ABSTRACT

DESIGNING TOOLSETS FOR IMPROVING THE ACCESSIBILITY OF IMMERSIVE TECHNOLOGY

by Jerald Daniel Belich

Designers and managers of escape rooms or live-action adventure games are encountering an increasing challenge of implementing highly immersive experiences without the use of (smart) technology, and those that are including technology face high expense, high risk, or both. The increasing complexity of technology opens the door for designing innovative immersive experiences while simultaneously excluding many immersive designers that would benefit from their use. Through a deeper understanding of the design process and common problems preventing or hindering this population's use of immersive technology, we can identify and design empowering solutions. These solutions not only have the potential to dramatically speed up innovation in the live-action game space but to save many existing businesses from failing due to being unable to compete. Focusing on accessibility and flexibility would allow for integrating technology much earlier in the design process thereby reducing risk and increasing the cohesiveness of the design; broadening the scope of what types of experiences are possible which increases competitiveness; and decrease overall time and cost by solving common reliability and maintainability problems that plague inexperienced and non-iterative technology design work.

DESIGNING TOOLSETS FOR IMPROVING THE ACCESSIBILITY OF IMMERSIVE TECHNOLOGY

Thesis

Submitted to the

Faculty of Miami University

in partial fulfillment of

the requirements for the degree of

Master of Fine Arts

by

Jerald Daniel Belich

Miami University

Oxford, Ohio

2019

Advisor: Dennis Cheatham

Reader: Michael Bailey-Van Kuren

Reader: Eric Hodgson

This thesis titled

DESIGNING TOOLSETS FOR IMPROVING THE ACCESSIBILITY OF IMMERSIVE TECHNOLOGY

by

Jerald Daniel Belich

has been approved for publication by

College of Creative Arts

and

The Department of Art

Dennis Cheatham

Michael Bailey-Van Kuren

Eric Hodgson

Table of Contents

List of figures vi

Dedication vii

Acknowledgement viii

Chapter 1: Introduction 2

Chapter 2: Literature Review 4

Categorizing "Escape Rooms" 4

Current Immersive Storytelling Techniques 5

Current Accessibility Tools 7

Theoretical Frameworks 13

Summary 14

Chapter 3: Methodology 15

Survey 16

Semi-Structured Interviews 17

Coding 18

Chapter 4: Results and Findings 21

Limitations of the Research 21

Demographics 21

Self-Assessment of Skills 22

Attitudes Toward Innovation 25

Potential Obstacles to Adoption 28

Themes Found in the Data 29

Theoretical Connections 32

Chapter 5: Phenomena Research Conclusions and Discussion 33

Challenges Identified 33

Recommendations for Future Research 34

Recommendations for Design Intervention 35

Software 35

Hardware 36

Chapter 6: Design Intervention 37

PAINT! - An Immersive Design Toolset 38

The Pillars of PAINT! 38

Network of Things 38

Accessible Iteration 39

Open and Off-the-shelf 40

Prototype Permanence Path 40

Open Software and Technology 41

Concept Testing 43

Suggestions for Future Design 46

Chapter 7: Design Research Conclusions and Discussion 47

Bibliography 49

Appendix A - Informed Consent 51

Appendix B - Participant Consent 54

Appendix C - Survey Questions 57

Appendix D - Interview Questions 74

Appendix E - PAINT! an Immersive Design Toolset Proposal 76

Colophon..... 89

List of Figures

Left: Screenshot of the Processing IDE - Right: Screenshot of the Wiring IDE 2.1

Screenshot of the Scratch Web Editor..... 2.2

Screenshot of Unreal Editor Blueprints Feature 2.3

Top: Node-RED Interface - Bottom: Particle Rules Engine 2.4

Dorst and Cross's (2001) problem-solution co-evolution model as derived from the observations in their study of design creativity. 2.5

Interview Coding 3.1

Code Occurrence Counts 3.2

Project Roles Typically Assumed 4.1

Participant Self-Assessment in Financial Tasks..... 4.2

Participant Self-Assessment in Design Tasks 4.3

Participant Self-Assessment in Implementation Tasks 4.4

Participant Self-Assessment in Installation Tasks 4.5

Do Participants Typically Use Custom Tech 4.6

Likelihood of Factors Inhibiting Use of Immersive Technology..... 4.7

Screenshot of an Example Logic Flow in Node-RED 6.1

Screenshot of Fritzing Software - Left: Arduino Footprint - Right: Feather Footprint ... 6.2

Dedication

I would like to dedicate this to my wife who gave more to me in support of this journey than I could have ever expected. For the countless acts of care and kindness large and small, I thank you. I could not have accomplished this without your unwavering patience, caring, and love. I love you so much.

To her family who made themselves my family, accepting me for all of my quirks and faults. You've taught me what family can be and I can't imagine my life without all of you in it.

To Dennis Cheatham, you took an unexpected and difficult situation and turned it into one of great value and enrichment for me. You have been a wonderful mentor and your encouragement made all the difference.

Acknowledgments

To the worldwide community of game designers, artists, and creators that supported me, listened when I needed, and reminded me why this is all worth it. Phoenix Perry, you were an inspiration and endless source of knowledge and clarity throughout; thank you for your intellectual support and friendship. Lisa Brown, your friendship and mentorship got me through many of my toughest moments; your wonderful laugh always managed to cut through my stress and anxiety. Finally, to all of our friends back home, thank you for believing in me and being there for us in so many big ways.

Special thanks to my Thesis Committee:

Dennis Cheatham, Michael Bailey-Van Kuren, and Eric Hodgson.

DESIGNING TOOLSETS FOR IMPROVING THE ACCESSIBILITY OF IMMERSIVE TECHNOLOGY BY JERALD BELICH

Chapter 1: INTRODUCTION

There appears to be a growing gap between the complexity of existing and emerging immersive technologies and their accessibility to the designers and stakeholders involved in creating immersive spaces. The purpose of this research is to identify the severity of this gap and where future immersive design tools can most effectively narrow this gap. Specifically, I will be focusing on the design and implementation of for-profit live-action adventure games, more colloquially known as "escape rooms", though not all of these games actually require escaping as part of the experience. In this research, I will be using the shortened term "live-action game" as a more inclusive and less evocative replacement for "escape room" or "escape game", and shortened from Nicholson's term "live-action adventure game" (2015).

Customizable immersive technology, especially the realm of microcontrollers and sensors, has quickly grown in capability and availability while simultaneously dropping in price over the last two decades. Although artists, designers, and academic researchers have been creating immersive spaces and exhibits through much of that time, it is difficult to compare work with such highly variable contexts. One of the earliest live-action games titled Real Escape Game opened in Kyoto, Japan back in 2007, yet it wasn't until about 2012 and 2013 that live-action games began growing rapidly worldwide (Nicholson, 2015). In the last six years they have become an enormous entertainment industry that shares many of the same practical challenges as the previously mentioned artists and academics, but unlike artistic and academic exhibits have far more consistent goals financially and structurally across the now thousands of live-action game facilities.

As a result of live-action games maintaining a similar financial and structural model, it may be easier to discover trends in designer needs and challenges. To further reinforce the quality and comparability of the research, the population was defined as individuals over the age of 18 that have completed at least two for-profit, or commercial, live-action games and have engaged in

any related work within the last two years (starting approximately from January 2019 when the survey was opened). They could have been responsible for design and/or financial decisions related to the creation of live-action games, including facility managers, business owners, or even clients commissioning the work. Through online surveys, the study reached 33 willing participants worldwide. Through the data acquired this research hopes to answer the following question: **As the complexity of immersive technology increases, how could access and flexibility be increased to empower story-driven experience designers?**

This research defines live-action games as group-based experiences involving interactive problem solving, potentially both cognitive and task-driven, over a limited amount of time and often in a themed environment. A key difference between these types of games and live-action role-playing games, or LARPs, is that players are not expected to roleplay but act as themselves as if they are personally having the adventure (Nicholson, 2015).

The term immersive technology is used in this research to refer to electronics and software that may be visible or invisible to players. Visible elements enhance the game by providing additional sensory immersion for players, including sight, sound, touch, smell, or even taste. Invisible elements help automate aspects of the experience or enhance the game master's ability to monitor or run the experience.

A live-action game that uses only mechanical components with no automated events or digital displays would be an example of not using immersive technology. A game master manually turning a light on or off would also not be included, though if that light were to be triggered or cued through electronics or software it would become an example of immersive tech usage.

Research into the methods and current practices for designing live-action games indicates that although most current designers are deeply interested in what immersive technology can do to increase the quality and revenue of their experiences, there are a few common barriers preventing them. For most, the technical expertise required is beyond the time and resources available simply making these solutions inaccessible; even for those using immersive technology, the ongoing support and maintenance required is a deep concern.

Finally, existing technology and software is difficult to integrate into the prototyping and design process of live-action games due to slow iteration cycles, even with technically savvy designers, making it difficult to take advantage of effective iteration based design models. The following research hopes to answer how new tools can bring immersive technology from an area of design risk to an integrated part of a co-evolutionary design process, increasing the understanding of a design problem space, improving the quality of the solution space, and increasing the overall possibility space for all designers.

Chapter 2:
LITERATURE REVIEW

Although the term "immersive design" itself is still quite new, (currently attributed to Alex McDowell in 2007 ("Immersive design," n.d., para. 2)), the embedded storytelling and worldbuilding aspects are anything but. Disney has been engaged with immersive design for nearly three-quarters of a century, even excluding their use of technology. What is new, however, is the expansion and quality of design education and the proliferation of powerful computers, microcomputing platforms, and a plethora of electronics to be controlled by them.

As it can be difficult to pull apart the tangle of design disciplines involved, I found it helpful to break the concept of "immersive technology" into two parts. In the first, the focus is on applied research exploring the techniques around telling stories using immersive design. Although some of these projects involve quite a bit of technology, the concern isn't how it was implemented, but how it contributes to achieving deeper immersion in the story and experience. In other words, what are some of the design principles that immersive tech must support? The second part will focus on design solutions directly focused on making technology more accessible for people without strong technical backgrounds. I believe a key takeaway from this literature review is that the central goal of immersive design tools should be to reduce friction between designers and their ability to express their design intent. New immersive technologies provide new capabilities, and so new tools must be designed to make those capabilities accessible to as many designers as possible to support innovation.

Categorizing “Escape Rooms”

Before diving into the research pertaining to immersive design and technology, it is important to address some of the basic terms and the categorization used within the “escape room” industry. As has been previously mentioned, I am choosing to avoid heavy usage of the term

“escape room” as it is a limiting and misleading term as Nicholson has brought up in his research (2015, p. 29). He has proposed an alternative, “live-action adventure games” as being more appropriate, making room for sub-genres to provide more clues as to the particular type of play, genre, or mechanics. This is a discussion that should continue and my use of “live-action games” is to encourage a departure from “escape rooms” except when narratively appropriate. Even the company SCRAP, responsible for the first game of this type which opened in Kyoto, Japan in 2007, now refers to the genre as Real World Adventures, a less misleading term (About SCRAP, 2019). The original inspiration, however, was online escape games, so the ‘escape’ moniker was still a heavy part of the branding as the industry took off in 2012 and 2013.

Nicholson also provided useful categorizations for identifying the narrative and technological complexity of live-action games which are used in the research surveys with only minor modifications to the descriptors for each (2016). Ultimately, I agree with Nicholson’s analysis that the trend of the industry is improving technology and narrative, with the latter perhaps requiring the former to continue advancing (2016). That, and the industry desire to design solutions for better replayability, what I’ve personally heard referred to as the ‘holy grail’ of live-action game rooms anecdotally. Once the puzzles are solved, the mysteries unraveled, or the culprits caught, there is no motivation to return; at least certainly not at the relatively high price-points.

Current Immersive Storytelling Techniques

Teams in this area consistently need techniques for prototyping that allow for immediate feedback and quick turnaround of adjustments to their initial strategies. The reduction in turnaround time decreases concern over any given strategy being the ‘right’ one, a common fallacy in design thinking, and increases the quality of final solutions.

A group of researchers at the University of Maryland documented their research into developing a storytelling system in conjunction with children called “StoryRooms” (Alborezi et al., 2000). What is compelling about this is not only the attempt to balance physical and electronic elements for enhanced storytelling, but the emphasis on involving children as co-authors and participants. Although the target audience differs, we share similar goals pertaining to accessibility integrating immersive tools into the design process, not to simply support a completed design.

Alborezi et al. (2000), identified a number of my concerns including cost, the complexity of technology to program or author, and technology or tools needing to be easily modifiable for new content. Much of what Alborezi et al. explore concerns the difficulty of designing with children, but they do touch on a few salient points for any immersive experience design, including live-action games. Instead of engaging in traditional brainstorming, a collaborative mental process meant to produce a list of ideas, they implemented a more active approach using "scenario walk-thrus, low-tech prototyping, and a lot of sticky notes" (p. 97). These

strategies are meant to support the concept of "idea elaboration", or the continual building of ideas from all designers involved, which according to Alborezi et al. (2000) “is the ultimate goal of the design process.”

There is significant research that shows how ineffective group brainstorming can be: Connolly, Routhieaux, and Schneider (1993) go so far as to label the traditional methods a "failure". Prototyping as a component of early ideation, or brainstorming, is highly supportive of the process of idea elaboration. The ability to test or demonstrate an idea as it is being conceived can quickly illuminate the benefits and flaws with little investment or stock in the concept. Neeley, Lim, Zhu, and Yang (2013) in their "Building Fast to Think Faster" also demonstrated the importance of prototyping during ideation as well as the additional effectiveness possible by tightening iteration deadlines. In their study, designers were compared by creating either one or five prototypes in the same timespan; those who created five showed increased performance and satisfaction in their work.

Alongside prototyping, Alborezi et al. (2000) made it clear that it is critically important to understand where a user is in time and space during the process of designing; simply sketching or writing designs is far less effective. Inhabiting the design space, and thus having tools that support spatial prototyping appears to be important. In a separate paper “Real-time immersive design collaboration” (Johns & Shaw, 2006) these challenges are explored with a team of students, but in a 3D virtual environment which “enabled rapid testing of design iterations and extended the range of creative conceptual design responses”. The spatial component, even when virtual, was vital to their design process.

If bringing immersive tools and technology into the design process and space as soon as possible has so much potential, the importance of any design system to be functional with minimal configuration or implemented logic is vital. Many technology systems, including one I built for an escape room that inspired this research, require a minimum level of complex infrastructure before any functional testing can occur, possibly even requiring all interactive components present as well (i.e. sensors, inputs, etc.). At this late point in the design process, the technology can have only a minimal impact on the design itself.

In order to be effective as early in the process as possible, an immersive design toolset would need to compensate for the non-linear nature of the iteration process and potentially include low-tech stop-gaps for bridging early design progress in physical space to increasingly elaborated high-tech digital representations. An example I considered while thinking about the third brainstorming technique Alborezi et al. (2000) listed - sticky notes - was how a toolset could support or even bridge such low-tech methods to defining a space, the objects within, and even events that take place. One could use a thermal sticker printer for quickly creating labels with scannable codes to place on objects. Labels could represent events, such as the 'incorrect' or 'correct' code entry on a considered keypad represented by the stickers on a door. By scanning with a phone the software could trigger additional logic or media such as light and sound. Augmented reality could even be used to emulate a physical device in virtual space to

further take advantage of smartphone proliferation. The key point is to support prototyping in the earliest stages of ideation.

When Alborezi et al. (2000) describe their design solution they list three parts: hardware, software, and "funware", or "the part of the system that supports users with ideas". They compare it to example code or an example LEGO construction in a LEGO kit. With microcontrollers the most common example is "Blink", a simple bit of software that makes the LED on your microcontroller flash on and off. Instead of a blank canvas and uncertainty as to whether or not the tool even functions, it provides that evidence and a bit of personal pride that you got it to work. Demonstrations and examples serve to show users the capabilities they may not be aware of and provide a runway for learning functionality before confronting the challenges of designing. An immersive design toolset should provide comprehensive examples to ensure users are fully aware of what they can do and how they can do it.

Hayden et al. (2013) explored a more abstract approach to immersive storytelling with the design of their product “Narratarium”. Instead of being a source or tool for designed content, Narratarium is meant to be a fast-to-setup, no effort enhancement of any language or text-based storytelling that occurs while active. It is essentially a dual projector with a reflective dome to send colored projection all around the space, with a language database and logic that will determine a color palette based off of the words it hears.

Live-action games do not result in final packaged products, but remain as living, evolving experiences as long as they operate. In a sense, they never fully leave the prototyping stage as once a game is running player data is acquired and improvements are made, both to the experience and the technical aspects of the room. Neeley et al. (2013) mention the value modern rapid prototyping tools have brought to the design process, but note that "less attention has been given to how these tools … affect the strategies used by designers during the earlier stages of the design process" (p. 2). The development of tools supportive of early stage design prototyping would help us better understand how they might "affect the mental mechanisms of design conception" (Neeley et al., 2013, p. 2).

Current Accessibility Tools

A lot of research and effort has already been applied to how both programming and electronics, including both in conjunction, can be made more accessible for a wide range of user types. I explore a few notable examples below, specifically work that has created a large impact that can be built upon or clarify how the design of an immersive toolset can be most effective.

Processing, Wiring, and Arduino

Barragán (2004) found that most prototyping tools at the time of his research into developing Wiring were geared toward engineers and others with highly technical backgrounds. It was a relatively new development that microcontrollers had become as cheap and accessible as they

had, but working with them was still a difficult task. Wiring, both a programming environment and microcontroller prototyping board, was meant to make working with electronics easy for designers and artists in the same way that Processing, the inspiration for Wiring (refer to figure 2.1), allowed a similar audience to learn computer programming and create media based art with technical backgrounds. Processing coined the term "sketch" to describe programs written using the tool, the equivalent of a prototype in the language of visual arts. The term was kept in Wiring and the Arduino software that branched from it.

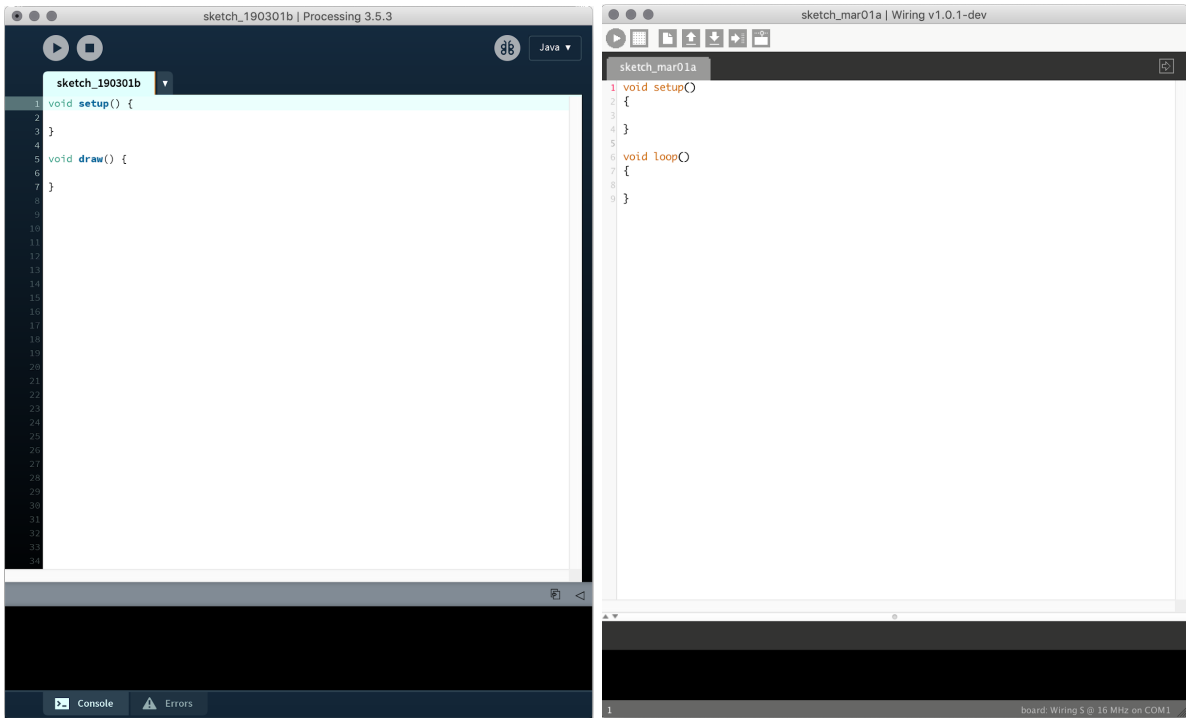


Figure 2.1 Left: Screenshot of the Processing IDE - Right: Screenshot of the Wiring IDE

In 2004, Processing already had a community of 5000+ and was successfully being used in educational environments and workshops around the world. The question for the design of Wiring was simply how to extend the same quality of access but to working with electronics instead (Barragán, 2004). On the software side, what Wiring ended up providing was a thoughtful extrapolation of the Processing tool.

When a user first acquires a piece of software, the first experience they confront is the initial setup and first start. Processing and Wiring both provide their software in the form of an Integrated Development Environment (IDE). This serves to encapsulate an entire coding environment that normally would consist of numerous console based tools (that is, without a GUI interface) with varying dependencies and difficult to understand, often sparse, documentation. Instead the user is provided a GUI with built in programming and debugging tools; the importance of this packaging cannot be understated. Even experienced programmers often get frustrated by the unfriendliness of setting up and maintaining various coding environments, so it is unreasonable to expect that users without technical backgrounds would

have the patience to wade through the complexity. Providing a straightforward installation package and easy way to verify that a tool is properly working can instantly fill a user with the pride and motivation to continue.

The verification step brings us to the second important lesson from these tools: as the tools are creative in nature, they have no function other than what their user brings to them. It is therefore vital to provide examples that demonstrate the general functionality of the tools. This serves two purposes: giving the user confidence that the tool is functioning as previously mentioned; and demonstrating the breadth of functionality available to the user thereby inspiring and educating them. Any creative tools that provide nothing but a blank canvas to new users are failing the growth of their community.

Processing and Wiring do still require coding, a challenge for users without previous experience. The Application Programming Interface (API) for both tools was designed to abstract the underlying technologies and to support prototyping and creative output with clear language and functionality. As Processing began as a coding tool designed within the context of visual arts, it provided a comprehensive graphics library integrated in the software (Reas & Fry, 2019). It's media functionality has greatly expanded since original release, with matching growth in example sketches and reference documentation. Barragán (2004) focused on developing an API that abstracts away the low level methods that are specific to the microcontroller chipset and board capabilities. This means that the skills a user learns working with Wiring can translate directly to any microcontroller kit once basic support implemented. Given enough popularity for a tool, individuals or companies releasing new prototyping boards are then highly motivated to provide compatible libraries and functionality as their audience can drastically increase with a relatively small amount of effort.

As Wiring was created as an open source project (similar to Processing), a group associated with Barragán (2016) forked (copied) the code renaming it Arduino. It is unclear to this day why the creator of Wiring wasn't invited onto the team using his work, but despite the questionable decision and even strange legal issues in recent years, Arduino became the brand associated with just about all hobbyist electronic prototyping kits. The IDE is still widely used even with competing products and it has successfully allowed many thousands to prototype their own electronic devices that would have been unlikely to do so otherwise.

Communication and Firmata

As accessibility grew with tools like Arduino, so did user needs. The innovation of microcontroller kits that are easy to set up, program, and interact with led to a rapidly growing community. This growth meant that the user desire to interact with their microcontrollers from a variety of software and other sources increased dramatically as well. With few exceptions, all microcontroller kits provide a basic method for sending and receiving data to and from other computer systems called serial communications. Both ends must agree on how they will communicate using the virtual pipe between them called a protocol. On top of the devices

agreeing how to send and receive data, a messaging protocol helps abstract the complexity of working with individual bits of data.

Firmata is an example of a communication protocol to help microcontrollers and host-computers talk but with the distinct goal of trying to "make the microcontroller an extension of the programming environment on the host computer in a manner that feels natural in a programming environment" (Steiner, 2009, p. 125).

Put simply, if I wish to interact with a microcontroller from my own software rather than the microcontroller running purely independently, I would then need to work within a high level programming environment for my host-computer software and also write microcontroller code using a second environment such as Arduino. If, however, the generic API popularized by Wiring were abstracted yet another level as a common library for popular high level programming environments, the microcontroller could function as an extension rather than a distinct unit (Steiner, 2009).

Firmata has had an important impact on accessibility, allowing users already comfortable with a variety of high level coding language and tools to interact with microcontrollers without having to write any code for them (Steiner, 2009). Once the Firmata sketch is uploaded to the microcontroller, any software using the Firmata protocol can access the functionality of the device directly. There is even a Processing library to support Firmata bringing all of this innovative work full circle. Support has also been added to a number of visual programming tools meaning it is possible to prototype with electronics without writing a line of code, potentially taking accessibility to an entirely new level.

The principles behind the design of Firmata, and possibly the protocol itself, has a lot to offer when considering the design of immersive design tools for live-action games. There are a few limitations when electronics with tight timing or high volume messaging requirements are used, but a hybrid approach based on categories of devices can be used to take advantage of computer-host control and local microcontroller processing.

Visual Programming

There are two predominant strategies that are being used to provide accessible means to create software logic without having to write any actual code. The first is the use of code blocks popularized by Scratch (refer to figure 2.2), a visual programming environment for kids development by MIT (Maloney, Resnick, Rusk, Silverman, & Eastmond, 2010). Code blocks are or drag-and-drop logic units that essentially handle managing the syntax and structure of the visual code. Users snap together blocks and the block change and expand to keep the scope of their functionality clear. It has been very successful in introducing kids to programming and the technique has been emulated in other software and game engines, including a version that allows interfacing with Arduino microcontrollers.

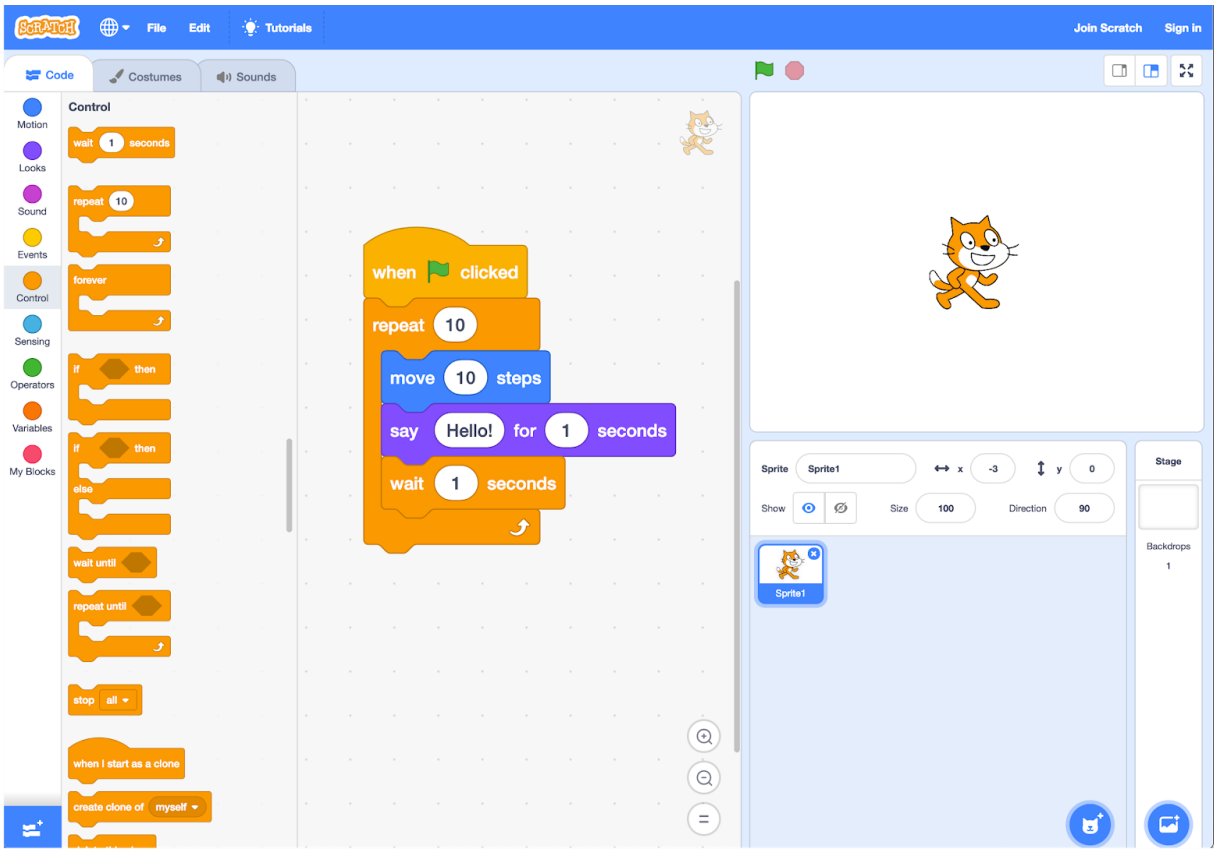


Figure 2.2 Screenshot of Scratch Web Editor

While the code block technique does a great job at making coding more accessible, its goal is fundamentally different from my own. The code blocks by design visually emulate the structure of written code, helping to familiarize users to the syntax and structure they will be required to use when writing code. The assumption is that it will be used as a stepping stone in their programming education rather than an abstraction meant to hide and remove the necessity for learning code at all.

The second popular code-free interface strategy uses Data Flow Systems, also described as flow or node-based programming and visual scripting. Although the exact implementation and functionality varies widely between applications, they are essentially an enhancement of data flow diagrams. Instead of merely representing how data flows through a process or system, they are actually functional and execute logic. Unreal Engine 4, a popular and powerful game development engine includes a data flow system called "Blueprints" (refer to figure 2.3) which provides node-based programming as an alternative to writing C++, a language considered difficult, especially by newer programmers. It's inclusion in Unreal Engine 4, an engine used for AAA or high budget games, is evidence of the enormous scope of work that can be achieved using visual nodes to represent logic, though the quality of experience and usability is open to question with particularly large or complicated projects, a topic worth a researching on its own.

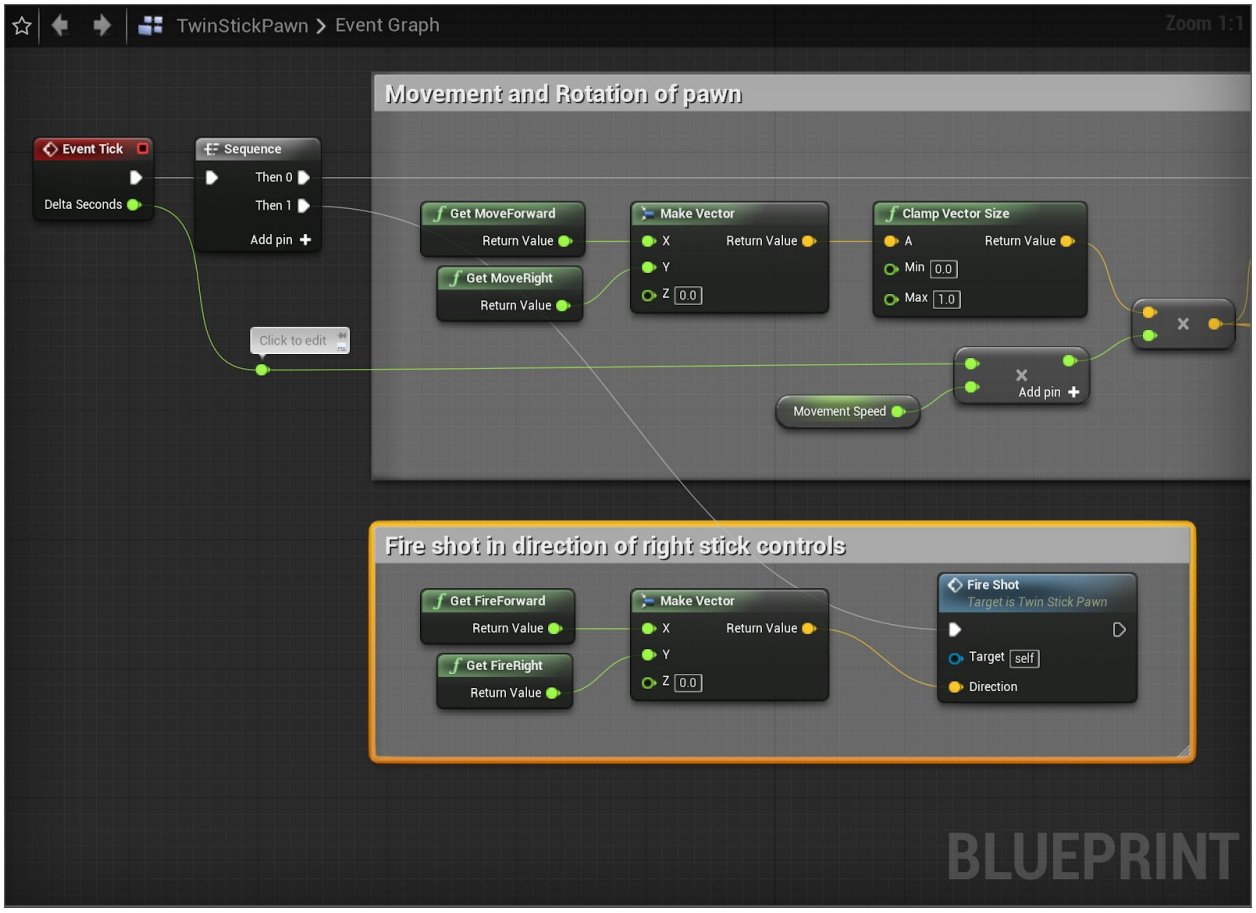


Figure 2.3 Screenshot of Unreal Editor Blueprints Feature

Node-RED (refer to figure 2.4 top) is a solution that falls much closer to the use-case of this research using flow-based programming to connect hardware devices like Arduinos, APIs, and online services, specifically citing the Internet of Things (IoT) as the target market for the tool (Blackstock & Lea, 2014). There are a number of potential benefits to the design approach of this software. Being web-based, it is widely cross-platform, including the ability to run on low cost microcomputing systems such as the Raspberry Pi Linux computer. Although it runs in a browser, it can be hosted locally and function without a connection online, something I consider vital for any solution to be maintainable for immersive experiences. The code is entirely open source which has allowed tools to spawn from it for other systems requiring a similar model. Particle, the supplier of the mesh capable microcontroller boards, created a branch of Node-RED they call Rules Engine (refer to figure 2.4 bottom), providing new nodes, or functionality, that hooks into their existing cloud services. This may be a very important find for this project as it would potentially allow for quickly getting a flow-based logic interface with custom functionality for user-testing key features of an immersive toolset.

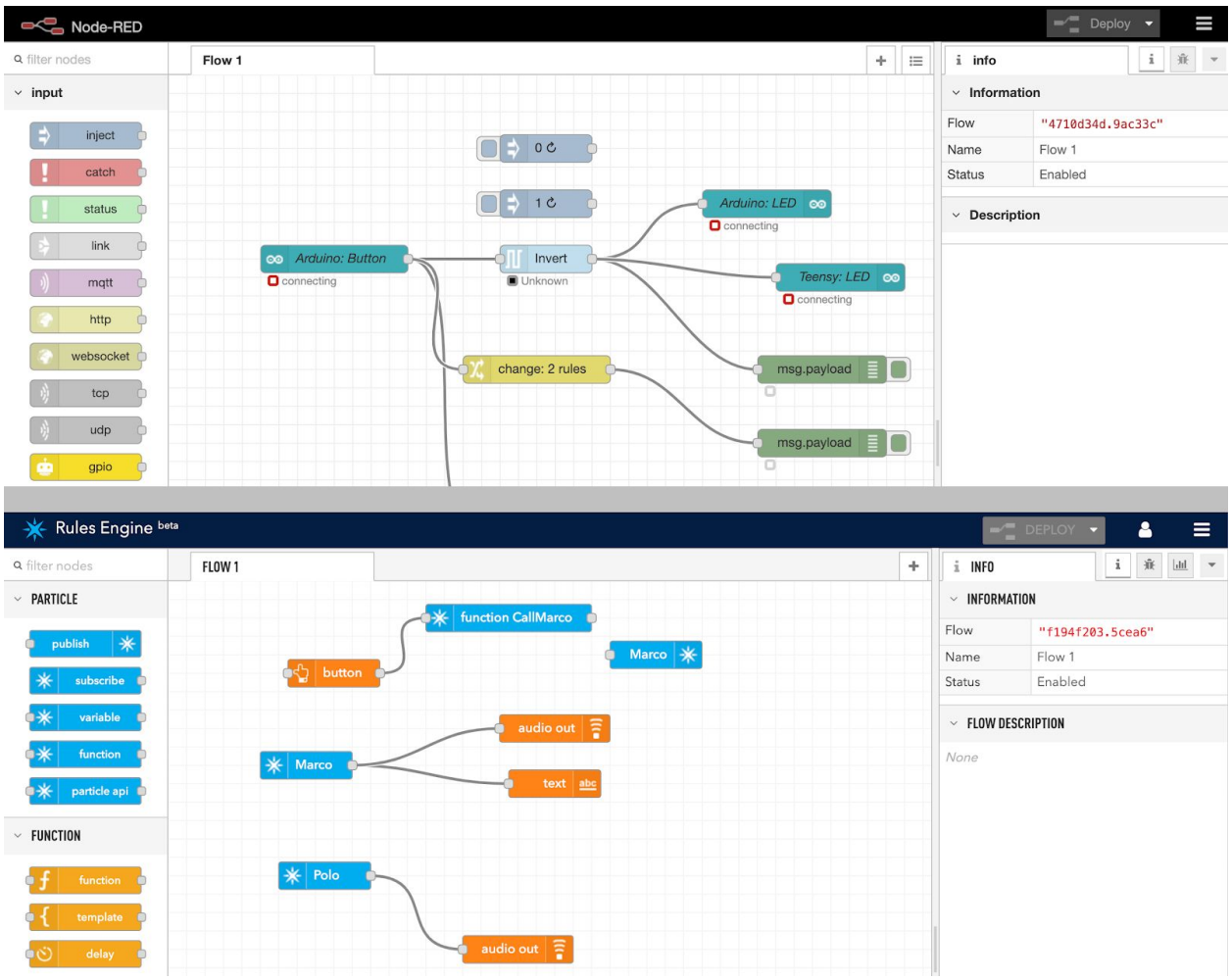


Figure 2.4 Top: Node-RED Interface - Bottom: Particle Rules Engine

Theoretical Frameworks

The theoretical model primarily guiding this research is the Co-evolution Model of Design (refer to figure 2.5) originally conceived by Maher (2000) and refined by Dorst and Cross (2001). Wiltschnig, Christensen, and Ball (2013) went on to show how co-evolution also applies to collaborative and team-based design. The design of live-action games requires strong multidisciplinary skills and is a highly collaborative design activity, and so immersive tools should be designed to take advantage of this, even encourage it. A crucial concept is that creative events in design primarily concern the creation of ‘bridges’, or incremental changes between problem and solution space as opposed to ‘creative leaps’ often associated with advancements in design. A new insight or surprise pushes us forward another step, from one problem or solution to a new understanding of the problem or improved solution (Dorst and Cross, 2001).

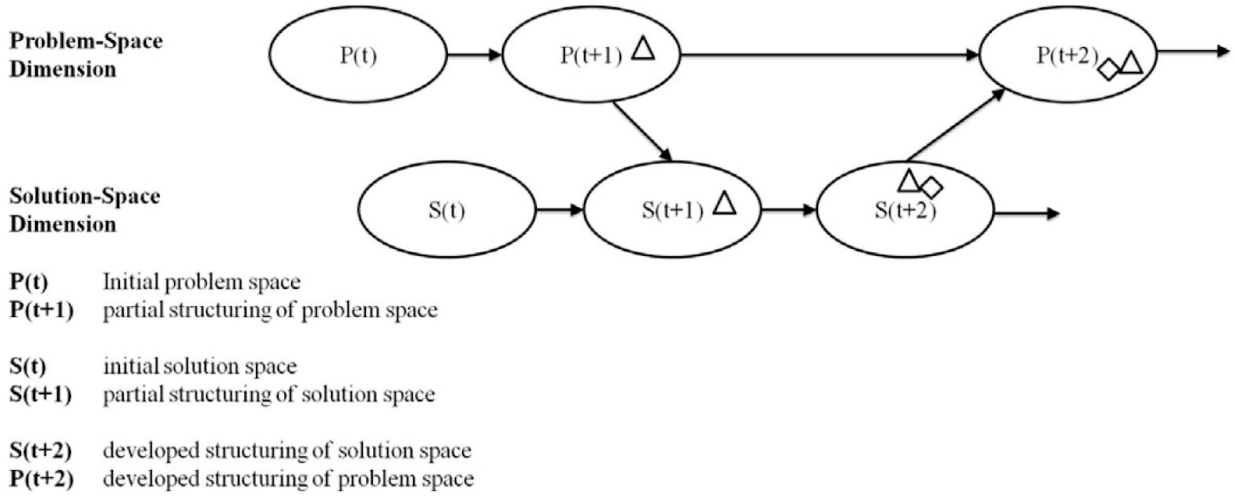


Figure 2.5 Dorst and Cross's (2001) problem-solution co-evolution model as derived from the observations in their study of design creativity.

Another valuable tool used in this research is Norman's perspective on *signifiers* as applied to design, a clarification on what he considers misuses of the term 'affordances' which were originally defined by J. J. Gibson as "the actions possible by a specific agent on a specific environment" (2008). Signifiers whether deliberate or incidental provide clues in how we understand our physical or social environment. For designers, the goal is to provide signals so users perceive the intended affordance. When deliberately placed, Norman calls this a *social signifier* to differentiate from incidentally perceived signifiers.

Summary

After reviewing available literature it is clear that focusing too closely on either technological design tools or collaborative design methodologies would be a disservice to the other. A holistic approach balancing the knowledge and innovations of each is required to succeed in developing a toolset that is functional and desirable to immersive designers. The danger for technology to create friction and derail productive exploration of the problem-space of design is high, but the potential rewards even higher, and success could mean an entirely new generation of designers innovating in the live-action game industry and other immersive design spaces.

Chapter 3: METHODOLOGY

The complexity of multi-medium designs such as live-action games cannot be fully appreciated without having been involved in the process personally. A primary motivator to pursue this research includes my personal experiences designing games of this nature along with other immersive installations also requiring a strong mix of skills, both technical and designerly, to complete successfully (of which any designer will tell you is measured in degrees). I have also noticed a pattern throughout my near two decades of professional work in this space, where my attraction to technology solutions was based not in a desire to become an expert in the technology, but in what such solutions could make possible. The limiting factor was always the same: how much time and resources would I need to dedicate to the technology until I could sufficiently take advantage of its capabilities?

This, of course, is far from simple to answer. What it highlights, however, is a struggle and what often feels like a gamble for designers and stakeholders using immersive technology. This tension is the motivation for the methodology of this research. To understand how we might create immersive tools that are more accessible and flexible than what currently exists, we must better understand the factors that drive live-action game stakeholders to innovate, in what forms they believe innovation should take, and what is holding them back.

Surveys were developed to provide a snapshot of the participants' skillsets and attitudes toward immersive tech, along with comparisons of their early and most recent live-action game to discover trends in costs, timelines, design characteristics, and the tools used. Interviews were developed to provide detailed qualitative data from a subset of the survey participants, focused primarily on their feelings concerning immersive experiences and the future of the industry, along with their own memorable experiences playing and designing live-action games.

Survey

The online survey was a vital component of this research as wide dissemination was necessary to acquire enough participants considering how narrow the participant requirements were. The most limiting factor was the experiential requirement of at least two completed for-profit projects along with having been involved with related work in the last two years. These requirements helped to ensure high-quality data and a viable pool in which to select participants to be interviewed as well.

The survey was carefully designed to avoid questions that would reveal narrative or game details which could unknowingly identify particular projects or reveal details that could spoil aspects of play. As the pool was already assumed to be difficult to access, it was important not to give a reason for valid participants to turn away. The survey consisted of 60 questions, with 20 of them repeated, once for their earliest project, once for their most recent. Questions were designed for quick selection but many allowed for text input to allow for unanticipated answers. Participants could also choose to be completely anonymous or provide a contact email for a potential interview. Once interviewees were conducted, their identifying information was removed and replaced with a numeric code to associate their survey and interview.

Google Forms was used to design the survey and was presented as a link directly to the survey in all dissemination copy, which included social media sites such as Twitter, Facebook, and LinkedIn, community tools such as Slack, and email. The copy included encouraged individuals to share the post or link if willing in an effort to increase the pool of people likely to see it. The following copy was used to disseminate on Twitter, followed by the copy used for all other methods:

Twitter

"If you design/manage/fund live-action games (ex. escape rooms), please take part in this thesis research survey so we can better understand needs for immersive tools! You must have completed 2 projects & worked on a related project within the last 2 years. *<URL to the survey>*"

All others

"If you design/manage/fund live-action games (ex. escape rooms), please take part in this thesis research survey so we can better understand needs for immersive tools! You must have completed 2 projects & worked on a related project within the last 2 years.
This study examines the design process of interactive game spaces, such as escape rooms/live-action game spaces. More specifically, we are looking at the use of immersive technology (or lack thereof) in these spaces and how accessibility and flexibility of this technology affect their use in the design and implementation of these experiences.
This survey asks for information about your experiences and your responses will be treated as

confidential information. At the end of the survey, you will be given the opportunity to provide contact information and volunteer to be interviewed for this study. If you are not chosen to be invited to be interviewed, your name and email address will be removed from the data downloaded for long-term storage. If you are chosen, a random code will be used to replace your identifying information and a linking list stored separately from the data.
We will not be asking any questions specific to the theming, narrative, or puzzles of your spaces. You will not need to provide any information that would reveal or 'spoil' any aspect of your designs.
Survey Link: *<URL to the survey>*
Sharing is appreciated. The following link is a tweet ready for retweets!
<URL to the tweet with the Twitter copy>"

The front page of the survey provided a brief summary of the research being conducted, along with the criteria for participation so those for whom it did not apply could simply exit the survey. The second page included all consent information and would not allow participants to continue unless they expressly provided consent through the form (refer to appendix A for consent and C for survey questions). Data was stored onto the Google Drive service behind two-factor authentication.

The survey was active from January 21st, 2019 to February 18th, 2019. Individuals coming across the survey were encouraged to share it in order to achieve wider dissemination. On February 5th the survey along with a short interview about my research intents was shared in a post on Room Escape Artist, a website that reviews and examines live-action games.

The Room Escape Artist interview URL:
https://roomescapeartist.com/2019/02/05/academic-survey-immersive-design-accessibility/

Semi-Structured Interviews

All participants of the interview were recruited from the pool of survey takers that volunteered to be interviewed and included a contact email to facilitate logistics. They were manually selected based on their survey answers to provide a variety of experience and perspectives. Of the twelve individuals invited to be interviewed, six participated.

Participants were emailed consent copy (refer to appendix B) and were provided large windows of potential interview time slots using the online tool Calendly. Interviews were conducted over Google Hangouts. Prior to the interview, a preamble was read to the participants asking for verbal confirmation that they received the consent information and that they allowed themselves to be recorded. They were then asked to repeat their consent to be interviewed before the questions began (refer to appendix D for interview questions). Audio Hijack, audio routing and recording software, was used to record both the researcher and the interviewee. The data was stored onto the Google Drive service behind two-factor authentication.

The questions themselves were organized into three different categories with a closing question. The first focusing on the perspective of players and their experience in live-action games. The second category was concerned with the interviewee's role and experiences working on live-action games. The third category explored the role immersive technology plays in live-action games. The final question asked interviewees to compare how their attitudes may have changed from their first to most recent projects to further shed light on the quantitative data already acquired in the survey.

Coding

The survey allowed for the selection from sets of qualitative answers along with participant entered answers. The survey results were coded to simplify participant written answers into themes more directly comparable to available answers with effort taken to not dilute the intention of their answers. The researcher-provided survey answer options were also coded to reduce the long-form descriptive answers meant to provide clarity to participants and multi-select questions were broken out into individual entries. The resulting simplification of the survey results, stored in Google Sheets, made it easier to compare and observe trends manually as well as export data tables able to be easily consumed by Tableau, data visualization and analysis software.

Interviews were transcribed, analyzed, then coded to discover trends and themes across the collected data, ultimately entered into a Google Sheet. Interview passages were coded with each containing one of a set of megathemes, one to three themes, and occasionally an additional subtheme. Each coding could also include a positive or negative modifying, indicating the participants general feeling toward the coded topic at that point in the interview.

#	Code	Megatheme	(+, -)	Code	Theme	Subtheme	Summary	Evidence Example
1	MEM	Memorable		SE	Social Experience		important to have experiences w/ friends	the chance to do something memorable with others
1	MEM	Memorable	POS	SE, ISO	Social Experience, Isolation		being w/ people but then isolated, realization of immersion	I knew there was a play going on in real time, but I dic
1	COH	Cohesion	POS	SOD	Suspension of Disbelief	World Design	all encompassing design to fully immerse players	I prefer completely breaking the audience from the re
1	AUD	Audience	POS	RO	Reduce Overload		audience should leave w/ understanding of xp or actions taken	Coming out of the experience with a nice clean under
1	CE	Co-evolution	POS	DES	Design		involved at all steps of design & testing	Beginning to end. Although I don't think I've gotten to
1	AUD	Audience	POS	APAR	Active Participation		involving audience was a fav part, active rather than passive	there was an idea that the bartender halfway through
1	AUD	Audience	NEG	PPAR	Passive Participation		forcing audience to be passive was frustrating for them	In a space themed room there was a character, a bra
1	PT	Prototyping		PP	Paper Prototyping		would work in space if availabe, focus on game/puzzles	We use paper prototypes, cards, and other stuff like t
1	RSK	Risk	NEG	IMTK	Immersive Tech		server/tech difficulties	For the whiskey immersion experience, in a beta test,
1	CON	Constraints	POS	IMTK, T&M	Immersive Tech, Time & Mone	Throughput	tech for better throughput, reduce time & increase revenue	One thing I'm surprised that no one is really talking ab
1	CON	Constraints	POS	IMTK, PR	Immersive Tech, Pro Resources		having people w/ expertise meant fewer limitations	I've been lucky, working with folks like Two Bit Circus,
1	CE	Co-evolution	POS	IMTK, ANL	Immersive Tech, Analytics		data about players would realyl help w/ design iteration	Data collection. Coming from mobile work what I reall
1	RSK	Risk	NEG	IMTK	Immersive Tech	Support	getting it working isn't enough	Support and maintenance. When I build stuff and get
1	ACS	Accessibility	NEG	IMTK	Immersive Tech	Support	staff won't necessarily know how to handle tech	But when I hand it over to the person running it, they
1	ACS	Accessibility	NEG	IMTK	Immersive Tech	Software	different people designing than running	I don't know if that would be useful. Usually it is differ
1	ACS	Accessibility	POS	IMTK	Immersive Tech	Software	if it worked really well with designing & monitoring	though if it worked really well sure, that would be grea
1	ACS	Accessibility	POS	IMTK, VL	Immersive Tech, Visual Logic	Software	if it works, great!	I haven't really had much experience with drag and d
1	COH	Cohesion	POS	IMTK	Immersive Tech	Hardware	off-the-shelf is great if it fits what you are doing	There are a lot of common themes used in the industr

Figure 3.1 Interview Coding

Overall this resulted in 9 initial megathemes and 107 unique codes. The megathemes were reduced down to three of strong relevance and reduced categorical overlap. Abbreviations were used as codes with + or - symbols representing the feeling or tone modifier. The Google Sheet automatically tracked and counted occurrences of each complete code as well as subcomponents of each code for more detailed investigation.

Code	Count	Code	Count	Codes	Count
ACS	34	AER	6	ACS+, DES	1
AUD	16	APAR	7	ACS+, DES, IMT	1
CE	15	APAR, CHG	1	ACS+, IMTK	11
COH	26	CAP	4	ACS+, IMTK, SII	2
CON	18	CHG	4	ACS+, IMTK, SS	2
MEM	15	DES	8	ACS+, IMTK, VL	1
PT	10	DES, IMTK	2	ACS+, SR	1
RSK	27	DES, THM	3	ACS+, VL	1
STF	15	IMTK	51	ACS, CHG	1
		IMTK, AER	2	ACS, IMTK	1
		IMTK, ANL	1	ACS, SE	1
		IMTK, CAP	3	ACS, VL	2
		IMTK, DES	1	ACS-, IMTK	7
		IMTK, IT	1	ACS-, IMTK, T&	1
		IMTK, PPAR	1	ACS-, T&M, CAI	1
		IMTK, PR	1	AUD+, APAR	2
		IMTK, REL	1	AUD+, APAR, C	1
		IMTK, SIM	2	AUD+, CHG	1

Figure 3.2 Code Occurrence Counts

Chapter 4:
RESULTS AND FINDINGS

The main goal of this research was to determine if there is a gap between designers' existing competencies, knowledge, or skills and those required to produce live-action games utilizing immersive technologies. The data acquired from the survey and interviewees strongly suggests that there is indeed a significant gap that designers and related stakeholders are heavily motivated to cross, despite the numerous challenges impeding progress. The data also highlights a number of pain points that may greatly benefit from focused design solutions and additional research.

Limitations of the Research

The target demographic for this research was extremely narrow to create a focus on experienced professionals involved in commercial work on live-action games. In order to be eligible to participate, participants were asked to have completed more than one commercial project of this type to allow for the comparison of attitudes and techniques over time. Although this study was interested in participants worldwide, this researcher was based and had the furthest community reach in North America when seeking participants, strongly biasing the region most participants do work. Given the limitations of the sample size, it is recommended to confirm these results in a much broader study; however, the participants were deemed high quality sources given their experience in live-action games and provided a great deal of insight. This industry is growing quickly around the world, originating in Japan, and would also benefit from research focused in other regions.

Demographics

There were 33 total participants in the study, 6 of which further took part in interview sessions. North America was the primary region where participants had created relevant projects, 29 of the 33, with 4 having projects installed in Europe and 1 in Asia. Only 1 participant had relevant work in more than 1 region: that being North America and Europe. The amount of professional experience participants had working with live-action games ranged from 1 to 9 years, with the average being 3.15 years. 31 of the 33 participants had 5 or fewer years, once again highlighting how new this industry is.

Participants were asked to identify the project roles they most often assumed through their project work. Four roles were provided to choose from but they were not required to select each one. They could be ranked, placed in equal importance, or both. Below, each column represents a role, divided into how many participants selected that role as their primary, second, third, and fourth most assumed roles.

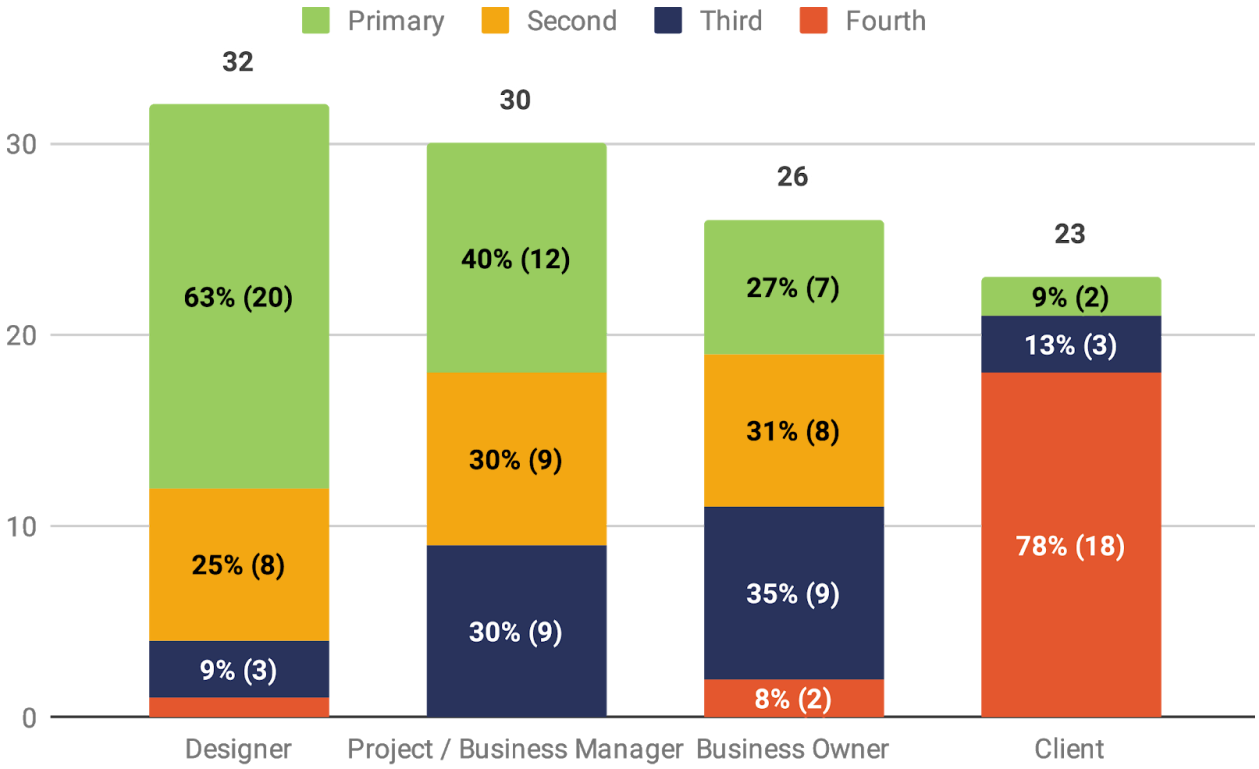


Figure 4.1 Project Roles Typically Assumed

Participants overwhelmingly identified as designers, with an almost even split between project manager and business owner as their secondary roles. It should also be noted that 4 participants identified as a designer, manager, and business owner as their primarily assumed roles equally.

Self-Assessment of Skills

Participants were asked to self-assess a number of skills in each of four broad categories. Financial and accounting, design, implementation, and installation skills. Answers were provided as values from 0 to 5, 0 being “No Experience” and 5 being “Very Adept”. The data was later simplified into three categories, “Below Average” or a low personal confidence containing values 0 to 2, “Average” for the value 3, and “Adept” or high personal confidence for values 4 to 5.

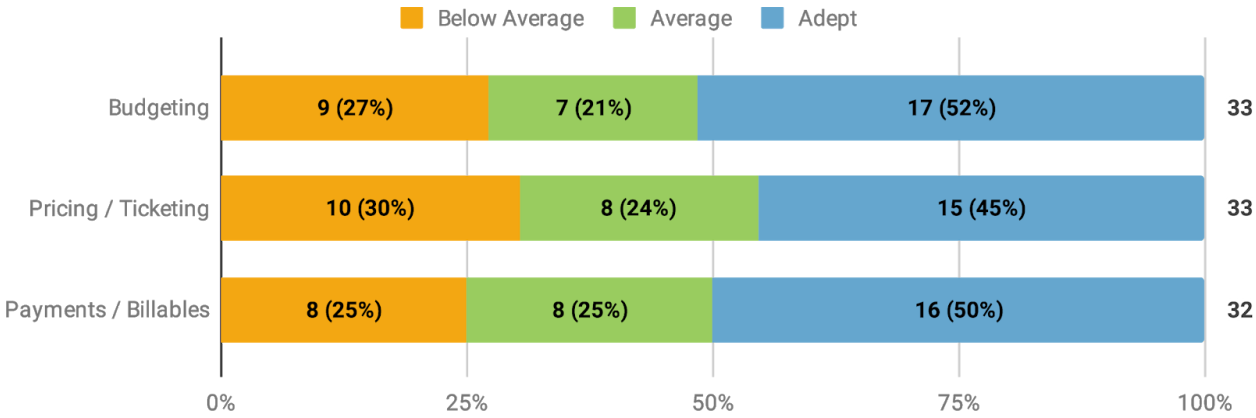


Figure 4.2 Participant Self-Assessment in Financial Tasks

Participants rated themselves reasonably well concerning financial tasks, with about 50% rated adept and 21% to 25% as average across all three categories. About a quarter to just under a third did not consider themselves skillful in this area.

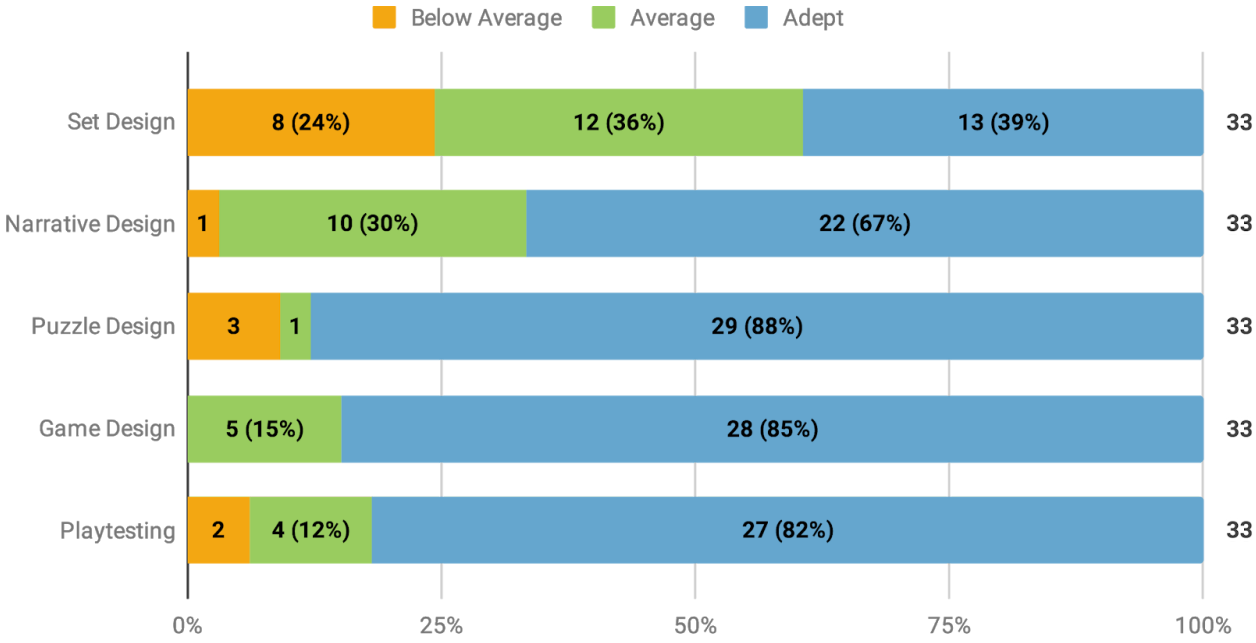


Figure 4.3 Participant Self-Assessment in Design Tasks

Considering that “designer” was the most assumed primary and secondary role by participants it isn’t surprising that self-assessments in this area are high. The lowest is set-design, most likely a skill for designers with a background in theatre.

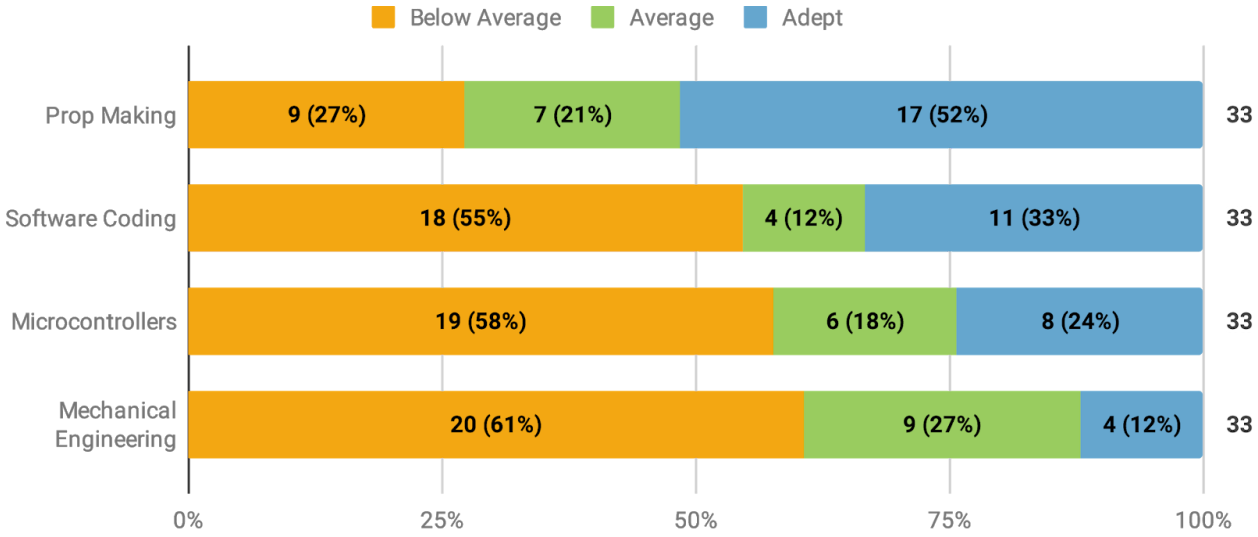


Figure 4.4 Participant Self-Assessment in Implementation Tasks

Only a third of participants considered themselves adept, or highly confident, with software coding and under a quarter with microcontrollers. More striking is the narrow margin of those with average experience, leaving 55% with poor software coding skills and 58% with poor if any skills with microcontrollers. Mechanical engineering, a skill often required to translate software and electronics in a complex physical form had the least overall experience, with only 12% adept and just over a quarter with average abilities.

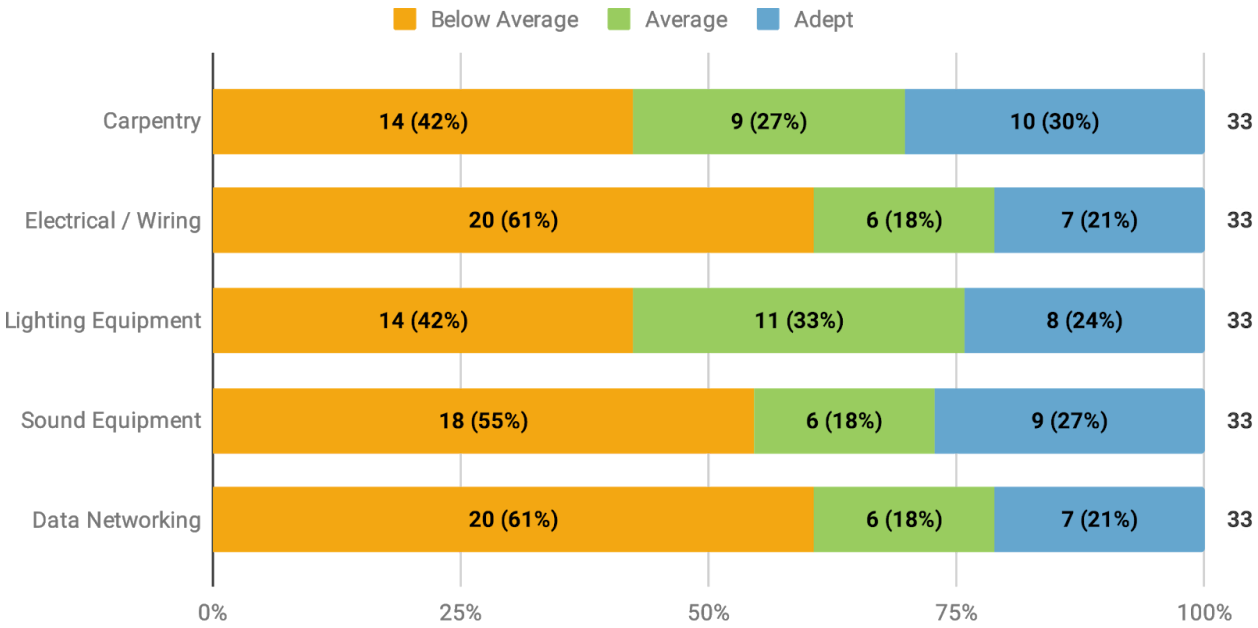


Figure 4.5 Participant Self-Assessment in Installation Tasks

Electrical and wiring work along with data networking compare with the low experience with software and microcontrollers. This poses a challenge as many designers seem to lack the types of technical skills required to develop an atmosphere in a space strictly from a basic theatrical level, meaning setup and basic use of lighting and sound, and working with electricity.

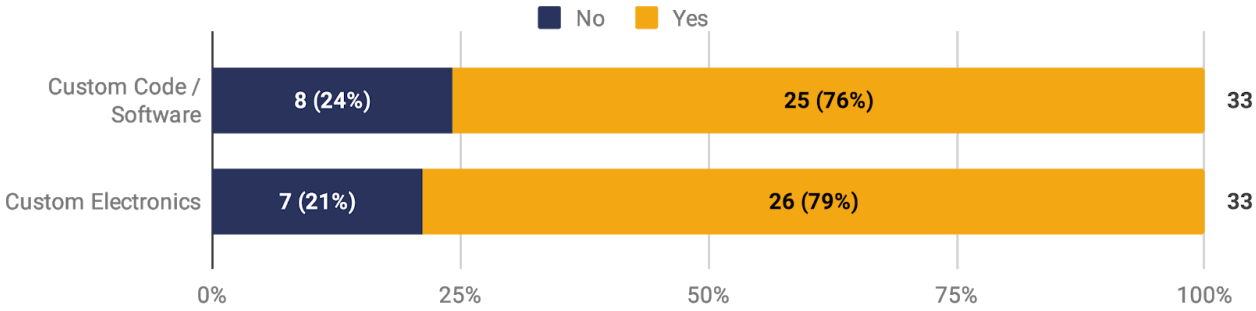


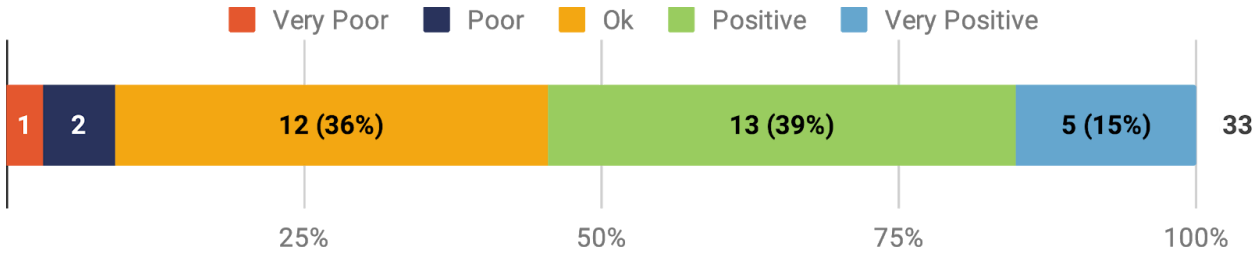
Figure 4.6 Do Participants Typically Use Custom Tech

Despite the fact that most participants consider their technical experience related to both implementation and installation quite low, 75.8% typically use custom software in their work and 78.8% use custom electronics, meaning a lack of experience is not preventing interest and use of immersive technology, even if limited.

Attitudes Toward Innovation

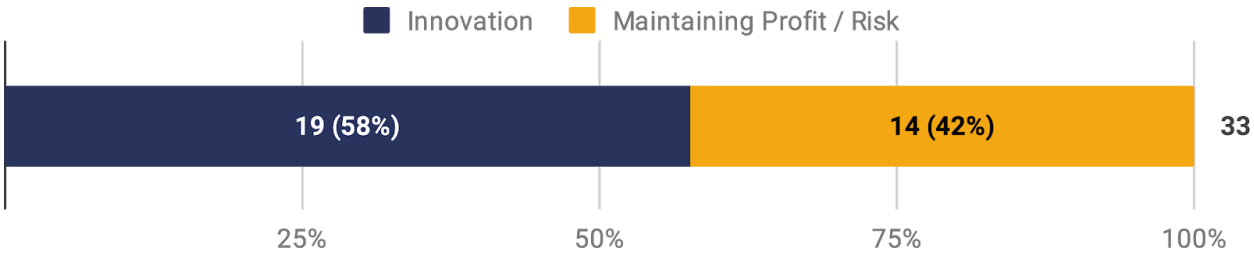
To better understand the drives and motivations of participants, they were asked a series of questions on the survey related to their attitudes toward innovation, immersion, and how immersive tech fits into their perspective of the industry and the player experience.

Survey Q: *If you have encountered immersive technology as a player of live-action games, please indicate your overall impression of the quality of its use below.*



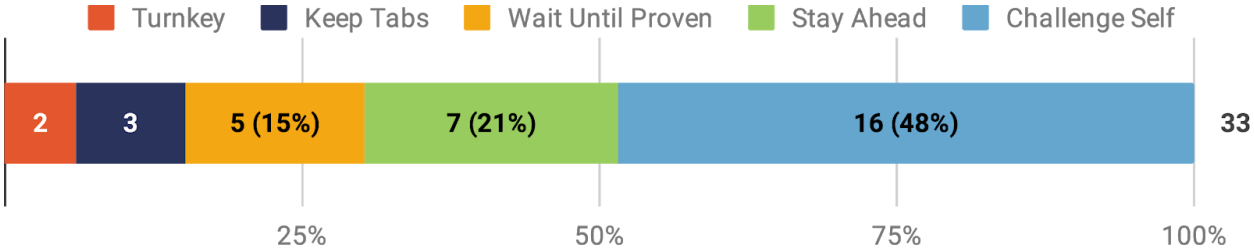
Almost 55%, or 18, responses had a positive experience with immersive technology in a live-action game. Over a third had an ‘ok’ experience, potentially fueling their motivation to do better work.

Survey Q: *Which of the following is most important to you when working on for-profit live-action games?*



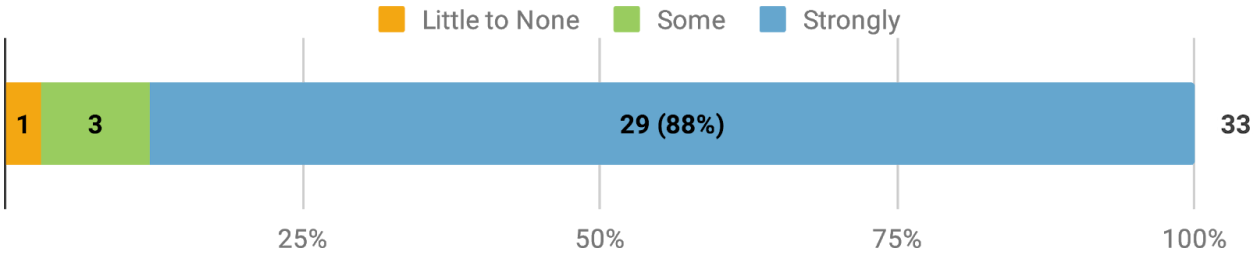
57.6%, or 19, responses indicated that they prioritized innovation and 42.4%, or 14, prioritized managing their profit and risk. Perhaps indicative of the type of people attracted to this work or the high percentage in the study identifying as designers.

Survey Q: *What best describes your pursuit of innovation when working on live-action games?*



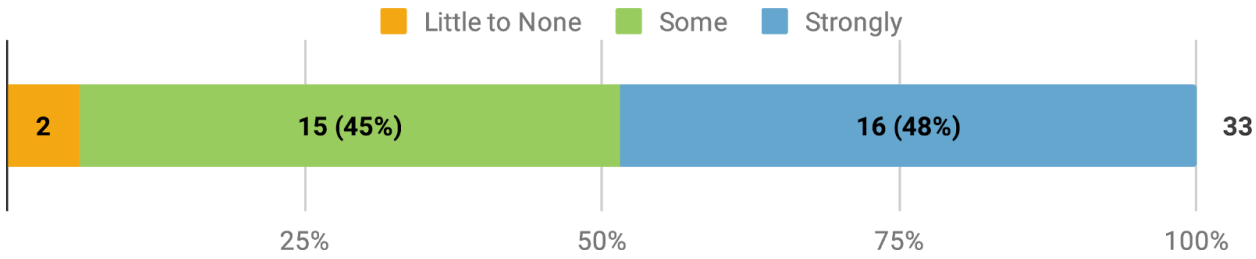
48.5% identified their drive as motivated by challenging themselves. A further 21.2% felt a competitive need to stay ahead of competition. The remainder were either risk averse or less compelled by being innovators.

Survey Q: *Do you believe that increasing the immersion of live-action games/escape rooms will lead to better player experiences?*



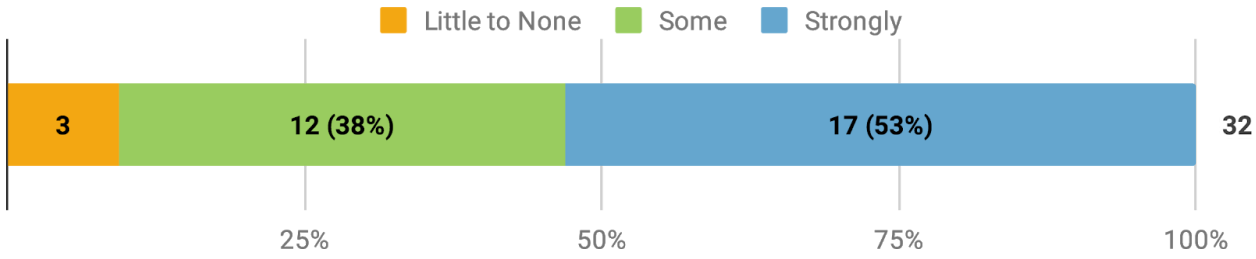
An overwhelming majority of 88% of respondents believe strongly that an immersive experience is a better experience for players.

Survey Q: *Do you believe that the use of technology (software and electronics) is important for achieving more immersive live-action games/escape rooms?*



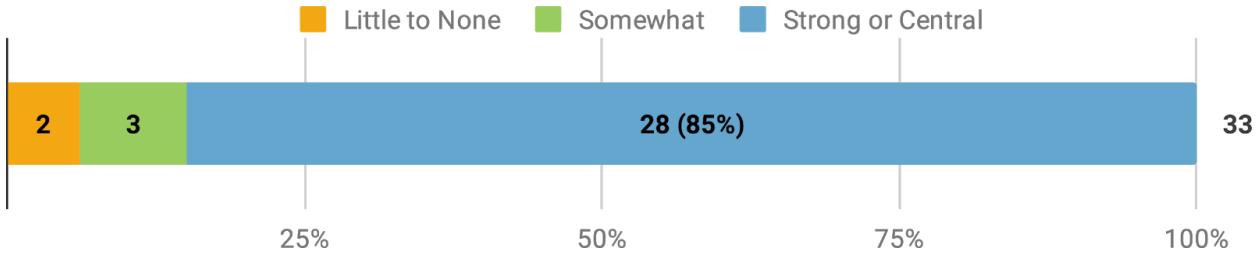
About half of respondents also felt strongly that technology was important to creating deeper experience immersion. Most of the remaining half, 45%, believe technology plays a part in more immersive live-action games, but are perhaps more skeptical on how big of a role that actually should be compared with other design elements. Overall, 93% believe technology plays at least a role in creating immersive games.

Survey Q: *Do you believe that the use of immersive technology is becoming more necessary in order to compete with other live-action games/escape room businesses?*



Similar to the overall feeling concerning immersive tech increasing immersion, 91% also believe immersive technology is important to consider in order to stay competitive in the business. Over half feel strongly that this is the case.

Survey Q: *How strong of a role is immersive technology likely to play in your future projects?*



Already surprising was the high percentage of respondents using custom software and electronics, 76% and 79% respectively. Given the overall attitude of technology being important for immersion and competition, it is less surprising that 85% of respondents expect immersive technology to play a strong, if not central role in their future projects. Almost 94% expect it to

play at least somewhat of a role. Given this expectation, it seems clear that tools designed to ease the process of integrating and designing with technology would be beneficial.

Potential Obstacles to Adoption

If we can state with confidence that immersive technology is useful and desirable in live-action games then the question turns to what obstacles are most likely to inhibit the adoption of this technology. Participants were provided nine categories of obstacles and asked to rank how likely each category was to inhibit their use of immersive technology. “Likely” being a category that has a high likelihood of inhibiting the participant.

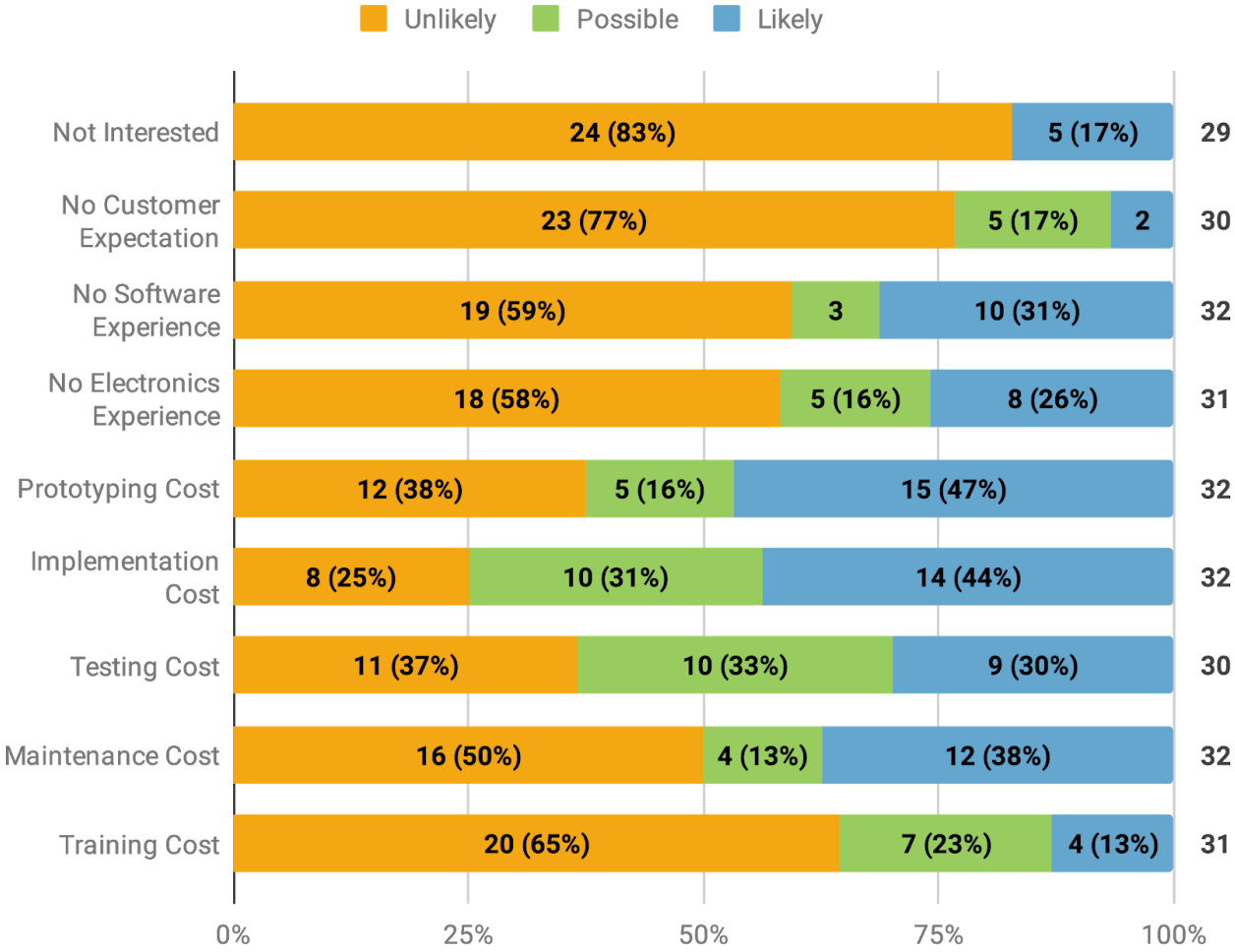
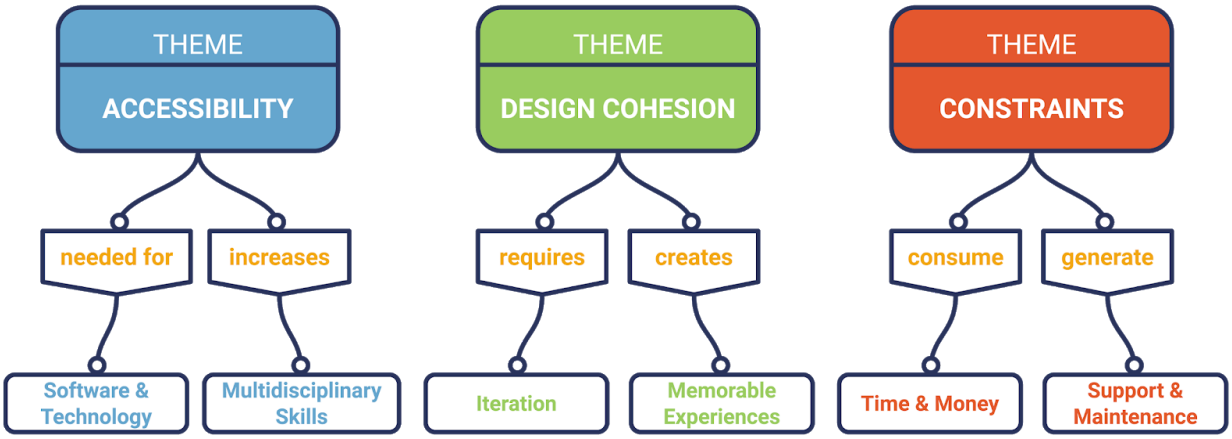


Figure 4.7 Likelihood of Factors Inhibiting Use of Immersive Technology

Costs ranked highest as inhibiting factors, even ahead of a lack of experience. Given that this set of participants rated themselves overall low on custom technology experience yet high on their typical use of it, it is clear that experience isn’t a primary factor. The financial and time cost, especially with prototyping and implementation are high, with test and maintenance close behind.

Themes Found in the Data

The qualitative data collected through semi-structured interviews, further supported by the quantitative survey data, resulted in the identification of three major themes and prevalent sub themes with strong relevance to this research. When technology was brought up, accessibility was close behind, especially in the context of what was unknown to them, for what technology could achieve and what skills would most benefit their ability to harness it. Across all interviewees design cohesion was core to the work they are doing. It was important to everyone that all design elements serve a unified experience and technology was no exception to that. Finally, each conversation was punctuated by the constraints of their work. Deadlines and cost were at the heart and there were often 'lessons learned' through the difficulties of maintaining games that affected the risks taken in the next design.



Accessibility

Interviewees spoke positively about the deep requirement for multidisciplinary skills with immersive technology. The desire to learn and apply that new knowledge simultaneously was a strong sentiment: "...learning as you're using is so much better than many of the other options for learning…". Also common was the frustration of running into a barrier, specifically with software and technology, that was going to use more resources than were available to either learn or hire help for, feeding into time and money constraints. Interviewees were excited at the prospect of immersive tools that would provide a visual language layer to game logic that would traditionally be only visible as software code. It wasn't just design accessibility that appealed with a visual logic system as a number of the participants were comfortable with software code, but the ability show the rest of the team: "I think that would be very helpful...for at least having people understand the flow of the design of the system, to be able to visualize it".

Designers in this space are not afraid of technical devices and tools, but it appears that a hodgepodge of learning and implementation is required to achieve the level of functionality

desired for live-action games: “I got the Arduino introductory kits and started figuring out what all kinds of sensors I had and what they could do…[I] start[ed] to build a repertoire of what electronic puzzles were possible…”. Although the tools themselves may be very functional they weren’t necessarily designed to interface the way live-action game design needs. Off-the-shelf electronics are often poorly documented and difficult to use: “...you have to follow the directions written by electrical engineers. I apologize if you're an electrical engineer, but if you are you should have somebody else write instructions...because they don't mean anything to me. They're really difficult to follow”. Another lamented, “...we used some RFID readers in some of our projects and I think all the documentation was in Russian”. Many of the electronics and devices available are simply designed for a different audience.

A frustration shared by interviewees with and without software coding experience was that to work with most microcontroller and computing devices required multiple levels of coding languages and development environments. Also common was confusion around how to reliably communicate between micro computing devices and full computing systems, such as your laptop or desktop. Often tutorials or examples for using various electronics are overly simplistic in order to be easy to follow but cause issues when new components are added or the solution is scaled, a problem cited a number of times in interviews.

Design Cohesion

The design iteration required for live-action games to go from rough theme to functional game was frequently brought up. Even once open to the public, interviewees expressed how games would continue to evolve: “...the language we use here is hardening a room. And that usually takes us a month to two. We have a game that's been open for a year that we just put a new puzzle into, just because we thought it would be helpful…. So our games are always changing”. Despite designers never considering their games completely finished, diminishing returns prevent continued effort; “There are games that...there are only very marginal improvements that we want to make that are either wildly too expensive or insignificant in the players actual experience”. Prototyping technology always took place as an independent process from designing the experience itself. Even for designers with the required experience, the time required to setup, code, wire, and power technology made it ill suited for the fast pace of the game design iteration process. Since working in the actual space or spatially equivalent environments was also important to interviewees, wiring was a significant barrier on its own.

The attitude of interviewees toward immersive technology is certainly positive, though most are also careful to express that simply throwing technology at the problem is not enough, it must be balanced with the overall theming, narrative, and activities within the live-action game design. That said, functioning immersive tech was described numerous times as feeling ‘magical’ even when the interviewee knew how it worked or even had a hand in the design. Most interviewees expressed numerous times how memorable they found surprising moments or special effects that were of a large scale compared with the size of the audience. One interviewee succinctly

summed up the importance of technology and special effects as a novelty draw: “People come for the special effects and they stay for the story…”.

Constraints

Time and money constraints were a major theme of the data collected, primarily falling into two categories: design implementation and the support and maintenance, a large concern in its own right. These constraints are not unique to the use of immersive technology but increased use of technology can drastically increase their impact on timeline and budget.

Common amongst interviewees was the frustration of having to either spend valuable designer time learning how to implement immersive technology, purchase ready-made technology, or hire outside talent to create custom devices. An interviewee describes the choice to do it themselves: “What I'm finding is there's technology I can purchase, but it takes me almost as long to figure it out as it does for me to design it myself. And it's way cheaper for me to do it myself”. Better understanding of the technology also increased their ability to support and maintain what they created, but could still be risky due to the unknown amount of time and in some cases money it would take, “Our third game...took us a year to build because it took me that long to learn wiring and power management and programming”. The unknown cost was often a major concern and timelines needed to be set as early as possible to avoid losing thousands in rent and other monthly costs related to running live-action games.

With regards to the support and maintenance of immersive tech, game staff was cited at all scales of live-action games as a constraint. This sentiment was echoed across interviewees from single game ‘escape room’ companies to a large chain of immersive games where, for example, each location has at least forty complex computing systems networked for a single experience. The larger the experience, the more complex the technology was and the less expertise the staff had; the interviewee for the largest example stated, “It was mostly college students on their summer break working the counter….if somebody was running into an issue, they didn’t know how to take bug reports….and so it was very, very difficult to support the game”. With staff lacking technical experience, the design team was forced to spend more time diagnosing and making repairs because the longer a game is unplayable the more revenue is lost:

> ...the heaviest traffic is over the weekend. Almost all the support calls are coming on like Saturday night, Sunday during the day. So we just had people working insane hours and some of them were...not necessarily trained to be computer support techs….So trying to have a programmer field a call of like, ‘...the hard drive on this machine died. What do I do to replace it?’ because we're losing money every second it's down, was hard.

Staff was also often brought up in relation to interviewee attitudes toward experience automation, where games are able to change state and trigger elements without intervention. For some of the interviewees there was a positive attitude toward automation; the perception being that there would be fewer opportunities for errors or that it adds to the experience: “[Automation] just adds something completely different to the room that you wouldn't expect to necessarily be there and...is more exciting than just a standard, ‘Right, here's the code, let's put it in a lock’”.

There was an opposing view with the concern that if automation meant the staff had ‘little to do’, they would fail to engage with their work, reducing performance in other aspects of their work, and be more difficult to retain: “One of our games requires very little...there's nothing for the Game Master to do but to deliver clues and they all hate running that game….I wouldn't be able to keep an employee if I had a fully automated room”. Automation is a broad concept that can be applied to a spectrum of areas in live-action games so no doubt there are many effective strategies for using it, but the perceived benefits and concerns will be useful in framing how it can best be used.

Theoretical Connections

A primary goal of this research is to better understand how immersive design tools could be designed to take advantage of and even encourage co-evolutionary model of design as conceived by Maher (2000) and refined by Dorst and Cross (2001). Design moves forward as a continuing series of small steps bridging between problem space and solution space, sometimes leading from one space to the other, or a new structuring of the same space. When designing such spatially anchored games, the ability to use design tools that take ideas quickly from the mind to testing them with your body could substantially speed up discovery as to the value of that idea and so further evolve the problem or solution space.

Currently the process of live-action game design is largely on paper or modeling physical spaces digitally to better understand them, sometimes having actual access to the final design space. Designers have expressed desire to be in the final design space whenever possible as it helps them understand the possibilities and constraints. Immersive tools could extend this value by providing spatial constraints of the final design space over a temporary one, virtualizing the borders of a room with feedback or projection. Or allow designers a deeper dive into the different possibilities for where they can implement immersive or interactive components.

By overlaying the conceptual and technical design iterations designers can also reduce the risk of impractical or overly costly designs which often aren’t discovered until the design process is complete and technical design begins. Using Maher’s co-evolutionary model of design as a guide will force a strong emphasis on accessibility of immersive design tools, which will require attention on designing clear social signifiers as defined by Norman (2008).

Chapter 5:
PHENOMENA RESEARCH CONCLUSIONS AND DISCUSSION

Challenges Identified

- Numerous overlapping technical and creative mediums each requiring specialized skills.
- Successful prototypes with immersive technology do not readily scale.
- Iteration over live-action game designs and immersive technology are difficult to overlap.
- Support and maintenance of immersive tech is time consuming and expensive.

Numerous overlapping technical and creative mediums each requiring specific skills. Creating innovative live-action games is particularly challenging when attempting to create original designs while knowing very little about the capabilities and limitations of your medium, in this case immersive technology. The common strategy employed by participants without significant resources is to acquire existing designs to study and explore, then modifying the designs to personalize them to their taste. This is an effective strategy although inherently limiting as it takes a significant bite out of the design solution space that the majority of participants claim is a driver for their desire to innovate.

Successful prototypes with immersive technology do not readily scale. There were multiple mentions of unwelcome 'surprises' when designers took a prototype they had after much effort gotten to function desired and tried to scale it up for installation within a game or included it in a

larger set of devices. The primary cause was a lack of power management, where overall power usage or spikes in power usage caused difficult to diagnose failures. Devices and software better able to communicate power requirements and faults would greatly reduce the time lost simply trying to understand ambiguous failures.

Iteration over live-action game designs and immersive technology are difficult to overlap. Although it is easy to attribute the inability of iterating design along with the technology meant to support it, even designers with technical experience expressed frustration. Technology such as microcontrollers with wiring together sensors and even connecting them to a data network often takes too much time to set up and test in order to be tightly integrated into an agile workflow. Fully functional or feature-complete technology often isn't what is actually needed, but simpler proof-of-concept level interactions. In web and app development interactive mockups have become commonplace, so may a similar solution help to bridge this gap.

If there were additional resources in both time and money for this research, I would include on site observational studies with multiple live-action game design teams in order to better identify how immersive design tools could fit earlier in the design process and where they might even improve the quality of overall designs while reducing time and cost.

Support and maintenance of immersive tech is time consuming and expensive. Even for experienced teams, this is a problem because staff who run live-action games have no technical experience. This prevents staff from fixing most problems and can even delay fixes further as they are unable to diagnose them as well. Design teams with less technical experience are more likely to have maintenance issues as their software or electronics will have more errors. Even theoretically error-free technology can lose significant reliability if the installers have little experience with implementing devices to withstand abuse from players and time itself. Electronics targeting immersive tools should be designed for dependability to reduce downtime and long term costs, including thought into maintenance access, secure mounting and wiring, range of operating temperature and cooling, vibration and shock, data communications, and power management.

Recommendations for Future Research

The need for immersive design tools that narrow the accessibility gap with the quickly growing library of available, feature-rich, and cost effective technologies is highly evident due to the high percentage of inexperienced yet extremely motivated designers, many of which intend to continue increasing their use of immersive technology. This research only scratches the surface of where hardware and software tools designers can focus additional research and effort for a high return in accessibility and flexibility; there is a wealth of low hanging fruit to be plucked to help immersive designers create higher quality work cheaper and faster. It is my hope that this research can also be used as motivating evidence for future investment into immersive technology and toolsets by government and private organizations.

I also recommend deeper research and observational studies with designers working with large scale immersive and interactive spaces. This may be difficult because of how protective large companies can be with internally developed innovations in technology and technique, but if possible, it could provide significant insight into how already existing advanced yet reliable innovations could be scaled down for accessible use. A challenge large manufacturers of electronics have faced over recent years is the influx of smaller customers not only wanting to purchase small numbers of products, but also have an increased quality of support that manufacturers haven't been used to providing. Some companies have adapted and grown and new companies have come into existence to serve this population. Scaling down is often as difficult as scaling up, even if you already have access to all of the knowledge.

This research would benefit deeply from observational studies where solutions to the primary pain points of prototyping are either emulated or themselves prototyped to better understand the effect on projects as holistically as possible. There are numerous areas of interest including the emotional perspective of the designers and stakeholders, the impact on estimated budget versus the reality, and the timeline to complete the project.

As there can be a large gap in the technical expertise of designers involved with immersive projects, there would also be value in measuring the change in adoption and under what circumstances the tools are abandoned and why. There is also an enormous challenge with design tools concerning the flexibility of the tools themselves. Increased abstraction and simplicity can in some cases exclude more technically skilled designers, not because they are unable, but because the tool begins to increase the difficulty of creating specific or custom results. Development of an immersive toolset would benefit from deeper understanding of the kind of control more experienced designers require and how it can be abstracted for greater accessibility while not making customization inconvenient or impossible.

Recommendation for Design Intervention

Live-action games and many other kinds of immersive installations may be meant to function for years at a time, meaning they must not be in danger of nonrecoverable disruption which can be caused by a number of factors. This is a large and multifaceted problem that requires deep consideration into both the software and hardware electronics used as part of a immersive toolset. It is also important to note, however, that there is a difference between tools meant to remain as a functioning part of a design, and tools simply meant to help with the design process; it should be noted that in this space there is a high likelihood that they end up overlapping. Immersive toolset designers should also consider long-term support and how existing designs might be affected if the toolset is no longer being actively supported. The tools should continue to function in their current state, even without active support.

Software

When possible, software should be available as open source which allows continued maintenance and even improvements without direct support from the creators. This can be difficult with a commercial toolset, but even allowing extensions of the core toolset to be open source can help, such as the firmware on microcontroller devices that are expected to communicate with closed-source design software. Even if design tools are closed-source, ensuring the communication protocols used are public, or even better an already existing open standard, third-party tools can be more easily created to enhance the usefulness of the closed source portion, or serve as intermediaries in the case that the software tool is no longer supported and standards continue moving forward.

Online or connected capability should also be viewed as a convenience and not a requirement. Many immersive designs do not require an online question to function fully, or at least fulfill their primary function. Requiring software to be online for licensing (or any other reason) will greatly reduce its usefulness to many designers. If software does phone home for other reasons it should always fail gracefully without impacting any running experiences. There are multiple “escape room” software packages currently on the market that provide basic audio, visual, and connectivity features but require monthly subscriptions, meaning the businesses using those products would likely need to temporarily close and find new solutions if the software was no longer being sold.

Hardware

The electronics world can sometimes rival software with the pace new sensors and microcontrollers come onto the market, change form factor or specifications, and even disappear. The biggest challenge of potential electronics solutions is being protected from costly changes or a loss of supply and stability because of deprecation. The solution, however, is similar to software; by allowing design files (including PCB layouts, build of materials, and specifications) to be open and available, communities can continue supporting existing devices and their work. If made commercially available this may seem risky, but in fact most development boards including Arduino and numerous spinoffs and competitors are open designs. It is a large and expensive task to replicate products such as these, however open designs allow for people to find or create alternatives on small scales if needed, or even augment other products to provide the needed features within the previous specifications.

Chapter 6:
DESIGN INTERVENTION

The research data gathered confirmed my initial hypothesis that there is a significant accessibility problem with immersive technology with regards to learning, understanding, and implementation. The data also clearly demonstrates that this problem is not a result of a lack of interest or motivation. Live-action game designers are motivated to innovate by the desire to challenge themselves as well as to better compete with other related businesses. The industry is highly competitive so innovation is necessary if designers wish to create experiences that advance the industry or at least remain competitive with it. This research was designed to be an exploratory study to establish priorities for an immersive design toolset and therefore prioritized finding high quality participants with professional experience in live-action games over a large number of participants. Computing platforms at all scales along with sensing and feedback electronics will only continue to increase in capability and therefor complexity, so it is the development of toolsets and usability features that will bridge larger audiences of designers to take advantage of the new capabilities. This returns us to the original question:

As the complexity of immersive technology increases, how could access and flexibility be increased to empower story-driven experience designers?

Immersive technology is a broad term, essentially a wildcard for any and all technology that could be used in live-action games or related experiences. As a result, it is impossible to anticipate each of the multitude of potential technologies used in design solutions. Hand-in-hand with this is determining the boundary of where an immersive toolset fulfills the needs of a designer in features and customizability and does not force designers into a certain way of creating that is not their own. Enabling a designer to ideate, prototype, and test a clever device that serves their narrative and game design goals without dictating what that device is creates a challenge, yet not an insurmountable one.

Technologies like hardware and software can enable people to create by reducing the need for highly technical specializations such as software coding. Before Photoshop (originally named ImagePro), graphics required software coding to achieve, but Photoshop has drastically increased the accessibility of graphics design without notably limiting what is possible. From experts and coders, to professionals, and now prosumers, it is a tool that has opened the gates of opportunity for countless talented individuals that simply needed the right tool to turn their vision into professional work. Immersive designers clearly desire and deserve a toolset that supports their motivation to push boundaries, innovate, and change the standard of live-action games and immersive experiences. Currently, designers experience significant frustration with the costs and risks of prototyping electronic devices for their designs, not to mention the additional challenges of scaling their solutions for their final experiences and maintaining those experiences. The desire to learn is there, but much of the electronics purchased are written in a language for lifelong engineers not designers.

PAINT! - An Immersive Design Toolset

In response to these findings, I developed *PAINT!* or *Prototype and install, no trouble!*. *PAINT!* is an immersive design toolset intended to lower barriers that make it hard for early or late career designers to develop functional, immersive experiences with modern software and electronics. Each component of *PAINT!* was designed to address concerns discovered in this project's primary research phase. The toolset is comprised of *PAINT! Flow*, software meant to map the technology and design the logic of an experience, and *PAINT! Palette* devices, custom electronics that provide a path to harnessing the power of microcontrollers and the ever growing ecosystem of sensors and parts. While a fully functional prototype of *PAINT!* could not be created due to the limited timeframe of this project, a prototype concept was developed and provided to experienced immersive designers to test and evaluate how well it achieves its goals.

The *PAINT! Immersive Design Toolset* prototype concept that was provided to participants is included in appendix E. A summary of PAINT!'s design goals and key features are detailed below.

The Pillars of PAINT!

Needs and constraints drive design decisions and immersive experiences are no different. The following pillars of successful immersive experience design tools were established to guide what features should comprise the final design.

Network of Things

No single computing device can support the infinite possible designs for an immersive space. Communication between devices at all levels of computation power is at the heart of a

successful immersive toolset. From full computing systems to microcomputers to microcontrollers and finally the variety of electronic devices that can be connected at each level of computing, the tools must support harmony across devices.

Benefits

- An immersive design can scale infinitely in functionality.
- Automation, monitoring, and intervention of experience becomes possible.
- Devices yet unknown can further enhance what is possible.

Challenges

- Wired and wireless communication each have strengths and weaknesses.
- Data protocols must be chosen which will affect hardware and software compatibility, plus ideally must be implemented to allow adding additional protocols.
- Mesh wireless solutions, though ideal for this design scenario, are in their infancy as far as open and reliable standards go.

Accessible Iteration

Technology tools and their features must strive to close the gap between creative design iteration and technology prototype iteration. These two iteration cycles should overlap as much as possible to become one to allow for the strongest possible design outcome and least amount of risk when it comes to eventual implementation. This pillar provides value across all size teams and businesses.

Benefits

- Reducing risks to time and cost caused by creative design solutions being out of sync with technology prototyping.
- Reducing design constraints when technology is prototyped first and becomes a project dependency.
- Increasing final design solutions by iterating with both creative and technological feedback, closer mimicking conceptual experiences.

Challenges

- Technology must have spatial freedom, easily placed and relocated within a design space.
- Provisioning of technology, be it a device or software flow, must be free of friction and process, avoiding bureaucratic setup and requiring details unknown early in the design process.

- Data networks must be effortless to setup with data able to move between devices easily and reliably with clear feedback.

Open and Off-the-shelf

Technology and standards can move fast so care needs to be taken that schematics, protocols, footprints, and interfaces are chosen that are supported by companies and communities with vested interest in them sticking around. Creating new standards from scratch, even if technically superior, will prevent adoption if it closes users off to the ecosystems already in place. Formats, protocols, and perhaps even electronic schematics should be open if at all possible so new communities can help support new additions to the ecosystem and bring confidence that they can continue to be used even if the provider is no longer able to support their own tools.

Benefits

- A large existing ecosystem of devices can potentially be plug-and-play with new tools, from microcomputers, microcontrollers, and a variety of sensors, inputs, and outputs.
- A large existing ecosystem of software can be interfaced with by supporting common protocols already used and supported widely.
- Community can grow around the design toolset that bolsters progress and accessibility further, faster.

Challenges

- You can't support everything protocol, but you can leave the door open for community to provide support for new protocols by providing basic support.
- Cost for design toolset device shields must be lost enough where designers will purchase them for prototyping without knowing their exact needs, so features must carefully balance with the BOM (bill of materials).
- This will always be a moving target which can create the temptation to pivot design repeatedly without getting tools into users' hands.

Prototype Permanence Path

Needs change as a project proceeds through the various phases of design. Technology tools and their features should be designed with the concept of project phases ingrained in their functionality. The designed proposal of *PAINT!* identified four phases of a project that were useful in associating the features of the toolset and how they could change to suit the design team from one phase to the next. Security of prototype devices, for example, is an impedance

early in the design process, but increasingly necessary as the project nears an audience ready state. Users must not be tempted to subvert security or safety in order to achieve ease of use.

The *PAINT!* proposal uses the following definitions when referring to project phases:

Design Phase: From initial ideas and concepts to project definition and active designing, the 'how' of a project.

Development Phase: Determining how to implement the design while continuing to refine and improve the design.

Implementation Phase: All parts of the design are clear and the team is prepared to connect and construct the numerous pieces until installation is complete and audience ready. This may include a phase of testing beyond the design team.

Maintenance Phase: The design is in active use. The designs experience is monitored, with intervention and support if there are technical problems or design experience problems.

Benefits

- Support design teams by providing flexible tools able to rebalance functionality based on project needs.
- Reduce error-prone and difficult to maintain installed devices a process for moving between project phases and tradeoffs of functionality.
- By associating technology behavior with project phases designers can be taught through example how to improve project process and prepare for the final phase of support and maintenance.

Challenges

- Despite commonalities, every design team has their own process. Over association of project phases with specific toolset features may negate the benefit. Guidance over rigidity.
- Inexperienced designers used to breadboard style prototyping will need familiarity along with a clear path to more reliable methods for when they are ready and the project deems it necessary.

Open Software and Technology

The *PAINT!* toolset proposal provides a detailed outline of the design and features intended for the toolset, but can be summarized in two symbiotic design solutions that resulted from two major design questions. First, should the *PAINT! Flow* design software be written from scratch or is there an existing software stack that would be viable to build upon? Second, what microcontroller specification or specifications should be supported by the *PAINT! Palette*

technology shield? The below summarizes the resulting design solutions intended to answer these questions.

PAINT! Flow - Design Software

This software is where designers will interact with the *PAINT!* toolset the most. It is where the physical design space is mapped to a digital one, where the variety of devices used throughout the space are connected to visual flows of logic, and where the experience can be monitored as it runs allowing designers an intimate knowledge of what they have built.

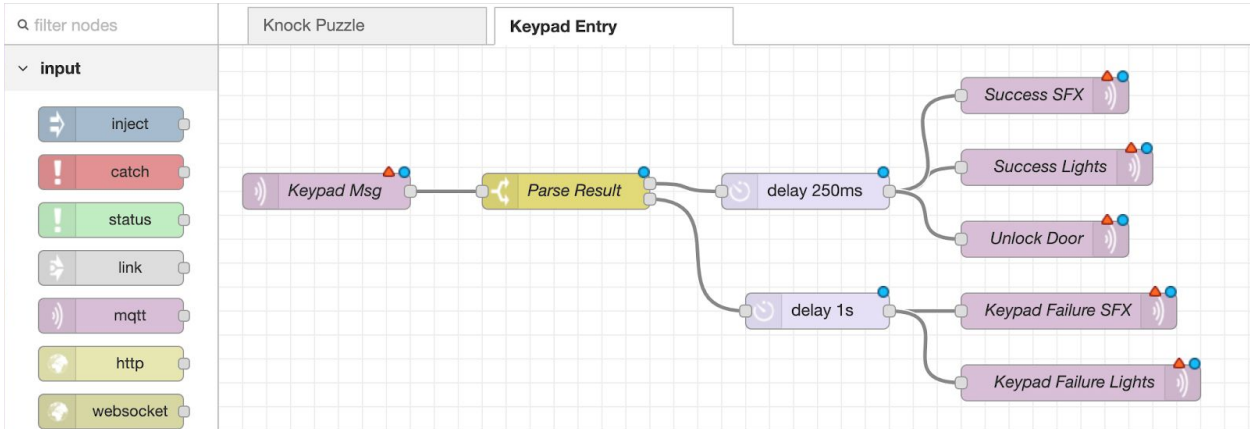


Figure 6.1 Screenshot of an Example Logic Flow in Node-RED

The *PAINT! Flow* software will build on top of the codebase of Node-RED, a visual language programming tool designed for connecting devices and services as part of the IoT (Internet of Things) ecosystem (Blackstock & Lea, 2014). The primary benefit of using Node-RED as a starting point for this tool is the flow based logic system where logic is encapsulated in a 'node' with various inputs and outputs. Due to the permissive Apache 2.0 license it is easy to repurpose, even commercially, and already has been by numerous companies for a powerful visual programming tool dedicate to their particular environment. The web-based nature of the technology it was built on means it is easily cross-platform, even able to run on microcomputing platforms such as the Raspberry Pi, and though it can easily manage working with online services it does not require connectivity in order to function. For this design intervention offline network capabilities are a requirement.

PAINT! Palette - Microcontroller Shield

The *PAINT! Palette* is about getting designers working in their physical design space as quickly as possible. Communication, wiring, and power should all be straightforward and safe while providing speed of setup and reliability of use.

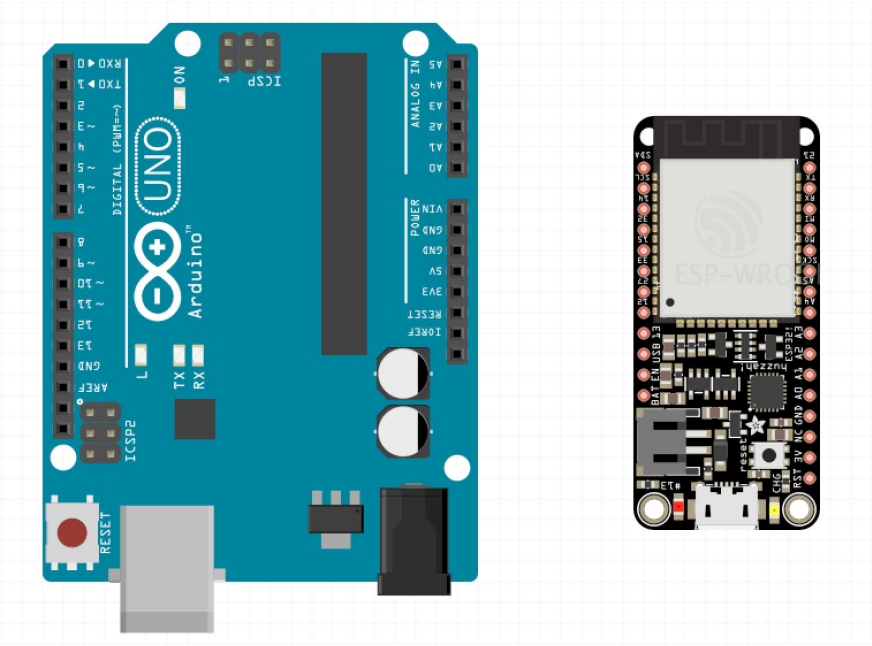


Figure 6.2 Screenshot of Fritzing Software - Left: Arduino Footprint - Right: Feather Footprint

In order to support the pillar of using open and off-the-shelf features to better support the overall community, significant time was invested in deciding the formfactor and microcontroller features this shield should, at least initially, support. For many years the Arduino form factor and featureset was the standard. The large size, lack of computing power, lack of built-in wireless connectivity, and the unwieldy stacking of shields has given way to a new generation of devices and standards. Adafruit has created a new specification called *Feather* that provides a new standard for board size, essential for creating shields that physically fit, and the pinout, meaning which physical pins lead to what components or functionality on the microcontroller (Fried, 2017). Competing companies such as Sparkfun and Particle have released their own boards that comply with these specifications, indicating strong support for some time. This specification means much better cross-compatibility between chipsets, meaning freedom with being stuck with a specific microcontroller and chipset without a large investment to upgrade. The Feather specification is therefore central to the design of the device shield itself.

Concept Testing

In order to gain a basic understanding of the potential effects of *PAINT!,* two participants, already qualified to take part in the research were approached, with at least one having virtually no immersive technology experience and one with a high level of experience. They were presented with a conceptual challenge. After a brief description of the exercise over email they were to read over the contents of the *PAINT!* proposal and mentally revisit previous immersive experience projects they had completed. After providing any requested clarification of *PAINT!*, this researcher walked the participant through each of four phases of project development:

design, development, implementation, and maintenance. At each stage they were asked to apply their understanding of the capabilities of *PAINT!* to their own projects, from process to technology solutions, and hypothesize the effect it would have had on their work, positively or negatively. This is hardly a replacement for live observations testing a prototype level design system, but was useful in gauging what aspects of these theoretical tools elicited the strongest reactions of excitement or concern.

Participant Reactions

Comments of particular interest have been collected from each participant and placed under the design phase they were contextual to.

Design Phase:

> *"I can't tell you how helpful it would be to have a setup that's networked, instead of a lot of electronics with each one functioning separately. It would be huge to be able to not only control things from one place, but also to be able to monitor them and troubleshoot easily."*

I found it interesting that the concept of any data network, let alone a wireless mesh based one, was so novel. This further reinforces how large of a barrier networked devices really are.

> *"The features described here would make it very easy to communicate with a development team and test new ideas on the fly. The node based system that lets different modules easily be added and removed from the system would make designing more hands on and less theoretical."*

This highlights the importance of iteration and speed, especially when it comes to changing the actions and roles of devices. Moving from a conceived idea to demonstrating it quickly allows a team the ability to react and change.

Development Phase:

> *"A lot of the time, we know we want to have "something" in a particular part of the design…but we don't know what that something is, because we don't know what sort of tech might be available, or how it might function in that specific place. I'm really excited about the idea of being able to quickly set something up and test it on the spot to see if it feels fun and if it works well in that environment and in that part of the game flow."*

Working around design gaps or fuzzy designs has been a particular challenge in my own immersive designs and solutions rarely seem to come in order.

> *"The ability to code in a visual way would decrease debugging and setup time. Also, developers would only need to learn one toolchain stack verses understanding the toolchain for each micro controller they wanted to use. Also, mesh networking is costly to set up and time intensive. This solution would just eliminate that development overhead."*

As a software developer as well as a designer, I experience constant frustration when having to move quickly between different tool chains, each with different expectations for the user depending on how archaic the original intentions of the tools happened to be. It is encouraging to have this particular technical problem recognized.

Implementation Phase:

> *"I'm not the most technologically inclined, but I'm very lucky to have people on our team that are. I would love to feel more capable of directly affecting the puzzles and tech, and to be able to diagnose problems and even repair them or make changes without needing to call in another person unless it's absolutely necessary."*

Empowering leadership to feel more capable communicating and working closely with their own talent could translate into higher quality leadership. Reducing dependency can allow team members to protect each other from distractions or wasted effort.

Maintenance Phase:

> *"Once a room is launched, there are a lot of times when you as the creator might not be the one running it—it could be an employee, for example. So it would be really useful for them to be able to look at a system and identify problems. It's also useful for me to be able to control who has access to those systems."*

This is a similar comment to numerous received during interviews, where restricting staff from accessing what they shouldn't while empowering them to support the game and customers is an important set of goals.

> *"This software would really eliminate the need for developers to need to keep updating and maintaining each board's development stack. One integrated system would mean one thing to maintain verses as many things to maintain as there are points of connection. Each connection would introduce a possible point of failure. Particularly, if a developer was using a IOT board and that board was depreciated, it would jeopardize the entire design. A company handling all of that research would save time and money for every small studio using this system."*

Most of the costs in maintenance in my experience and of those interviewed involves simply diagnosing problems. The ability reduce points of failure and provide better tools to diagnose then repair or swap out problems quickly could drastically reduce costs.

Final Comments:

> *"I think this project it worthy of venture capital funding and government investment as it will drive development of immersive spaces and systems, creating new markets."*

The promises made with *PAINT!* are many but as this comment recognizes, there is value in the work and I believe it is worthy of investment.

Suggestions for Future Design

A major focus of the current design centers around speeding up the iteration process around immersive technology allowing it to occur earlier in the design process. Going forward, there could be value in reframing this focus to include the speed and efficiency in which team members are able to successfully communicate design intention with each other. Visual logic should not only be easy to create, but for any member of the team to ‘read’ even without prior experience with the tool. Future metrics for studying the effectiveness of any prototypes for this toolset should not focus too narrowly on speed, but broaden to how the dynamics and communication between team members are effected. If this toolset is capable of increasing multidisciplinary confidence in team members and democratize the ability to wield immersive technology, in what ways will this change the dynamics of how immersive design teams work?

Chapter 7:
DESIGN RESEARCH CONCLUSIONS AND DISCUSSION

I was first inspired to do research into immersive design tools after designing, implementing, and installing my first live-action “escape room” game in 2017, an intensive process working with my project design partner, David Pisa. Our core design goal was a pushback against trends we had seen in other games, specifically around the use of large numbers of props, clues, and objects scattered around the game space. We were particularly frustrated with ‘red-herrings’, or clues that are intentionally or unintentionally misleading. So we conceived *Utopia*, a room that would begin as a deceivingly empty and sterile space, and focused on reveal and surprise.

The catch was it would require either deeply involved game masters to run or need to be heavily automated, and considering my years of software and electronics experience the choice was easy. The task, however, was not. I spent countless hours wiring and testing devices with code, spending more time shopping, purchasing, and connecting electronics and hardware than on the aspects of the design an audience would ever even see. The result was a functional, fully automated game that even won a Golden Lock-In Award the year it opened (Spira, 2017). The problem was the months of delays before opening followed by months of debugging seemingly unpredictable software and electronics issues. I didn’t realize it at the time, but automation at our level was rare and there were good reasons for it. Eventually issues were fixed and support dropped to a minimum of time. *Utopia* continues to run at the time this was written, but it took

an extreme toll on our health with long hours and stress; was over budget by nearly 25%; and very little of the work can be transferable to future projects.

After talking with numerous professionals in the industry and searching for new tools and devices better suited to creating complex immersive work like live-action games, I came up short. But at the same time I was so inspired by many of the new microcomputing technologies, wireless and data protocol specifications, and open-source creative tools that I thought it might be the perfect time to start examining this design space to see what can be done to improve it.

This research has also helped me to better understand a trend I have noticed while working with design teams on live-action games and other immersive projects. I am often one of few, sometimes the only, immersive designer with significant experience in software and electronics. As a result, it becomes my de facto task to solve technical design problems and thus the majority of my effort is directed there out of necessity. Certainly it is nice to be *needed* but I have personally found the dependency on the technical skills of designers such as myself creates a feeling of imbalance in the immersive design process. I am pushed further into the technical support role and away from the experience design as those without technical skills are pushed further into the conceptual design work. Design challenges become an exercise of throwing ideas and solutions over the wall that divides expertise, providing fewer overall resources to each discipline and preventing both groups from participating fully in the process. I find this unfulfilling and based on this research, I believe it to be equally frustrating for designers that lack these skills.

The feedback to the toolset proposal was extremely positive and this research has given me a lot of hope that immersive tools such as I have proposed could empower many new immersive designers to join the industry and push it further. More surprising and exciting to me, however, is the potentially dramatic effect an accessible toolset could have on the dynamics of an immersive team by allowing greater shared responsibilities. Instead of teams stabilizing into separate disciplines highly dependent on each other as I've previously experienced, perhaps they could stabilize as multidisciplinary mix without any one clear point of failure.

This is of course just a beginning; not just of this research but of an industry. Resources need to be directed into producing a functional toolset prototype that supports these ideals in order to conduct testing with actual design teams creating immersive and live-action game designs. I do believe that we are at or nearing an inflection point in immersive design, where available technology, designer motivation to innovate, and consumer demand will provide the momentum needed for a new generation of immersive design tools to emerge that allow for some truly spectacular new experiences.

BIBLIOGRAPHY

Alborzi, H., Hammer, J., Kruskal, A., Lal, A., Schwenn, T. P., Sumida, L., . . . Best, J. (2000). Designing StoryRooms. Proceedings from Proceedings of the conference on Designing interactive systems processes, practices, methods, and techniques - DIS '00, New York, New York, USA.

Barragán, H. (2004). Wiring: Prototyping Physical Interaction Design. Interaction Design Institute, Ivrea, Italy.

Barragán, H. (2016). The Untold History of Arduino. Retrieved February 9, 2019 from https://arduinohistory.github.io/

Blackstock, M., & Lea, R. (2014). Toward a Distributed Data Flow Platform for the Web of Things (Distributed Node-RED). Proceedings from Proceedings of the 5th International Workshop on Web of Things - WoT '14, New York, New York, USA.

Connolly, T., Routhieaux, R. L., & Schneider, S. K. (1993). On the Effectiveness of Group Brainstorming. Small Group Research, 24(4), 490-503. doi:10.1177/1046496493244004

Dorst, K., & Cross, N. (2001). Creativity in the design process: co-evolution of problem–solution. Design Studies, 22(5), 425-437. doi:10.1016/s0142-694x(01)00009-6

Fried, L. ". L. (2017). Introducing Adafruit Feather. Retrieved April 10, 2019 from https://learn.adafruit.com/adafruit-feather/feather-specification

Hayden, K., Novy, D., Havasi, C., Bove, M., Alfaro, S., & Speer, R. (2013). Narratarium: An immersive storytelling environment. Proceedings from International Conference on Human-Computer Interaction.

Johns, R., & Shaw, J. (2006). Real-time immersive design collaboration: conceptualising, prototyping and experiencing design ideas. J. of Design Research, 5(2), 172. doi:10.1504/jdr.2006.011361

Maher, M. L. (2000). A model of co-evolutionary design. Engineering with computers, 16(3-4), 195-208.

Maloney, J., Resnick, M., Rusk, N., Silverman, B., & Eastmond, E. (2010). The Scratch Programming Language and Environment. ACM Transactions on Computing Education, 10(4), 1-15. doi:10.1145/1868358.1868363

Neeley, W. L., Lim, K., Zhu, A., & Yang, M. C. (2013). Building Fast to Think Faster: Exploiting Rapid Prototyping to Accelerate Ideation During Early Stage Design. Proceedings from Volume 5: 25th International Conference on Design Theory and Methodology; ASME 2013 Power Transmission and Gearing Conference.

Nicholson, Scott. “Ask Why: Creating a Better Player Experience Through Environmental Storytelling and Consistency in Escape Room Design.” (2016):

Nicholson, Scott. “Peeking Behind the Locked Door: A Survey of Escape Room Facilities.” (2015):

Norman, D. A. (2008). THE WAY I SEE IT: Signifiers, not affordances. interactions, 15(6), 18-19.

Real Escape Game. (2019). About SCRAP. Retrieved March 31, 2019 from https://realescapegame.com/about/

Reas, C., & Fry, B. (2019). Processing. Retrieved February 15, 2019 from https://processing.org

Spira, D. (2017). 2017 Golden Lock-In Awards. Retrieved April 14, 2019 from https://roomescapeartist.com/2018/01/02/2017-golden-lock-in-awards/

Steiner, H.-C. (2009). Firmata: Towards Making Microcontrollers Act Like Extensions of the Computer. Proceedings from NIME.

Wikipedia contributors. (2018, July 8). Immersive design. In Wikipedia, The Free Encyclopedia. Retrieved 22:34, February 11, 2019, from https://en.wikipedia.org/w/index.php?title=Immersive_design&oldid=849317629

Wiltschnig, S., Christensen, B. T., & Ball, L. J. (2013). Collaborative problem–solution co-evolution in creative design. Design Studies, 34(5), 515-542. doi:10.1016/j.destud.2013.01.002

Appendix A:
INFORMED CONSENT

Survey - Online

Survey - About this Study

This survey is part of a research project about Immersive Design Accessibility run by Jerald Belich, an MFA candidate in Experience Design, and advised by Dennis Cheatham, both affiliated with Miami University. Invitations to complete this online survey have been sent by email to hundreds of people. In addition, open invitations have been posted on social networking sites such as Facebook and Twitter.

The purpose of this research is to examine the design process of interactive game spaces, such as escape rooms/live-action game spaces. More specifically, we are looking at the use of immersive technology (or lack thereof) in these spaces and how accessibility and flexibility of this technology affect its use in the design and implementation of these experiences.

We would highly appreciate your participation if you meet the following criteria:

- You are at least 18 years of age.
- You are or have been responsible for design and financial decisions in the creation of escape rooms/live-action game experiences or like spaces (group based games involving interactive problem-solving over a limited amount of time).
- You are or have been paid or profit from your role in the work described above.
- You have completed at least two experiences fitting each criteria above and have done related work within the last two years.

Participants can live and work from anywhere in the world.

Next **[Button - Proceeds to Consent Information]**

Survey - Research Consent Information

You are not required to participate in this study; it is entirely voluntary. If you choose to participate, here are some important things to know about your involvement in the study:

Completing the survey should take about 25 minutes. Your participation is voluntary, most questions can be skipped if you do not want to answer, and you may stop at any time if you do not wish to answer a required question. This survey asks for information about your experiences and your responses will be treated as confidential information. At the end of the survey, you will be given the opportunity to provide contact information and volunteer to be interviewed for this study. If you are not chosen to be invited to be interviewed, your name and email address will be removed from the data downloaded for long-term storage. If you are chosen, a random code will be used to replace your identifying information and a linking list stored separately from the data.

If you inadvertently include identifying information, such information will be removed from stored data. All data and individual responses will be stored securely behind two-factor authentication only accessible by the researchers. Results of the survey will only be presented publicly as aggregate summaries.

Foreseeable Risks: No foreseeable risks to your physical or psychological well-being are involved in this study. You will not be asked any questions specific to the theming, narrative, or puzzles of your spaces. You will not need to provide any information that would reveal or 'spoil' any aspect of your designs.

Benefits to the Subjects and/or Others: The data gathered from this survey will inform the development of immersive design systems with the potential to be used in creating technology-driven creative installations and live-action games.

If you have any questions about this research or you feel you need more information to complete this survey, you can contact the lead researcher, Jerald Belich, at belichjd@miamioh.edu or the research advisor, Dennis Cheatham, at cheathdm@miamioh.edu.

If you have questions or concerns about the rights of research subject, you may contact our reviewing body: the Research Ethics and Integrity Office at Miami University at (513) 529-3600 or humansubjects@miamioh.edu.

I understand my rights and protections as a participant, I agree to participate in this study for purposes outlined above, and I am at least 18 years of age.

Please indicate your consent to the above to continue.

- Yes, I consent. **[Forwards to 'Definitions' page.]**
- No, I do NOT consent. **[Forward to 'Lack of Consent' page ending the survey.]**

Survey - Definitions

Below are a few of the phrases we use throughout the survey and our definitions so you can better respond.

Live-action Games: Often labeled “Escape Rooms”, these are group-based games involving interactive problem solving over a limited amount of time, often in a themed environment.

Immersive Technology: Electronics and/or software that may be visible or invisible to players. Visible elements enhance the game by providing additional sensory immersion for players, including sight, sound, touch, smell, or even taste. Invisible elements help automate aspects of the experience or enhance the game master's ability to monitor or run the experience.

Arduino-Type Devices: This is meant to indicate any microcontroller style device (Arduino simply being the most known). These devices run small amounts of dedicated code to handle various inputs and outputs, but do not have an operating system.

Raspberry Pi-Type Devices: This is meant to indicate low-cost computing devices that run an operating system but also allow direct control over sensors or other devices through input and output pins, similar to Arduino-Type devices.

For-Profit Work: Any projects that involve the exchange of money. It could be that you/your team was commissioned, gets a percentage of sales, or you own the spaces and sell the tickets. If you are a client, your employment in a position to hire others for live-action game design also qualifies.

Next **[Button - Begins Survey]**

Survey - Lack of Consent

Thank you for your interest, but without your consent we are unable to use your survey results. If you selected this in error, simply hit refresh or back on your browser.

Survey - Potential Debriefing Statement

Thank you for your participation in this research about Immersive Design Accessibility. Your help is greatly appreciated.

If you have any questions about this research or you feel you need more information to complete this survey, you can contact the lead researcher, Jerald Belich, at belichjd@miamioh.edu or the research advisor, Dennis Cheatham, at cheathdm@miamioh.edu.

If you have questions or concerns about the rights of research subject, you may contact our reviewing body: the Research Ethics and Integrity Office at Miami University at (513) 529-3600 or humansubjects@miamioh.edu.

Appendix B:
PARTICIPANT CONSENT

Interview - Online

Interview - Emailed Participation Consent

Immersive Design Accessibility Research

You are invited to participate in a research project being conducted by Jerald Belich from the Interactive Media Studies Department and MFA candidate in Experience Design at Miami University. The purpose of this research is to examine the design process of interactive game spaces, such as escape rooms/live-action game spaces by examining the accessibility of immersive technology.

Participation in this research is restricted to persons 18 years of age or older.

The interview should take about thirty minutes on a prearranged day and time. Your participation is voluntary, you may skip questions you do not want to answer, and you may stop at any time. Notes accompanying this interview will not include information about your identity.

With your permission, the audio of this interview will be recorded to ensure accuracy. Later, notes will be taken based on the recording and the recording will then be deleted. If you inadvertently include identifying information, such information will be removed from stored data. All data and individual responses will be stored securely behind two-factor authentication only accessible by the researcher. Results of the survey will only be presented publicly as aggregate summaries, including an MFA thesis and potentially presentations and journals.

Foreseeable Risks: No foreseeable risks to your physical or psychological well-being are involved in this study. You will not be asked any questions specific to the theming, narrative, or

puzzles of your spaces. You will not need to provide any information that would reveal or 'spoil' any aspect of your designs.

Benefits to the Subjects and/or Others: The data gathered from this survey will inform the development of immersive design systems with the potential to be used in creating technology-driven creative installations and live-action games.

If you have any questions about this research or you feel you need more information to complete this survey, you can contact the lead researcher, Jerald Belich, at belichjd@miamioh.edu or the research advisor, Dennis Cheatham, at cheathdm@miamioh.edu.

If you have questions or concerns about the rights of the research subject, you may contact our reviewing body: the Research Ethics and Integrity Office at Miami University at (513) 529-3600 or humansubjects@miamioh.edu.

Please keep a copy of this information for future reference.

Interview - Verbal Participation Consent

My name is Jerald Belich. I am an MFA candidate in Experience Design and professor in the Interactive Media Studies department of Miami University, where this research is being conducted. This interview should take about thirty minutes.

Did you receive a copy of the consent information I sent by email? Do you have any questions before we begin? Please remember you can end this interview at any time for any reason and decline to answer any individual questions. May I record the audio of this interview for use later to take notes?

This study examines the design process of interactive game spaces, such as escape rooms/live-action game spaces. More specifically, we are looking at the use of immersive technology (or lack thereof) in these spaces and how accessibility and flexibility of this technology affect their use in the design and implementation of these experiences.

This interview will focus primarily on your personal experiences in this design space, as a player and professional, and your perspective on how things might and should change going forward.

If you understand your rights and protections as a participant and agree to participate in this study and interview, please accept by stating, "I consent to participation in this study and interview".

Interview - Definitions

There are a few terms or phrases we may use over the course of the interview, so we'll quickly go over the definitions we are using.

Live-action Games: Often labeled “Escape Rooms”, these are group based games involving interactive problem-solving over a limited amount of time, often in a themed environment.

Immersive Technology: Electronics and/or software that may be visible or invisible to players. Visible elements enhance the game by providing additional sensory immersion for players, including sight, sound, touch, smell, or even taste. Invisible elements help automate aspects of the experience or enhance the game master's ability to monitor or run the experience.

Appendix C:
SURVEY QUESTIONS

About You

Q: If you have encountered immersive technology as a player of live-action games, please indicate your overall impression of the quality of its use below. **[Linear Scale]**

Description: From 0 being “not applicable” to 5 being “very positive”.

Q: Which of the following is most important to you when working on for-profit live-action games? **[Multiple Choice]**

Description: Both may be important to you, but consider which is the stronger factor.

- Innovating design.
- Maintaining profitability/low risk.

Q: What best describes your pursuit of innovation when working on live-action games **[Multiple Choice]**

- Trying new things before other businesses/designers.
- Trying new things to challenge myself.
- Keeping tabs on the innovations of others and following suit.
- Waiting until techniques are proven before adopting.
- Not worrying about trends and/or using turnkey solutions.
- *Other…* **[Short Answer Text]**

Project Roles

There are many individual roles in design work, but the next question will ask for you to categorize yourself in a broader sense. Brief descriptions of the roles are included below to assist you.

Designer: You are a designer / part of the design team defining the experience.

Manager: You handle logistical and practical concerns of a physical location.

Business: Live-action games are your core business.

Client: You commission a 3rd parties to design / build the experience.

Q: It is possible you assume different roles for this type of project work. For each role column, please check which roles you typically assume from most to least. **[Checkbox Grid : Limit 1 check per column]**

Description: If you don't ever assume a particular role, leave that column empty.

	Designer	Manager	Business	Client
Most Often Assume				
Second Most				
Third				
Fourth				

Q: About how many for-profit projects of this nature have you been involved with? **[Short Answer Text]**

Q: How many years of experience do you have designing and/or working with live-action games/escape rooms? **[Short Answer Text]**

Q: In what continent(s) have you done the majority of your work on live-action games/escape rooms? **[Checkbox]**

- Africa
- Asia
- Australia
- Europe

- North America
- South America

Q: There will be a few budget related financial questions. Please indicate what currency your answers will be in. **[Dropdown]**

- U.S. Dollar
- Australian Dollar
- Brazilian Real
- Canadian Dollar
- Czech Dollar
- Czech Koruna
- Danish Krone
- Euro
- Hong Kong Dollar
- Hungarian Forint
- Israeli New Sheqel
- Japanese Yen
- Malaysian Ringgit
- Mexican Peso
- Norwegian Krone
- New Zealand Dollar
- Philippine Peso
- Polish Zloty
- Pound Sterling
- Singapore Dollar
- Swedish Krona
- Swiss Franc
- Taiwan New Dollar
- Thai Baht
- Turkish Lira

Skill Assessment

In this section you will be asked to rate yourself as fairly as you can on a variety of skills as related to the finance, design, implementation, and installation of live-action games/escape rooms.

Q: What are your experience levels with the following financial / accounting skills? **[Multiple Choice Grid]**

Description: From 0 being “no experience” to 5 being “very adept”.

Budgeting	**0**	**1**	**2**	**3**	**4**	**5**
Pricing / Ticketing	**0**	**1**	**2**	**3**	**4**	**5**
Payments / Billables	**0**	**1**	**2**	**3**	**4**	**5**

Q: What are your experience levels with the following design based skills? **[Multiple Choice Grid]**

Description: From 0 being “no experience” to 5 being “very adept”.

Set Design	**0**	**1**	**2**	**3**	**4**	**5**
Narrative Design	**0**	**1**	**2**	**3**	**4**	**5**
Puzzle Design	**0**	**1**	**2**	**3**	**4**	**5**
Game Design	**0**	**1**	**2**	**3**	**4**	**5**
Playtesting	**0**	**1**	**2**	**3**	**4**	**5**

Q: What are your experience levels with the following implementation based skills? This involves any prototyping and building prior to final installation. **[Multiple Choice Grid]**

Description: From 0 being “no experience” to 5 being “very adept”.

Simple or Non-Mechanical Prop Making	**0**	**1**	**2**	**3**	**4**	**5**
Software Coding	**0**	**1**	**2**	**3**	**4**	**5**
Microcontrollers (Arduino/Raspberry Pi/etc.)	**0**	**1**	**2**	**3**	**4**	**5**
Mechanical Engineering	**0**	**1**	**2**	**3**	**4**	**5**

Q: What are your experience levels with the following installation based skills? This involves the act of building and installing everything needed for the experience. **[Multiple Choice Grid]**

Description: From 0 being “no experience” to 5 being “very adept”.

Carpentry	**0**	**1**	**2**	**3**	**4**	**5**
Electrical / Wiring	**0**	**1**	**2**	**3**	**4**	**5**
Lighting Equipment	**0**	**1**	**2**	**3**	**4**	**5**
Sound Equipment	**0**	**1**	**2**	**3**	**4**	**5**
Wired or Wireless Data Networks	**0**	**1**	**2**	**3**	**4**	**5**

Q: Do you typically have any custom code or software running any aspect of your projects of this type (internally or contracted)? **[Multiple Choice]**

- Yes
- No

Q: Do you typically have any custom electronics and/or Arduino style products running any aspect of your projects of this type (written internally within team/company or contracted)? **[Multiple Choice]**

- Yes
- No

Early Work

In this section we will be asking about the earliest for-profit project you worked on in the live-action game space. For any monetary answers, please answer in the currency selected earlier.

Q: What year did you complete your first for-profit design project of this nature? **[Short Answer Text]**

Q: To the best of your recollection, what was the total proposed budget for that project? This is the amount estimated or defined before design work began. **[Short Answer Text]**

Description: If you don't believe you can estimate within a 20% margin of error, please leave blank.

Q: To the best of your recollection, what was the actual spending for that project? **[Short Answer Text]**

Description: If you don't believe you can estimate within a 20% margin of error, please leave blank.

Q: What aspects of the project do those costs represent? **[Checkbox]**

Description: Pick each category that was primarily paid for through the budget. Ignore if you didn't enter an actual spending amount just above.

- Financial / Accounting
- Design
- Implementation
- Installation
- *Other…* **[Short Answer Text]**

Q: How would you rate your feeling concerning the available budget for this project? **[Multiple Choice]**

Description: Please answer even if you didn't know the estimated budget.

- Heavily limited.
- Constrained.
- Right amount for the job.
- Some headroom.
- Money was no object.

Q: Approximately how many months of work did the project take to complete? **[Short Answer Text]**

Description: Assume a month is 30 days, so entering 1.5 would be 45 days of work.

Q: Were any ready-made props, puzzles, or set pieces purchased for this project? **[Multiple Choice]**

- Yes
- No

Q: If so, did any of these props require electronics or software to function? **[Multiple Choice]**

- Yes
- No
- Not Applicable

Q: Did you use any impactful cost-saving measures (unpaid resources), such as not paying yourself, volunteer labor or using pre-existing resources? If so, please list briefly, otherwise leave blank. **[Paragraph Text]**

Q: Select the definition below that most closely matches the highest level of technical complexity in the design. **[Multiple Choice]**

- **Human Powered:** Mostly mechanical in nature and require human engagement and human power, either of the player or the game master, to make things change in the room.
- **Electrical:** Room uses some electronic sensors, magnetic locks, and remote controls to change elements in the room, but they are still human triggered or isolated systems.
- **Automated:** Room integrates technology and computer control to automate the game sequence, so that the room is able to respond to the actions of players without human involvement. Clues still human triggered.
- **Artificial Intelligence:** Room is fully automated and controls the flow of players through the experience. It can also change the game space or flow dynamically based upon the performance of the players. It may also automate the clue systems.

Q: Select from below the definition that most closely matches the level of narrative design in the experience design. **[Multiple Choice]**

- **Puzzle Room:** Puzzle rooms have a series of puzzles, but no overarching genre, setting, or narrative. The player does not have a role other than puzzle-solver.
- **Thematic Room:** Thematic rooms are set in a specific genre and setting, but the role of a narrative is not a key part of the room. The set and challenges will be themed around the setting to evoke a player experience of being somewhere, but the roles that the players have is limited to puzzle-solver. There may be a light narrative, but it is not a significant part of the game design.
- **Narrative Room:** Narrative rooms have a specific genre and setting, and also have a narrative that is important to the escape room design. The players may have defined

roles, and the challenges are tied into the narrative. A quest-based structure helps the players to find meaning in their activities.

- **Hyper-narrative Room:** Hyper-narrative rooms are narrative rooms where the players have choices about the direction the narrative takes. There is more content designed than will be seen in any one play through, as the players choices will affect what content they engage with.

Immersive Tools Used

Please select any of the following technology and software tools that were used to run or manage the final project. You will have a chance to include anything important that isn't listed.

Q: Off-the-shelf Escape Room Software **[Checkbox]**

- Escape Room Command Center
- Escape Room Master
- Houdini Master Control
- Escape Room Builder
- Escape Assist
- Director (software by FrightProps)
- *Other…* **[Short Answer Text]**

Q: If you indicated use of off-the-shelf Escape Room Software above, please check the features of that software you used. **[Checkbox]**

- Timer / Countdown Clock
- Hint Managing / Display
- Sound Mixing / Cues
- Microphone (game master to game room)
- Microphone (game room to game master)
- Lighting Cues
- Video Cues
- Video Monitoring (from room cameras)
- Hardware Integration (Arduino or similar / Raspberry Pi)
- Scoreboard (display times / success rates / upload to web)
- Digital Waivers
- Sales / Ticketing
- Other… [Short Answer Text]

Q: Cueing or Triggering Software **[Checkbox]**

- Max/MSP (or any Max products)

- Pure Data
- Touch Designer
- Vuo
- Vvvv
- QLab
- SFX (sound playback software)
- OpenFrameworks
- Custom Software
- *Other…* **[Short Answer Text]**

Q: Game Engines **[Checkbox]**

- Unity 3D
- Unreal Engine
- GameMaker
- *Other…* **[Short Answer Text]**

Q: Smart Technology **[Checkbox]**

- Arduino-Type Microcontrollers
- Raspberry Pi-Type Microcomputers
- DMX Controllers
- Off-the-shelf Voice Assistants (Google Home, Alexa, Siri, Cortana, etc.)
- Off-the-shelf Smart Lighting (Hue bulbs, etc.)
- Simple Inputs / Triggers (buttons, keypads, displays, electronic locks, etc.)
- Advanced Inputs / Triggers (RFID/NFC readers, pressure / temperature / light sensors, etc.)
- Simple Effects (speakers, relays or on/off triggers for lights or consumer electronics, etc.)
- Advanced Effects (addressable LED lighting, smoke machine, projection mapping, etc.)
- *Other…* **[Short Answer Text]**

Q: Computers or Tablets (for monitoring or running aspects of the final design in or out of the space) **[Checkbox]**

- Running Windows
- Running Mac OSX
- Running iOS (phone or tablet)
- Running Android (phone, tablet, etc.)
- Running Linux

- *Other…* **[Short Answer Text]**

Q: Data Communication / Networking **[Checkbox]**

- Wired networking solutions (routers, switches, cabling)
- Wireless networking using WiFi
- Wireless networking using Bluetooth, Zigbee, Z-Wave, etc.
- *Other…* **[Short Answer Text]**

Q: Tools for Managing Live Games **[Checkbox]**

- Monitor Display (for countdown, hints, etc.)
- Walkie Talkies (for requesting / receiving hints)
- Microphones (for monitoring / requesting hints)
- Cameras (for monitoring)
- *Other…* **[Short Answer Text]**

Q: If you used any software or technology that was particularly important in running or managing the project that you weren't able to select or list above, please include here. **[Paragraph Text]**

Recent Work

This section is almost identical to the previous, except we will be asking about your most recent for-profit project you worked on in the live-action game space. This should be a project either completed or in final stages of completion.

Q: What year did you complete your most recent for-profit design project of this nature? **[Short Answer Text]**

Q: To the best of your recollection, what was the total proposed budget for that project? This is the amount estimated or defined before design work began. **[Short Answer Text]**

Description: If you don’t believe you can estimate within a 20% margin of error, please leave blank.

Q: To the best of your recollection, what was the actual spending for that project? **[Short Answer Text]**

Description: If you don’t believe you can estimate within a 20% margin of error, please leave blank.

Q: What aspects of the project do those costs represent? **[Checkbox]**

Description: Pick each category that was primarily paid for through the budget. Ignore if you didn't enter an actual spending amount just above.

- Financial / Accounting
- Design
- Implementation
- Installation
- *Other…* **[Short Answer Text]**

Q: How would you rate your feeling concerning the available budget for this project? **[Multiple Choice]**

Description: Please answer even if you didn't know the estimated budget.

- Heavily limited.
- Constrained.
- Right amount for the job.
- Some headroom.
- Money was no object.

Q: Approximately how many months of work did the project take to complete? **[Short Answer Text]**

Description: Assume a month is 30 days, so entering 1.5 would be 45 days of work.

Q: Were any ready-made props, puzzles, or set pieces purchased for this project? **[Multiple Choice]**

- Yes
- No

Q: If so, did any of these props require electronics or software to function? **[Multiple Choice]**

- Yes
- No
- Not Applicable

Q: Did you use any impactful cost-saving measures (unpaid resources), such as not paying yourself, volunteer labor or using pre-existing resources? If so, please list briefly, otherwise leave blank. **[Paragraph Text]**

Q: Select the definition below that most closely matches the highest level of technical complexity in the design. **[Multiple Choice]**

- **Human Powered:** Mostly mechanical in nature and require human engagement and human power, either of the player or the game master, to make things change in the room.
- **Electrical:** Room uses some electronic sensors, magnetic locks, and remote controls to change elements in the room, but they are still human triggered or isolated systems.
- **Automated:** Room integrates technology and computer control to automate the game sequence, so that the room is able to respond to the actions of players without human involvement. Clues still human triggered.
- **Artificial Intelligence:** Room is fully automated and controls the flow of players through the experience. It can also change the game space or flow dynamically based upon the performance of the players. It may also automate the clue systems.

Q: Select from below the definition that most closely matches the level of narrative design in the experience design. **[Multiple Choice]**

- **Puzzle Room:** Puzzle rooms have a series of puzzles, but no overarching genre, setting, or narrative. The player does not have a role other than puzzle-solver.
- **Thematic Room:** Thematic rooms are set in a specific genre and setting, but the role of a narrative is not a key part of the room. The set and challenges will be themed around the setting to evoke a player experience of being somewhere, but the roles that the players have is limited to puzzle-solver. There may be a light narrative, but it is not a significant part of the game design.
- **Narrative Room:** Narrative rooms have a specific genre and setting, and also have a narrative that is important to the escape room design. The players may have defined roles, and the challenges are tied into the narrative. A quest-based structure helps the players to find meaning in their activities.
- **Hyper-narrative Room:** Hyper-narrative rooms are narrative rooms where the players have choices about the direction the narrative takes. There is more content designed

than will be seen in any one play through, as the players choices will affect what content they engage with.

Immersive Tools Used

Please select any of the following technology and software tools that were used to run or manage the final project. You will have a chance to include anything important that isn't listed.

Q: Off-the-shelf Escape Room Software **[Checkbox]**

- Escape Room Command Center
- Escape Room Master
- Houdini Master Control
- Escape Room Builder
- Escape Assist
- Director (software by FrightProps)
- *Other…* **[Short Answer Text]**

Q: If you indicated use of off-the-shelf Escape Room Software above, please check the features of that software you used. **[Checkbox]**

- Timer / Countdown Clock
- Hint Managing / Display
- Sound Mixing / Cues
- Microphone (game master to game room)
- Microphone (game room to game master)
- Lighting Cues
- Video Cues
- Video Monitoring (from room cameras)
- Hardware Integration (Arduino or similar / Raspberry Pi)
- Scoreboard (display times / success rates / upload to web)
- Digital Waivers
- Sales / Ticketing
- Other… **[Short Answer Text]**

Q: Cueing or Triggering Software **[Checkbox]**

- Max/MSP (or any Max products)
- Pure Data
- Touch Designer
- Vuo
- Vvvv

- QLab
- SFX (sound playback software)
- OpenFrameworks
- Custom Software
- *Other…* **[Short Answer Text]**

Q: Game Engines **[Checkbox]**

- Unity 3D
- Unreal Engine
- GameMaker
- *Other…* **[Short Answer Text]**

Q: Smart Technology **[Checkbox]**

- Arduino-Type Microcontrollers
- Raspberry Pi-Type Microcomputers
- DMX Controllers
- Off-the-shelf Voice Assistants (Google Home, Alexa, Siri, Cortana, etc.)
- Off-the-shelf Smart Lighting (Hue bulbs, etc.)
- Simple Inputs / Triggers (buttons, keypads, displays, electronic locks, etc.)
- Advanced Inputs / Triggers (RFID/NFC readers, pressure / temperature / light sensors, etc.)
- Simple Effects (speakers, relays or on/off triggers for lights or consumer electronics, etc.)
- Advanced Effects (addressable LED lighting, smoke machine, projection mapping, etc.)
- *Other…* **[Short Answer Text]**

Q: Computers or Tablets (for monitoring or running aspects of the final design in or out of the space) **[Checkbox]**

- Running Windows
- Running Mac OSX
- Running iOS (phone or tablet)
- Running Android (phone, tablet, etc.)
- Running Linux
- *Other…* **[Short Answer Text]**

Q: Data Communication / Networking **[Checkbox]**

- Wired networking solutions (routers, switches, cabling)
- Wireless networking using WiFi
- Wireless networking using Bluetooth, Zigbee, Z-Wave, etc.
- *Other…* **[Short Answer Text]**

Q: Tools for Managing Live Games **[Checkbox]**

- Monitor Display (for countdown, hints, etc.)
- Walkie Talkies (for requesting / receiving hints)
- Microphones (for monitoring / requesting hints)
- Cameras (for monitoring)
- *Other…* **[Short Answer Text]**

Q: If you used any software or technology that was particularly important in running or managing the project that you weren't able to select or list above, please include here. **[Paragraph Text]**

Looking Forward

This is the final section of the survey. We will be asking questions about the future of live-action games and your intentions with future work.

Q: Do you believe that increasing the physical and narrative detail of live-action games/escape rooms will lead to better player experiences? **[Linear Scale]**

Description: From 1 being “not at all” to 5 being “very strongly”.

Q: Do you believe that the use of technology (software and electronics) is important for achieving more immersive live-action games/escape rooms? **[Linear Scale]**

Description: From 1 being “not at all” to 5 being “very strongly”.

Q: Do you believe that the use of immersive technology is becoming more necessary in order to compete with other live-action games/escape room businesses? **[Linear Scale]**

Description: From 1 being “not at all” to 5 being “very strongly”.

Q: How likely are you to use or encourage the use of immersive technology in your next project? **[Linear Scale]**

Description: From 1 being “not at all likely” to 5 being “definitely”.

Q: How strong of a role is immersive technology likely to play in your future projects? **[Linear Scale]**

Description: From 1 being “none” to 5 being “central to the design”.

Q: Please indicate which factors are likely to prevent you from using immersive technology in future projects. **[Multiple Choice Grid]**

Description: From 1 being “unlikely” to 5 being “likely to prevent”.

Not Interested / Don’t Need It	**1**	**2**	**3**	**4**	**5**
Lack of Customer Expectation	**1**	**2**	**3**	**4**	**5**
Lack of Software Experience	**1**	**2**	**3**	**4**	**5**
Lack of Electronics Experience	**1**	**2**	**3**	**4**	**5**
Time/Money Prototyping Cost	**1**	**2**	**3**	**4**	**5**
Time/Money Implementation Cost	**1**	**2**	**3**	**4**	**5**
Time/Money Testing Cost	**1**	**2**	**3**	**4**	**5**
Time/Money Maintenance Cost	**1**	**2**	**3**	**4**	**5**
Time/Money Staff Training Cost	**1**	**2**	**3**	**4**	**5**

Interview Request

Interviews will take a maximum of 30 minutes if you are selected. You may decide against participating at any time.

Q: Would you be potentially available for an interview? **[Multiple Choice]**

- Yes **[Forwards to 'Interview Contact Info' section.]**
- No **[Forwards to 'Submit Survey' section.]**

Interview Contact Info

Your contact information will only be used for the purposes of arranging an interview and will not appear in the study results.

Q: Email address to best contact you with. **[Short Answer Text : Email Validation]**

Q: Name you wish to be identified with. **[Short Answer Text]**

Description: Only used for communication with you. It is not required or a part of the research.

Q: What pronouns should we use communicating with you? **[Multiple Choice]**

Description: Only used for communication with you. It is not required or a part of the research.

- Unspecified
- He/Him/His
- She/Her/Hers
- They/Them/Theirs
- *Other…* **[Short Answer Text]**

Appendix D:
INTERVIEW QUESTIONS

These first questions will primarily center around the perspective of a player and their experience in live-action games.

1. What do you consider most important to the player experience in a live-action game?
2. What is the most memorable experience you've had in a live-action game or immersive experience?
    a. What do you think made it so memorable to you?
3. What does immersion mean to you and how do you go about crafting it for players?
4. What do you think is most important when it comes to the emotional arc of the player in these types of experiences? This can draw from your experience as a designer and/or player.

Next, we're going to focus more closely on your role and experiences working on live-action games.

5. What is your involvement in the design process for these types of projects?
    a. If actively a designer, please describe the general steps you use in your design process.
    b. If not actively designing, please describe your involvement in the process.
6. What was the biggest design risk you took that paid off, even if it wasn't how you expected?
7. What was the biggest design risk you took that didn't pay off?
    a. What sort of losses did it result in, monetarily or otherwise?
8. In the prototyping phase, what sort of physical or technical tools do you use to facilitate that process?

9. Can you recount an example of technology or immersion going spectacularly wrong, either in a playtest, running a game, or if neither of those, you participating in others' games?

Now we're going to talk about the role of immersive technology with live-action games.

10. What role, if any, do you think immersive technology could play in improving live-action games and better compete with other experience-based entertainments?
11. There can be many limitations for using immersive technology in live-action games, such as the capabilities of the designers, cost, what is available for purchase… What would you say are the biggest limitations preventing you from incorporating a higher degree of immersive technology than you currently are?
12. If there were no boundaries or technology limitations what software and technology features would most benefit how you design and run live-action games/escape rooms?
13. When you consider adding or increasing the use of immersive technologies, what are your biggest concerns?
14. What are your thoughts on a software system that you both design game logic in and also use to monitor the game as it runs?
15. What are your thoughts on drag and drop visual logic versus coding logic?
16. What are your thoughts on purchasing custom technology props versus a technology system that simplifies creating your own technology props?

This is the final question.

17. I'd like you to think back to your earliest related projects and compare them to your current work. Has your attitude toward these technologies changed? If so, how?

Appendix E:
PAINT!

an Immersive Design Toolset Proposal - *Last Revised April 18th, 2019*

Immersive designers need an operating environment that allows for rapid iterations, ease of use and testing of design concepts on tight deadlines. Small businesses and teams don't have time or resources to train designers to code, or learn the principles of engineering. They simply need them to have the tools that will enable them to create great work.

PAINT! or *Prototype and install, no trouble!* is a proposal for an immersive design toolset meant to increase the accessibility of technology to designers of immersive spaces such as live-action games, commonly dubbed 'escape rooms'. It starts with ***PAINT! Flow***, cross-platform software that allows designers to connect and visualize the flow of data and logic between all of the devices in the design network. For managing the myriad of inputs, outputs, effects, and sensors there is the ***PAINT! Palette***, a microcontroller device shield that provides solutions to connectivity, wiring, power, and more while supporting a transition from prototyping to installation for more reliable, audience ready experiences.

The Pillars of PAINT!

To ensure design features stay consistent with the overall mission of the toolset, four supporting goals were created based off research involving experience professionals in the live-action game design space.

Network of Things

No single computing device can support the infinite possible designs for an immersive space. Communication between devices at all levels of computation power is at the heart of a

successful immersive toolset. From full computing systems to microcomputers to microcontrollers and finally the variety of electronic devices that can be connected at each level of computing, the tools must support harmony across devices.

Accessible Iteration

Technology tools and their features must strive to close the gap between creative design iteration and technology prototype iteration. These two iteration cycles should overlap as much as possible to become one to allow for the strongest possible design outcome and least amount of risk when it comes to eventual implementation. This pillar provides value across all size teams and businesses.

Open and Off-the-shelf Support

Technology and standards can move fast so care needs to be taken that schematics, protocols, footprints, and interfaces are chosen that are supported by companies and communities with vested interest in them sticking around. Creating new standards from scratch, even if technically superior, will prevent adoption if it closes users off to the ecosystems already in place. Formats, protocols, and perhaps even electronic schematics should be open if at all possible so new communities can help support new additions to the ecosystem and bring confidence that they can continue to be used even if the provider is no longer able to support their own tools.

Prototype Permanence Path

Technology tools and their features should be designed with the concept of project phases ingrained in their functionality. Needs change as a project move from the design phase, to testing, to implementation, and finally support and maintenance, and so the technology change along with it. Users must not be tempted to subvert security or safety in order to achieve ease of use. Security and safety should increase naturally with project needs.

Project Phase Definitions

To better illustrate how behavior and features of the toolset adapt over the course of a project, the following project phases have been defined as they are universally applicable, even if the sequence or presence of a phase doesn't occur as expected.

Design Phase: From initial ideas and concepts to project definition and active designing, the 'how' of a project.

Development Phase: Determining how to implement the design while continuing to refine and improve the design.

Implementation Phase: All parts of the design are clear and the team is prepared to connect and construct the numerous pieces until installation is complete and audience ready. This may include a phase of testing beyond the design team.

Maintenance Phase: The design is in active use. The designs experience is monitored, with intervention and support if there are technical problems or design experience problems.

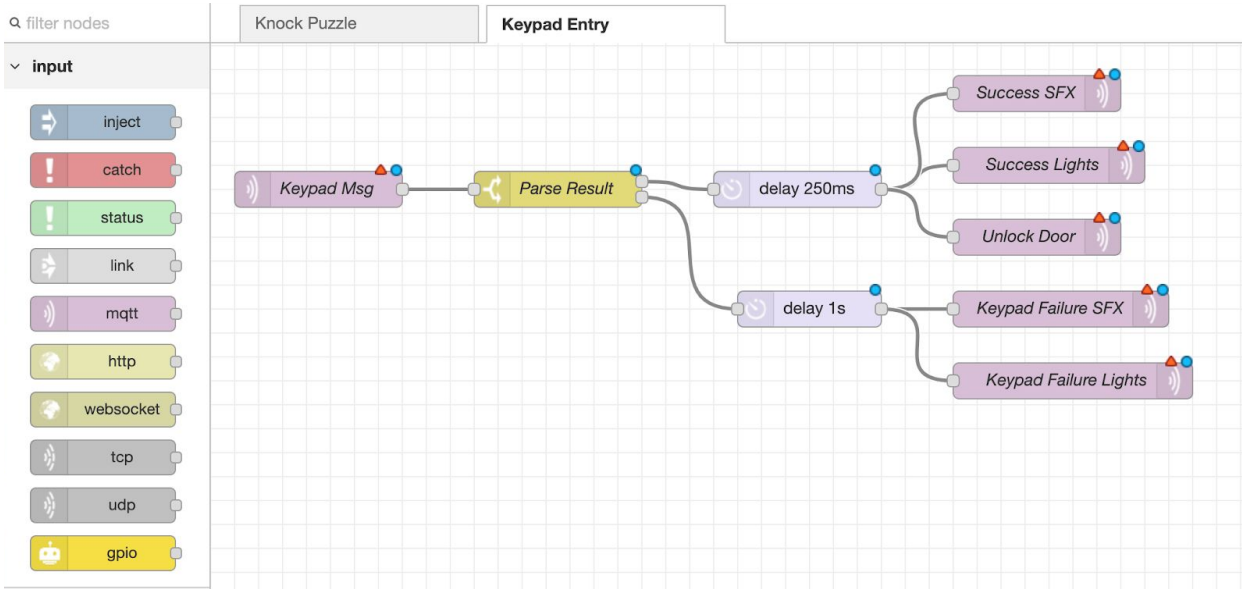
PAINT! Flow - Design Software

To simplify designing, debugging, monitoring, and maintaining, the *PAINT! Flow* software means to provide a single point of entry for these tasks while moving forward with you through each phase of your project.

A Visual Language

The *PAINT! Flow* software is built off of the codebase of Node-RED, a cross-platform and web technology based visual language programming tool designed for connecting devices and services together. The ability to host and run offline and on microcomputing devices such as the Raspberry Pi provide a great deal of power and flexibility.

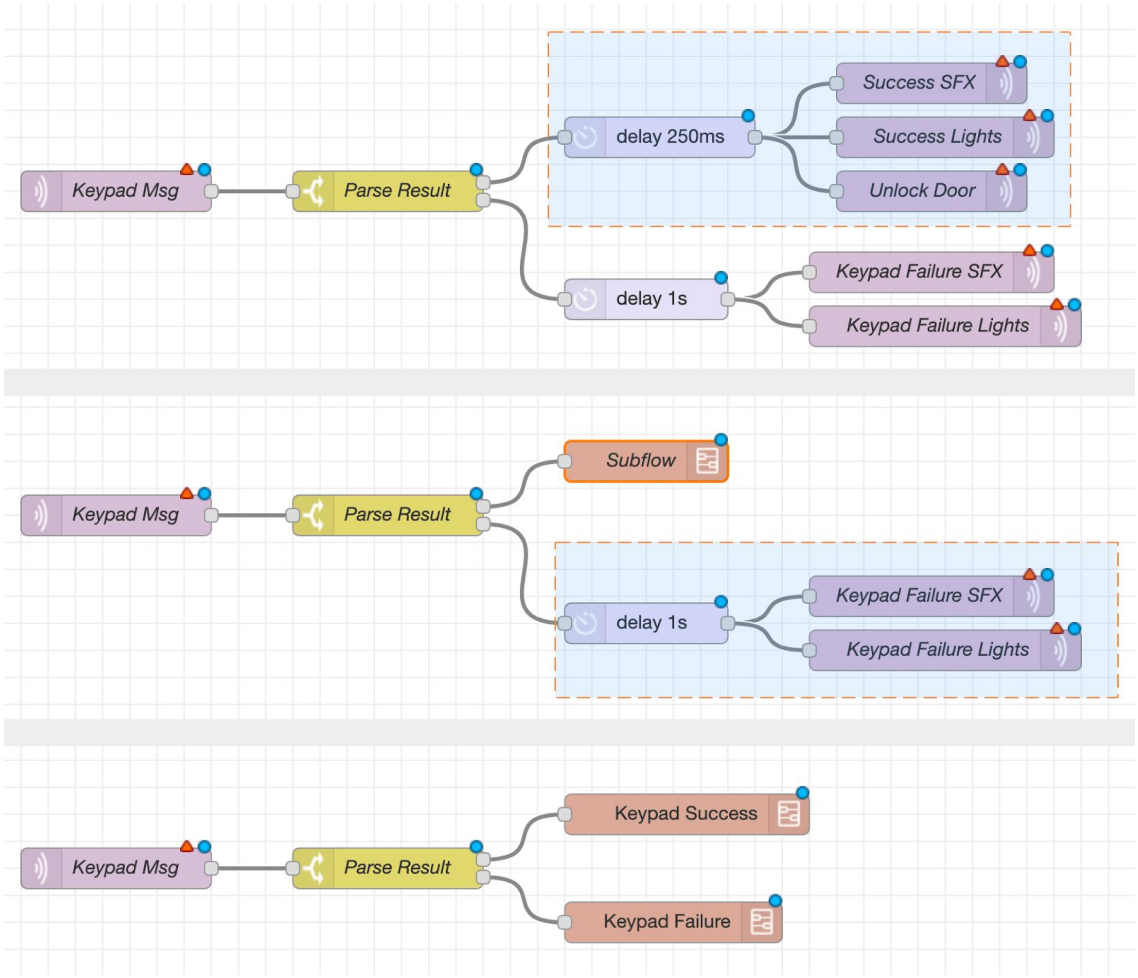
PAINT! Flow expands on this visual language by providing tighter focus on local (usually offline) network project flows with the *PAINT! Palette* microcontroller shields described later in this document. The goal being to remove the opaqueness of what the various devices, often microcontrollers, are doing on the network and what their current status is. Visual nodes are designed to take full advantage of devices part of *PAINT!*



An example logic flow for reacting to the success or failure of a keypad code.

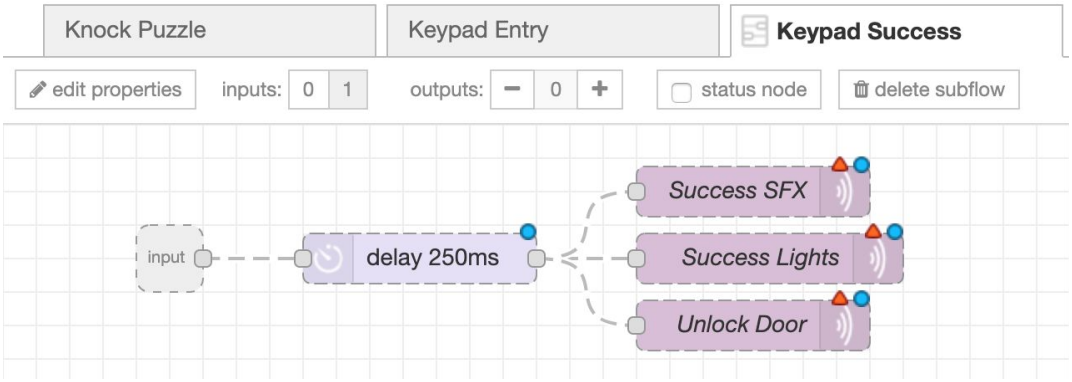
Subflows

Also vital to a flow based logic system is the Node-RED established concept of *subflows*. The concept being that any logical flow of nodes can be encapsulated into a single node, abstracting the functionality and simplifying higher level logic.



Creating two subflows to simplify the flow.

At any time the subflow can be opened to examine the internal logic. This means that a large library of basic and combinational logic nodes can be defined to provide a robust set of building blocks for deeply complex behavior, all while allowing the designer at any time to dig deeper and understand how that behavior is actually playing out without ever seeing a line of code.



Examining the contents of a subflow.

This focus on dynamic layers of abstracted visual logic allow for designers to increase their own understanding of the logic and tool at their own pace, discovering capability within the context of how it works. This also enables powerful ways to visually demonstrate to the entire team and other stakeholders how a designed experience flows, diving only as deeply as if needed or useful for that audience.

Post-It Nodes

Developing logic flows may not be a huge challenge if you know exactly how you want something to work, but what about early in the design process when everything is up in the air? Introducing *Post-It Nodes*. These are a special set of logical nodes that serve as either passive or interactive placeholders to functionality. They allow for manually switching their behavior before the node is reached or prompting designers in *PAINT! Flow* or on a smartphone to decide how the logic flow should continue.

Example Scenario

There is a locked door that will require some sort of code or keypad. You want to test the electromagnetic lock along with some light and sound cues. Nodes are placed together in a flow for the results of a successful and incorrect code. A *Post-It Node* is placed into the flow connecting to each outcome. When testing the scenario, designers are prompted in *PAINT! Flow*, on a smartphone, or both to select which outcome to trigger. This allows them to move forward without having to wire up an electronic keypad, decide on the code, or even if a keypad is what they end up wanting to use!

Network Status

For a given project, an overview of the network of devices can be brought up for a quick overview of all devices associated with a particular mesh or wired (or hybrid) network. Current connectivity status, running tasks, and even notifications associated per device. Network security can be up or downgraded, devices can be temporarily taken out of service, and devices

can even be marked for replacement, allowing for easy swapping of potentially fault components and quickly pushing the appropriate software to the new device.

Spatial Mapping

A simple blueprint style editor accompanies the network status details, allowing you to outline the dimensions of the space where devices are being installed. This simple connection to the physical environment allows you to identify what devices are what without physical examination and even hypothesis how wireless signals can be improved by retrieving signal quality from each device in the context of their location and surrounding barriers.

PAINT! Firmata

Firmata is a protocol that was developed to simplify communicating with microcontrollers from computers, allowing low level manipulation that normally required manually writing code for the microcontroller to accomplish. Based on this concept is the *PAINT! Firmata* developed with tight integration with the *PAINT! Flow* design software. In many cases this allows all logic to be designed and executed from *PAINT! Flow* further reducing the requirement of working with code in multiple languages to zero coding whatsoever.

This integration also provides a number of other highly valuable features for prototyping, debugging, and maintenance including:

- Retrieve or set various configuration values on the device, such as the current datetime, logging level, security level, and more.
- Device logging for a higher level understanding of what is occurring on the network, when, and even why.
- Signal status of each device for an overall view of the signal health of the network.
- Logic status of each device with the current task being run if any.
- The ability to query for specific device data at any time, such as the state of electronics connected to the device.
- Manually triggering events on the devices or electronics attached to it.
- Retrieving a dump of log information on demand without physical access to the device.

Firmata Plugins

There are a number of useful electronics that are more difficult to support with Firmata based functionality. For instance, fading a large number of LEDs would require a flood of messages every second in order to create a smooth visual fade, each message a slight adjustment of the previous color values. In this case logic on the microcontroller is better suited to large amounts of fast updates to a piece of electronics.

In order to simplify this, *PAINT! Firmata* management in the *PAINT! Flow* software will provide selections of specific device support in the form of firmware plugins. Additional logic to support that, in our example a strip of LEDs, will be added to the default *PAINT! Firmata* firmware, and be

uploaded to that device. Specific visual nodes will be associated with each plugin giving higher level access, such as a **fade** node, where you decide various attributes for how the fade should take place and over what amount of time, then send the single command message right from *PAINT! Flow*. The *Paint! Firmata* device will handle the large volume of changes that need to be communicated with the LEDs themselves without the data network being overwhelmed with messages. The data network should be capable of handling a high volume of messages for a limited number of devices concurrently, so even during early prototypes or testing the easy road can be taken, knowing there is a path forward if the limits are reached.

PAINT! Flow will track firmware and plugin bundles for each device along with their software versions. This will allow fast cloning or replacement of devices, along with easy updates and the ability to freeze or snapshot network configurations so you can always rebuild to a working state!

PAINT! Library

As important as making tools accessible to designers without deep programming or engineering backgrounds is ensuring they *stay* accessible to those with certain levels of experience. If a designer is finding that *PAINT! Firmata* is not enough for their needs or they can achieve the specifically desired result faster by custom coding the software for their microcontroller device there is an alternative. The *PAINT!* Integration library will ensure they are able to quickly connect their device their device network and report device and task status to the network so it can be integrated into the overall experience flow being designed.

Basic programming hooks will allow for subscribing to specific message from *PAINT! Flow* software as well as reporting when tasks begin, end, or certain inputs or interactions are received, for example a user entering a correct or incorrect code, allowing *PAINT! Flow* to trigger unique lighting and sound feedback for either state.

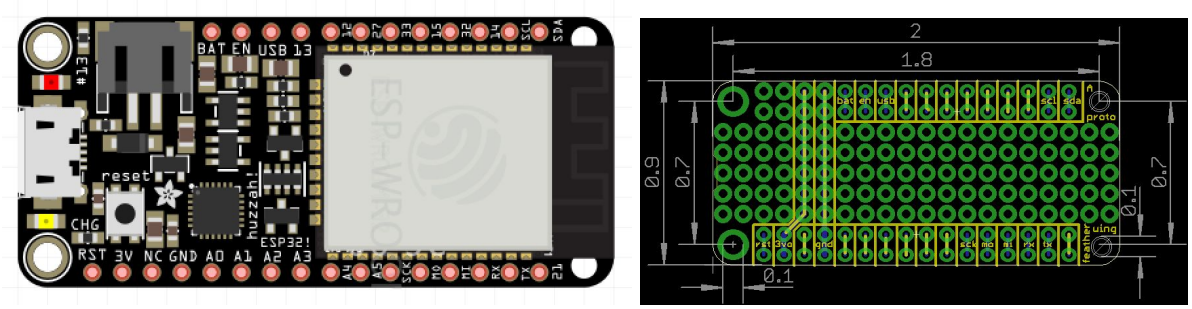
PAINT! Palette - Microcontroller Shield

This microcontroller shield device is what makes prototyping technology fast, easy, and sustainable through each of the phases of your project. A ‘shield’ is a modular circuit board meant to piggyback with a microcontroller (which acts as the brain of the device) to add new features.

The Brain

The *Paint! Palette* shield will use the *Feather* specification developed by Adafruit. This provides a more compact, far more powerful standard than the aging Arduino, with excellent cross-compatibility between microcontroller chipsets. This will allow compatibility across a number of existing products, such as the Adafruit HUZZAH32 or Sparkfun “Thing” Plus, both Espressif ESP32 chipset boards, or the Particle Mesh trio of boards the Xenon, Argon, and Boron, Nordic nRF5240 chipset boards. All of these named will allow for high degrees of

connectivity that *PAINT!* will take full advantage of, including mesh networking and dual Bluetooth mode for paired and passive data connections.



Left: The Adafruit Feather HUZZAH32. Right: The Feather footprint specification.

The Body

The purpose of the *PAINT! Palette* is to harness the power of modern microcontroller and connectivity to solve common needs of immersive designers and reduce impediments.

PAINT! Palette Shield Features	Purpose and Benefits
Feather Specification Support [Informational Link]	A well supported standard for physical shield connections and cross-compatibility with numerous chipsets. Stacking headers could be used on the microcontroller to allow additional shields to stack.
2 Pin Wide Feather Headers	Simplifies fast prototype access directly to the pins of the plugged in microcontroller.
Screw Terminal Pin Connectors	Stronger, more resilient connections for wiring microcontroller pins to external devices or sensors. May take a few more seconds to connect, but it'll last!
Feather Shield Slot Sample of currently available shields: Music Maker w/ Amplifier Power Relay	Provides an open slot to connect a single Feather compatible shield for prototyping, debugging, or a simple way to add a permanent feature to this *Palette*.

DC Motor + Stepper Controller PWM or Servo Controller	Assuming pin requirements don't overlap, additional shields could be stacked using a Feather Doubler.
Optional Security Status LED	This RGB LED status light is meant to visually communicate the security level of the network for prototyping and debugging.
Provisioning Button	To prove access to the device and transition to alternate communication modes for being added to a network or other device related tasks.
Ethernet Port w/ WIZnet W5500 Controller [Informational Link]	Provides a reliable way to connect to a wired network is wireless reliability is a concern.
Micro-SD Slot	Provides swappable data storage for media, such as sound, images, or raw data. Allows for long term data logging, even in the case of losing connection with the rest of the network.
Real Time Clock (RTC) + Coin Cell Battery	Allows for accurate datetime to be associated with data logging. Battery ensures time even during power loss events. Tasks can be scheduled to run at particular times.
Qwiic JST Connector or I2C Communication [Informational Link]	Sparkfun easy I2C connector system. Allows simple chaining of a large eco-system of Qwiic sensors and devices. Incompatible devices can be easily
5V LED Driver + 4-pin JST SM Connector for Addressable LED Control	This driver allows for fast and stable control of a large number of individually addressable RGB (or other color configuration) LEDs.
12V Expected 2.1mm DC Barrel Power Input +	Up to 12V power input is supported by

Optional Screw Terminal Power Input	the device in order to provide regulated power at a number of useful levels. 2.1mm is a very common power supply input size for wide compatibility. Alternatively, directly wiring in power to the screw terminals may simplify powering in unique environments.
Power regulation from 12V down to 9V, 5V, and 3.3V + Screw Terminal Outputs for Each	Logic and power need vary between devices and sensor. Electromagnetic locks are commonly 12V, while a thermal printer may be 9V. Providing four common voltage levels to tap into can greatly simplify complex power needs. Power status LEDs will provide feedback as to what levels of power are available if a lower voltage is being input into the board (the minimum being 3.3V)
Mounting Holes + Removable 'Feet'	Flexibility to attach or mount the board through simple PCB holes. Removable 'feet' provide safety for the board during prototyping allow you to set the board on various surfaces without touching the components on board, also protecting against electrostatic.
Optional Two Piece Enclosure	The enclosure consists of two pieces: a small, flat mountable base and the enclosure box itself. The base is screwed onto a surface as a semi-permanent mounting location that the box can be attached or detached from for easy access. The enclosure can be additionally screwed down if accessibility is not desirable.

Project Phase Use Cases

Many of the *PAINT! Palette* shield features are meant to provide ease of use on the front end and reliability on the back. Attention is being paid to methods of wiring, power routing and regulation to support a large variety of electronics, easy methods for adding or altering devices, and more to support the path from prototyping to permanence. Below are a few specific capabilities that will be guided by software as a project progresses.

Data Network Communications

The PAINT Shield will provide both wireless mesh network capability and wired ethernet. Mesh is quickly improving in reliability and is particularly useful in the early phases of project design and development. With a well placed mesh network and conducive install location it may be reliable enough for permanent install. Direct wiring is possible as a fallback or target for the implementation phase and even a mix of the two as the situation dictates.

Project Phase	**Device Network Communications - Prototype Permanence Path**
Design	**Recommendation:** Wireless Mesh Communications Time and resources can be saved by not requiring cabling or the purchasing and installing of cables, switches, and routers. Devices may be relocated within the design space at will supporting quick concept iteration and a more accurate spatial experience.
Development	**Recommendation:** No Change
Implementation	**Recommendation:** Evaluate Transition *Transition to wired ethernet recommended if any of the following are true:* Final install will be difficult to provide support and maintenance resources. Experience up-time is mission critical. Place devices in expected install location, run signal evaluation feature in the design software, follow provided recommendation. **Transition Benefits** Selective devices can be hardwired if distance or interference singles them out. Wired ethernet is highly reliable and battle tested for strict up-time requirements.

	Spatial constraints are now known, cutting cables to length, routing them, and testing them requires only basic instruction. Off-the-shelf hardware such as ethernet testers, routers, and switches work with no special configuration.
Maintenance	**Recommendation:** No Change Wireless can continue to be permanently viable. Switching to wired ethernet is viable but may be more difficult after the design space is fully installed as access may be limited. Wired ethernet can be selectively installed to problematic devices, a full switch is not necessary.

Wireless Device Security and Provisioning

Security is certainly a vital concern for your wireless network of things as the last thing you want is for an audience member to change the behavior or configuration of your network, even by accident. However, security is a need that scales as a project progresses and inherently introduces barriers to making changes to devices on a network or even the addition and removal of those devices. This also discourages designers from subverting security early in the process to speed up designing only to forget about the vulnerabilities later on.

The PAINT Shield device and PAINT Flow software will provide color and text based feedback on the current security level of a device network:

Blue: No security. Anyone with a smartphone or computer can create or destroy networks, make changes to PAINT devices on the network, add or remove devices, and push new software to devices. Networks are simple unique names or IDs.

Green: A four digit pin or password with no minimum requirements must be set for the device network, one per network. Using a smartphone or computer to add or remove devices from the PAINT network will require this pin or passcode. It will also be required the first time per session that software is pushed from PAINT Flow to the PAINT devices.

Yellow: A password with minimum quality requirements must be set for the PAINT network. With the password a smartphone can add devices and receive requested data. New devices will automatically act as routers to pass messages and extend the network range. Destructive actions such as removal of a device or changing behavior is no longer allowed on a smartphone but must be done from PAINT Flow or with physical access to the device.

Red: Changes are not allowed, even from PAINT Flow. This is for security and to prevent accidental changes while an experience is in production. The security level must be downgraded to **Yellow** to make changes.

Once a network is at security level **Green** or above, the network will automatically log any access and changes to the network for auditing, including basica identifying details about the smartphone or computer that accessed it.

Project Phase	Device Network Security - Prototype Permanence Path
Design	**Recommendation: Blue Level** Highly flexible, can be changed easily and quickly. New networks can be created by powering the PAINT device and pressing a button to put them into provisioning mode (which may occur by default with an out-of-box device). Network details can be provided through a nearby smartphone or computer via Bluetooth with PAINT Flow software. USB is also available. Device network role, software, pin behavior and any other details can be changed instantly with a smartphone or computer via Bluetooth.
Development	**Recommendation: Green Level** Still highly flexible but allows designers to work in the same space on different networks without interference. Helps prevent accidental changes to the network or devices.
Implementation	**Recommendation: Yellow Level** Production ready but supportive of testing and monitoring, while still able to make changes from PAINT Flow software. Malicious 3rd parties should be unable to make changes without physical access to devices or the password to the network.
Maintenance	**Recommendation: Red Level** The network is locked down. The security level must be downgraded to **Yellow** in PAINT Flow before being allowed to make changes.

COLOPHON

Typefaces used: Times New Roman, PT Sans Narrow, Roboto

Layout: Adobe InDesign CC 2019

Writing: Google Docs

Survey tool: Google Forms

Interview scheduling: Calendly.com

Data analysis: Google Sheets

Graphics: Adobe Photoshop CC 2019, Adobe Illustrator CC 2019, Fritzing v0.9.3, Google Draw

Visual logic research: Scratch v3.0, Node-RED v0.20.5, Unreal Engine v4.22

Article reference: Bookends

Computer: MacBook Pro 15”, Late 2013

Audio recording: Audio Hijack

Transcription: Otter.ai

Note taking: Microsoft OneNote