Schmidt, 2000, p.2). The formalities of explicit context are integrated less into practice because implicit context is subtler to work with and thus creates more room for personalized reflection and unique experiences.

I applied the use of both kinds of context during my earlier to later prototyping stages. Explicit context was explored briefly with my first prototype *Personal Reactive Soft Sensory Mechanics (P.R.S.M)* through soft touches and calming 2D visuals. *Air + Water* used both forms of explicit and implicit context through the visual manipulations from the breath input and its resulting watercolor stain output. Through each input applied, I explored the system's contextual relevance to them more in-depth as I formulated an explanation for their purposes later on in my design process.

I have looked into design frameworks and models that applied context to existing applications and systems for better future uses for them. Charith Perera et al., conducted a survey to analyze and compare existing context-aware applications, devices and systems through an Internet of Things (IoT) paradigm (Perera et al., 2014, p.1). With the evaluation of 50 projects in the span of a decade, the authors compared their own taxonomy to existing and widely used research methods that evaluated better uses and applications for context-aware applications (Perera et al., 2014, p.32-33). They arrived at middleware solutions such as the use of ubiquitous devices and other research related solutions to improve context-aware computing. Their simplified version of the context awareness model was presented and analyzed to better understand its role in IoT.

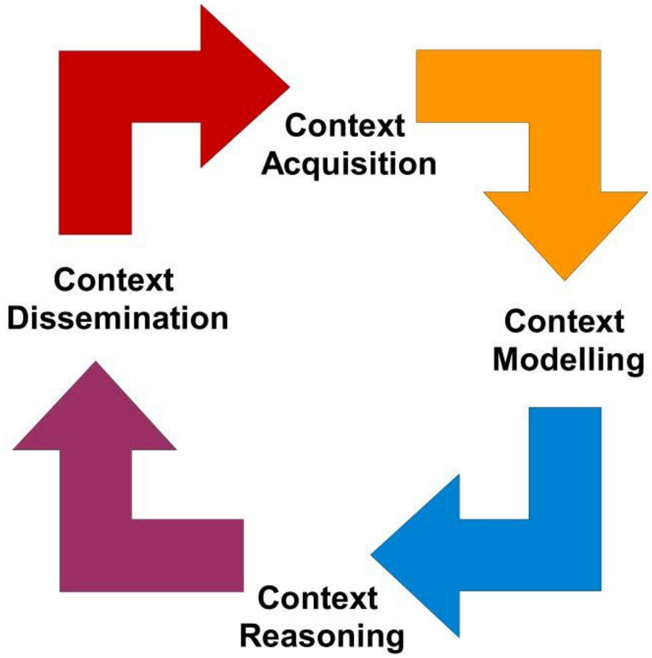


Figure 1. Perera, C., Zaslavsky, A., Christen, P., & Georgakopoulos, D. (2014). Context Life Cycle Model. Context aware computing for the internet of things: A survey. IEEE Communications Surveys and Tutorials, 16(1), 414–454. Retrieved from: arxiv.org/

The above figure shows the context life cycle. This cycle explains and explores the use of context for applicable devices and tools (Perera et al, 2014, p.13). I had applied this model to my own understanding of a contextual-aware smart space and the appropriate ways to requiring, reasoning and applying context to the use of interactive behaviours. The cycle starts at *Context Acquisition* where context is acquired from various sources in a space (Perera et al, 2014, p.13). The next is *Context Modelling* where context is represented in a meaningful manner (Perera et al, 2014, p.13). *Context Reasoning* is processing high-level context from low-level raw sensor data (Perera, 2014, p.13). *Context Dissemination* is the distribution to users (Perera et al, 2014, p.13). This model helped ground the foundation of what I understood as attaining and understanding context. The article went into the various kinds of context and their relative uses of information. Implicit and explicit context models are highlighted in great detail that expressed their fit with the use of context-aware tools and applications. According to Perera et al., implicit context models were more difficult to bound context to since their nature requires more understanding from users. Explicit on the other hand uses an infrastructure that requires little understanding due to its outright implications of use (Perera et al., 2014, p.7). Albert Schmidt discusses the uses and applications to implicit context for situational context and HCI research. Since implicit context is not directly applied physically, it is necessary to use perception and the situational means to bridge a connection (Schmidt, 2000, p.3). It is always complex when actions do not line up and it is not based on expectation alone. "…lack of control and mismatch between expectations and actual experiences produces negative effects" (Bilda et al., 2007, p.526). I believe that there is good interaction and poorly done design, but the control over both is something that should not cause worry. It would be nearly impossible to anticipate what a user would do based on many factors but thanks to existing research, these connections of information and various forms of context can make the placement of sensors and the use of their data more relevant to the space and the actions that take place. The following section provides examples of these as interactive installation spaces and examines them within the applied understanding of interaction and interactivity along with my own critiques of these works. This critique is not to point out what these works had done poorly in their design or to judge their expressive choices, but rather to discuss their strengths and weaknesses in order to formulate possible ideas and factors that could further prompt new and strong forms of user-engagement.

2.3.2 Applied Interactive Design Frameworks for User Engagement and Related Interactive Installation Works

Interactive installation works so far have expressed the traits, attributes and characteristics of people into abstract forms of the artist's desired visual output. Camille Utterback's installation pieces such as *Flourish (2013)* and *Abundance (2007)*, have both used motion tracking to trigger animated events in their visual display elements or keep memory of passive participants' movements. While most of Utterback's work has illuminated the essence of human life through ambience, others have illuminated it through entertainment or recall of actions and behaviours. Examples of this are Karolina Sobecka's *Sniff (2009)*, which used a 3D generated dog that would interact with pass-byers behind a glass window. Misha Sra and her team's *BreathVR (2018)* project, used the utilization of breathing techniques as special projectile abilities within a VR immersed environment. These all have made computerizing data more correlated and complimentary to our actions and inputs within the interactive installation space. However, the design of communicating the significance of these interactions to users and benefit their understanding and engagement within an interactive installation space is still quite challenging to execute. Designers and researchers have been exploring ways on how to present this user-installation relationship to users while at the same time give meaning to the installation space these interactions take place in. Zafer Bilda's paper "Designing for Creative Engagement" looked at the multitudes of expressing input and data provided from the space for better synchronized user-engaged experiences.

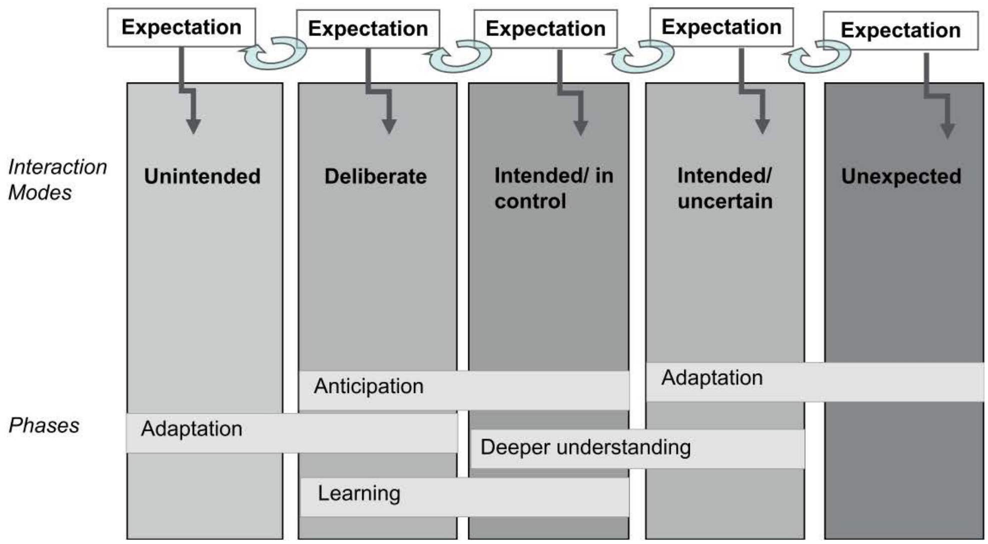


Figure 2. Bilda, Z., Edmonds, E., & Candy, L. (2007). Model of Engagement: Interaction Modes and Phase. Designing for creative engagement. Design Studies, 29(6), 525–540. Retrieved from: dx.doi.org/10.1016/j.destud.2008.07.009.

This framework explored the types of actions users could exhibit when expecting some form of outcome. Their actions and expectations were all processed through familiar behavioural patterns that most of us would do to obtain and understand information about an interface. They used observational and qualitative data to examine these behavioral patterns across ten different interactive installations and interfaces over the span of three years (Bilda, 2007, p.539). They formulated this interaction model into an HCI scenario that revolved around a smart sketch pad in order to explore each mode and phase (Bilda, 2007, p.534). Users who were or were not exposed to a similar interface had expectations about its capabilities while others learned and adapted (Bilda, 2007, p.531-533). According to Bilda, these expected outcomes shaped the user's experience. I found this interesting, because I resonated with the idea of an impressionable experience and perceived information through the context of an installation. When I confronted an interactive space, I expected my actions to align with the outcome. When they did not, I felt as if the installation had failed to keep my interest and engagement as I questioned its full potential and design. "'I experience interactive artworks all the time, so I look at them critically and expect to enjoy them'" (Bilda, 2007, p.533). Bilda expresses that users tended to go into these spaces with their own expectations but explains if users changed their expectations to 'enjoying the moment', then they could also change the outcome of their experience (Bilda, 2007, p.532). Users familiarizing themselves with an interface guided them to either understanding their outcomes and intentions or help them learn and gain better understanding. Out of the five modes, intended/uncertain interactions caused higher creative engagement (Bilda, 2007, p.534) while unexpected interactions caused a greater shift in dialogue (Bilda, 2007, p.535) that impacted the experience for a user.

This interaction model helped further my understanding of possible expectations and forms of user interaction that could elicit new possibilities for interactive understanding and reflection. The intent for *Air + Water* was to create an interactive installation space that made all the actions performed related to one another. Sensory inputs such as touch, smell, heartbeat and breath have been explored to meaningfully express and enhance the experience of an object or an environment. The article "Designing emotional, metaphoric, natural and intuitive interfaces for interactive art, edutainment and mobile communications" by Laurent Mignonneau and Christa Sommerer looked at the variety of interactive installation works that heavily focused on these types of design. With the availability of sensors, creating these kinds of spaces have made collecting, storing and expressing direct-user input more flexible to design with and less obstructive to communicate and present feedback. Mignonneau and Sommerer explored similar grounds of this type of design with one of their natural and intuitive inputs that produced intimate experiences through tangible communicative devices presented in their paper. One of their projects *Mobile Feelings (2001)*, used custom-made objects with embedded sensors to hear and feel one's heartbeat and breath (Mignonneau and Sommerer, 2005 p.11-13). For museum exhibition engagement, Jamie Kwan and his team explored the affordances of a rosary prayer nut and used its affordance information through visually displayed feedback, scents and lights to enhance its story-telling experience (Kwan et al, 2016). Opening and closing these prayer nuts would trigger events that immersed users in a backdrop projection of an animated narrative to create impactful connections with our senses and awareness of the prayer nut (Kwan et al, 2016, p.3). They incorporated these outputs to better immerse the user in the intimate grasp of storytelling through an object that is not easily accessible to the public. Both of these projects used affordances of objects and sensors as mediums to translate personal information from one user to another in order to bridge a connection or tell a narrative.

Artist Rafael Lozano-Hemmer created an interactive installation known as *Pulse Room (2006)*. The installation recorded the pulse of an individual through the light of a lightbulb. Installed at Plataforma, Fábrica La Constancia, Puebla México, there were 100 light bulbs in total and every new recording would push down the last recorded pulse on the lightbulb grid (Lozano-Hemmer, 2006). It was a spectacle when there were a lot of pulsing lights. However, users found it much harder to find and connect with their input when surrounded by so many other pulsing lights. "It is beautiful but when I arrived all the lights were already on and I wished I could have seen the beginning with only one lightbulb flashing and then more and more…" (Pulse Room by Rafael Lozano-Hemmer, 2011, 03:17-03:31). Multi-user installation works such as Lozano-Hemmer's are difficult to retain individual engagement, but this was mostly due to the design and layout of the installation. Good interaction had always stemmed from proper timing of events and of proper placement of information. All the pieces that make stronger engagement possible depend on users being aware of what is happening and why it is happening.

2.3.3 Critique

I strongly believed that the design of objects and their placement of sensors truly could either make or break user engagement. Mignonneau and Sommerer's custom design of their tangible medium lacked contextual reasoning of why they exhibited their inputs through the objects they used. There was little to no connection to their design that related or complimented their use of pulse and breath inputs. Utterback's works usually dealt with utilizing movement data from a camera or motion sensor and applied that data to effect or trigger the visualizations of her installations. However, the interactions between users and her installations were quite passive and did not leave much room for users to reflect or gage about their inputs purpose. The mechanics for *Abundance (2007)* involved abstract interactions among the visualizations sourced from people passing by it. These playful interactions would not come across easily to viewers if they had passed by it.

Mignonneau and Sommerer expressed how users could feel less intimidated, less confused or less lost by applying direct-user inputs to natural interfaces in a space that was accepted by their own reasoning and thinking. Migonneau and Sommerer discussed examples of this natural user input in installation pieces such as David Rokeby's *Very Nervous System* or their own mobile installation work *Mobile Feelings (2005)*. Rokeby's pieces usually dealt with the body as an interface, while user input such as heart rate and breath were used in *Mobile Feelings* to share an intimate experience exchange through hand-held diegetic objects (Mignonneau and Sommerer, 2005, p.839). Lozano-Hemmer's *Pulse Room* dealt with the capturing of one's pulse through a light bulb but associating that connection amongst multiple pulses became difficult for users as more pulses were added to the light show. This is why it was integral for the design of whichever medium the inputs were placed in to make contextual sense to the user and audience for better perception of information.

Alternatively, what was commonly present in these examples was the user's attempts to find and understand a piece of themselves based on what they had contributed to an installation. Whether it was feeling one's breath as wind, visualizing a pulse, or understanding how our bodies triggered certain sounds, these interactive experiences guided the user to a deeper meaning through the use of their input. "All this feels very easy and intuitive to the user, almost playful, and users will not even realize that they are being tracked and that they have become part of a computerized system" (Mignonneau and Sommerer, 2005, p.839).

2.3.4 Design Considerations for a Context-Based-Smart Interactive System

As my research progressed, I wanted to apply these concepts of direct-user input into *Air + Water's* design. I wanted to express the users' input in a meaningful way that made their input worth something, not only to them, but to the space they occupied within a scenario that orchestrated the purpose of actions taking place from the input including its administration. Setting the stage for these outcomes had to include the right pieces so that these individual inputs could be processed and translated into something rewarding and worthwhile to the user. The ideas, design models and critical examination of interaction and context from the supporting literature have led me to create my own conceptualized idea of an interactive installation space illustrated in figure 4. My working ideas stemmed from the use and placement of sensors, their relevance to the incoming data, the data's processed and transformative effects to the output and lastly the output itself. The applied uses and the evaluation factors presented other possibilities of interactivity, evaluation of that interactivity and evaluation of the experience within the system.

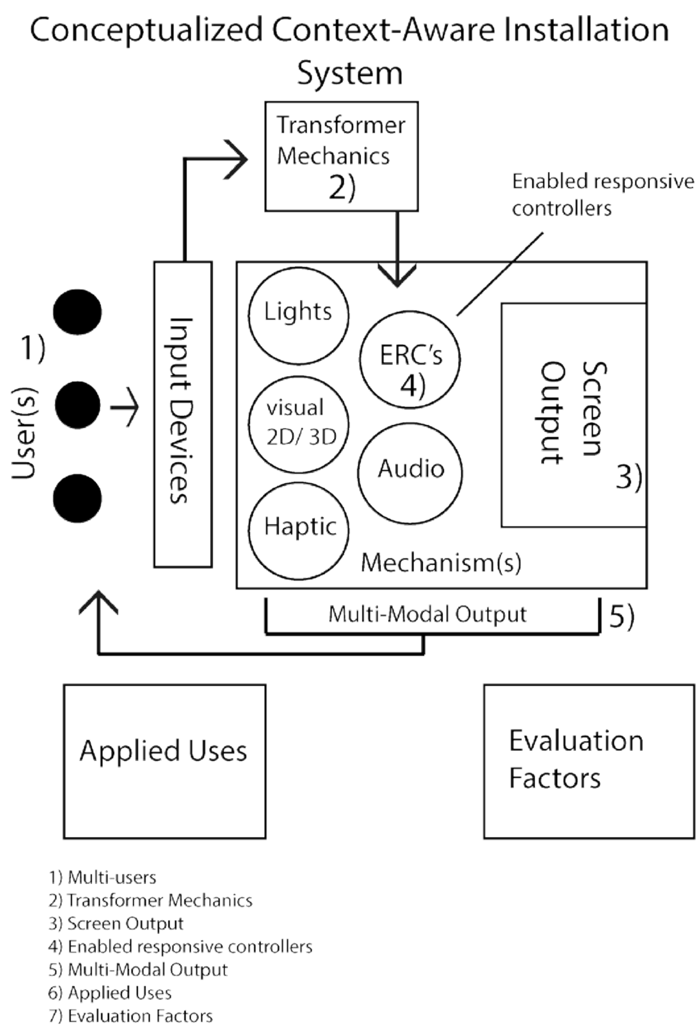


Figure 3. My Conceptualized Idea of a Context-Aware Installation System.

Figure 3 presents my conceptualized idea of a context-aware installation system. I attempted to apply this diagram when working with the chosen inputs touch and later breath. The diagram detailed the process of a user's interaction with the system and what types of modalities could be affected by their input. Starting with the user(s), they offer their input into the system through the devices that help elicit the required actions. The input is then transformed into complimentary attributes and mechanics within the nature of the interactive installation system. *Air + Water's* breath pressure input is extracted from the use of bubble wands. I have utilized ubiquitous computing devices such as sensors to not be obtrusive yet effectively capture the data of user input through a customisable and relevant tool. Once extracted, the breath pressure inflates the virtual bubble on a monitor and those generated properties are left to stay with the resulting size of the bubble. Location of where the bubble blows depends on which bubble wand is used and is left to float until it pops. A watercolor stain is left where the bubble popped. This watercolor stain also inherits the size of bubble.

The visualized display is the first source of output that presents the expressed input's data. Other modality sources such as lights, audio and haptics and other enabled responsive controllers are physical attributes of the system that can be controlled or react to the user's input in real-time. Dennis Lupiana iterated about the nature of a ubiquitous computational device or the use of invisible computers. This ubiquitous characteristic makes sensors appear less intrusive and more freeing to become relevant and adaptive. "UbiComp environments are highly dynamic and saturated with computing devices embedded in everyday objects that gracefully integrate with human activity" (Lupiana et al., 2009, p.518). Applied uses and evaluation factors are all included into the system's existing parameters that can be added to improve the experience of the system.

I have taken these required steps into account from what I have learned about smart spaces. The clarification and classification of a smart space environment that Lupiana targets towards for the sake of clarity falls within the conceptual idea of context-aware information and how it is used. His term “true user mobility” (Lupiana et al., 2009, p.521) focuses on these four components that define the idea of a smart space within ubiquitous computing: Ubicomp devices, Wireless Networks, Sensors and Reasoning Mechanisms (RM’s) with RM’s in the center (Lupiana et al., 2009, p.521).

I have briefly taken into consideration this idea of the true user mobility because it had fallen in line with my formulated distribution of context and information. I wanted to apply my conceptualized idea of an interactive space through the idea of context and context-based tools, inputs and outputs through a harmonic and complimentary process. I started to think of characteristics and attributes that would work within the context as I prototyped and looked at the forms of interaction as explicit forms of context. I would later exploit inputs through, attributes, characteristics and tools. The implicit connection would then stem from these explicit actions and later inspire multiple ways of visual expression.

2.4 Chapter Summary

In this chapter, the exploration of context was looked at in a deeper meaning. The ideas and examples that utilized context and direct-user inputs shaped the idea of using and understanding information in order to act accordingly. This relationship of relevance and information became a thought process that began to structure my design process. Through the works and examples of context-aware applications, interaction design frameworks and the nature of smart spaces, I began to critically formulate these pieces into a conceptual contextual-aware interactive system. The next chapters look into applying what I have learned and studied into practice. I start to brainstorm and develop a blueprint in order to start bringing my ideas, research and theory into fruition. The following chapter contains subsections that explore the unique applied methodology of research through design and interaction design methods. Guidelines and evaluation methods from the user-centered design methodology are explored to better understand the kinds of interactions I wanted to produce in order to build better forms of communication through the information provided by these user inputs.

Chapter 3: Mixed-Methodology and Methods

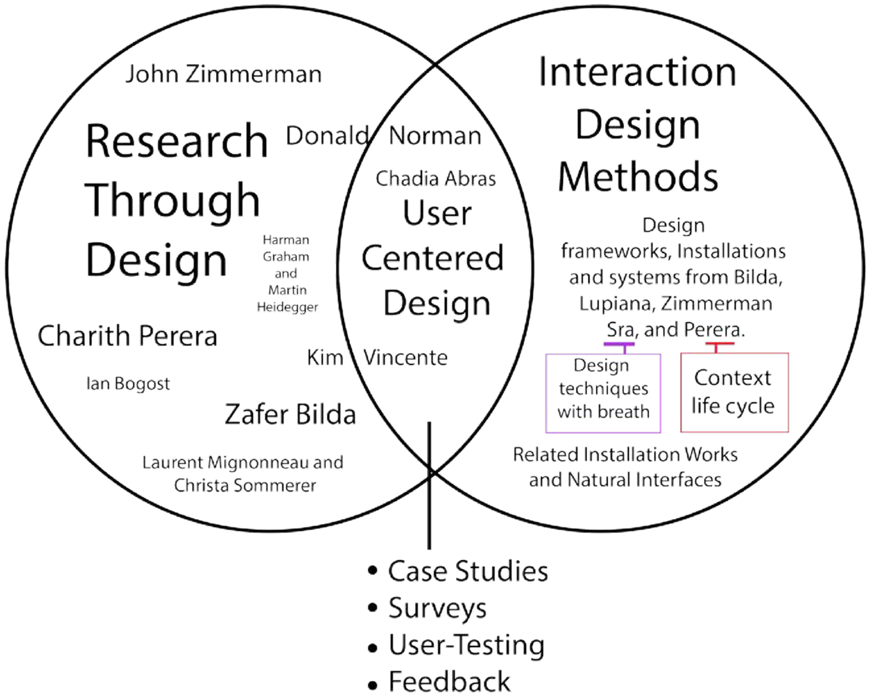


Figure 4. Use of Methodologies and Methods in a correlation to one another.

Through the use of literature and better understanding of interactive practices, I have developed a mixed-method approach to help me design with the direct-user inputs touch and breath in more complimentary ways that could provide more effective outputs. The above Venn diagram illustrates background literature, related works, case studies and frameworks I have looked at within my research. The research through design methodology began at the early research stage starting with philosophical views. As I continued to connect ideas from literature to design practices presented in frameworks, examples and case studies, I began to move onto more technical forms of interaction design methods. This later led into evaluation methods on how to understand the effect at which the interactive installation was grappling on the user's engagement. The following presents the information I have gathered within the research through design methodology as I applied significant lessons from literature into practice. The Interaction design methods bridged my concepts and sketches of what kinds of feedback I knew could be associated with my chosen inputs touch and breath. Lastly, I placed my research and work into action with evaluation methods I derived from a user-centred design methodology as I tried to figure out how I could evaluate the capabilities of my latest installation system *Air + Water*.

3.1 Research Through Design and Understanding User Interfaces

Research Through Design was a methodology I came across in one of my readings that I had applied toward similar processes of understanding user engagement. The methodology is usually a designer inquiry that focuses on the making of an artefact with the intended goal of societal change and a part of iterative process that could help envision potential futures and possibilities (Roggema, 2016, p.3). I have seen commonalities of this approach within Charith Perera's "Context Aware Computing for The Internet of Things: A Survey" and John Zimmerman et al.,'s "Research Through Design as a method for Interaction Design Research in HCI" papers. They both applied similar forms of the methodology to better understand existing design approaches produced by designers within the Human Computer Interaction (HCI) design research in return for better research benefits. "Design researchers also undertake problem framing that helps identify important gaps in behavioural theory and models" (Zimmerman, 2007, p.497).

These papers helped me understand the process of making better refinements and iterations of existing systems in which have forced me to think critically about the design mechanics of complimenting the user inputs of interest. The Zimmerman paper specifically helped ground my own context-driven design practices by showcasing where my interaction design research and practices fall within this line of HCI research and exploration.

Zafer Bilda's "Designing for Creative Engagement" article developed a framework of models and phases of cognitive learning to evaluate the engagement of users in interactive artworks. The paper's scope addressed different situations of interaction design that could be iterated into other, if not, better forms of engagement through observation methods, workshops and surveys (Bilda, 2007, p. 529). What both Bilda and Zimmerman's frameworks have in common is the study and conceptual understanding of people's ability to constantly make connections with information from a variety of sources, backgrounds and disciplines and learn from them (Zimmerman, 2007, p.498). Humans, who are constantly making connections to what they see, do, sense and feel have always been the backbone of interaction design research. Putting the user's senses first potentially could lead to understanding the expected or otherwise unexpected outcomes that could act as complimentary feedback.

I applied research through design as a foundational pathway into understanding user-interaction within the context of an interactive art installation and smart space. Donald A. Norman's "The Design of Everyday Things" provided examples of these unintentional design mishaps from designers. In most cases, the human thought process to a designer of how the user would interact with a system, space or object was usually omitted in the design process and became one of the main reasons why certain affordances, manuals, instructions or placement of buttons and switches did not come easily or make much sense sequentially to the end-user engaging or using it (Norman, 1990, p.21-23). In the first chapter of Kim Vicente's "The Human Factor: Revolutionizing the Way We Live with Technology", he used case studies that looked into poor design of complex systems and what could have led into high possibilities of human error following catastrophic tragedy. His first chapter touches upon the Chernboyl nuclear catastrophe in 1986 (Vicente, 2004, p. 9-13). In another example, he touched upon the case of the E320 Mercedes-Benz model, where designers had aim to make certain technological factors and features easier and simpler, yet in practice they were more difficult and not the most practical for the users use or time (Vicente, 2004, p 14-15). Vicente also discussed how extensive workplace hours that affected workers' sleep patterns such as pilots, nurses and doctors, could greatly affect everyone within such complex systems (Vicente, 2004, p.22-23). I believe that this could also be applied to interactive installation art works. If the user is confused or cannot make a connection to the piece through their actions or input, then the full experience of the interaction may not be met. The full potential is also lost in translation and users become victim to poor design. Complementary actions that are meant to weave and guide the user to the resonating feedback could be robbed from them due to poor design and might possibly never become aware of what experiences were lost.

The ideas surrounding engagement and uses for objects are always aligned with how we approach and apply information. This helped me think more critically about the steps I wanted to take for the user, so they could have much more engaging and synchronized interactions. With the user in mind, I started to carefully think about the direct-user input I wanted to work with and what kinds of interactive scenarios I wanted to fabricate. This is when I started to think about intuitive, free-flowing forms of engagement that required less thought of how to go about performing an action. The next section discusses this exploration, as I learn about interaction design methods that focus on natural and intuitive design practices.

3.2 Interaction Design Methods using Natural and Intuitive Design Practices

Natural interfaces and interaction design methods have been very common in many interactive installation spaces that aimed to use comfort, intuitive thinking and familiarity as a guide to achieve stronger user engagement and significance of the user's input. Laurent Mignonneau, Christa Sommerer and Misha Sra have all used natural interface methodology to help design and express these inputs in applicable ways and outcomes. The use of a gesture or action required from the user could be easily done when the right parameters of creating that action are capable of becoming recognizable. The less complicated the interactive tool or space is to the user, the more likely they will perform the correct action. Actions following afterwards can lead into more complimentary states of expression. "Natural interfaces are for example gesture, speech, touch, vision and smell based interactions or basically actions and sensations that refer to our daily life experiences" (Mignonneau and Sommerer, 2005, p.839). Natural interfaces became a playing field of complimentary. They questioned what could or could not work in an interactive scenario that gathered sensory data. The interfaces I design could bring out the best out of the user-inputs they applied to.

3.3 User-Centered Design and Evaluation Guidelines

User-Centered design revolves around the iterative process of a project, system or prototype where the user is heavily involved in the iterative process (Abras, 2004, p.1). I had researched user-centered and iterative process design methodologies through Chadia Abras's article "User-Centered Design Methodology" and articles from the Interaction Design Foundation website. Chadia's article referenced Norman Donald's design practices. The user-centered methodology originated from the research laboratory at the University of California, San Diego in the 1980's where Norman worked (Abras, 2004, p.1). It would later be used widely after his publication of "User-Centered System Design: New Perspectives on Human-Computer Interaction" (Norman and Draper,1986 as cited in Abras, 2004, p.1). The different ways on how to include the user varied but the main factor was that the design of any system or prototype was heavily influenced by the user. Applying this concept to my design process was critical to designing around a user's input along with the input's context. The thoughts from users on their overall experiences with the utilization of their engagement, the input and its relevance to the system would come much later through user-testing and an evaluation process I later discuss in chapter six. I had read and touched upon a lot of Donald Norman's perspective on human to object relationships in his book "The Design of Everyday Things". However, in his earlier publication, "The Psychology of Everyday Things", Abras mentioned this guide Norman used to cater to the design and needs of the user:

- "Make it easy to determine what actions are possible at any moment.
- Make things visible, including the conceptual model of the system, the alternative actions, and the results of actions.
- Make it easy to evaluate the current state of the system.
- Follow natural mappings between intentions and the required actions; between actions and the resulting effect; and between the information that is visible and the interpretation of the system state. (Norman, 1988, p.188 as cited in Abras, 2004, p.2)."

These guides have been helpful in placing the user's needs and actions to help shape the design of an interface. I found this quite powerful in regard to the user taking ownership of what would make sense to them in order to build a better relational engagement with a computerized system. The iterative design process that came from within this user-centered methodology placed the usability of a prototype into action. In order to see whether or not the interactions from my system would happen, the design itself needed to go through some form of user testing. Rapid-prototyping and user feedback are heavily involved in iterative design and helps the designer determine whether the idealized expectations of the prototype are being met (Interaction Design Foundation). Feedback from the previous iteration is then taken into consideration for the next iteration for hopefully better results.

Prototypes can go through this process at any stage of production. It is always best to get any hiccups out of the way in the earlier stages so the next iteration can be delivered in a better state with fewer fixes and design changes, especially when there is a deadline (Interaction Design Foundation). Jakob Nielsen's article "Iterative User Interface Design" used four case studies where user interfaces were being iterated to meet certain needs until they were proven to do so. He also discussed measuring usability using ratio scaling and improvement. It is what designers should be looking for at each iteration stage to help them determine if their prototype is reaching any of the following points:

• "Easy to learn: The user can quickly go from not knowing the system to getting some work done with it.

• Efficient to use: Once the user has learned the system, a high level of productivity is possible.

• Easy to remember: The infrequent user is able to return to using the system after some period of not having used it, without having to learn everything all over.

• Few errors: Users do not make many errors during the use of the system, or if they do make errors they can easily recover from them. Also, no catastrophic errors should occur.

• Pleasant to use: Users are subjectively satisfied by using the system; they like it. (Nielsen as cited in Nielsen, *Usability Engineering*)."

3.4 Chapter Summary

These guidelines both produced by Nielsen's list and Norman's showed reasonable evaluation marks to look out for when designing for favorable user interactions to occur. Less cognitive overload and timely appropriate use could effectively improve the state of a prototype at each iteration stage. Other forms of evaluation have not only looked into the usability of the interface but how it also made the user feel. I had an idea of what to look for and consider when going about the utilization and understanding of a the direct-user input's context within an interactive installation system.

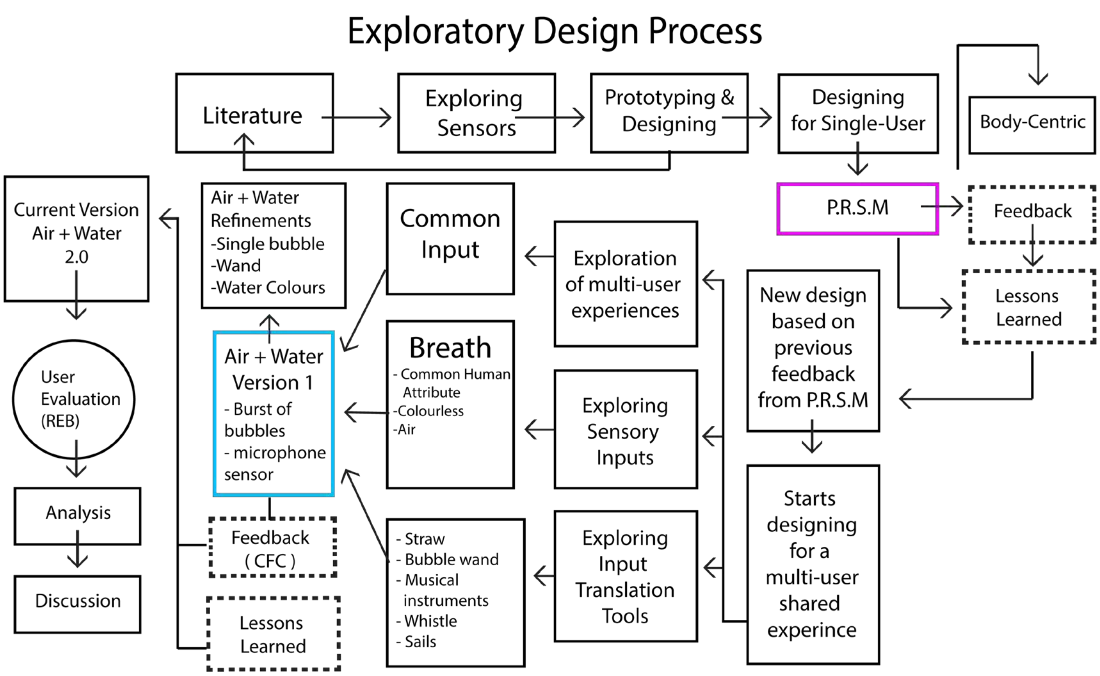


Figure 5. The Design-Process Diagram that follows the design process from creating a single-user interaction system to a multi-user one.

Figure 5 illustrates my entire design process from literature, to prototyping for single-user interactions and later, to multi-user shared experiences. Using what I have learned from literature on context, smart spaces and the applied uses of user input within interactive installation spaces, I started to develop prototypes centered around user inputs that came directly from the body. In the next chapter, I present my design process and explain my approach to designing an interactive installation system through the contextual attributes of touch and breath.

Chapter 4: From Single to Multi-User Interaction Spaces: An Exploratory Design Process

Air + Water became the result of an experimental design process of complementary input using tools and 2D visuals to express its input breath. I first began this exploration through experimenting with touch through *Personal Reactive Soft-Sensory Mechanics (P.R.S.M)*, as a single- user interactive interface (See Appendix A for images). It used a reward-feedback loop through soft touch and playfully projected animations. I wanted to experiment with intimate forms of input to output communication and feedback before moving on to designing a common experience amongst multiple parties. *Air + Water* became the targeted multi-user interaction system, where users could share an experience through their actions, breath input and visual output as they created a variety of collaborative digital art pieces.

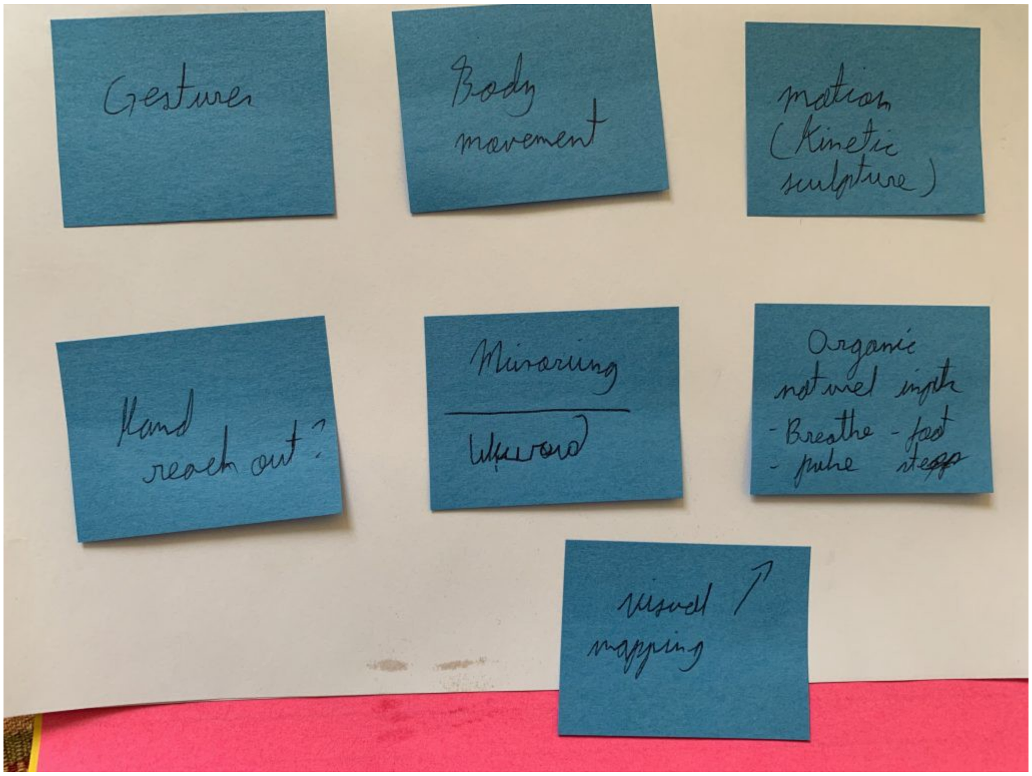


Figure 6. Brainstorming sources of actions from the body into mapped visual outputs.

I began my development with a few notes on what inputs I could formulate visualizations that could closely relate and work well with. The ideas at first were very broad, ranging from gestures to kinetic sculpture manipulation from natural inputs within the body such as breath or heart rate. I eventually chose to work with inputs derived from the body because such inputs held more personal meaning than any other kind of input source. Expressing this form visually aspired opportunities that could allow for a shared experience amongst users since each user's input would be produced from their own being and continue to be complimented within a collective common visualization. The following chapters explore this documented process of designing around these forms of direct-user input and how *P.R.S.M's* design influenced the following design prospects of *Air + Water*.

4.1 First Beginnings of Sensory-Input with *P.R.S.M* (*Personal Reactive Soft-Sensory Mechanics*)

Personal Reactive Soft-Sensory Mechanics or *P.R.S.M* for short, is an interactive soft-sensory interface that projected 2D geometric shapes on an octagonal-prism glass plant box. Using Processing and the Arduino IDE, the visuals were activated through pressure being applied to the soft mat. The mat consisted of four touchpads where each touchpad outputted a different visualization. Each visualization was a 2D geometric animation that rotated and took the shape of some kind of flower. *P.R.S.M* used life-like attributes such as nature to become a transformative median that translated a negative attribute such as tension into a positive release of calm. *P.R.S.M* was powered via USB cable from the FLORA microcontroller. Each analog pin is connected to a 1.0K ohm resistor. An LED was placed in the centre of the mat pad and faded into another color when a touch pad was pressed. Earlier documentation of P.R.S.M can be found in Appendix A.

Figure 7. Personal Reactive Soft Sensory Mechanics' First Iteration and Design Process. 2019.

P.R.S.M was first created through one of my elective courses at OCAD University known as Body-Centric Technologies. I was exposed to a lot of interactive design elements that could further immerse the user's interactions with soft-touch interfaces. *P.R.S.M's* design process was heavily influenced through the thoughts and ideas I had consumed through literature, so it became integral to include in this thesis. When I first developed *P.R.S.M*, I was interested in making an experience that made me feel less anxious and calmer. I had an old blanket that was very soft and its vibrant mustard colour made me feel a bit cozier. Essentially, I was aiming to make a system that resulted in me feeling good or better. I wanted to visualize this feeling further through a sensory experience and decided to take the next steps in creating *P.R.S.M* from a pure emotional context through touch. I thought a touch pad could become an easily approachable interface, that could bring about more single-personal experiences to the table and not have much thought on what else to do with it other than apply pressure.

P.R.S.M's soft interface was all correlated to the idea of ease, calm and pleasantry. Just as the interface itself, I aimed to make *P.R.S.M* as simple and easy to use as possible. I also started to frame *P.R.S.M's* design further by attaching the idea of calmness to nature. The sensation of this specific-feel good feeling, was something that was shaping *P.R.S.M's* interaction system. Everything about *P.R.S.M* needed to be correlated with ease and calm. That was when I was inspired to create visuals to work with this calming theme relating to life, plants and nature. The addition of the plant glass box really started to bring out the best out of *P.R.S.M's* design. I later presented *P.R.S.M* to my colleagues and instructors and received their feedback after their brief interactions with the soft-sensory system.

4.1.1 Lessons Learned from P.R.S.M and Next Steps

The feedback I received on P.R.S.M's design was overly positive but I also got interesting feedback on *P.R.S.M's* aesthetic, its visual display choices and thoughts on using the system. I received comments such as: "*It could look neater, I actually like the roughness of the touch pad! The fur reminds me of a pet, the touch pad is quite shaggy, the visuals are nice, The box really brings out the colours and works with the theme, It's a cool idea for a desktop object, the touch pad could be bigger"* (Multiple comments from my class, 2019.

I also noticed people trying to press on more than one touchpad to make a combination. What struck me the most however was that there were little comments about the connection between the elements of *P.R.S.M* (such as the touchpad and flower visuals) to their feelings of calm through touch. This was not because I had expected them to underline the meaning and personal attachment I had with the blanket during *P.R.S.M*'s process, but because the actions, the interface and the visuals were not mentioned once as contextual or working well together but expressed only as a pleasant experience. *P.R.S.M's* visuals were projected through the glass box and a laptop screen at the same time. This was where I learned that the visual effect through what medium the output is being presented also made the experience much more effective.

My class and instructors all agreed that the plant box really made *P.R.S.M* more effective as a visual output than the visuals being presented on a flat screen. What I really took away from *P.R.S.M's* feedback however, was the lack of conscious relations presented from *P.R.S.M's* interface. Users expressed it felt soft but also associated with things that reminded them of their furry pets due to the softness and shedding of the touch pads. Associations to the visuals did not matter so much and I later wanted to improve the appearance of *P.R.S.M* and the functionality of the touch pads as each pad could activate one visualization at a time but not combine the two. I had taken these design considerations into account for *P.R.S.M's* development but I also accounted for other design and user input explorations.

4.1.2 Stepping Away from Touch and Working with Breath Input

The lessons and feedback I had learned from *P.R.S.M's* design process lead me to think about other sources of context that could still link directly to a user's input. With *P.R.S.M's* system, it provided a feedback reward loop to produce calmness and it focused on soft touches and pleasant visuals in order for the user to make them feel good. At this stage, I was also looking for other sources of input that I could design with. Touch could be applied to anything and its informational bandwidth varied to focus on interfaces rather than itself as an input. This was difficult to illuminate in *P.R.S.M* so I began to think of inputs that required more focus and attention on them. Breath posed so many possibilities mainly because it was an input that everyone could execute and was also an integral direct-user input that came directly from the body. It was an exciting and also less obtrusive input to capture. The next design phase of this process continued to a multi-level user interaction where the output became a collective of a shared experience. After the observations and feedback I had received on *P.R.S. M's* design and interaction experiences, I reflected on what had been said and what I wanted to expand on in a multi-user interaction system that required a collaborated effort to create a montage-like visualization of human breaths. This is when I started my development with *Air + Water*.

4.2 The Formation of a Multi-User Interactive System: Air + Water

Air + Water was a design process that I began to explore based on my findings and observations with *P.R.S.M*. It dealt with my choice of wanting to explore a more specific source of input that would not fade into the background like *P.R.S.M's* soft-touch interaction did. With breath as an input, I could explore and learn more about the characteristics of air that came from a living person and translate that idea into a visualization. The system comprised of a laptop, a monitor and three 3D-printed, customized bubble wands that each encased a Rev.P wind sensor. *Air + Water* was first developed using Processing and the Arduino IDE but its software component later was moved to the P5.js library with the use of TypeScript.js. The Rev.P wind sensors measured the intensity and temperature of wind pressure however only wind pressure was used. Users could simply pick up a bubble wand, blow into it and watch a bubble generate its growth on screen. A watercolor stain would appear and stain the blank canvas upon popping after a few seconds. The locations at where the bubbles would grow were correspondent to the placement of the bubble wands.

The system in earlier stages was only able to visualize the user-input through the growth of a bubble and produce a watercolor stain based on the bubble's size. Watercolour stains were randomized, and users had no control over which colour they wanted to produce. The latest iteration of *Air + Water* used context-aware features that generated information from users and affected the visualization based on this data. With the laptop's web camera, the system was able to detect how many users were using *Air + Water*. Bubble sizes also had set-size limits so bubbles would pop when it reached the size limit instead of continuously growing larger. Based on how many people were in *Air + Water's* space, the system would generate different hues of watercolour stains. If one person was detected, only watercolor stains of blue and green would appear. If a second person was detected, there were possibilities of yellow and orange watercolor stains appearing on the screen in addition to the previous watercolors. Three people or more could allow access for the addition of red and purple watercolor stains to appear. The more people that came close to engaging with *Air + Water*, the more water colour stains it would generate. These watercolour activations states were ranked from cool blue to hot red, leaving a spectrum of colours to become warmer and more intense when more people participated. The system would present this information through a smiley face icon. If the icon was greyed out, this indicated that that watercolor set was not available due to the lack of people being around *Air + Water* (See Appendix B for images).

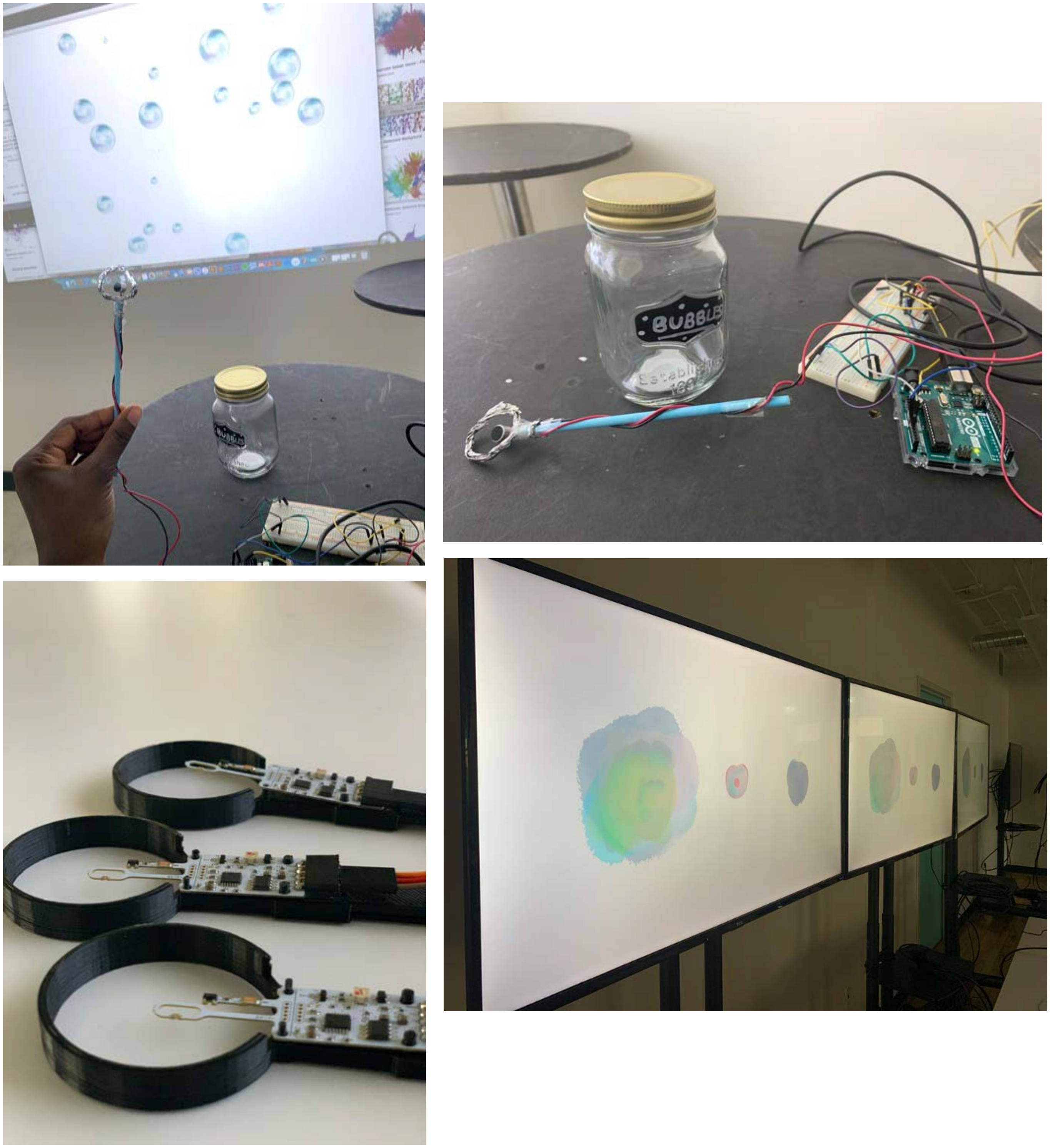


Figure 8*. First and Second Iterations of Air + Water from left to right. (2019-2020).*

When I first began this exploration with *Air + Water*, I started to think about the attributes of a breath. *Humans breathe out air. What can they breathe out into? What would that result look like?* Breath was colourless and it could be closely associated with air. I started to think about the kinds of tools, objects and environments that humans used to execute a breath or associate breath with. This train of thinking led me to further investigate this relationship and explore the kinds of visual outputs I could come up with. The first thing I thought of was watercolours due to their airy yet vibrant characterises of expression. They had the ability to present the vibrancy of life within a person. They also reminded me of raw and powerful feelings I could associate as a common attribute of being human.

However, I did find the idea of people blowing out watercolors to be a bit odd and not fitting well with the relativity of actions I wanted to illustrate in a contextual system. People would not generally blow out watercolours, so this mismatch led me to think of other ways to transfer this physical action of blowing into a contextualized space to represent breath as a watercolour stain through a better form of context.

The next visualization I pictured were bubbles because they had the ability to carry air. I figured I could apply the manipulations of creating bubbles with my breath and have the water colour be that resulting surprise of a visualization. Using Processing and the Arduino IDE, I started experimenting with this concept and began making virtual bubbles using my breath.

The first iteration started with a sound sensor and a few items in my household that I could make into a bubble wand. Because I was now working with bubbles, I figured the use of the bubble wand tool would help encourage the user to take the next steps to blow into the wand. To maximize this informational cue, I had a bubble jar next to the wand that read *Bubbles* across from it. The resulting visualization was a cluster of bubbles that spawned in a variety of sizes through the act of one blow through the wand (See Appendix B for images). As I was still experimenting with the visualizations and effects at the time, I later showed this concept to my colleagues and a few staff members at the CFC in Toronto, Ontario. I received feedback and comments from them on *Air + Water's* premise and their ideas on input-visual translation with other kinds of sensors I could use.

The following feedback is listed as follows for both the concept and technical choices I made at the time:

1. *"I would like to see some form of a response from the user simply touching the wand that could follow up to the act of blowing."*
2. *"You could present different kinds of blowing pressures? and show such intense inflation through the bubble?"*
3. *"What does the water colours create and connect with through the piece? Feels the water colours have little agency at this point."*
4. *"You could present one bubble per breath and size depending on how long the breath is."*

Feedback I received on the programing process and the use of sensors:

1. *"Do a timer countdown for the bubbles of how long they will live…"*
2. *"Instead of a microphone you could use a temp sensor instead. Much more controllable and you'll pick up less noise that way!"*
3. *"It'd be cool if once the bubble popped you could smear the colours on the digital canvas or have people pop them themselves."*

   (Comments from Colleagues and Staff at CFC Media lab).

The feedback I received at CFC helped shape my ideas to better present the creation of the bubble. It got me thinking about interactions with the wand, the formation of bubbles, and the engagement I was trying to produce through these actions. For instance, instead of having the breath generate a cluster of floating bubbles through one blow, I could use the input to generate a growing visualization of a bubble. When a user stops blowing, the bubble floats away on screen until it pops, making for a clear translation.

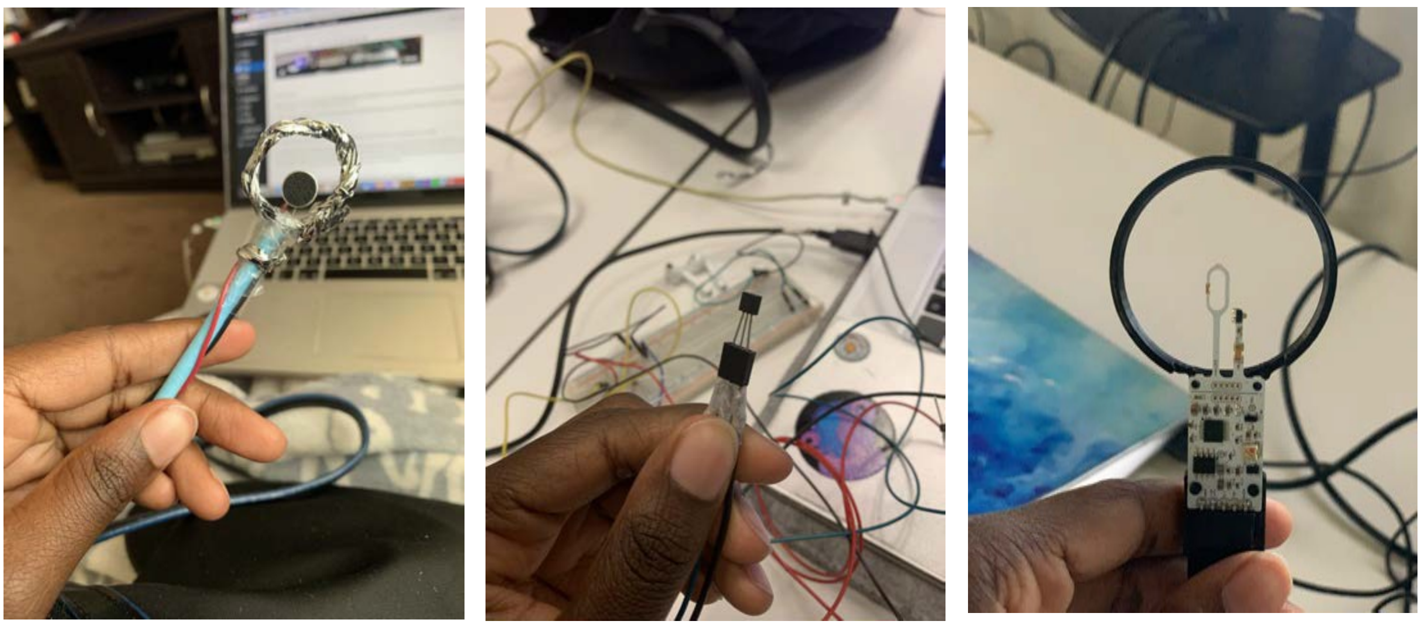


Figure 9. Earlier uses of sound and temperature sensor before moving to Rev.P wind sensor.

I attempted to make this happen as I still explored with other sensors before settling with the Rev.P wind sensor. The sound sensor that I had initially used created too much noise in the data and made visualizing such a transition difficult to create. I had tried a temperature sensor that would capture the temperature data of one's breath but translating this data into the growth of a bubble did not go as well. Finally, I settled on the use of the Rev.P wind sensor, which specialized in measuring not only temperature but wind pressure successfully.

4.2.1 Air + Water's Feedback and Next Steps

The feedback I had received from my peers and the staff from the CFC group all came up with a few other mediums that I could use for executing breath other than the bubble wands: *whistles, musical instruments, straws, balloons, wind sails, kites* and the list went on. These were all interesting suggestions to consider as I tried to apply other attributes and contextual information of the input from one related action to another. However, the feedback I received from my peers made me think more about the vision and output I had envisioned for *Air + Water*. It was its thematic state of air and translation of life through one's breath. Some of the proposals from my peers seemed to only illustrate additional variables such as sound into the mix of these interactions that could potentially distract from the initial execution of the breath input, I wanted to express. This multi-modal execution at this stage of the interaction did not appeal to me or my thoughts of *Air + Water* so I continued with my plans to work solely with breath, using it as a tool to execute just that input and visualize it.

Air + Water also had yet to become a contextually aware interactive system at its current state. This element of the installation system, as well as its visual counterpart, required to be implemented to test my research question and to take what I have learned through literature and explorations into practice and further development. The next stage of *Air + Water* would integrate context aware elements such as machine learning, user count and pose detection using a library called poseNet to help utilize the use of the user's input within the context of the system and express the user's engagement more effectively.

4.2.2 Sources of Context

After exploring the user inputs and their characteristics within their respected interactive installation systems, I wanted to properly list the existing sources of context I had come up with and created with *P.R.S.M*. I then began to come up with other sources of context for *Air + Water*.

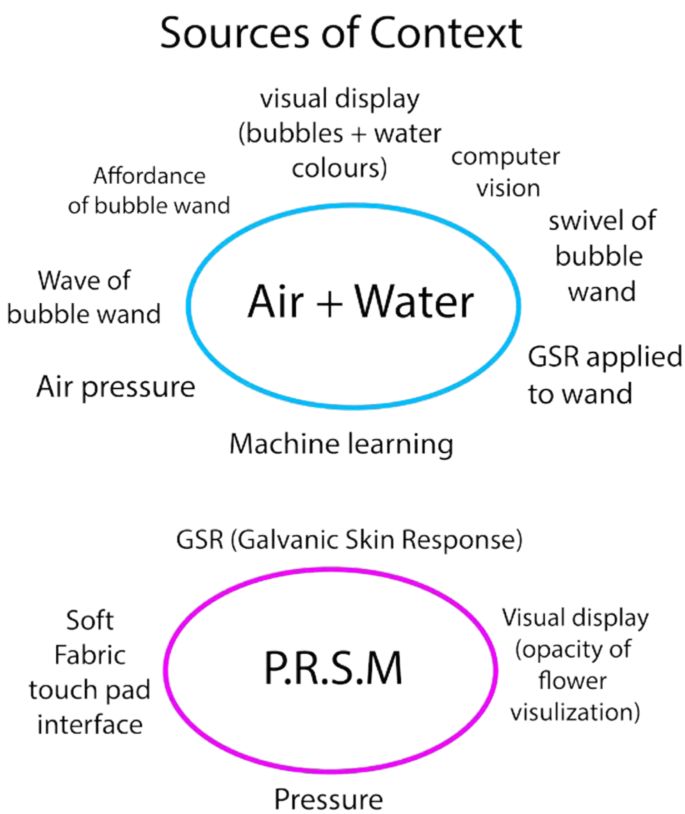


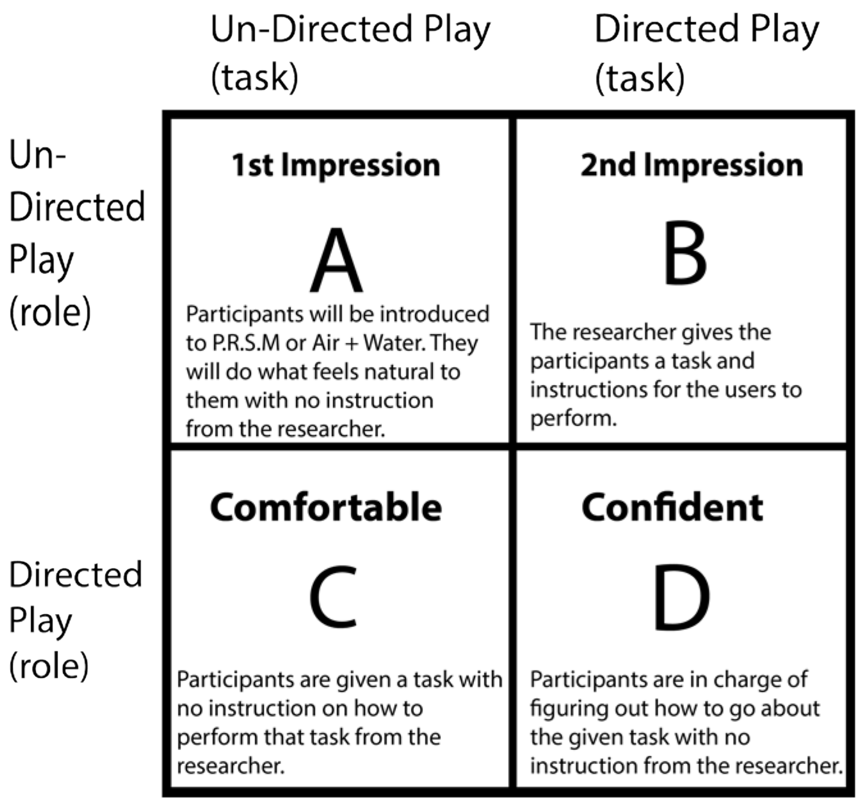
Figure 10. Sources of Context Diagram for Air + Water and P.R.S.M.

In addition to listing existing sources of context that I had already added in both systems, *Air + Water* showed promise in the utilization of many sources of context from its user input. Certain actions could happen based on past actions such as the act of blowing into a bubble wand or swivelling the wand instead. Information from the computer's camera could affect the output of the types of watercolours the system would output. So far, the data from the wind sensor was only able to manipulate the growth of a bubble and later, generate a random watercolor stain upon popping. I evaluated this version of *Air + Water* through an evaluation model to see how it fairs with users and their interactions. In a later version, I tested the version that encompassed contextual-aware elements. This version would detect how many participants were using *Air + Water*'s system through the computer's camera. This list would expand *Air + Water's* watercolour list and grant access to more colour outputs as more people joined in and participated.

4.3 User Study for Air + Water

4.3.1 *Evaluation Methods and Investigations*

An in-depth user study was conducted to test the effectiveness of *Air + Water's* context and non-context aware features to users as well as its visual output and its use of breath input. Four tasks were facilitated to observe the user's comfort and experience with the installation as they continued to engage with it. Tasks were structured into an interaction model that fit *Directed-Play (Tasks)* and *Un-Directed-Play (Roles)* scenarios. *Roles* and *Tasks* shaped a scenario that gave more control of a situation to either the users or the researcher. Users would take on roles to complete a task delegated by the researcher. The level of what users were instructed to do in each given scenario depended on the task (See Figure 11). The first two tasks were introductory and exploratory exercises whereas the last two tasks were user-confident exercises and were slightly more goal-oriented than the first two.



A) **Undirected play (role) + Undirected play (task):** Participants will be introduced to Air + Water. They will do what feels natural to them with no instruction from the researcher. This is the first impression scenario to see how they first interact with P.R.S.M or Air + Water.

B) **Undirected play (task) + Directed play (role):** Participants are given a task with no instruction of how to perform that task from the researcher. This is the second impression scenario to test to see if they understand the mechanics of Air + Water's interface.

C) **Directed play (task) + Undirected play (role):** The researcher gives the participants a task and instructions for the users to perform. This is the comfortable scenario to see if the participant understands Air + Water's interface and is comfortable performing the required actions based on practice.

D) **Directed play (role) + Directed play (task):** Participants are in charge of figuring out how to go about the given task with no instruction from the researcher. This is the confidence scenario; to see how confident the participants are with their actions to complete the given task.

Figure 11. User-Task Model used to conduct user study.

This task model was also planned for user-tests with *P.R.S.M* but was not conducted due to the direction of the thesis moving away from touch inputs to breath inputs. Blida used qualitative data such as interviews and observational methods such as video recording to obtain the results of their study. They iterated how usability is not the only form of evaluation but aesthetic appreciation and various engagement qualities within HCI research.

> "Similarly, the evaluation of audiences' experience of interactive artworks goes beyond usability and often involves measurement of aesthetic appreciation and the various engagement qualities which are dependent on personal traits, motivations, expectations, emotions and cognitive states of the audience"
>
> (Bilda, 2007, p.529).

Each of their 10 case studies acquired the team a user engagement model that they believed could help apply certain design considerations for interactive installation practices. I had designed my user studies for similar reasons and to evaluate the effective utilization of the chosen user-inputs and visuals my installation was presenting to users. Each prototype had slightly different timed frames to complete a task with a break in between each task. Each task was later evaluated through a Likert-Scale based questionnaire with two valence questions and two short summary questions that expressed their feedback on the system and their overall experience. Notes on behavior and interaction was recorded and other observational methods such as photography and video recording were used.

4.3.2 Participants

There was a total of 18 participants for this study. Participants were arranged in groups of three. Two rounds of testing were conducted. In the first round, three groups underwent user study sessions that did not include the context-aware feature. In the second round, groups underwent sessions that did include the context-aware feature. Groups were selected and formed at complete random.

4.3.3 Apparatus

Each user study session usually ran for half an hour long. Participants were required to perform four tasks. Each task was timed for 4-6 minutes. Participants were not told this time frame. The first two tasks dealt with impressions and understanding the mechanics of the system. The last two were goal-oriented where users had to reach a specific target to complete the task. The nature of the tasks went as followed:

1. *You are welcome to explore the interactive installation system. Inspect or do whatever feels natural to you.*
2. *Blow bubbles until you spot an x watercolor after your bubble pops on the screen. Each of you is required to do this.*
3. *Each of you will be assigned a specific bubble size to make. To each participant in the group: Please make a small bubble, a medium bubble and large bubble. Do this in whatever way feels right to you.*
4. *Each of you is assigned a different bubble size and a watercolour target. Please make x size of bubble until the product of x watercolor appears.*

After the completion of a task, participants would take a break and fill out the interactive experience questionnaire (See appendix C for this questionnaire). Duration of completing this questionnaire would take roughly 2-3 minutes. This was to examine how user responses would change given the nature of the task and their experiences of doing the task, thus affecting their experience and understanding of the system over time.

Figure 12. Usability testing for Air + Water during first and second rounds of user-testing.

The contextually aware elements incorporated into *Air + Water* were compared to its previous version that did not use context aware elements. *Air + Water* had previously acted more as an interactive system that received and outputted an expressed input through visualizations as oppose to a system being aware of these events and presenting that knowledge to participants through its visualizations.

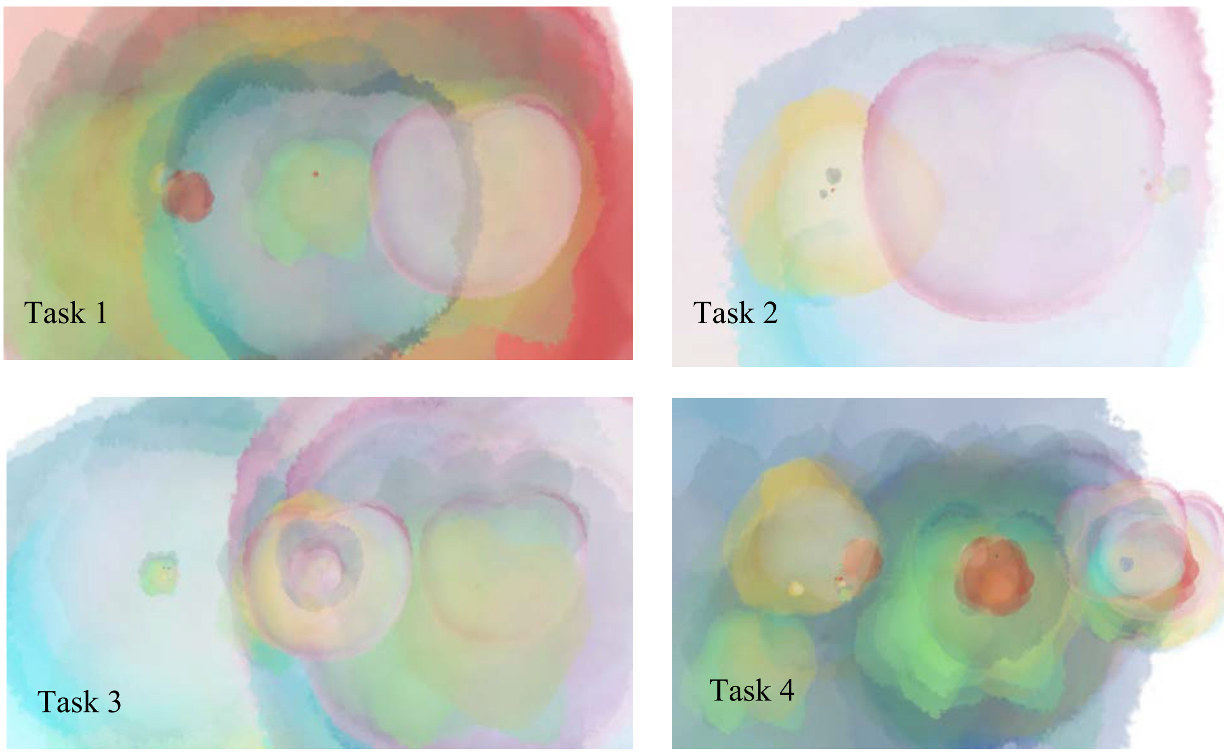


Figure 13. Visual Outputs Screenshots for Air + Water Per Task during a session Round 1 with non-contextual features. (Top left to bottom right: Task 1, Task 2, Task 3 and Task 4).

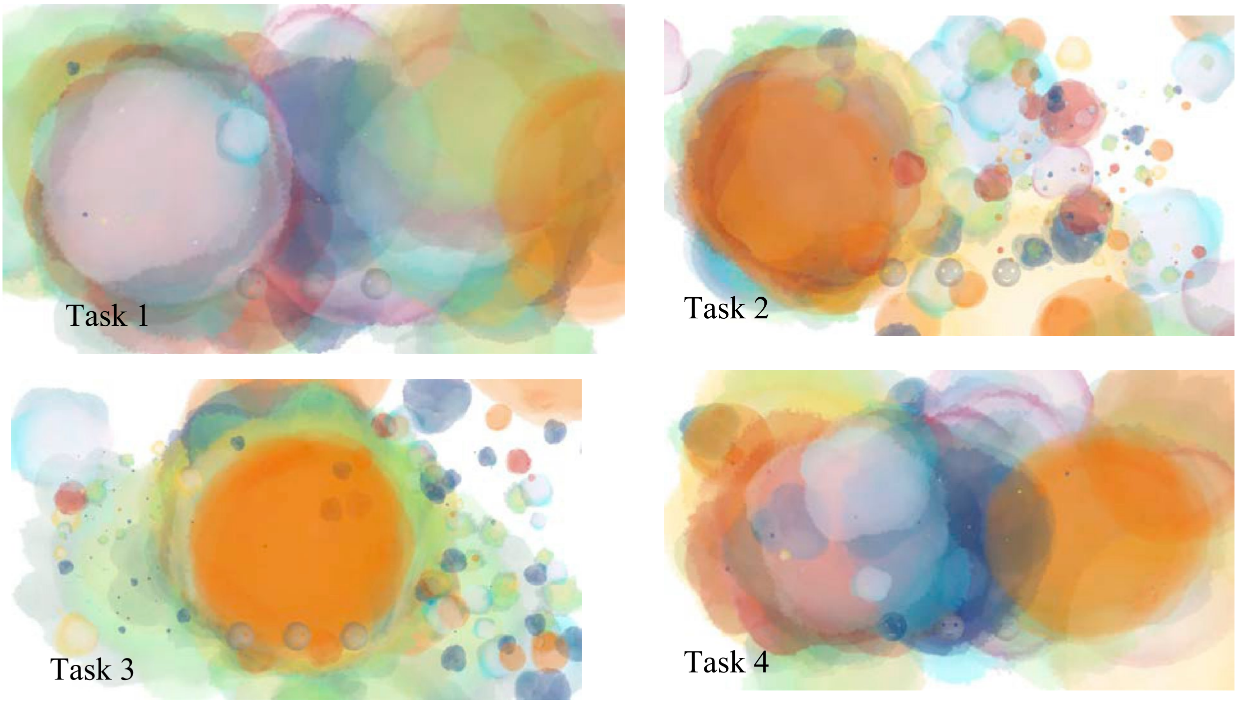


Figure 14. Visual Output Screenshots for Air + Water Per Task during a session. Round 2 with contextual features. (Top left to bottom right: Task 1, Task 2, Task 3 and Task 4).

4.3.4 Findings

Scores related to users' confident use of the system, enjoyment and overall feelings towards their experience were calculated. Confidence and Enjoyment scores were ranked from 0-9 using a Likert Scale (See Figure 15). These questions dealt with arousal. Scores for each task were summed up amongst each group. These scores were then added to the sums of the other groups and then divided by three to determine the average. This was also done for the remaining Likert Scale questions ranging from 1-5. Findings showed that confidence and enjoyment levels increased during Task 3 (Comfortable) at Directed play (task) and Undirected play (role) when participants were tasked to make the bubble a certain size (small, medium or large) but not told how to go about doing the task. Task 2 (2^{nd} Impression) showed the lowest scores at Undirected play (task) and Directed play (role) where users were told to blow bubbles until the bubble outputted a red watercolor stain. Confidence and enjoyment levels decreased at Task 4 at Directed play (role) Directed play (task) but were slightly higher than when participants started at Task 1.

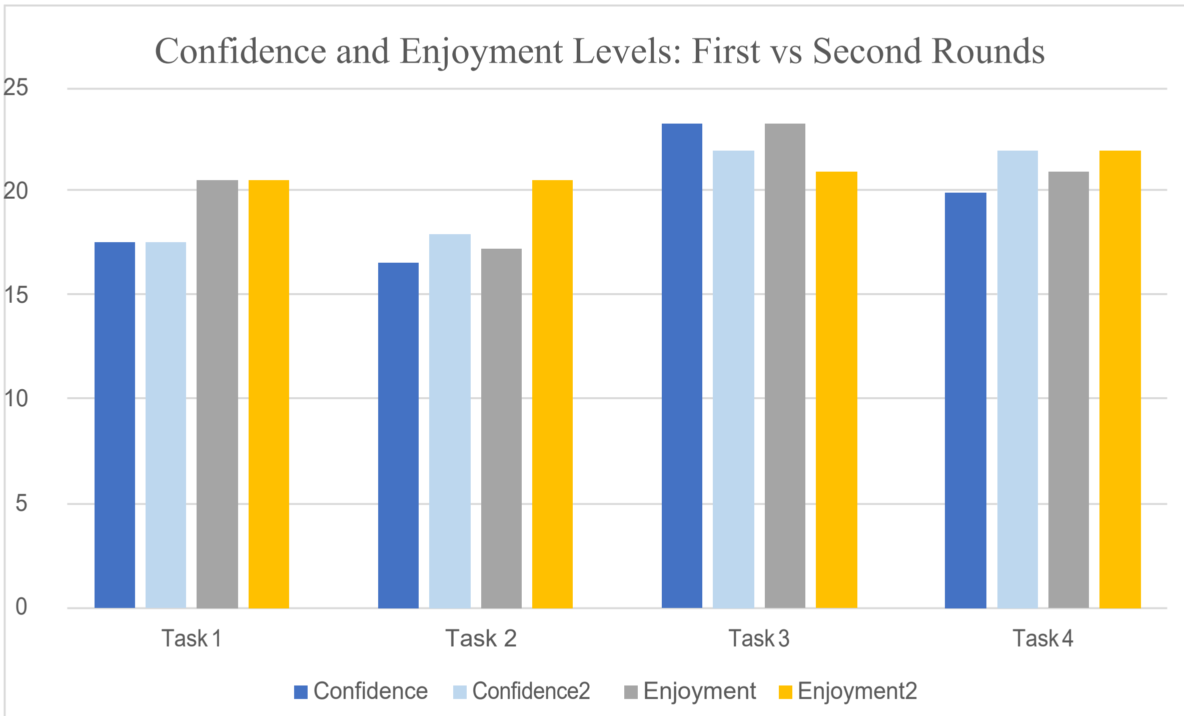


Figure 15. Confidence and Enjoyment levels from first to fourth task within all three groups.

Air + Water seemed to be more enjoyable as a non-specific task interaction system that allowed users to assume roles and have control over how to go about their objectives as opposed to not having a lot of control on achieving a specific task. Figure 16 shows engagement levels for both rounds below. Engagement levels were high during Task 3 (comfortable) Directed play (task) and Un-Directed play (role) in the first round and fell in task 4. In round 2, levels stayed at similar values until they slightly increased in Task 4 Directed Play (role) Directed Play (task).

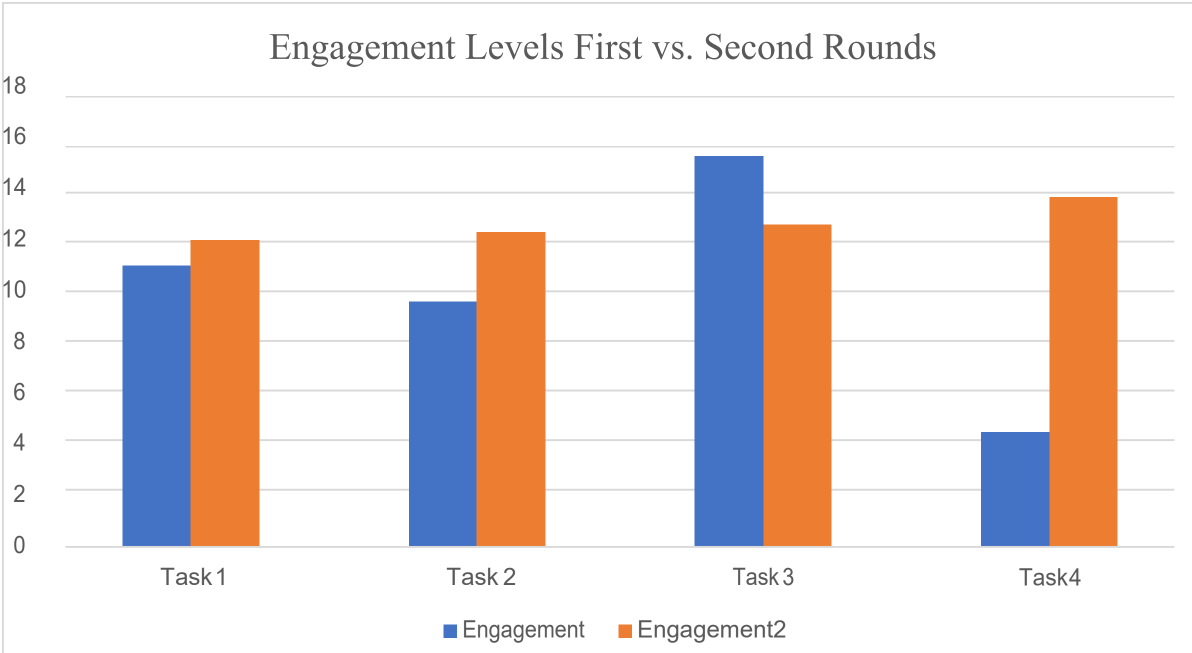
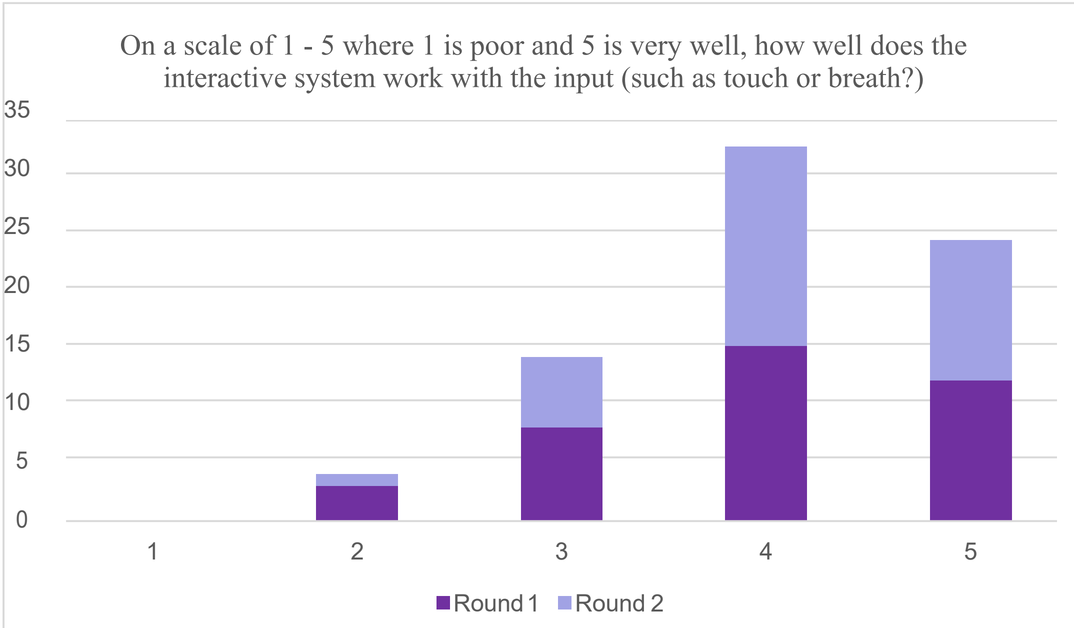


Figure 16. Engagement levels from first to fourth task within all three groups.

Scores for complimentary input and visual feedback are presented below in Figure 17. For the first round, 39.5% of participants found that the breath input worked well with the installation. 47.2% of participants felt the same in the second round. 47.4% found the visualized feedback mapped well with their inputs in the first round and 55.6% in the second round. Participants overall thoughts on the experience being rated in positive, neutral or negative are presented in figure 18. In round 1, 65.8% of users enjoyed using *Air + Water* and had a positive experience. 28.9% felt neutral towards *Air + Water* and only 5.3% had a negative experience. 75% of users in round 2 however enjoyed using *Air + Water* with its context-aware feature despite groups not acknowledging its use much later in the session. 25% felt neutral towards it and 0% of participants had a negative experience.



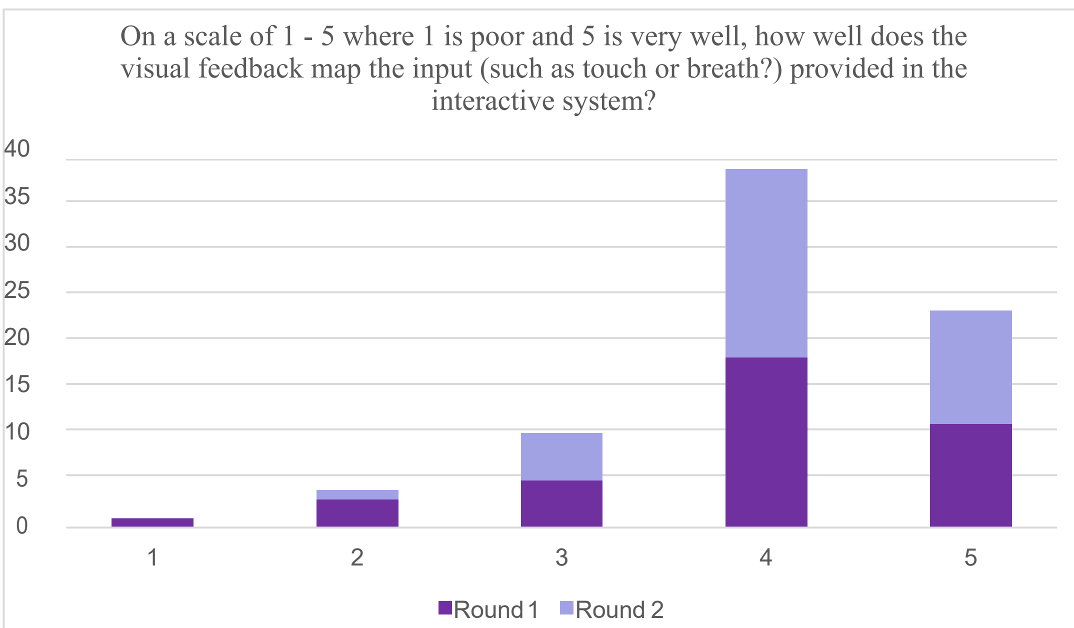


Figure 17. Complimentary Visual Feedback and Input Use scores for both rounds.

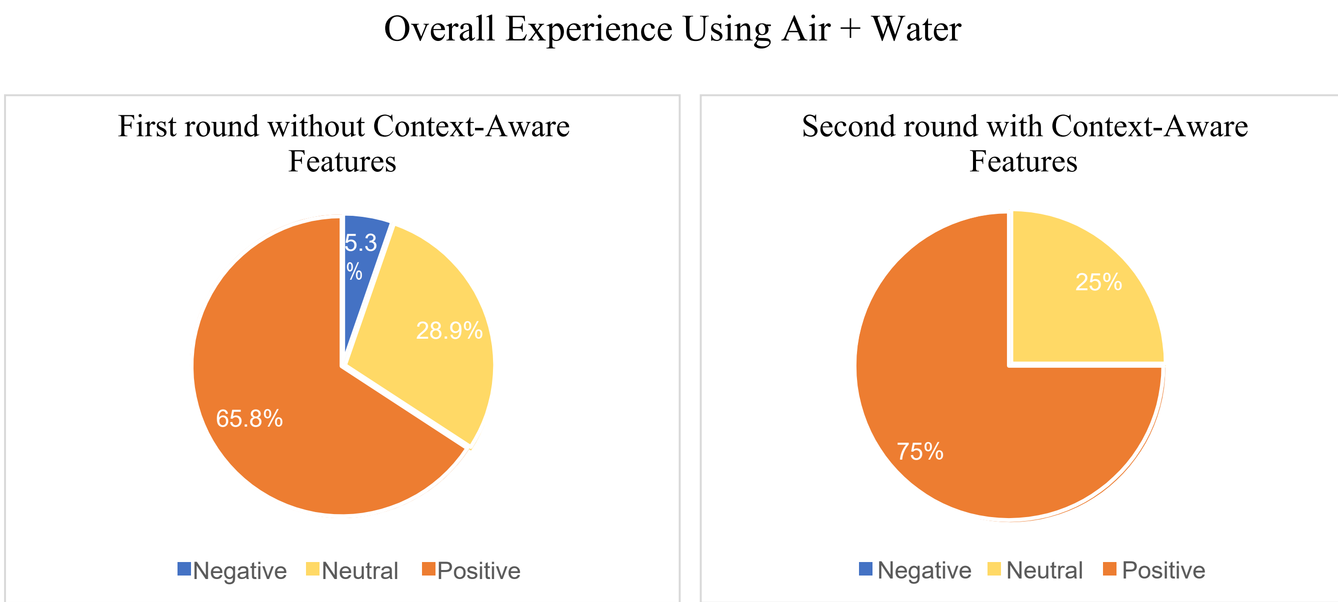


Figure 18. Overall Experience levels from first to fourth task within all three groups.

4.3.5 Observations and Feedback

Participants had positive feelings when they used *Air + Water* and enjoyed the watercolor visualizations. “Love the watercolours in the background as they popped. That made it a positive experience for me” (200306-P03, *Air + Water Round 2*). “The visualization looks great. The paint bubbles bursting creates a beautiful output” (200212-P05, *Air + Water Round 1*). Each group in both rounds commented on how they enjoyed the collaborative aspects of the 3rd and 4th tasks to create something together and expressed their thoughts how it felt like a game in later tasks.

> “I felt most in control with this activity. I noticed a pattern in which my bubbles would come out through the centre and I felt like I had a task in hand to make the perfect medium sized bubbles. This could become a game in which you have different sized circles and the person has to make the exact size by controlled blowing. That would be fun!” (200306-P02, *Air + Water round 2*).

According to the survey, most participants indistinctly wanted to blow at first. However, after the 2nd task, they wanted to manipulate the bubble size through either touching the sensor or swiveling the wand. Other gestures resulted in waving their hand over the sensor, clapping near the sensor, snapping their fingers near the sensor or whistling at the sensor.

Participants in both rounds vocalized how they wanted more control over the system’s colour scheme. *Air + Water* in round 1 could only generate watercolor stains at random. “It was challenging to figure out how to manipulate the colour of the bubbles” (200212-P05, *Air + Water Round 1*). Without knowing that the watercolours were randomized, participants were usually trying to control this particular part of the output and make connections to their actions. “I was able to deduce the rainbow color structure and that tiny bubbles would create red spots as red is the first color of the rainbow and the colors on the screen were related to the bubble size” (200212-P02, *Air + Water Round1*).

In round 2, the generated water colours came in hue sets based on how many people were detected using *Air + Water*. Cooler colors were outputted more frequently if the system detected one person. Warmer colours would appear the more people were detected. Watercolour stains within their sets were still randomized but the probability of getting the desired watercolor stain was higher based on this behavioral information if users figured out this feature. However, almost all participants in each group during the second round did not notice this context-aware feature while using *Air + Water* nor did they make the connection between the icons and the watercolor stain outputs. “I wasn’t able to fully understand the system, there were three smiley faces that I could not understand their roles and wanted to explore the machine more to figure out how it works…” (200305-p02, *Air + Water Round 2*). Directed play tasks and roles made *Air + Water* feel like an achievement case where users thought they had more control over their outputs.

Participants who participated in the first round felt that the interaction of *Air+ Water* was lacking in characteristics of the bubbles and commenting on how static the bubbles were. “It would be good if there was more drift to the bubbles” (200212-P01, *Air + Water Round 1*). They also wanted more control of the bubble’s direction and have them move in a direction they wanted.

4.4 Discussion

Air + Water was evaluated though a usability study that aimed to evaluate its design, visualizations, use of breath input and overall experience amongst users. The study provided significant insight into the participants’ interactions and experiences within the system. Referring back to Norman and Nilsen’s evaluation guides, along with my own expectations, I have learned where the strengths and limitations lied within *Air + Water’s* context-driven installation system. Referring back to Norman and Nilsen’s evaluation guidelines, I have developed a simplified criteria table in figure 19 that summarizes and includes both of their criteria points that had also aligned with my own expectations.

Criteria and Evaluation Table	
Criteria	**Evaluation**
Easy to learn and determine possible outcomes.	*Air + Water's* bubble visualization achieved this.
Follows natural mappings between intent and action; action and resulting effect; information and interpretation of the system.	*Air + Water* did not achieve this very well, as users constantly tried to control or understand how the watercolor stain output worked.
Efficient to use and easy to remember.	*Air + Water* achieved this to some degree. It inspired other forms besides blowing into the bubble wand to create its visual effects.
The system caused few errors.	The system overall did not show any signs of malfunctioning. However, oversized bubbles slowed down or stopped the system in round 1 briefly.
The system was pleasant to use.	Overall, participants enjoyed using *Air + Water* and praised it for its visualized feedback.

Figure 19. Criteria and Evaluation Table based on Nielson and Norman Guidelines.

Air + Water had a simple interaction between users. Creating variety of sizes during Task 3 proved this. Participants also enjoyed creating the watercolor stain visualizations together in earlier tasks. “It was interesting as group activity and there was some element of play involved where we tried to create bubbles together” (200305-P05. *Air + Water round 2*).

The ease of generating bubbles and experiencing that transition of breath input in real time was *Air + Water*'s strongest design mechanic. It was an action that users could achieve fairly quickly and had little to no trouble performing. The first round allowed users to blow bubbles as large as they wanted but the second round had a size limit that would pop the bubble if this limit was reached. Users who blew fast and witnessed their bubble popping as a result would blow slower afterwards and not as long as participants in the first round. Therefore, the bubble visualization mapped its intended and required actions after users familiarized themselves with this part of the system's mechanics. Most participants found the watercolor visualizations beautiful, fun and calming to produce "overall a nice experience and calming" (200212-P02, *Air + Water round 1*). The limitations of the system lied in control over the watercolor stain output and the directional location of where the bubbles would float on the screen. These two seemed to effect *Air + Water's* interactive performance the most. Its context-aware feature also did not help encourage to pursue this kind of control as users had trouble connecting the smiley icons to themselves and the watercolor hue sets. Overall, I have learned that *Air + Water* has several interaction opportunities that can become more prominent and clearer in its design than it does now. The lessons learned from the user study will help build better future interactive experience's for *Air + Water* and grant users more control over their outputs from their actions.

4.5 Chapter Summary

This chapter covered my design process and choices for working with the direct-user inputs touch and breath along with my reasons for working with breath for a larger multi-user experience. A usability study was conducted and the results for confidence, enjoyment, engagement, overall experience and complimentary use of the breath input to its mapped visual feedback were presented. An evaluated criteria table was also presented and discussed within the guidelines presented by Donald Norman and the Nielsen in chapter 3.

Through my efforts of creating an interactive installation system that aimed to compliment the design and actions that it encompassed, I have learned a lot about user-engagement and the desire to understand the relationship of outputs and inputs as much as possible. I aimed to create an installation that showed its full potential to its users. The later iterations of Air + Water had little control over what type of watercolour output could appear. This changed once the context-aware feature was installed and this visual output behaviour became dependent on user-count. Due to this addition however, *Air + Water's* true potential could only be fully experienced with multiple users, ironically undermining what I had set out to do. If a user was alone, then they could only experience one water colour hue set.

At the same time however, this visualization behaviour showcased the context of how *Air + Water's* environment and its perceived information as it was supposed to. This ultimately became a good thing to present as it reflected well into the context and available information *Air + Water* had gathered. However, on the user's end, depending on the user-count, it proved to also be an undeserved experience that ultimately costed the user to fully access the rest of *Air + Water's* features.

The lessons I have learned from the user study have helped me understand the strengths and limitations of *Air + Water's* current design and what aspects of the design could be improved. This could potentially give users more control and clarity of the systems' mechanics rather than present the context of the direct-user input through a context-driven installation system.

Chapter 5: Conclusion and Future Work

5.1 Conclusion

The earlier beginnings leading up to this research's journey lied in my desire to design experiences that created opportunities for clearer, intuitive and fun forms of interactivity within interactive installation spaces. After my experience with *PlayOn (2013)* at the Ryerson META 2013 show and working with virtual reality hybrid systems for several years, I wanted to create an experience that utilized direct-user inputs that had the potential to shape its interactive installation space through its context. My investigation focused on the utilization of direct-user inputs such as touch and breath to design effective visual feedback in a meaningful way, shared amongst users, within a contextually aware smart-environment. *Air +Water* was a step forward in understanding user-engagement within a context driven installation system that aimed to explore the context of breath input through its visualizations, design interface and its context-aware feature. It had gone through the process of what kinds of capabilities and interaction ideas I could deduce to users through my own idea of conceptualized interactive installation system. From there, I prototyped around the direct-user input breath itself and put forth my best efforts to convey the inputs' properties and characteristics well within *Air + Water*. A usability study was conducted to evaluate its use and interactive experiences and I learned about the strengths and limitations of *Air + Water's* current design. *Air + Water* has demonstrated its use of context and information to users through the actions it offers to take place in and the visuals it provides. The work conducted within this thesis could offer possible design considerations to interaction designers, HCI designers and designers in other related fields when working with direct-user inputs and their use in interactive installation systems and interfaces.

Although the experience of *Air + Water* can vary for users who are in groups as oppose to users who are alone or part of a pair, this has shown how visualized behaviour can change based on the information the system perceives from its environment. This is a powerful use of contextual information because it suggests that an interactive installation system like *Air + Water* can be adaptable and its visualizations can change based on its environmental context. Ideally, *Air + Water*'s colour hue set behaviour should be experienced fully and enjoyed by all users, but this is a property of the system that can be explored into another feature, that could make such an experience possible without undermining and dismissing the use of its contextual data.

5.2 Future Work

The design considerations explored within this thesis has shed some light on how far interactivity within interactive installation spaces can transcend and process information to participants. *Air + Water* gathered user count and breath pressure to affect its visual output using sensors, visuals and customisable tools that were integrated well within the system's context. For future work, other context-aware elements within this system could be investigated and make the features of its interaction clearer, easier and more accessible in other ways than it does in its current state. Placing *Air + Water* in different environmental contexts outside of the exhibition space is also possible and the system could use alternate tools that could be relevant to not only its environment but its audience as well.

Air + Water could be placed outdoors, or in other indoor residencies such as retirement homes. Air masks or other respiratory tools could replaced the bubble wands and still fit within the context of providing life into the system. The visuals could still add their calming ambience within any type of environment and still illustrate the harmonic, calming charm they present to participants. Developing a system that clearly presents and behaves on context-aware related information is difficult and sometimes all the features may not come across to users as clearly. However, the attempt to bridge inputs and outputs for the ease of interactivity and experience is not impossible and is always worth exploring further. There are no limits to the power of design when it comes to translating and expressing sensory-data. As long as humans continue to make connections within these spaces, there will always be room for exploring intermediate connections between the physical and digital capacities of the interactive installation system.

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Appendices

Appendix A: Earlier Iteration Documentation for P.R.S.M

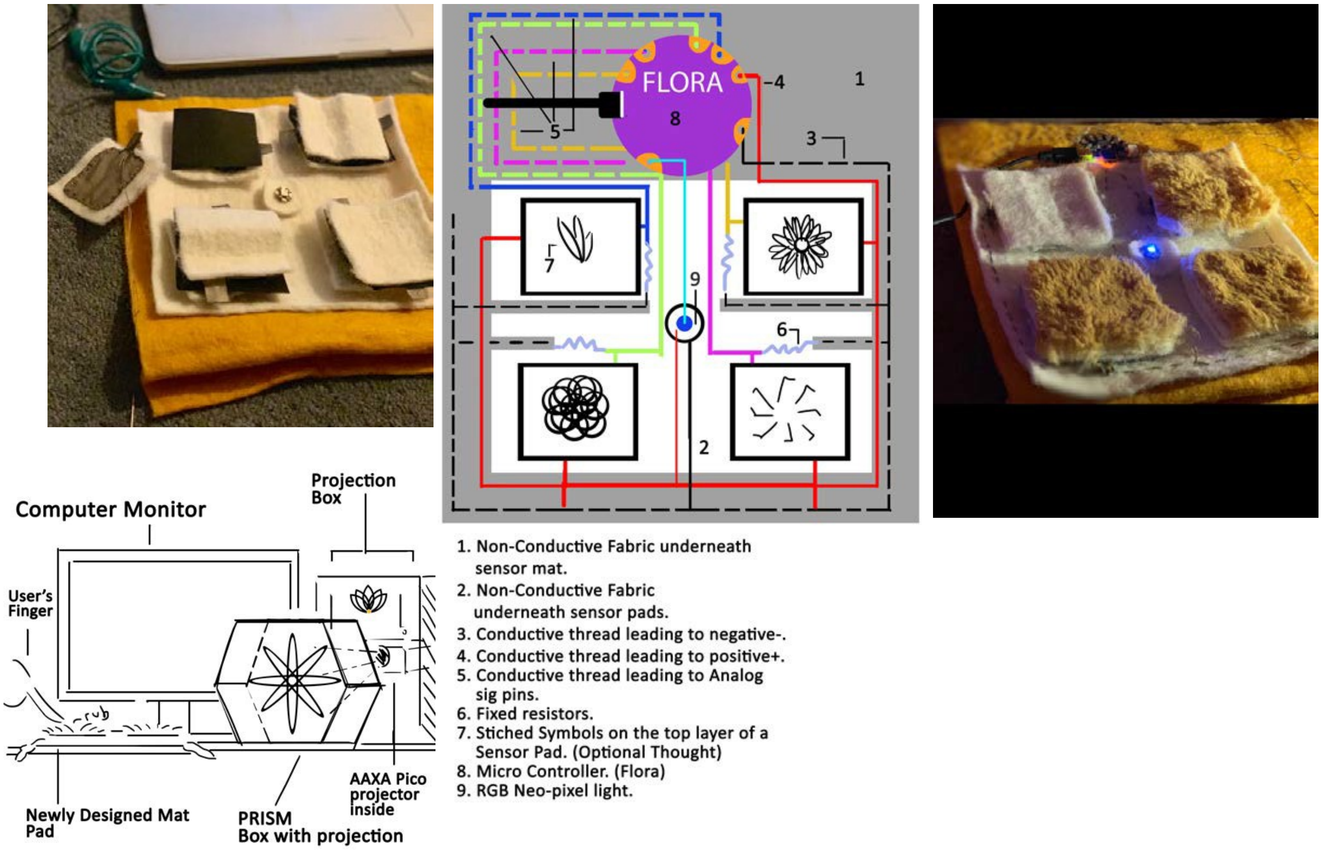

Figure 15. Earlier Iteration Documentation for P.R.S.M (2019).

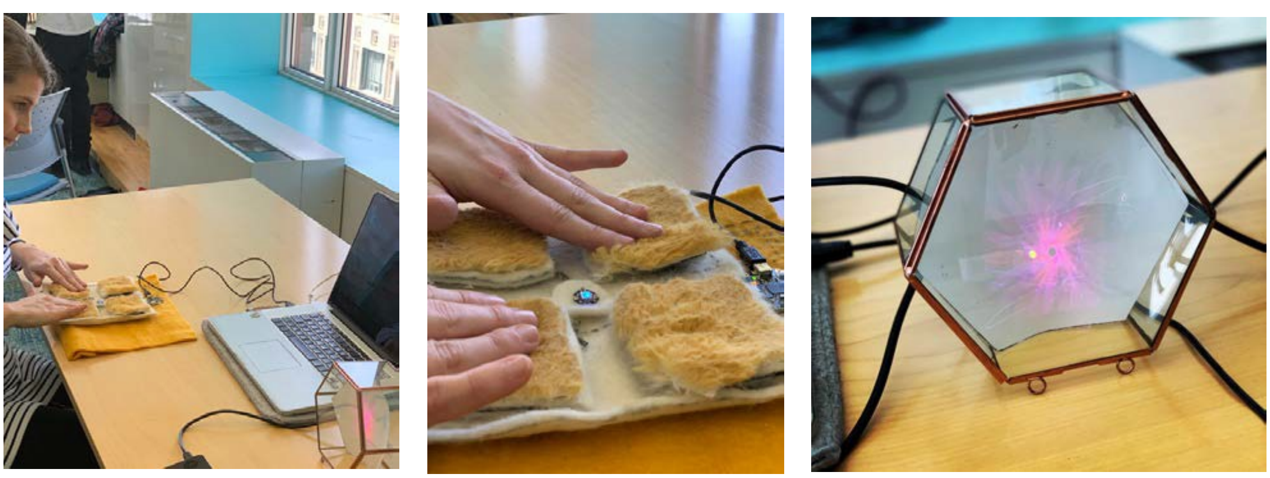

Figure 16. Personal Reactive Soft Sensory Mechanics' Showcase in the Body-Centric Course at OCADU. 2019.

Appendix B: Earlier to Later Iteration Documentation for Air + Water

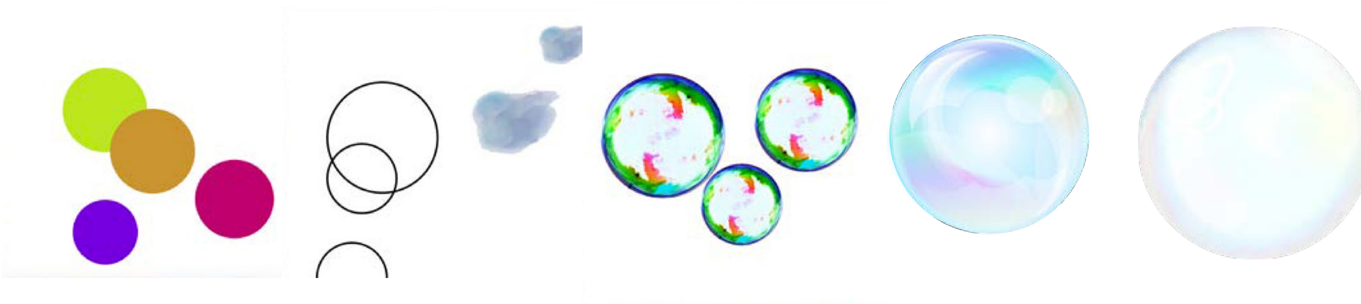

Figure 17. Earlier to Later Bubble designs for Air + Water (2019-2020).

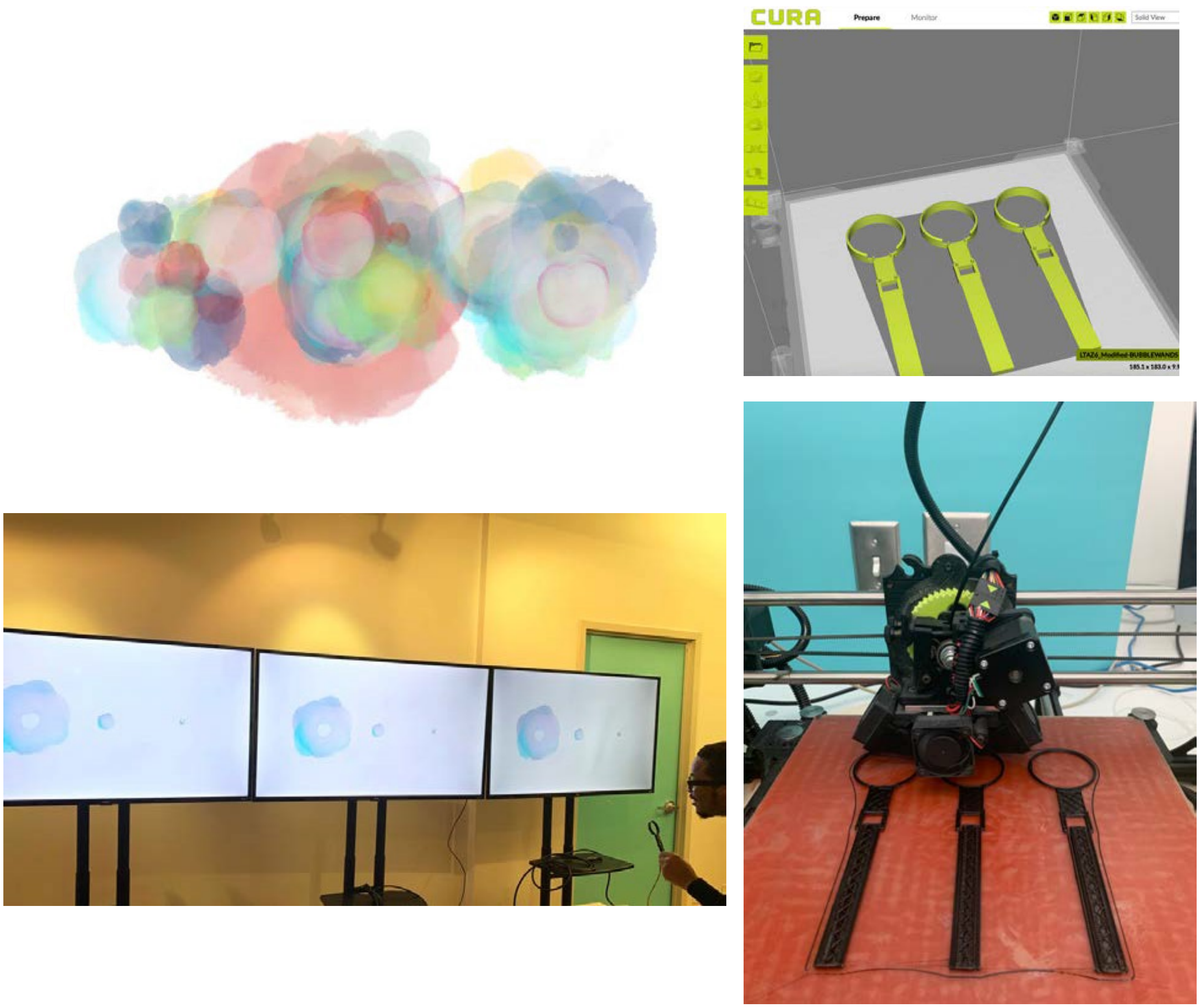

Figure 18. Documentation for second iteration of Air + Water (2020).

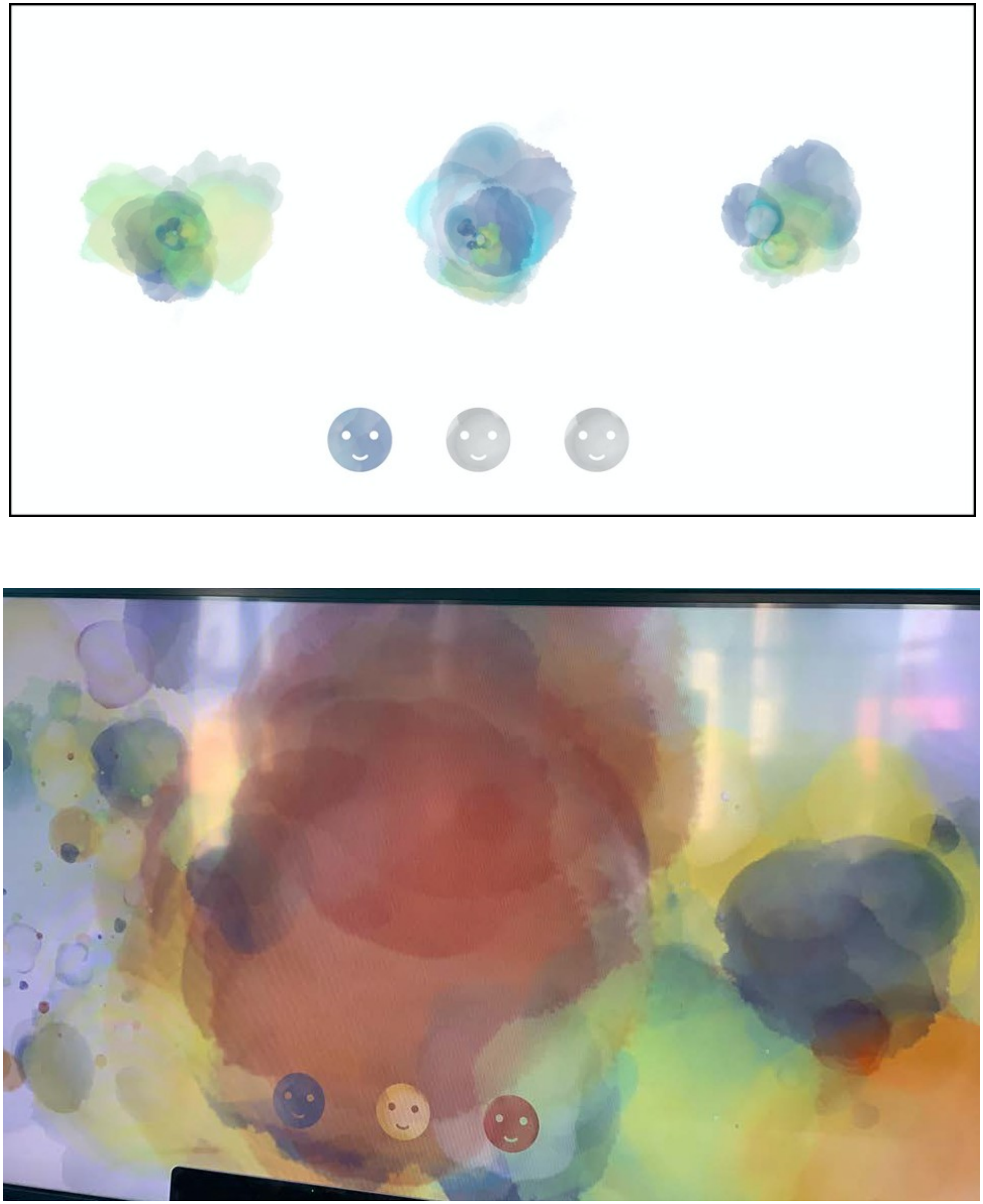

Figure 19. Latest Iteration for Air + Water (2020) with context-aware elements.

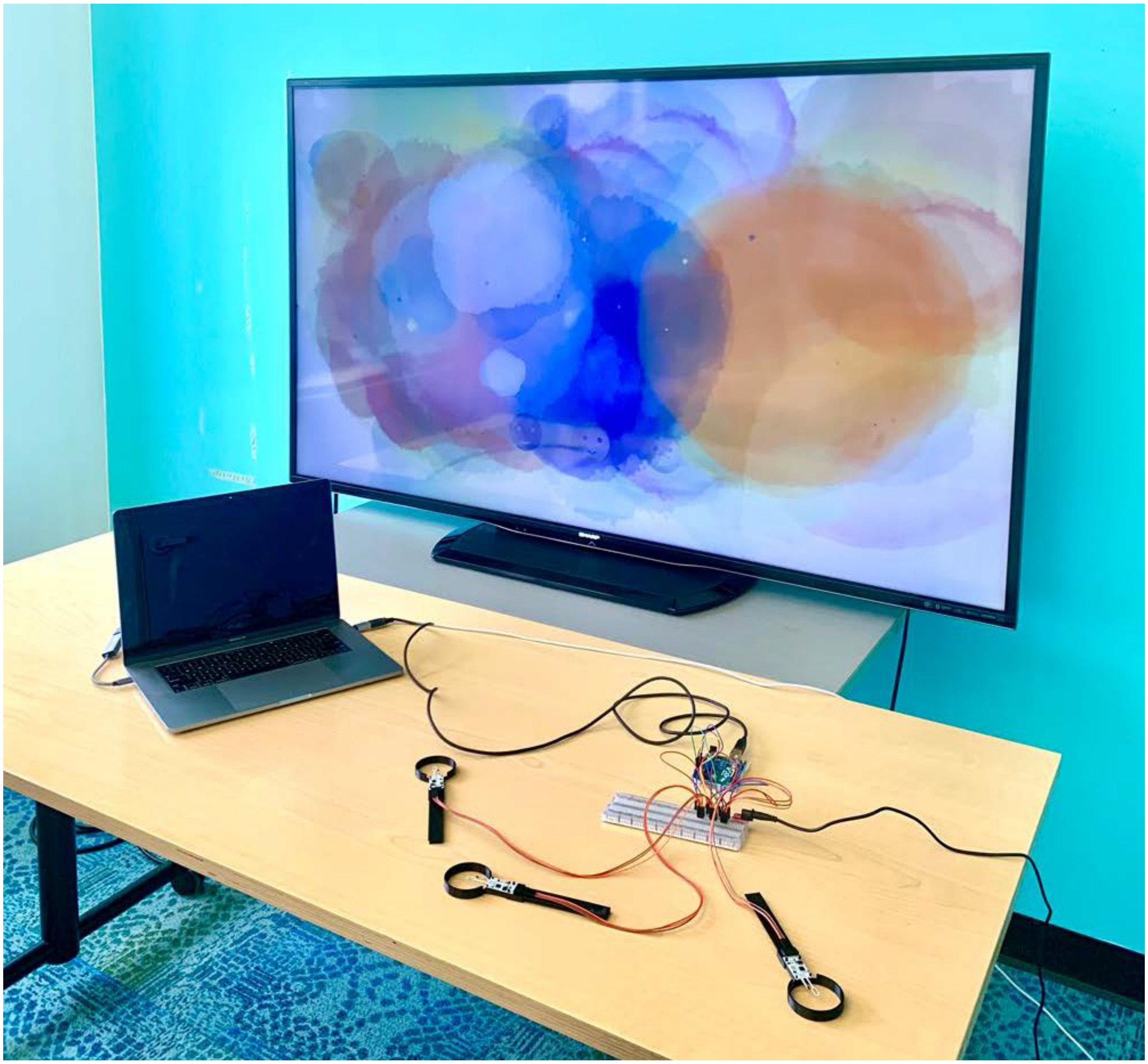

Figure 20. Air + Water Installation setup for user study (2020).

Appendix C: Interactive Experience Questionnaire

12/5/2019 Interactive Experience Questionnaire

Interactive Experience Questionnaire

Please answer the following to the best of your ability

1. **On a scale of 0 - 9 where 0 is bored and 9 is energetically motivated, how confident are you when performing your actions within the interactive system ?**

   Mark only one oval.

   0 1 2 3 4 5 6 7 8 9

2. **On a scale of 0 - 9 how much did you enjoy your experience with the interactive installation system?**

   Mark only one oval.

   0 1 2 3 4 5 6 7 8 9

3. **On a scale of 1 - 5 where 1 is poor and 5 is very well, how well does the interactive system work with the input (such as touch or breath)?**

   Mark only one oval.

   1 2 3 4 5

4. **On a scale from 1 - 5 where 1 is poor and 5 is very well, how well does the visual feedback map the input (such as touch or breath) provided in the interactive system?**

   Mark only one oval.

   1 2 3 4 5

5. **On a scale of 1 - 5 where 1 is not engaging and 5 is very engaging, how engaging is the interactive installation?**

   Mark only one oval.

   1 2 3 4 5

https://docs.google.com/forms/d/1jtIqv0YnF-bZj2kqYgljvj906957F8ZA5eQdN1LbITA/edit 1/2

Figure 21. Interactive Experience Questionnaire page 1.

6. **On a scale of 1-5 where 1 is I hated it and 5 is I loved it, how much did you enjoy your experience with the interactive system?**
Mark only one oval.

1	2	3	4	5
◯	◯	◯	◯	◯

7. **Did you feel you had a positive, neutral or negative experience?**
Mark only one oval.

◯ Negative
◯ Neutral
◯ Positive

8. **Describe the first actions you wanted to perform with the interactive system.**

9. **Do you have any other feedback/thoughts on your overall experience interacting with the installation (visualizations, interactions or inputs?)**

Powered by Google Forms

Figure 22. Interactive Experience Questionnaire page 2.

Appendix D: Software and Resources

Software, Hardware and Resources for P.R.S.M

- GitHub Repository
- Arduino IDE 1.8.7
- Processing 3.5.3
- Soft fabric
- Conductive fabric and thread
- Non-Conductive fabric and thread
- 1x FLORA microcontroller
- 1x neo-pixel light.

Software, Hardware and Resources for Air + Water

- GitHub Repository
- Arduino IDE 1.8.7
- P5.js library 1.0.0
- TypeScript.js 3.8.2
- PoseNet
- Adobe Photoshop and Illustrator CS6
- Procreate
- 3x Rev.P Wind Sensors
- 3x 3D Printed Bubble Wands
- Arduino Uno Shield and Wires
- 1x Ardunio Uno
- MacBook Laptop

Appendix E: Thesis Exhibition Documentation

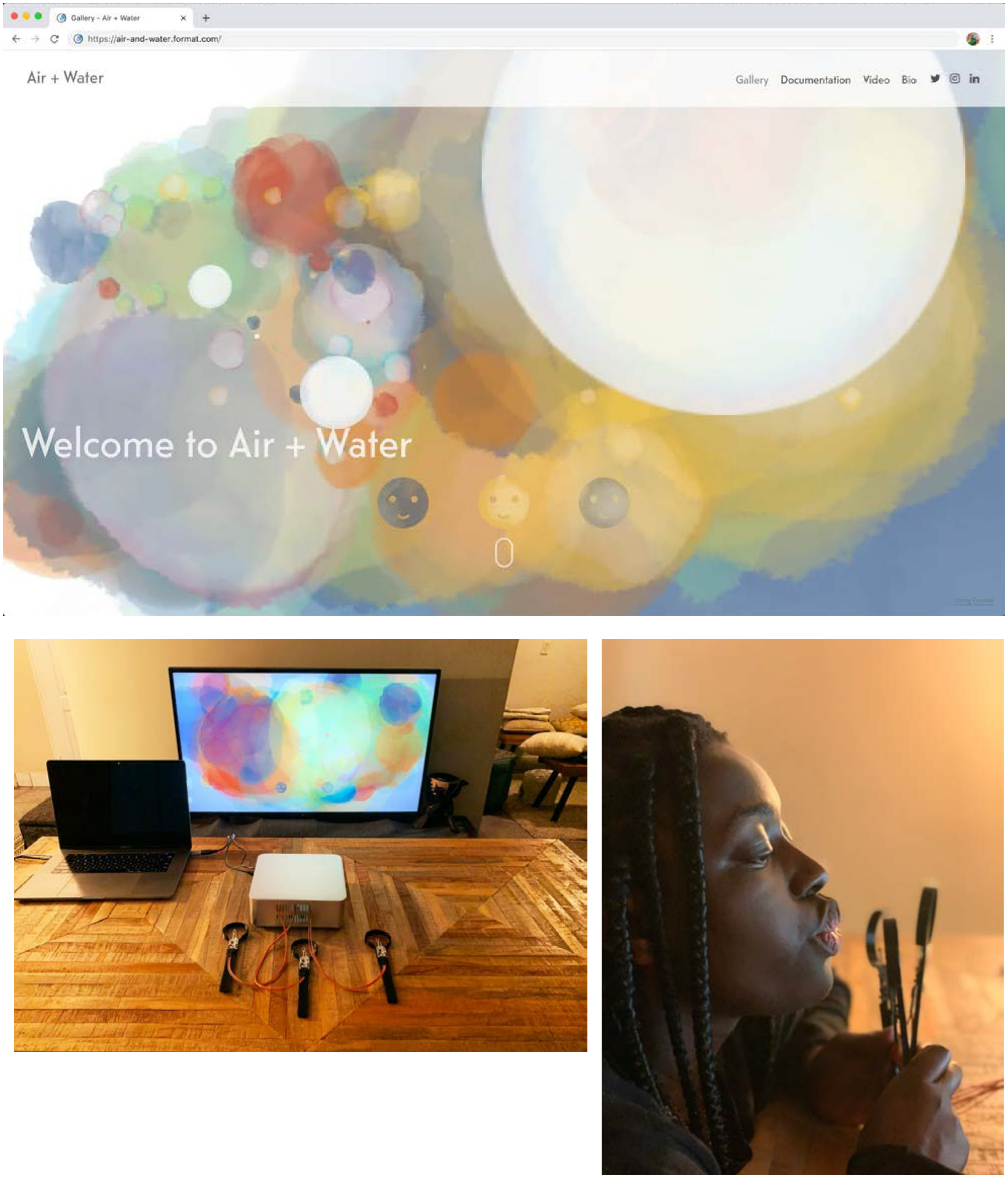

Figure 23. Thesis Exhibition Documentation. Due to the Covid-19 Pandemic, the thesis exhibition of 2020 was showcased online. You can find more information on Air + Water and its process at air-and-water.format.com/gallery.