UNIVERSITY OF BERGEN

Department of Information Science and Media Studies

Master Thesis

Expanding Digital Workspaces Using Cross-Device Interactive Applications

Simen Larsen Johansen

01.june.2022

A thesis submitted for the degree of master's in media and interaction design in the Department of Information Science and Media Studies

Simen Larsen Johansen
Master's program in media and interaction design at the University of Bergen
kuz006@uib.no

1.juni 2022

SUMMARY

In this thesis I explore the use of a cross-device interactive application and how single individuals could make use of multiple connected devices by themselves for their work. I have created a functional prototype that is used to evaluate the workload of a single device versus the use of multiple devices with the use of in-built cross-device interaction capability. The process of this study consisted of research, prototyping, programming the application, and performing a study to analyze the data gathered. Due to the covid-19 situation, the project had major re-routes in 2021 to handle its effects, resulting in an additional year of work to complete it.

ACKNOWLEDGEMENTS

I would like to thank my study supervisor Morten Fjeld; a professor of Human and Computer Interaction at the University of Bergen for aiding and guiding me through this project.

I would also like to thank my friends and family for continuously backing me up throughout this project. You have all been a great help to both this project and me.

.

TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION

This chapter takes us through the motivation behind the project, problem area, research question, and structure of this thesis.

In this thesis I will be exploring the use of a cross-device interactive application and how a single individual could make use of multiple connected devices together for their work. This thesis consists of a practical and theoretical component. The practical component is a functional prototype that consists of a website, a server, and a database. Instructions as to how this prototype works will be covered in this thesis with visuals.

Digital media assets using digital tools are becoming increasingly popular as computer devices become more accessible to the general population. The competition to develop new and better digital tools is only intensifying as the digitalization is increasing in all areas of life. Many companies now invest in digital tools as a productivity booster, speeding up product design and development. [1]

Today's digital media consists of numerous types of digital formats that make up what we see on our displays. Digital information is often created using computer applications that are made for these tasks. The media market is big, and many individuals work with media creation daily. Therefore, it is safe to say that the improvement of production tools to help produce media assets is an important area to explore, to boost productivity.

1.1 MOTIVATION

As the ubiquity of digital media continues to increase among the general population, the amount of information flowing back and forth on the internet is massive and most of us are exposed to this information daily.

The master's program I am taking within Media and Interaction Design focuses heavily on prototyping and innovation related to technology. As I have worked with numerous media production applications in my free time and during studies, I have developed enough experience with media production applications to find myself exploring areas in which they could be improved. My mindset was to explore areas that most media production applications share and see if there is room for improvements in these areas.

By making use of various media production applications to locate potential shared areas to improve, I noted that almost all applications share; not just media production applications. Applications in general have some issues regarding the use of space when users navigate through them to reach a goal such as locating and

making use of certain functionalities. Applications can also squeeze parts of the window to make room for other parts of the application. Let's say you are using a drawing application and you want to adjust the size of your brush. As a user you would either adjust it from a section in the window that already takes up space in the window, or by navigating to a button that opens a floating brush settings window upon being clicked. This sequence of interaction applies to most applications. Managing colors in a drawing application result in space on the screen being occupied by the color manager, but for physical drawing you would place the drawing tools next to the drawing and not on top when selecting the tool. Traditionally you would keep these two separated but close, so the question would be whether you could place the tools and functionalities within media production applications elsewhere as well and see if it helps separating these two. This could be possible by making use of additional screens placed next to the screen with the drawing.

The motivation for exploring this area comes from me having multiple devices at hand that I had never used together before, and it seemed an exciting area to explore. In fact, the general population in modern societies tends to have more than one device at hand. According to a 2015 study, 36% of Americans own a smartphone, tablet, and a computer [2]. As such a big portion of the population owns multiple devices with the potential of being used together, exploring such an area could make a difference in how we use our devices.

The video link below demonstrates the functional prototype in use.

YouTube link: https://www.youtube.com/watch?v=jXFb24BqXTY

1.2 OBJECTIVE

This thesis explores media production applications and the use of a cross-device interactive application being used by a single individual to accomplish desired goals. The aim of the thesis is to create a better understanding in creative media production about how the workload differs from a cross-device interactive environment to a single device environment. Therefore, the research question is as follows:

> *How does a cross-device interactive application affect*
> *workload among digital artists in creative media production?*

Despite the question being targeted towards digital artists, the response will provide insights that can be used in other areas. Performing a single study that applies to all areas within media production would involve too much work, as applications tend to be built and interacted with differently depending on their use and purpose. However, despite having the study focus in specific areas, the data gathered should be useful for other areas that involve the use of applications as it is thought to be a shared application area.

The workload in which digital artists experience will be the focus when exploring cross-device interactive applications, as the variety of similar applications can cause differences in how you work. Exploring the workload being experienced can help pinpoint potential benefits and challenges of creating such an environment.

1.3 CONTRIBUTION

The thesis will describe the use of a cross-device interactive application that has been developed for this study. The methods used to research, prototype, conduct studies on workload and to do analysis are intended to help determine the benefits and drawbacks of such a way of working.

1.4 COVID-19

The development and studies related to this thesis were unfortunately heavily affected by COVID-19. A functional prototype was developed, but due to the situation at that time it was too difficult to locate suitably qualified local participants and carry out the study. I therefore redid the functional prototype and constructed a new study structure to allow anyone from anywhere to participate in the study, meaning the functional prototype would be available anywhere. The two functional prototypes will be discussed in detail to show how a global pandemic can affect a study such as this.

1.5 BREAKDOWN OF THE CHAPTERS

Chapter 1: Introduction

The introduction chapter introduces the thesis and what to expect, and outlines the motivation behind the focus area, the objective and contribution of the thesis, and breakdown of the chapters.

Chapter 2: Background

The background chapter describes a variety of relevant research and sources related to this topic.

Chapter 3: Technologies

This technologies chapter lists the different software, programming languages, and services used to develop the design prototype and functional prototype.

Chapter 4: Methods

The methods chapter describes in depth the methods used in the project to analyze, design, and develop a functional prototype, conduct the study, and analyze the data.

Chapter 5: Design Prototyping

The design prototyping chapter goes through the process of developing a high-fidelity prototype from start to finish.

Chapter 6: Functional Prototyping

The functional prototyping chapter goes through the process of developing a functional prototype that takes inspiration from the high-fidelity prototype. This is a technical chapter, but also gives examples to show how the functional prototype works.

Chapter 7: Summary and Evaluation

The evaluation chapter goes through the evaluation process of the functional prototype and the results from the evaluation.

Chapter 8: Discussion

The discussion chapter discusses the results from the evaluation.

Chapter 9: Conclusion

The conclusion chapter summarizes the thesis.

CHAPTER 2: BACKGROUND

This chapter takes us through some of the literature that helps build up knowledge related to the areas in which this thesis will explore, including studies related to digitalization of our daily lives and existing media production applications today. The chapter also discusses why it matters to perform this study of prototyping and development of the functional prototype, and why the kind of data we gather provides the best insight.

2.1 PREVIOUS WORK

Back in Spring 2020 I carried out a field study as a pre-study for the proposed project. This study involved professional users within creative media production with at least four years of experience. These professionals were interviewed to gain insights about their work, what personal devices they had and made use of, and how they would approach the use of multiscreen for their work. By interviewing four participants all from different fields, I found that they came up with multiple ideas of how they could make use of multi-screen for their work. Further, by making use of multiscreen, it also became apparent that others might get involved as well because it would introduce an alternative form of collaborative work to more traditional ways of working [3].

By referring to the insights gained from this study, it became clear to me that people have different perspectives on the use of multi-screen for their work. Despite these differences, they were all interested in this way of working and provided different use cases within their fields of work. As the people were from different areas within media production, it shows that the objective of this thesis could potentially be useful in other areas besides digital art.

2.2 CROSS-DEVICE INTERACTIONS

A paper published in 2017 discusses the use of cross-device interactions and its challenges that we could face in the field. A workshop was organized where topics surrounding cross-device interactions were discussed. [4] The workshop covered topics such as top-down tabletops and spatial awareness, but the points being made in this paper also cover general cross-device interactions. We will be looking at key factors in this paper that played a role in this project:

> **Enabling easy configuration of device ecologies** by allowing users to easily combine, pair, attach, and stack different physical devices to create a seamless shared input and output space. Even after decades of research on this area, we still lack fundamental understanding of how people perceive

such device ecologies. We also lack the technology, concepts, and established interfaces for creating such connections.

Designing for scale and interoperability by creating a design that does not focus on interaction with just a single device, but multiple ones. Devices and operating systems still largely have the perspective of a single user interactive with a single device, and it tends to be complicated to introduce interconnections with different or large numbers of devices. Current approaches expose users to demanding manual work involving connecting, pairing, or installing additional software to make them work together. In addition to this, sharing content across devices and people is not an inherent part of the current computing paradigms. These computing paradigms are still based on the desktop metaphor and its menus, icons, windows, and pointer interaction.

Addressing cross-device interaction challenges by creating a set of core design principles for cross-device interaction which has yet to be made, and guiding principles on how to represent content across devices, action possibilities, and capabilities across a diversity of devices. Having guiding principles should help designers with how information can be conveyed, and help users recover from potential mistakes. These are a few of many other questions that need to be addressed to make cross-device interaction a reality.

Building supporting infrastructure and toolkits, which requires appropriate development tools, supporting infrastructures, and prototyping tools. Designing cross-device systems involves distributed systems, distributed interfaces, and networking in a full-stack process. Other factors in such process could include sensor processing if necessary.

2.3 Examples of Cross-Device Applications

Performance, workload, and usability have previously been studied with the use of monitors and tablets in a multi-screen setting by Saleem and Weiler. [5] In this paper the tablets have their own primary task and act as independent devices. The dual monitor with a tablet performed better than the single monitor with two tablets. Fewer errors were found, and it had higher usability ratings. It was however recommended to use an optional tablet for complex and information-rich computing tasks. [5] This is, as is mentioned in the paper, because independent devices that are not connected to an application cannot be used to support the workflow except for displaying other information. It does however give an indication that some find it convenient to have easy access to a tablet.

Another related study is MochaTop; a prototype system that enables new interaction patterns in a multi-device environment. [6] Using this system, different sensing methods that provided spatial awareness for

the mobile devices were used to investigate if navigation in digital tools using spatial awareness was effective. The study concluded that 61% (n = 14) of the participants had a strong desire to further explore the application. This proves that there is a potential for extending everyday interactive spaces with mobile tabletops. [6] As this study mainly focused on spatial awareness in a multi-device environment, it still shows that the use of multi-devices has the potential to become useful, depending on the circumstances.

2.4 Design and Adaptation Challenges in CSCW

"Computer Supported Collaborative Work (CSCW) is a community of behavioral researchers and system builders at the intersection of collaborative behaviors and technology. The collaboration can involve a few individuals or a team, it can be within or between organizations, or it can involve an online community that spans the globe. CSCW addresses how different technologies facilitate, impair, or simply change collaborative activities.". [7] In CSCW there are several design and adaptation challenges described that have often been used to help developers and others to avoid pitfalls when going through design processes. The Grudin table describes such challenges and is in fact one of the most cited topics in CSWC. This is an indication that these challenges not only affect developers, but also those who are involved in acquiring and deploying collaboration support tools. Eight challenges are listed in the table that explains challenges that can occur when working with such tools. [7] Only those relevant to this project are shown below.

1.	Weight of effort required and the benefits for individuals making use of the technology.
2.	The technology to research, develop, or deploy and how it is based on the intuitions of managers who might not appreciate how the technology will be received by other group members.
3.	Avoiding other social & motivational pitfalls when new tools disrupt existing channels. This can lead to information being hard to find and that it challenges existing authority structures.
4.	The difficulty of evaluating these technologies
5.	Adopting to the technology is something designers must keep in mind when designing. This is important to promote successful adaptation from the outset.

Figure 1: Grudin table showing five out of eight challenges [7].

The use of multi-screen is a new area that has not been vastly explored in a professional setting, so designing it well enough for it to be adapted to is challenging. This is important to keep in mind during the design process to avoid possible pitfalls. For the technology itself, it is crucial that the benefits justify the effort,

the technology is not solely based on the managers intuitions, and the technology does not result in a social and motivational pitfall when it disrupts existing channels.

This project is intended to improve the workflow of professional users, but it can also give collaborative support because there are multiple devices to interact with in a multi-screen setting. These challenges apply to any areas where devices must collaborate. As a web application can be accessed from anywhere, there are also possibilities for synchronous remote collaborative work.

2.5 CROSS-PLATFORM DESIGN AND INTER-USABILITY

In 2004 Charles Denis and Laurent Karsenty came up with the term "inter-usability" to describe UX design across multiple devices. [8] User Experience (UX) design is a process used to create products that provide relevant and meaningful experiences to users. Design teams go through this process to design the entire process of acquiring and integrating the product, including aspects of branding, design, usability, and function. [9] In a paper from 2010, Minna Wäljas, Katarina Segerståhl, Kaisa Väänänen-Vainio-Mattila, and Harri Oinas-Kukkonen propose a practical model for the term "interusability". Wäljas et al. propose that the goal of cross-platform design is that the experience should feel coherent on the platforms. [8]

The practical model by Wäljas et al. consists of three key concepts which together form a coherent experience:

Composition

Composition in cross-platform design refers to how devices and functionalities are organized. It is how functionality, especially user-facing functionality, is distributed across devices. Having a good composition means to make the most out of the capabilities of each device. With this in mind, the context in which each device will be used is something designers should consider during the design process. [8]

Appropriate consistency

Consistency is well known as a general user interface design heuristic. It means that words, data and actions that are the same across devices should be understood to be the same, and those that are different should be understood differently. Take for example a button. Do you make every single button look the same, or does that cause confusion by implying that certain functions are similar when they are not? It is a simple concept to grasp, but it can be hard to decide what needs to be consistent and what does not, as too much consistency can be as damaging as too little. [8]

Continuity of content and data

Continuity in cross-platform interaction design refers to the flow of data and interactions in a coherent sequence across devices. Users should feel as if they are interacting with the devices as a composite group, not as a number of separate devices. Continuity in cross-device UX has two key components: data and content must be synchronized, and cross-device interactions must be clearly signposted. Data and content can sometimes be out of sync around the system, and clear signposting is needed when interactions begin on one device and switch to another. Designers may need to find creative ways of dealing with this. [8]

These three key concepts of interusability play a role in how the prototype will be designed. The composition is important, as the task is to create a good working environment around the multiple devices that will be used in the prototype as monitors, smartphones and tablets are all in different resolutions and size. Reducing the learning curve is important as the use of multiple devices simultaneously already requires some time and effort to get used to. Making use of appropriate consistency across the multiple devices can reduce time and effort to learn the design.

CHAPTER 3: TECHNOLOGIES

This chapter takes us through the different technologies that had been used in the design prototyping and the programming of the functional prototype. We will go through each technology, what they do, and how they were used in the project.

A variety of software, programming languages, and services were used throughout the process of creating and hosting the functional prototype. They will be listed as an indication as to what was used for what purpose within the project.

3.1 SOFTWARE

3.1.1 DESIGN PROTOTYPE

Adobe XD is a vector-based design tool for UX (User Experience) within web and app development. The design tool is developed by Adobe Inc. This software was used to create the design that would end as a basis for the functional prototype.

Adobe Illustrator is a vector-graphic editing tool by Adobe Inc that captures a user's creative vision with shapes, color, effects, and typography. It was used as part of the high-fi prototyping as icons were needed. It was not necessary for this project as there are many royalty-free icons out on the web, but it was useful for gaining more personal experience using this tool.

3.1.2 FUNCTIONAL PROTOTYPE

Visual Studio Code, also commonly referred to as VS Code, is a source-code editor developed and managed by Microsoft. This software was used to code the functional prototype, which involves both front-end and back-end development.

CyberDuck is an open-source piece of software that acts as a client for FTP (File Transfer Protocol) but offers other uses too. CyberDuck was used in this project to transfer the front-end code created in Visual Studio Code to a server that hosts the website itself.

3.1.3 STUDY

Nasa TLX is an assessment tool used to rate perceived workload to assess different aspects of performance. It will be described more closely in the next chapter to show what it does and how it is used in the study.

3.2 Programming Languages And Others

Hypertext Markup Language, also commonly referred to as HTML, is the most basic building block on the web. It ensures proper formatting of information such as text, images, videos, and sound for your internet browser. It is at most times used together with CSS and JS which are described below.

Cascading Style Sheets, also commonly referred to as CSS, is a stylesheet language for describing the presentation of Web pages, including colors, layout, and fonts. It also allows the presentation to be adjusted to devices of different sizes, which makes it responsive. HTML is what CSS provides the presentation information to.

JavaScript, also commonly referred to as JS, is a high-level programming language that can be used to make the web pages dynamic and interactive. JavaScript is commonly used together with HTML and CSS. JavaScript can not only be used in the front end, but also back-end / server side.

React is a JavaScript library that allows you to create large single-page web applications, and therefore to manipulate data and change interfaces without the need of reloading the page. It was used in this project to create a web application that lets you more easily manipulate data on the page without refreshing it. This is useful for a drawing application that is dependent on different types of user interaction.

Sass is an extension to CSS, providing new sets of features that allows you to do more functional CSS. Sass is a preprocessor that compiles into plain CSS. It was used in this project to make styling of the web application easier to manage.

TypeScript is a superset of JavaScript that trans piles into JavaScript. It provides strict syntax to regular JavaScript and is developed to be used in large-scale web applications. Due to the complexity of the web application and the server, it was used both in the front end and back end.

Node is a JavaScript runtime environment that executes JavaScript code server-side. Node is very useful for developing applications that require persistent connection between the browser and the server. It is often used in real-time applications such as chat, push notifications, news feed, online web games, and others. It was used in this case to allow persistent connection with the web application and to manage drawing sessions for all devices and unique users.

3.3 Services

Heroku is a platform as a service (PaaP) that enables developers to build, run, and operate applications entirely in the cloud. This service has been used in this project to host the Node JavaScript server. It can

also be used to host the Web application itself, but in this case, I chose to go with DomeneShop due to familiarity and that it provides a security certificate to the domain name.

DomeneShop offers hosting of websites, domain names, and other relevant services. This service was used in this project because it offers a reasonable price for its services, and I was already familiar with it from previous projects. A domain was rented to make the web application look more professional, and web hosting was paid for to host the web application. CyberDuck, as mentioned earlier, was used to transfer files to this web hosting service.

Auth0 is a platform that offers an easy implementation of authentication and authorization to your applications. It works universally, is very fast to implement into the application, and offers a free plan that is sufficient for small user groups such as these. It had been used in this project to authenticate users so that the server can easily identify and separate which devices belong to which people.

CHAPTER 4: METHOD

This chapter takes us through the methods that were used throughout the project. This chapter will go in depth into the methods and how they were used to analyze, design, prototype, develop a functional prototype, conduct the study, and analyze the data.

The aim of the thesis is to create a better understanding in creative media production of how the workload differs from a cross-device interactive environment to a traditional single device environment. The methods described in this chapter will provide insight as to which and how the different methods were used in the project.

4.1 AGILE METHODOLOGY

Knowing how to proceed further within a set time schedule is important for planning. There are different methodologies for project management one could focus on, but in this case Agile Methodology was selected because it promotes iterative development, team collaboration, and change recognition. [10] Team collaboration refers to both the development team and customer collaboration, but it is the customer collaboration that is most useful to this project as this is an individual master project.

Agile project management was chosen partly because of its adaptive capability. Further, it pays extra attention to collaboration, flexibility, continuous improvement, and high-quality results. It involves using six main deliverables to track progress and creation of the product. This is to create a clear and measurable project management process. [10] The deliverables are described below.

The deliverables	
1	**Product vision statement:** A summary that articulates the goals for the product.
2	**Product roadmap:** The high-level view of the requirements needed to achieve the product vision.
3	**Product backlog:** Ordered by priority, this is the full list of what is needed to be done to complete your project.
4	**Release plan:** A timetable for the release of a working product.
5	**Sprint backlog:** The user stories (requirements), goals, and tasks linked to the current sprint.

6	**Increment:** The working product functionality that is presented to the stakeholders at the end of the sprint and could potentially be given to the customer.

Figure 2: Agile project management deliverables. [10]

Because the goal of this project is to create a new functional prototype for drawing that provides the basic features needed as well as new features, it requires one to collaborate closely with potential consumers for feedback, flexible project management to allow changes to the project management, and iterations to create high quality results. The functional prototype that will be developed for this project must meet with the standard needs of a consumer for it to feel natural to work with. This is to create as precise feedback as possible on how cross-device interaction differs from that of a single device. Because the project is centered toward the users, consistent user feedback should be given to improve the prototype. There is always room for improvements of a prototype, but the iterative methods should only be used until users are able to work with the prototype without any major drawbacks.

4.2 TARGET GROUP

In an article published at the Interaction Design Foundation, it was written that if you wish to conduct an effective user research, you will need to recruit participants who represent your potential users. In other words, your potential participants should possess specific characteristics found in your eventual consumers. Different types of products and services can have various user types, so you would have to recruit participants in these varieties. [9]

The article also describes how one should be careful of biased data that could occur if you are not careful with who you recruit. People may frequently direct themselves towards colleagues if they are short on time for finding participants that fulfill particular criteria. The reason why the data could become biased is because if you happen to recruit someone who knows you personally, they might feel obliged to be positive towards the study. Another issue that might arise is if too many from one profession participate in the study, it will create an unbalanced dataset. Also, if the design solution does not align with the target audience's needs, they will analyze the design based on the industry they are known to.

So far in the thesis digital artists have been indirectly defined as the target group. The goal of the study is to evaluate a cross-device interactive environment versus a single device environment. The study requires a piece of software that participants can use for the evaluation, and there is no software that all digital artists use commonly. Digital artists are a group comprised of sub-groups that work for different purposes using different software. So, for us to carry out a study that makes sense, we must narrow down the scope of digital artists in which the study can be conducted efficiently, but at the same time provide reliable data that can be applied to other areas as well.

In this study, I chose digital artists who work with digital sketching and painting because of my personal experience within this area, my knowledge of the different software tends to offer a vast variety of functionalities, and that it was possible from a technical standpoint to create such software. After narrowing down to this specific group of artists, I needed to make sure that the data gathered from this study would be able to be used to provide a response to a more general question regarding cross-device interaction for individuals. Therefore, the analysis of the data will focus on general digital artists and not the group that participated in this study.

The target group was identified as experienced digital artists who work with digital sketching and painting in the sense of knowing how to interact with and use drawing applications. They must also be experienced with creating something like different objects, people, landscapes, illustrations, and such. This is due to the drawing tasks they would be performing during the study. This will be explained later in the evaluation chapter.

4.3 Comparative Analysis

The process of comparing items one to another would uncover their similarities and differences. This is useful for analyzing an idea, problem, theory, or question to create a better understanding of the issue and come up with strategies in response. [11]

In this project, it was used to locate similarities and differences to the interface and functionalities in popular drawing applications. The similarities would be used as a skeleton for how the drawing application would function and look.

4.4 Bubble Map

After carrying out the questionnaire for some insights, responses were shown in a bubble map along with all other components within the project. A bubble map consists of connected bubbles each with their own adjectives and phrases. It is used to define something visually. As an example, “mammal” is defined as the main topic, and surrounding bubbles that are connected to it will be definitions of this mammal. These bubbles could include lifespan, type of fur, body structure, what it eats and so on. [12]

“The bubble map’s purpose is to define the main topic with specific adjectives and phrases. In this instance, the center circle stems off into other circles or bubbles which surround it. Each connected circle will include a defining adjective or phrase.”. [12]

Bubble maps are used in this project to create a visual map of all the main components that reside within this project. Two main topics are used in the bubble map: the paint tool itself and all its functionalities; and the multi-screen functionality as it involves multiple devices, server infrastructure, and the internet.

4.5 Low-Fidelity Prototyping

One of the most crucial stages of app development is the design stage, where the viability of a project is recognized and confirmed. In this stage, one can choose a variety of methodologies that implement various techniques. The most popular methodology today, however, for agile methods of development, is prototyping. [13]

A low-fidelity prototype serves as a rough guide on visual design to allow designers to feel their way towards how content can be laid out on each screen. One can start with hand-drawn sketches as they are fast and cheap to produce, and then refine them in a wireframe on the computer. [14]

As low-fidelity prototyping is cheap and efficient and works well with creating multiple design solutions from which one can select the most comfortable and familiar to the users. The prototype considers what results from the comparative analysis and the bubble map.

4.6 High-Fidelity Prototyping

A high-fidelity prototype should have a close resemblance to a product. This kind of prototype does not only cover the user interface, but also the user experience as both detail and functionality are focused on. The user interface covers the visuals and aesthetics while the user experience covers the interactions, user flow and behavior. Creating a high-fidelity prototype allows one to examine usability questions in detail to make conclusions about the user behavior. [15]

A phrasing saying “in the wild” implies getting as close to a naturalistic usage as possible. The technology is only introduced to certain number of people who are unknown to the research team. To reach such naturalistic usage among users, a robust prototype that may be near the level of “beta” should be developed. [16]

As the goal is to compare cross-device interaction versus single device, it is important that the functional prototype reaches a naturalistic state of usage that is comparable with competitive paint tools. Creating prototypes before developing it will help discover errors or improvements so that the quality of the functional prototype can become better.

4.7 Functional Prototyping

A functional prototype is the type of prototyping that provides a more dynamic outlook to a software project. These prototypes are interactive, clickable, and have dynamic content. A non-functional prototype, however, focuses mainly on the look and feel. Situations where functional prototypes work better than non-functional ones can occur if most of the requirements are functional, if the selected process design reveals a need for testing in most of the design process, if the prototyping tools are adequate, or when there are limited resources for development. What you will get in return for developing a functional prototype is that it provides a platform for adequate testing and provision of feedback, but also that it provides the platform for incremental delivery of an app. [13]

In the case of this project, a functional prototype is necessary due to it being a highly interactive application that responds to user interaction. Because users will be interacting frequently with the application, adequate prototyping tools are necessary. Due to the need of adequate prototyping tools, there will be testing to ensure they work as intended for the study itself.

4.8 Pilot Study

Pilot studies should be run at least once even though you might be under pressure to start collecting data. This is because those who participate in the pilot study can reveal typos, unclear instructions, technical installation issues with specific phone models, time zone logging issues, extraneous and missing pings, and other assorted issues. It can really save time when dealing with real participants. [17]

Performing a pilot study on a small scale can greatly help avoiding mistakes before performing the larger studies. The pilot study is a method that can easily be iterated several times during the prototyping and the development of the functional prototype to discover errors or improvements. Pilot studies will be done just before each of the focus groups that will be conducted, and then multiple times throughout the functional prototype development. This is to ensure that as few errors as possible can be found when carrying out the larger studies such as the focus groups and comparative usability testing. This might result in better feedback as there are fewer errors to distract the participants.

4.9 Structured Interviews

Interviews are classified as a qualitative research method that is used to collect data by asking a series of questions. Interviews include two or more people with one of them being the interviewee. In the structured

types of interviews, the questions are predetermined and are set in order. Conducting structured interviews is beneficial if you feel very comfortable with your topic, or if you have limited time or resources as analyzing the data will be more straightforward due to their closed-ended nature. The closed-ended type of structured interviews makes use of yes / no or multiple-choice questions. Closed-ended structured interviews are more common than open-ended ones. [18]

This study makes use of both open-ended and closed-ended questions as some questions consider the users' evaluations of certain aspects of the study. The open-ended questions that will be asked are often grouped together depending on the overall response, while some answers might be distinguished from the others and discussed when analyzing the data.

4.10 NASA TLX

Nasa TLX is a technique that was developed by NASA to assess the relative importance of six factors in determining how much workload the participant experienced while performing a recently completed task. The six factors are as follows:

Mental Demand

How much mental and perceptual activity was required (for example, thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, forgiving or exacting?

Physical Demand

How much physical activity was required (for example, pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?

Temporal Demand

How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?

Performance

How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?

Effort

How hard did you have to work (mentally and physically) to accomplish your level of performance?

Frustration Level

How insecure, discouraged, irritated, stressed, and annoyed versus secure, gratified, content, relaxed, and complacent did you feel during the task?

Participants are asked shortly after the task to rate their score for each of the six factors on an interval scale ranging from 1 to 20. The TLX also employs a paired comparisons procedure which presents 15 pairwise comparisons where participants are asked to select one or another depending on which scale factor was the most effective on their workload during the task they recently completed. This procedure gives two potential sources of between-rater variability for the analysis. Participants usually have some training or experience in using the TLX. [19]

This method of evaluation was chosen because it asks just how much workload the participant experienced in different types, and that kind of data can easily be compared between cross-device interaction and single device interaction. The paper version can be found on the official NASA website. [20]

4.11 Qualitative Comparative Usability testing

Comparative usability testing can be referred to as benchmarking the usability of an existing design against that of its competitors. In this type of testing, you would be using quantitative metrics such as task-completion, error rates, and time on task to compare existing user interfaces with each other. In this case, the participants would perform test tasks uninterrupted and be required to not think aloud. Participant's responses can therefore be compared to a questionnaire. [21]

Qualitative, comparative usability testing has an entirely different purpose. When conducting qualitative, comparative usability testing early in the design cycle, you can address the pros and cons of various design directions. Here, you should create lower-fidelity prototypes that provide the user with enough functionalities to compare the differences in each solution presented. Doing so while allowing participants to think aloud and discuss their opinions on each solution and the problems they encounter in each test session will allow you to note if they are confused about any design aspects. This type of qualitative, comparative testing will help uncover what works and what doesn't in each design solution. [21]

> "Seeing two or more ways of doing the same tasks makes it much easier for participants to contrast and discuss the differences between each design solution." [21]

When you conduct a qualitative, comparative usability test with multiple design solutions, you will notice right away that participants provide more useful feedback compared to quantitative tests. If participants are exposed to more than one design solution, the responses suddenly become more animated. Seeing different ways of doing the same tasks makes it much easier to contrast and discuss differences found in each design solution. [21]

In addition to the participant's comments and opinions, you can use the quantitative data gathered from the tests to locate successful and problematic design aspects of the design solutions.

> "When you get to the second and third solutions, participants will naturally start making comparisons with the previous designs, whether you ask them to or not" [21]

"Usability testing is the systematic observation of end users attempting to complete a task or set of tasks with your product based on representative scenarios". [17] A comparative version compares one usability testing with another which is in this case the use of single screen and the use of multi-screen.

In this project, this methodology was used in the study that aims to respond to the research question "How does a cross-device interactive application affect workload among digital artists in creative media production?" The article describes early use and preferably with low-fidelity prototypes, but it applied very well to the two different versions of the functional prototype developed for this study because they can be compared to each other; one version that involves cross-device interaction; the other with just a single device interaction.

CHAPTER 5: DESIGN PROTOTYPING

This chapter takes us towards ending up with a high-fidelity prototype. The different sections in this chapter go through comparative analysis, bubble map, low-fidelity prototyping, high-fidelity prototyping, and pilot studies.

5.1 COMPARATIVE ANALYSIS

A comparative analysis was conducted before the design stage due to lack of foundation to build upon. To first understand what we are building, a comparative analysis would be conducted. This would give us the information regarding what interface and functionalities should be considered in the functional prototype of a drawing application. Regarding the functionalities of a drawing application, there are no clear fundamental guidelines as to what makes a drawing application function. In this regard, I used my own experience with drawing applications and the results from this analysis to determine which functionalities should be prioritized.

5.1.1 APPLICATIONS

In this analysis, three well-known drawing applications have been chosen to help map out differences and similarities these applications have, and to understand how they tend to be structured both in interface and functionality. The chosen drawing applications for this analysis is Clip Studio Paint, Autodesk Sketchbook, and Pro Create.

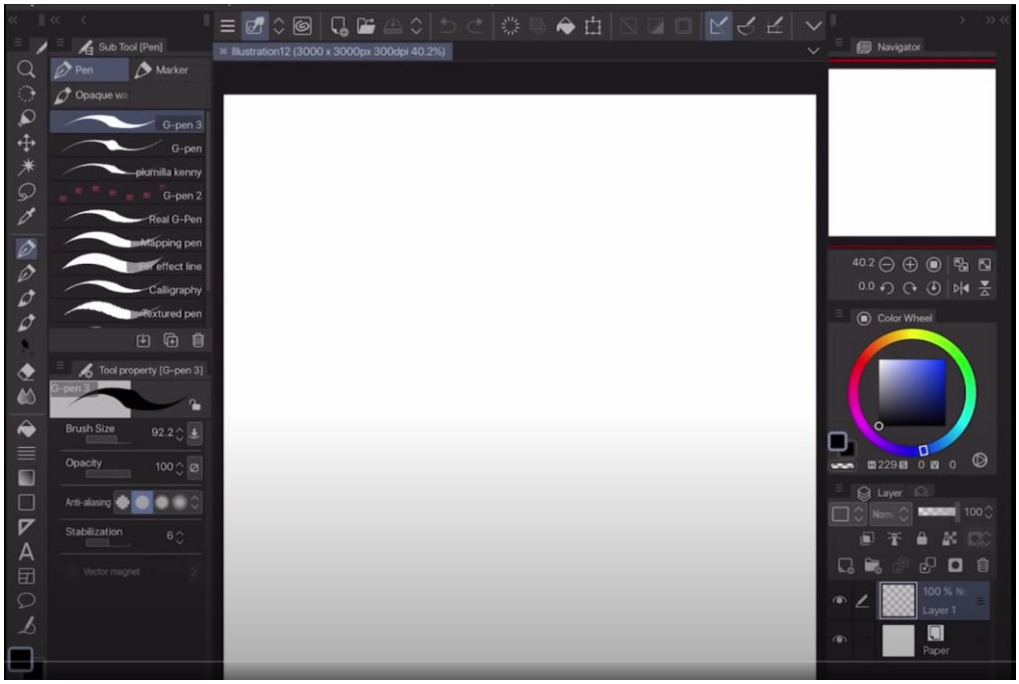


FIGURE 5.1 SCREENSHOT TAKEN OF THE DRAWING APPLICATION CLIP STUDIO PAINT

Clip Studio Paint Celsys, Inc own Clip Studio Paint that was released in 2001. Clip Studio Paint is available on Android, iOS, iPadOS, macOS, and Windows. [22]

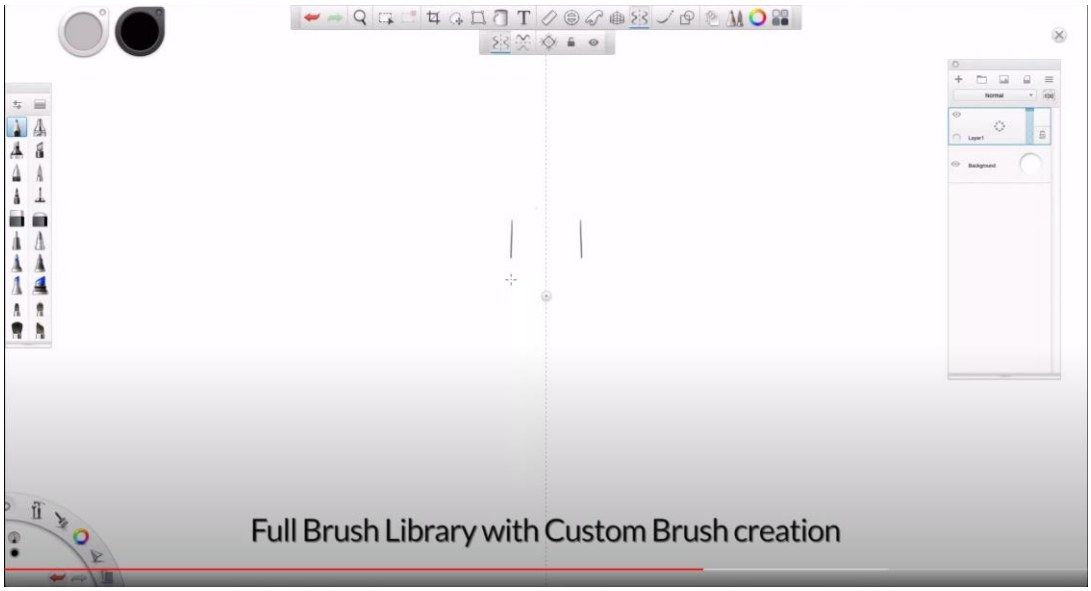


FIGURE 5.2 SCREENSHOT TAKEN OF THE DRAWING APPLICATION AUTODESK SKETCHBOOK

Autodesk Sketchbook is owned by AutoDesk and previously owned by Alias Systems Corporation. AutoDesk SketchBook is available on Android, Windows, iOS, and macOs. [23]

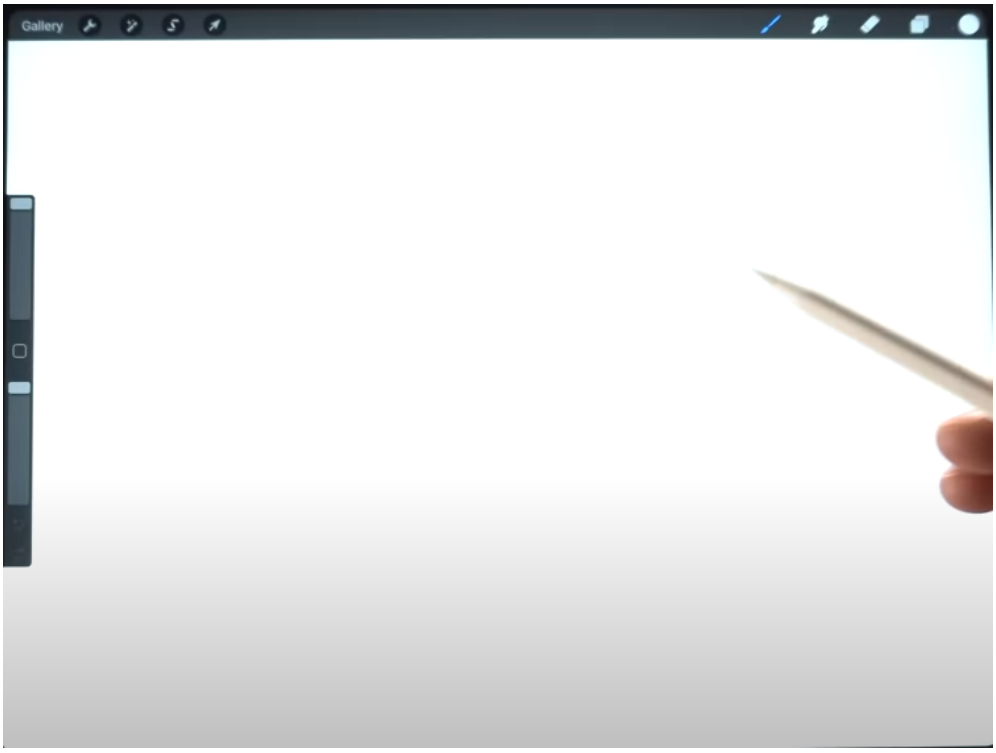


FIGURE 5.3 SCREENSHOT TAKEN OF THE DRAWING APPLICATION PRO CREATE

Pro Create is owned by Savage Interactive and was released in 2011. Pro Create is available on iPadOS only. [24]

5.1.2 EXPECTATIONS

A comparative analysis is intended to gain data that can be compared to gain insights. It was expected that the comparative analysis of the three applications would provide enough knowledge about what makes a drawing application and how we can apply it to our own. This knowledge is expected to help in the development of the drawing application.

5.1.2.1 INTERFACE

It is expected that one would wish to give the canvas as much space as possible without limiting the workflow. The functionalities of the application will be somewhat hidden within menus, but some of the crucial functionalities will be somewhat visible for the user. Dark Theme has become more popular in recent years since white themes tend to stress the eyes.

5.1.2.2 FUNCTIONALITY

It is hard to expect what functionality a drawing application should have when one does not have the knowledge to know what makes a drawing application. It is however expected from my own experience

that one can move, rotate, and zoom the canvas freely, use different brushes and erasers with different settings, use undo and redo when mistakes occur, and use of a layer system.

5.1.2.3 Cross-Device Interactive Environment

Sharing an application over multiple handheld and computer devices to allow them to work together simultaneously is not something that is common these days. Previously in 2020 I had written a paper for this project that investigates how people in different fields work with their computers and handheld devices. Questions regarding cross-device interactive working environments were asked, and it seemed that none of them had ever touched anything like that in their field. [3] Because of this finding, I don't expect any of today's products to off er support for cross-device interaction.

5.1.3 How the analysis was conducted

5.1.3.1 Locating The Applications

To locate popular drawing applications, I made use of YouTube and Google to find the most well-known and respected professional drawing applications. This was determined by the number of times they had been mentioned in a list of popular and good applications, how many people were using the software and their impression on them.

5.1.3.2 Creating The Template

The template was created to make it easier to compare the data in the analysis. The template was created by taking a quick look at tutorials of each application and note down every question that came to mind about the interface and functionality. It resulted in a lot of keywords in a list that involves elements within the interface, theme, the different windows that can be shown/hidden, and functionality. There would be three copies of the template for each application and data would be written down on each element in the list as you do the analysis.

5.1.3.3 Gathering The Data

One by one, I went through the list and watched beginner tutorials to learn the fundamentals about the drawing applications as well as what the interface feels like and how the application functions.

5.1.3.4 Performing The Analysis

As this is not a large-scale analysis and the results are easy to compare, the answers are directly written into this document. The analysis divides into two main sections; the interface and the functionality, with a smaller section being the Live cross-device working environment. The three lists for each application have the same template, so it was easy to divide the lists into these three sections. A summary of each

application was written, then the differences and similarities compared. If they all had something similar this would be noted. The differences were written separately.

5.1.4 Discoveries

As it turns out, each of the applications took a different approach in how they were built. The interface was vastly different in each of these providing different working environments. The functionalities were somewhat similar in each of the applications but different approaches in how they were intended to be used.

5.1.4.1 Similarities

There are many similarities to be found among these three applications exactly because they aim to achieve the same goals. The interface of the applications all prioritizes multiple important things for the user to have easy access to: brush settings, color settings, layers, and a menu. Pro Create and Clip Studio Paint both have dark theme as a standard. Pro Create and Autodesk Sketchbook have few or to no windows that fill up the screen open. They all have similar interfaces of the color wheel and settings.

5.1.4.2 Differences

There were major differences in how the user would reach the different functionalities and work within the applications, and the interfaces were built for different purposes.

All three applications had different interfaces that prioritized accessibility of functionalities differently. Pro Create focused on maximizing canvas area by minimizing all windows and only had a menu and a small window for brush size and opacity. Clip Studio Paint focused on letting the user have easy access to important functionalities of the app, so it had multiple windows open to achieve that but made the canvas area smaller. Autodesk Sketchbook was a mix where it focused on shortcuts to most of the functionality found within the app. It did not have many large windows open but several smaller windows with shortcuts to different functionalities. Autodesk Sketchbook also went with a lighter theme compared to the other two.

Functionalities within the app were mostly the same but Pro Create did something different, which is finger taps and gestures. To undo/redo/cut/copy/paste, you would perform different taps with multiple fingers, hold multiple fingers to undo/redo quickly, and use multiple fingers and swipe to cut/copy/paste something. Clip Studio Paint was the only application that had a navigator; a small window displaying the canvas and what the working area covers of the canvas. This makes sense as the canvas area is small due to the other windows taking up a lot of space. Sketchbook has a background layer which you can use to change the color of the canvas.

5.1.5 Which Approach to Take

Analyzing these three applications has given me knowledge regarding how a drawing application functions and what approaches one can take when designing the interface. There are certainly pros and cons for each approach, but they all function well in their own way. It does in the end come down to personal taste in how you would want to work within a drawing application. The approaches here are specific things that I have decided should be considered when creating the functional prototype. It does give a full overview of what will be included in the prototype.

The window management of Pro Create seems like a good fit for this kind of application as you would usually move the windows to the other connected handheld devices instead of using portions of the canvas area. The idea of floating windows from Sketchbook will be considered as it gives the freedom of placing the windows anywhere precisely on the screen and that it might be easier when moving windows to the other devices. As Pro Create and Clip Studio Paint have a darker theme than Sketchbook, it suggests that dark theme should be considered. For long sessions dark theme would be a better choice as bright light can be stressful for the eyes.

Pro Create has these multi-touch taps and gestures that activate specific shortcuts. This could be considered if you want to save screen space. This is however not a necessity and will be only considered if time allows it. Autodesk Sketchbook has a layer at the bottom of the layer list which is specifically for the Background. This layer has a circle within it in the list and you tap that to change the color of the canvas. This is a smart idea as some artists tend to lower the brightness of the canvas for the sake of their eyes.

5.1.6 Summary

Only the most well-known drawing applications were analyzed due to time constraints. It is also only intended to give an overview of what makes a drawing application. This analysis only gives insights on the most fundamental things to focus on within a drawing application as this project is only a functional prototype.

5.2 Bubble Map

The bubble map was created after conducting the comparative analysis, which resulted in gaining more insight into which building blocks to use for the drawing application. All functionalities of the application were drawn in bubbles and lines were drawn between bubbles that had a connection.

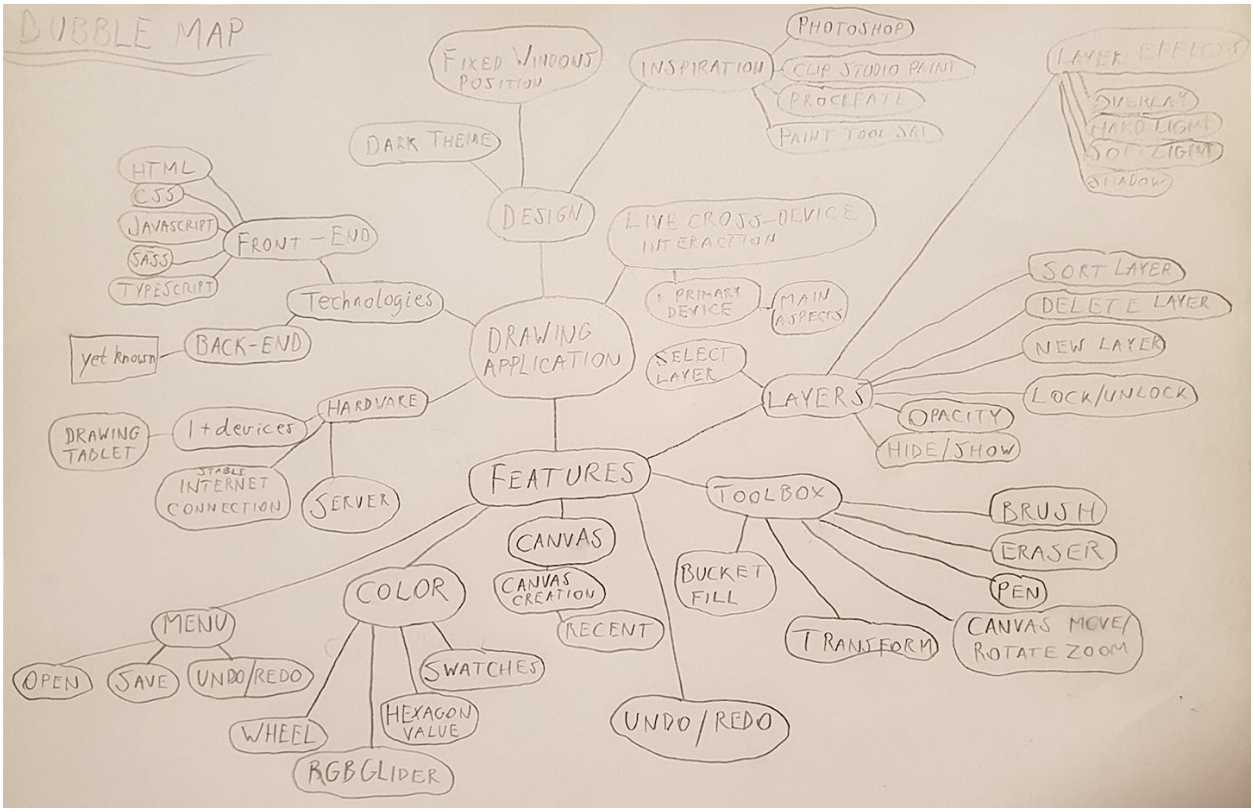


FIGURE 5.4 PICTURE OF FINISHED BUBBLE MAP

The created bubble map was used for structuring all the parts that this project involved. This is valuable for prototyping as you map out the parts that will be considered in the design solution. That they are also categorized and connected to each other helps to create a structure of where the different parts belong and connects to. The bubble map was created in a quick session for personal use as I had worked alone on this ambitious project.

5.3 Low-Fidelity Prototyping

A low-fidelity prototype was created in Adobe XD while using the bubble map as reference to the structure of the prototype. Since the bubble map lists the functionalities and how they connect to each other, it reduces the risk of creating a design that has structural errors or missing functionalities. A digital prototyping tool

such as Adobe XD was chosen for creating the low-fidelity prototype instead of paper prototyping and there are several reasons for why this choice was made.

A digital prototyping tool does not require physical materials and saves cost and time of achieving this material. Creating the prototype digitally removes the need of managing the physical material. Sharing the prototype digitally does not affect quality and is usually simple to do, while paper prototyping must either be shared by hand, or by taking a picture of the prototype which can affect the quality of the prototype. In this case, the prototype benefits from being shared digitally due to most participants being remote.

Continuation of the prototype is more efficient and simpler digitally as you can re-use or continue the prototype that was already made, making high-fidelity prototyping more efficient compared to a paper prototype which requires it to be transferred at some point to a digital prototyping tool. This can depend on the type of product you are developing, but in this case the product functionalities are complicated, and it would take time to transfer the design solution from paper to digital format. Creating the prototype digitally instead of on paper is also already a step closer to the finished product because in this case the finished product will be digital. If the low-fidelity prototype were to be created on paper, every interaction and navigation would require manual adjustment, which could affect how one would perceive the prototype once they interact with it. The arguments described here were developed from personal experience and prototyping. These arguments apply to products being made for websites and mobile applications but may not be applicable to products being made for other platforms.

The low-fidelity prototype design solution made in Adobe XD primarily focuses on creating the structure of the application with simple color implementation, which is inspired by the insight gained from the comparative analysis. Each screen within the low-fidelity prototype will be shown below with a description.

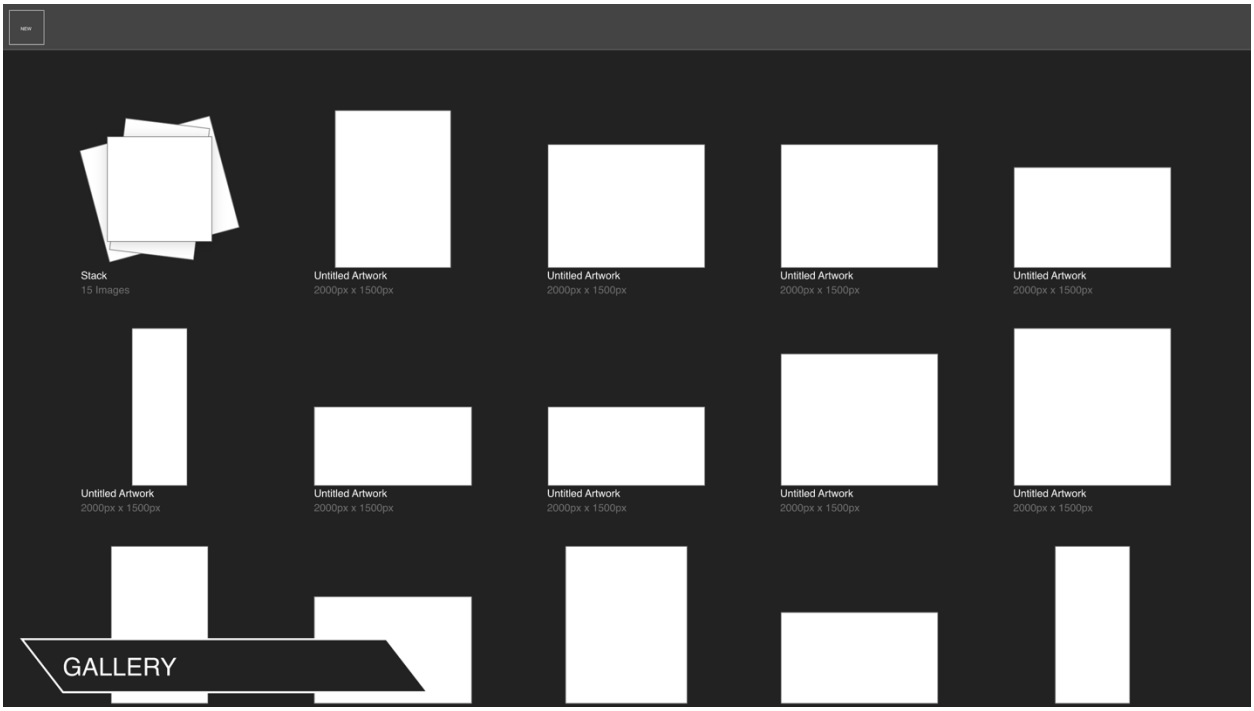


FIGURE 5.5 SCREENSHOT OF THE GALLERY

5.3.1 GALLERY

This is the first interface a user will see once entering the application. This is the gallery of the drawing application, serving the purpose of managing and showing the projects the user might have. On the top left corner, the user will see a box that when you click on it, a box will open that allows you to create a new project. The different white boxes with names and pixel sizes underneath are the projects that you have created within the application. The top left section is a folder containing multiple projects allowing you to manage and structure your projects. When you click on the folder, you will be shown the projects residing inside that folder, and if you click on one of the projects, you will be taken to the canvas working area where you can start working on your selected project.

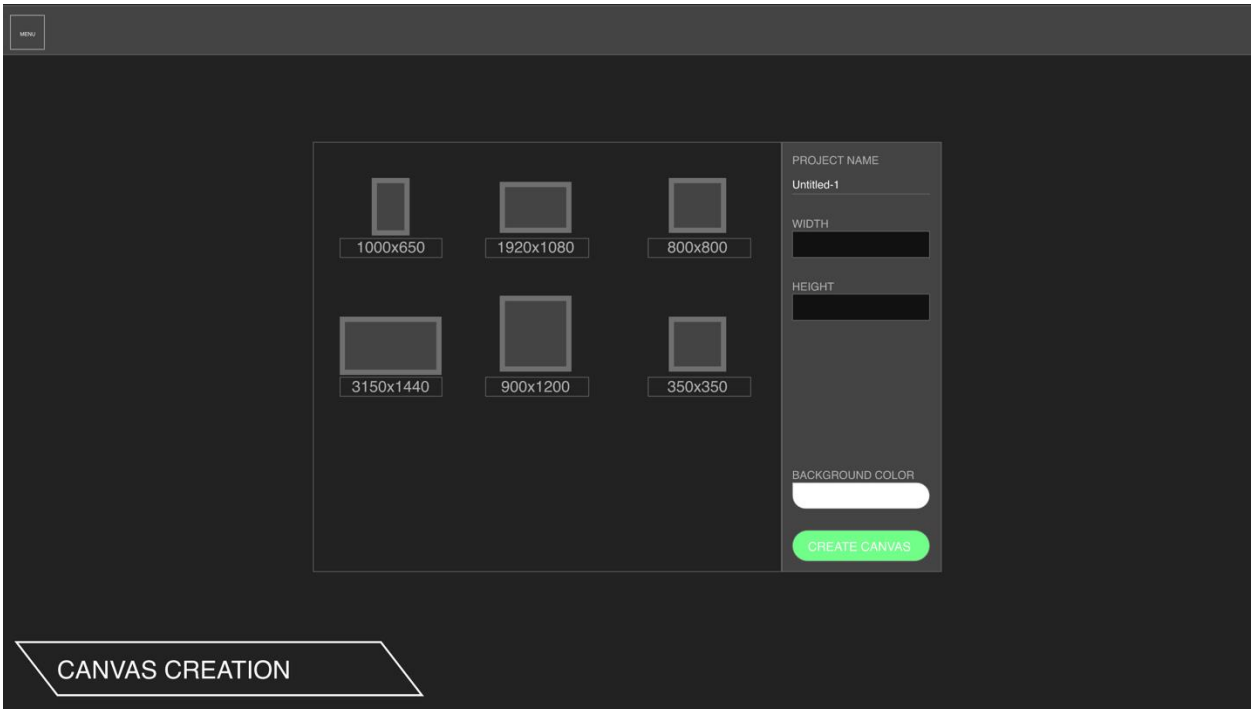


FIGURE 5.6 SCREENSHOT OF THE CANVAS CREATION

5.3.2 CANVAS CREATION

This screen can only be accessed through clicking the box on the top left corner of the gallery screen. This screen allows the user to create a new project by specifying the name of the project and the resolution you want the drawing to be in pixels. On the left size of the box, you can select a pre-defined size by clicking on any of the boxes, or by typing in manually on the top right side. At the bottom right you can select the canvas color of your project as well as creating the new project. Once you click on the green button saying create canvas, you will be taken to the canvas working area.

FIGURE 5.7 SCREENSHOT OF THE CANVAS WITH THE MENU AND TOOLBOX WINDOW OPEN

5.3.3 CANVAS WITH MENU AND TOOLBOX OPEN

This screen will display once a user has selected a project in the gallery screen or by creating a new project from within the create project screen. This is the working area where you can work on the project you had selected or created. In the header at the top of the screen you will be seeing more clickable boxes. On the left, you have three clickable boxes which from left to right are the menu, undo, and redo buttons. When you click the menu button, a window with a list of options will display below the button as shown above. Here you have the option of creating a new project, go back to the gallery, or manage devices. The undo button is meant to revert changes you made to the project, while the redo button is meant to reapply the changes you reverted.

On the right side of the header, you have five clickable boxes. From left to right you have brush selector / brush settings, eraser selector / eraser settings, toolbox, layers, and color. Each of these functionalities will be described later in the chapter. Clicking the brush or eraser box once will activate the brush or eraser tool, and if you click on it again after either being active, the window settings for the active tool will display. The other boxes will display a window associated with the clicked box on the first click.

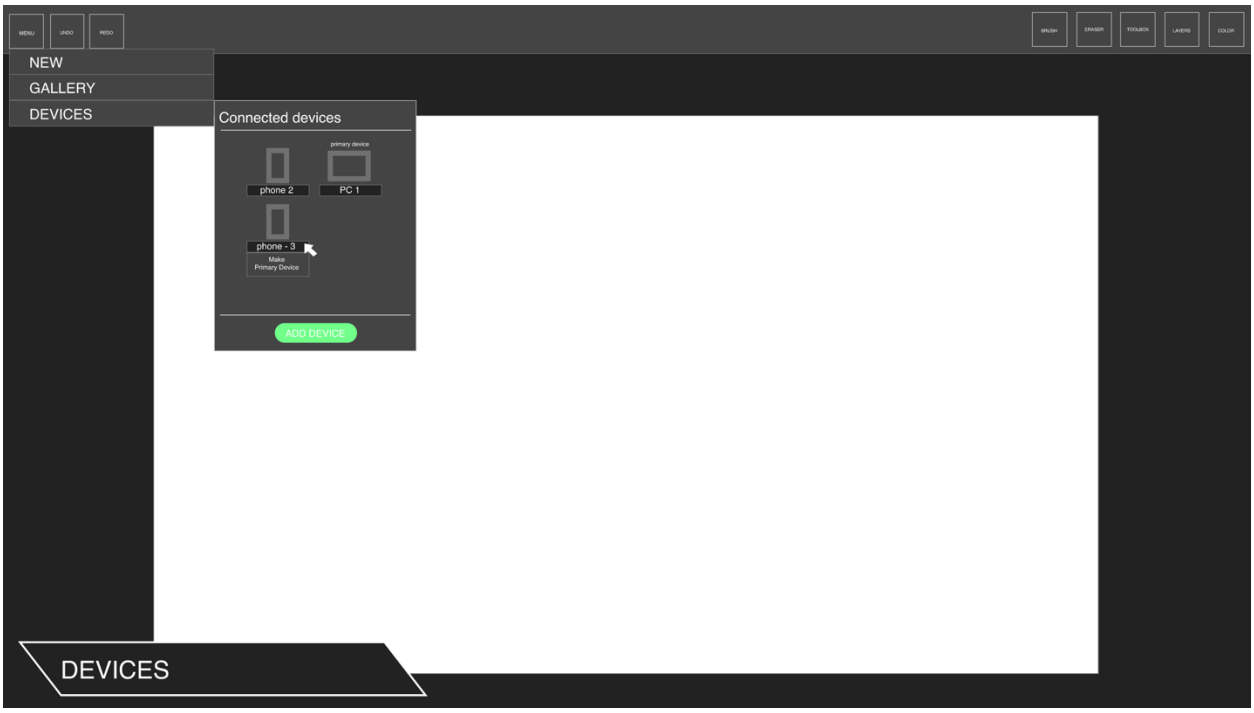


FIGURE 5.8 SCREENSHOT OF THE DEVICE MANAGEMENT WINDOW

5.3.4 Device Management

The device management window opens when a user clicks on the devices button inside the menu. Here you will see all the devices that are connected to the application. In here, you can click on any of the devices, and choose if you want to make the selected device the new primary device. In this application the devices are split into two groups, primary and secondary devices. In the drawing application, there can only be one primary device that will act as the work area, the place where you draw on the canvas. Secondary devices act as external controllers that can be used to manage the tools and settings of the application. When a primary device is connected, all other devices that are added will automatically be assigned the role of a secondary device. By clicking the green button on the bottom of the window saying add device, you will be taken to a new section of the window that provides the information to connect new devices.

In figure 5.3.5, you will see two options of connecting a new device, using a QR code or an URL link. The idea behind this is that you can point your phone or tablet camera towards the QR code to connect your device fast and efficiently, or by copying and pasting the URL link shown at the bottom. The two buttons named new and copy are used to generate a new link, or to copy the link that is being displayed on the right. When you connect a new device, this device will be displayed in the list of devices as shown in figure 5.3.4.

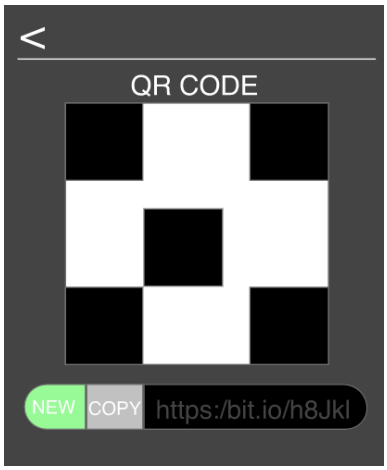


FIGURE 5.9 SCREENSHOT OF ADDING A NEW DEVICE

The functionalities described so far have been shown on primary devices. The next functionalities such as layers, color, brush / eraser settings, toolbox, and canvas control will be shown on secondary devices. All of these have the same design solution on primary devices, except that they are shown as hovering windows like the menu.

5.3.5 LAYERS

The layers window allows the user to manage the layers within your project. A way of describing layers within a drawing application would be to imagine a set of transparent papers with each their own drawings and stack them on top of each other to see them all together. You can also change the order of these papers to place some drawings on top of or under another paper. Layers as shown here provide the same functionality.

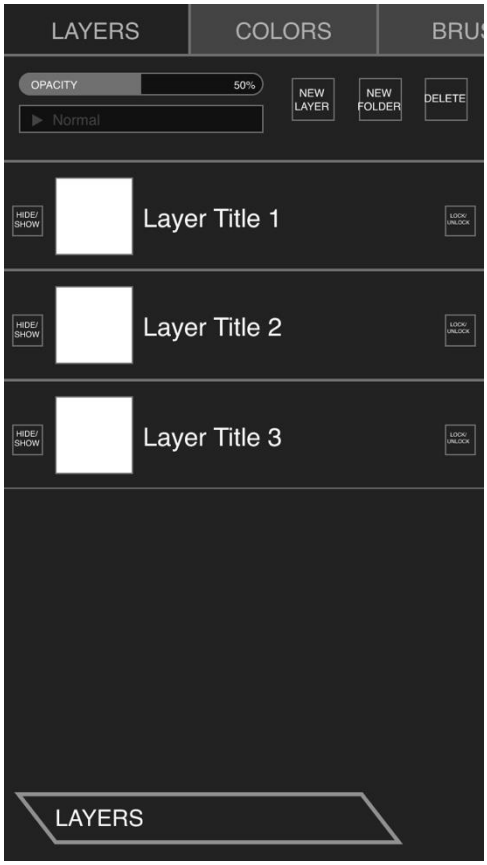


FIGURE 5.10 SCREENSHOT OF LAYER MANAGEMENT

Here you can change the settings of specific layers such as opacity, visual effects, hiding the layer, locking the layer, or changing the order of which the layers will be shown. You can also add new layers, delete layers, or add a folder that holds a group of layers for structural management. The white box displayed on each layer will show a preview of what drawings exist on that layer, as well as the name of the layer on the right side of the white box.

5.3.6 COLOR

The color window allows the user to manage the colors for the brush. In this window you can select a variety of colors from various types of selectors. On the top left of the color window, you can see one white and one black box with two arrows on the upper right side. This is a clickable box used to toggle between two colors that you have selected. On the right side you have a pill shaped element with a single color that shows what color you have currently selected. On the right side of this element, you have a clickable box that acts as a color selector, meaning you can click anywhere on the canvas to get the pixel color available. The one row with different colored boxed just below contains your most recent chosen colors.

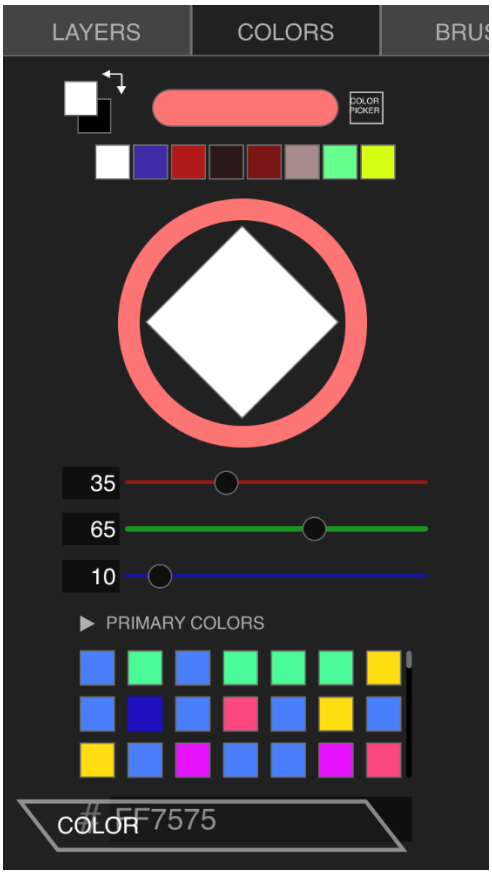


FIGURE 5.11 SCREENSHOT OF COLOR MANAGEMENT

In the upper middle of the window, you will see a big circle with a square placed in the middle. Both the circle and the square serve the purpose of making it visually easier for users to locate and select colors. The effects are not shown in this window due to complexity, but the circle is covered with a hue and the square containing brightness control of the color that is selected in the hue circle. Below these, you have three sliders that together control the RGB value for a color.

Below the RGB sliders you will find a primary colors dropdown along with a set of boxes with different colors. This is a customizable color palette so the user can keep track of colors used in the project.

At the very bottom of the window, you will see the text saying color, but behind it you can faintly see an input box containing the hexagon value of the color chosen. All these various input types reflect upon each other as you choose and manage your colors.

5.3.7 Brush And Eraser Settings

The brush and eraser settings window allows the user to select various types of brushes and manage the size, opacity, and flow settings of selected brushes. The interface, settings, and types of brushes are all the same for both the brush and eraser.

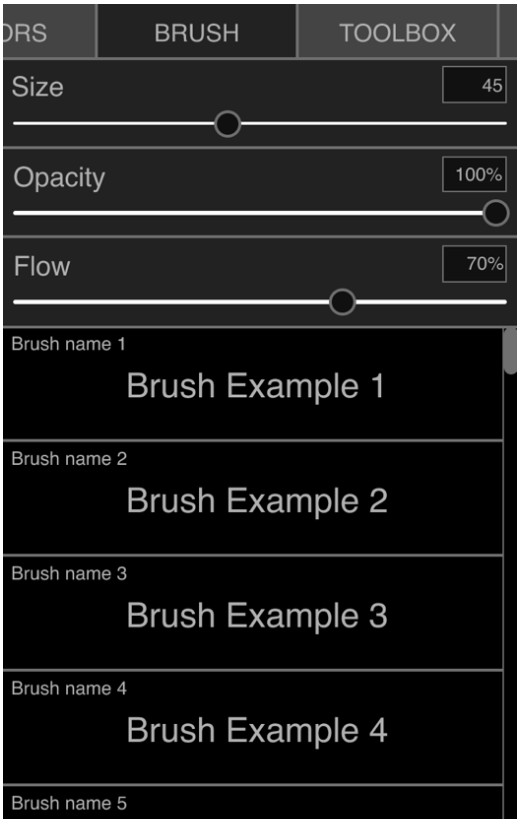


FIGURE 5.12 SCREENSHOT OF BRUSH AND ERASER SETTINGS

Differentiating between the brush and eraser goes back to which one of the navigation buttons you pressed previously, where one is a button for the brush and the other for the eraser.

The three different types of settings have a slider and an input box that is used to see the setting value and to type in a custom number. Changing the size of a brush would change the size of the area in which the canvas will be drawn on. Changing the opacity of a brush would change the overall transparency of a single brush stroke a user performs on the canvas. This means that when a user clicks or taps on the canvas, the stroke being made until the user lets go of the click will start with a transparency related to the opacity of the brush set and increase in visibility as more strokes are being made. Changing the flow of a brush tells the application to only apply the brush to the canvas with a certain distance between them as a user creates a movement while holding down the click or tap.

Beneath these three sliders you will be seeing a list of various brush types to choose from. In the low-fidelity prototype you will only be seeing a text saying, “Brush Example x”, but the idea is to have the user see what the brush type looks like. The most common brush types would be a circular brush with a soft edge, another with a hard edge, and a pen variant that acts like how a realistic pen would act. Selecting one of the brush types within the list would change the values of the size, opacity, and flow because each brush type has its own values.

5.3.8 TOOLBOX

The toolbox window allows the user to activate a variety of tools and functionalities from within a single screen. The toolbox includes already implemented functionalities and tools in the application, but these have been placed here for accessibility.

The select tool, pen tool, bucket fill tool, move canvas, rotate canvas, and zoom canvas are the new functionalities and tools that the toolbox introduces. The select tool allows you to select and transform the size and placement of a selected layer. The pen tool allows you to draw a shape and perform different actions such as fill the shape with a specific color, select and move, delete, or copy a portion of a layer. The bucket fill tool allows you to select an area of a layer and fill the space around with a specific color. The area which will be filled might be smaller or larger depending on if the area is surrounded by a stroke shape or different colors.

The brush and eraser buttons will simply activate the tool, allowing the user to quickly change between the brush or eraser.

Move canvas, rotate, canvas, and zoom canvas allows a user to transform the canvas work area to view the entire canvas in a specific position, or zooming in on a specific area to place more focus on that area.

The undo and redo actions will perform the same action as mentioned earlier this chapter.

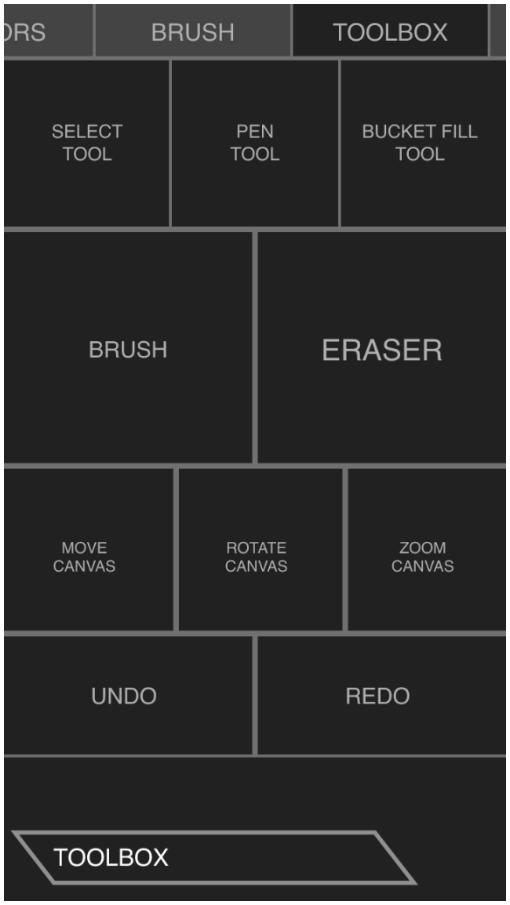


FIGURE 5.13 SCREENSHOT OF TOOLBOX

5.3.9 CANVAS CONTROL

The canvas control window allows a user to use finger gesture on a touch device to move, rotate, and zoom the working area of the canvas. This window is only available on secondary devices and will only work on devices that have touch input support. This is because if you use a touch device as the primary device, you will be able to use the same finger gestures on the canvas working area.

This is one of the functionalities that cross-device interaction can benefit from using, as you can extend your workspace across various input and output devices. For example, if you were to use a computer as a primary device that uses a mouse and a keyboard as input, it will not be possible to perform multi-finger gestures to transform the canvas working area. If you were to have an additional device such as a smart phone with the canvas control open, you could make use of a different input type because you included a device with touch input to your digital workspace.

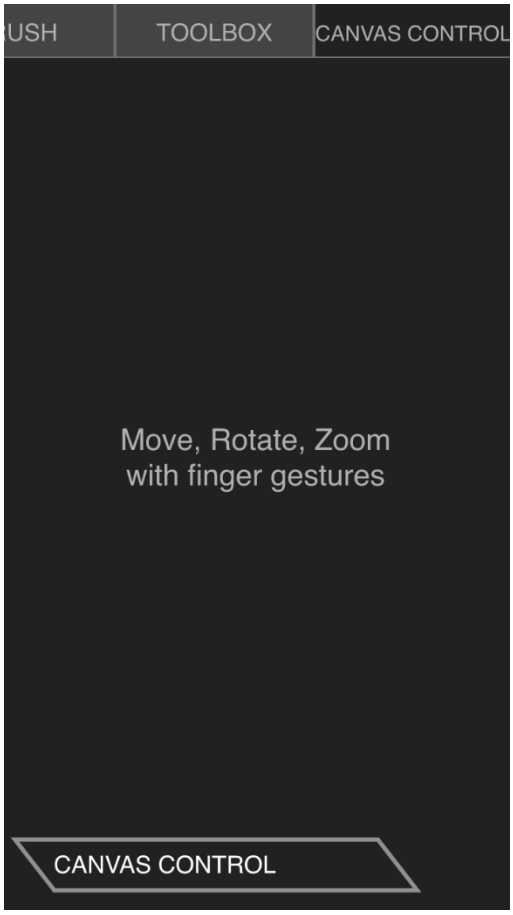


FIGURE 5.14 SCREENSHOT OF CANVAS CONTROL

5.3.10 PILOT STUDY

After putting everything together for the low-fidelity prototype, it was time to find out how real users would think of the interface, structure of the application, and how they reacted to the cross-device interactive part of the application. Because the interface and functionalities of this application were heavily inspired by existing popular tools, I only conducted small pilot studies with relatives and friends who had good understanding of these tools and good experience with digital drawing.

There would be two instances of the low-fidelity prototype: one for primary devices and one for secondary devices. This was to have participants have a prototype on two different devices to allow a better feel of the cross-device interactive functionality. The participants would go through the screens on first the primary, then the secondary device. Participants would proceed at their own pace to allow them to get the feel of the application and ask questions underway regarding the application or the cross-device interaction functionality.

Study structure

A pilot study guide for the low-fidelity and high-fidelity prototype was created (See Appendix 1). The participants who took part in the pilot study were also part of a small semi-structured interview afterwards. The average time to complete the study was around 30 minutes.

The study began with an introduction to the project, its goal, and the structure of the study, and handing over the information letter document. Each participant was given two links, for the computer and the phone. These links directed the participant to the prototypes made for these devices. The evaluation of the prototypes was guided as the participant was given tasks to perform such as locating different functionalities and explaining what they could see. After going through the prototype, some questions regarding the prototype and their familiarity towards drawing applications were asked.

Feedback

The feedback gathered from this small study was that it felt much like the tools they already used, and the interface and tools were easy to find and activate. This application offers limited functionality, so the few functionalities were familiar to them and easy to locate in the interface. After conducting the pilot study and analyzing the feedback, it was time to create a more defined prototype.

5.4 High-Fidelity Prototyping

As the low-fidelity prototype was created using the Adobe XD prototyping tool, I could make use of the low-fidelity prototype to create the high-fidelity prototype, saving plenty of time not having to create a similar prototype all over again. I made the low-fidelity prototype more detailed and defined, putting effort into coloring the application properly, implementing icons, and such. The high-fidelity prototype was structurally like the low-fidelity one, but with additional features and a few changes for a more complete overview of the application.

As some of the screens remained untouched, such as new canvas, gallery, brush and eraser settings, and canvas control, for the sake of not repeating these screens, this chapter will only focus on the changes made.

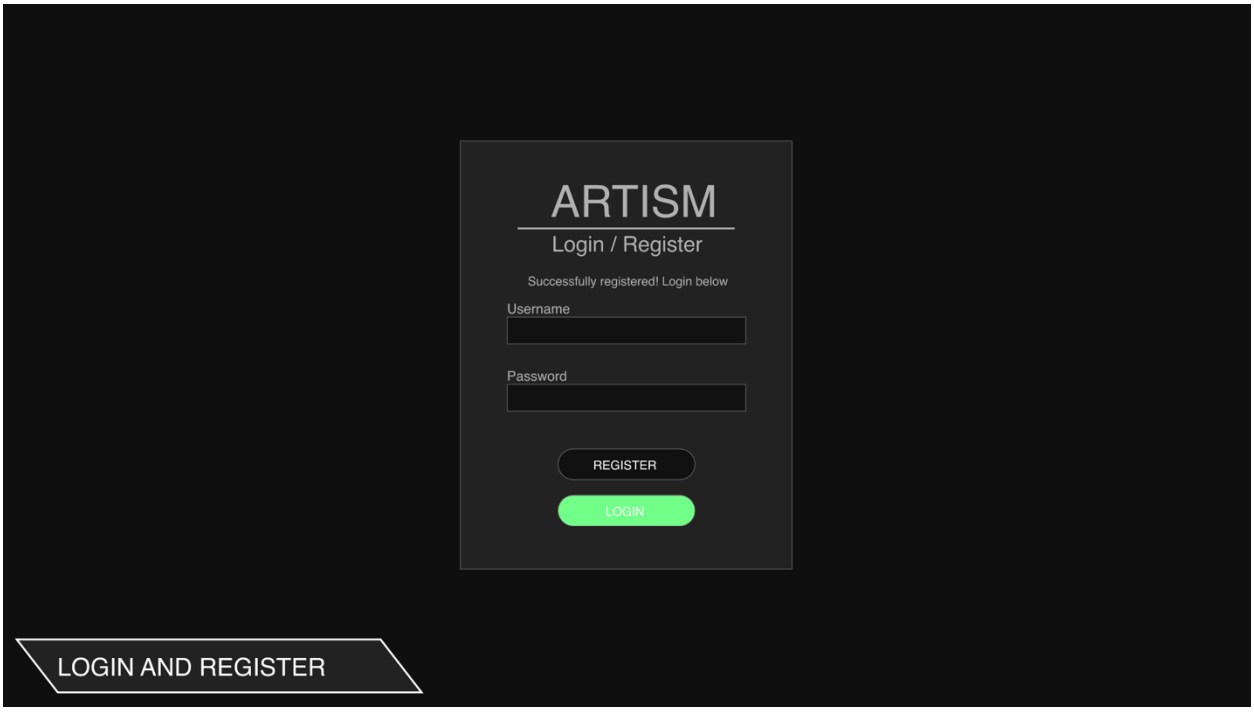


FIGURE 5.15 SCREENSHOT OF THE LOGIN AND REGISTER

5.4.1 Login And Register

This is the login and register screen. This is what the user will see when they enter the web application without being signed in as an authorized user. This screen is only used for authorizing a user before accessing the web application itself, so there was no need to pilot study this part of the prototype. Authenticating a user for a functional prototype is not necessary for the sake of this thesis as only one participant will use it at a time, but it was implemented due to personal learning experience and because

each authenticated user would have their own gallery with their projects. In the login and register screen users would be able to log in using a username and a password, or by registering a new user. Registering a new user works the same way as you simply type in the username and password, click register, and you will be logged into that user. After authenticating the user, the user will be taken to the gallery page where their personal projects are being displayed.

5.4.2 Primary Disconnected

This is the screen that will appear on all secondary devices if the primary device would disconnect. Here, the connected secondary devices would be given the choice of either becoming the new primary device, or to log out. Once one of the secondary devices presses the become primary button, it will become the new primary and the secondary devices will go back into the application.

The idea is that if a new device connects while there are no primary devices, the new device will automatically become the new primary one.

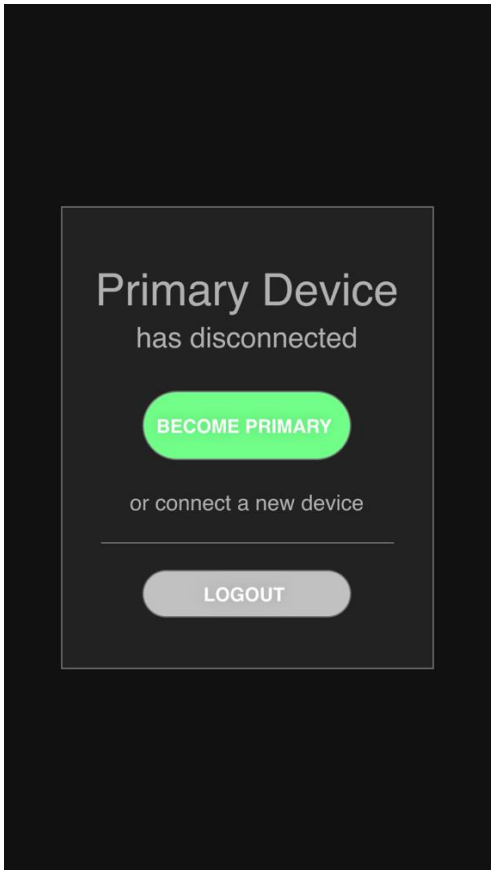
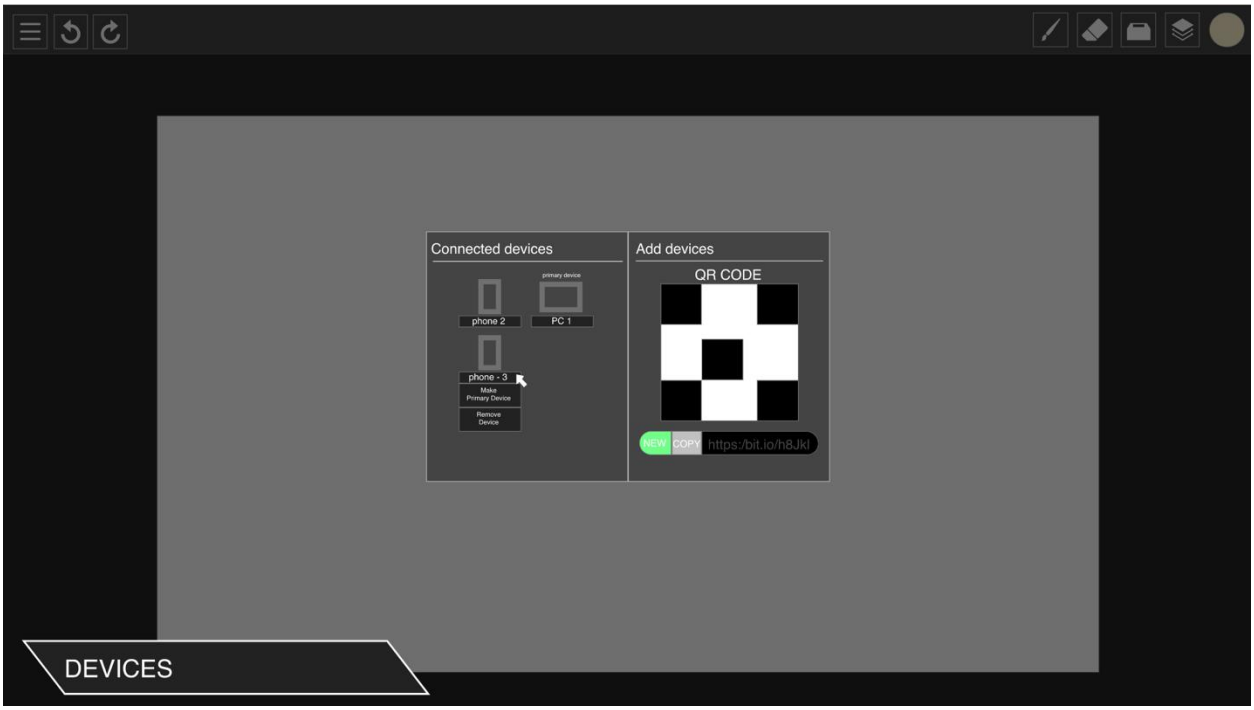


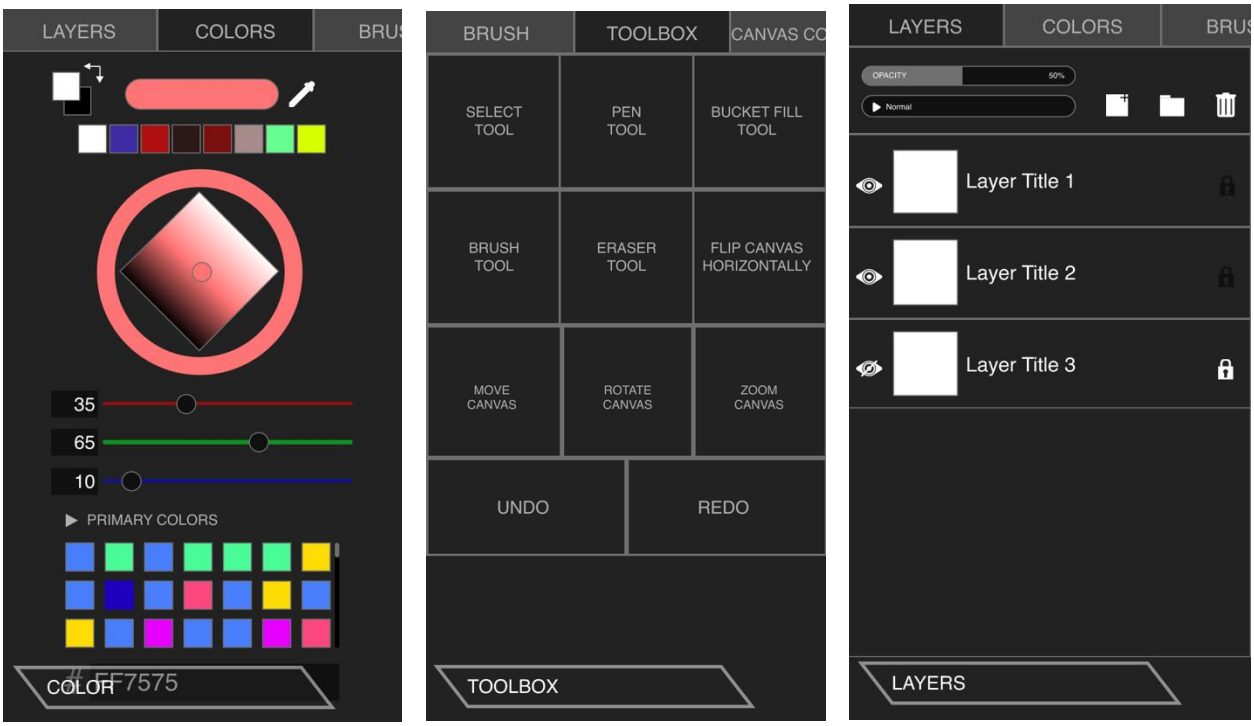
FIGURE 5.16 SCREENSHOT OF THE DISCONNECTED PRIMARY DEVICE


STANDARD

(A)


Connected devices
primary device
phone 2
PC 1
phone - 3
Make Primary Device
Remove Device
Add devices
QR CODE
NEW
COPY
https://bit.io/h8JkI
DEVICES

(B)



(C) (D) (E)

FIGURE 5.17 SCREENSHOTS OF UPDATED SCREEN VISUALS

5.4.3 SCREENS WITH UPDATED VISUALS

The overall changes made to the figures in 5.4.3 include new icons, new coloring, and some interface changes. These figures show the final version of the high-fidelity prototype after conducting four pilot studies. What changes that were made will be described in the last part of this chapter. In figure 5.4.3.a you can see the canvas working area, but the header has been updated to display icons instead of text. These icons have been chosen to represent what was previously texted for a more visual appeal and visual language.

In figure 5.4.3.b you have a new interface for managing your devices. This screen can be accessed through clicking the devices button in the menu list. The device management has now been made as a modal floating on top of the application, and both screens are now showing. This way the user has access to both the device list and the possibility to add new devices which reduces the number of interactions required. Clicking outside of the device management will close the modal.

In figure 5.4.3.c, the color switch on the top left, you can see that the square in the center of the circle now has a brightness gradient added to it. The ring itself remains a single color in the design prototype because

it proved difficult to implement such a hue around. The color picker on the top right now has an icon instead of a text box.

In figure 5.4.3.d the toolbox now has a different layout and an additional feature. The feedback gained from the pilot study for the low-fidelity prototype indicated that being able to flip the canvas horizontally was an important feature because it helps artists see their own drawing from a new perspective, allowing them to see mistakes more easily in how they drew the shapes. The layout is very similar to the previous; the only difference being that the button for flipping the canvas horizontally has been placed on the right side of the brush and eraser tool.

In figure 5.4.3.e the layers screen now has the boxes with text replaced with icons.

5.4.4 Pilot Studies

As mentioned earlier, the figures in 5.4.3 were the final changes to the high-fidelity prototype, meaning the feedback from the pilot studies was already implemented. In this pilot study there were four different participants going through the high-fidelity prototype and being interviewed. The guide that was used for the low-fidelity prototype pilot study was used here as well. The feedback from the participants played a crucial part in tuning the prototype so that every action that a user takes is predictable, that the users feel more comfortable using the application, and that the interface seems soothing to the eyes.

It was ensured that all participants were familiar with one or multiple drawing applications and proficient in digital drawing. It was also required for the participants to have one computer and a smartphone or tablet available during the pilot study as the high-fidelity prototype consisted of a primary and a secondary version.

After conducting four pilot studies, the amount of data collected was sufficient to evaluate the prototype itself and to make necessary changes to it. Every participant gave important feedback that made changes to the prototype itself, and every participant took a liking to the prototype and found themselves familiar with it. All participants were able to navigate through the application without any major issues. There were a couple of misunderstandings about how some functionalities worked, but these were addressed in the functional prototype. Several participants felt that it would have been nice if they could have created their own shortcuts. The learning curve of the application did not seem complicated as described by the participants. The changes made to the prototype are described in the iterations below:

First Iteration

- No changes were made as the participant felt comfortable with how the applications functioned.

Second Iteration

- Fixed the lock/unlock icons in the layers window so that they displayed properly.
- Made “Normal (Overlay, hard light, etc.)” in the layers section more visible.
- Specify that the height and width of the canvas makes use of px.
- Change “New” to “New project” in the menu.

Third Iteration

- Specified that “Background Color” upon creating a new project changes the background color of the canvas and not the application.
- Removed primary and secondary color as the color circle on top right shows only one color that might be misunderstood as a profile.

Fourth Iteration

- No further changes were made as the participant felt comfortable with how the applications functioned.

Wishes

Participants had several wishes they would like to see in the application. This might or might not be implemented in the functional prototype as it depends on the time required to make it. Below is the list of wishes made:

- Grouping up brushes
- Undo/Redo on the secondary devices by using multiple fingers
- Flip Canvas function
- Customizable workspace. Place things wherever you want.

Conclusion

Four participants gave their thoughts about the high-fidelity prototype and given data about their use of digital applications and their wishes for this project. Minor changes were made to the prototype, but it was overall well accepted among the participants, and they felt familiarity with it like the other drawing

applications they had been using. This study gave an indication that the high-fidelity prototype was now finished, and that the development phase could start.

CHAPTER 6: FUNCTIONAL PROTOTYPING

This chapter takes us to a working functional prototype that would be inspired by the high-fidelity prototype. This chapter is technical and will introduce different programs, programming languages, cloud services, and technical vocabulary.

6.1 A SMALL NOTE

Before we get into this chapter, I would like to point out that two different functional prototypes were made for this study whereas only the second one was used for this study. It is of high importance that this topic is described in detail before we dig into the chapter due to the massive changes that were made to the high-fidelity prototype and the infrastructure of the application.

The first functional prototype that was developed for this study only worked on a local network that the computer hosting the application and server were connected to. This would prove to be a problem as the COVID-19 pandemic struck the world and this would prevent local studies to be conducted. The other issue was the lack of local participants that fulfilled the requirements to participate in the study. Without local participants, it was time to think anew how to complete the project. The solution would be to allow anyone from anywhere to participate using their own devices. The structure of the first functional prototype was not built for this kind of task, so a new structure had to be put in place.

Due to functional prototyping consuming a massive amount of time, there was no time to create the second functional prototype in what was left. This resulted in an extended year for the master's program in media and interaction design at the University of Bergen, during which I had also started working full-time as a developer. I thus created a new mindset and gained new knowledge that allowed better technical understanding of how to build the functional prototype. What will be seen in this chapter is the second functional prototype and the technical background behind it. The changes made from the high-fidelity prototype to the functional prototype will be integrated into the description.

6.2 INFRASTRUCTURE

6.2.1 AUTHENTICATION AND AUTHORIZATION

Authenticating a user in the application helps identify every device and which user the authorized device belongs to. It was not required for this study to implement authentication due to the application only being used by one user at a time but doing so provides an example of how one would set up a cross-device environment and identify each device to its corresponding user. Authenticating a user requires complex architectural solutions that are both efficient and secure. Such solutions take time and relevant knowledge to create, but there are ready-to-use solutions available on the market. Auth0 provides a ready-to-use solution that allows us to implement authentication seamlessly within hours. Using this, we would be able to identify each user accessing the web application and store a local authorization token that allows one to access the application without having to log in every time.

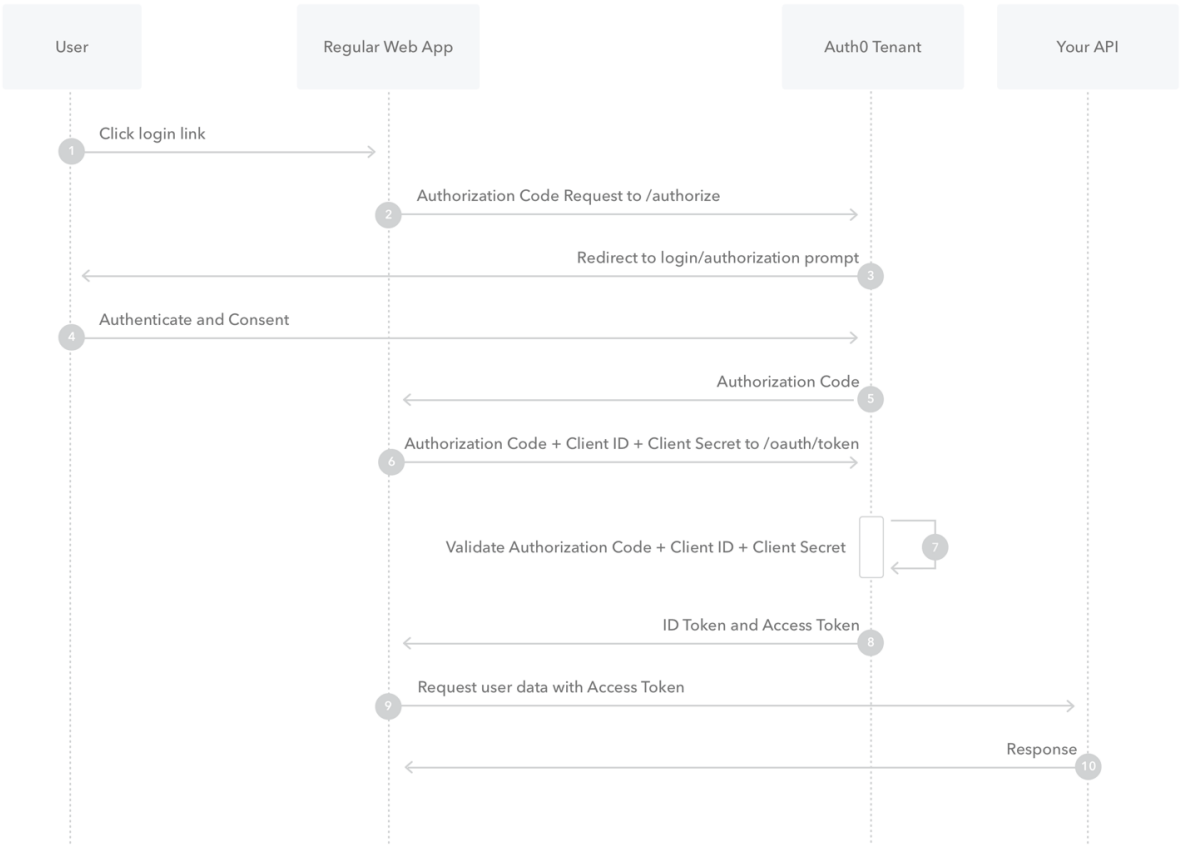


FIGURE 6.1 AUTHORIZATION CODE FLOW OF AUTH0 SOURCE: HTTPS://AUTH0.COM/DOCS/GET-STARTED/AUTHENTICATION-AND-AUTHORIZATION-FLOW/AUTHORIZATION-CODE-FLOW

In figure 6.1 the authorization code flow diagram shows how the authentication process works. The steps are described below.

1. The user clicks the login link in the web application.
2. The web application requests Auth0 to authorize the user.
3. Auth0 redirects the user to their login / authorization webpage.
4. The user authenticates through one of the login methods and may be required to provide consent to Auth0 permissions to the web application.
5. Auth0 redirects the user back to the web application with an authorization code.
6. The web application then sends back to Auth0 the authorization code, client id, and client secret. Client id helps the Auth0 tenant to identify the web application. The client secret is confidential, meaning it must never appear in the web application where the user can expose it. The client secret is used by the server to authenticate that a user has in fact logged in. Exposing this secret would mean anyone could authenticate on the server.
7. Auth0 verifies the authorization code, client id, and client secret.
8. Auth0 responds with an ID token and access token (and optionally, a refresh token).
9. The web application can now use the access token to ask your server to access user information.
10. The server responds with the user information that was requested.

When these steps have been completed, the access token can be stored in the browser so that the user does not have to log in every time. This token should expire at some point so that a new access token is needed by having the user log in again for security reasons.

With this solution in place, the application can successfully identify which user each device connected to the web application is connected to. This allows all devices that belong to one user to be grouped together on the server.

6.2.2 Device Management

In the previous section we had a look at the authentication and authorization process for authenticating a user. When the user's first connecting device is authenticated and proceeds to enter the web application, a user session in the server must be created to keep track of the application status and connected devices that belong to the user. If the user connects other devices after the first one has connected, these devices will be added to the user session in the server. Whenever devices disconnect, the devices must be removed from the session, and the session must be deleted once no more devices are connected.

The high-fidelity prototype had shown a solution for device management by sharing a QR code or a link to connect new devices, but this is no longer a necessity as it was discovered that one could use the user as an identifier and save the login details in the browser for a faster setup after the first-time logging in.

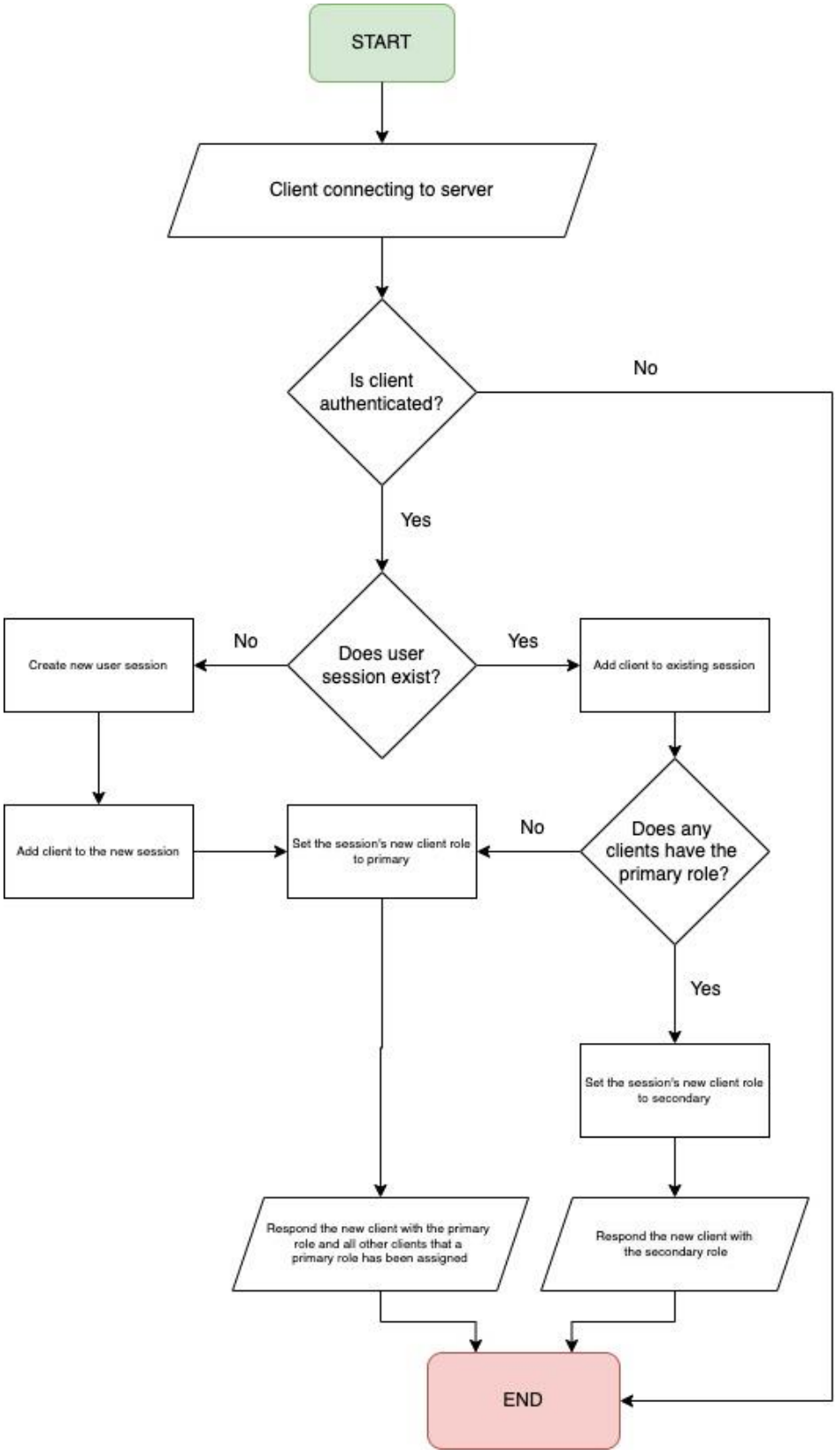


FIGURE 6.2 FLOW CHART DIAGRAM OF CONNECTING DEVICES

In figure 6.2 you can see a flow chart diagram that shows how the procedure of connecting clients works on the server side. It starts off with the client being authorized in the web application before attempting to connect to the server. The server then checks if the user is authenticated or not. If the user is not authenticated, the process ends, and the client will not be assigned a role or to be connected to a session. If the user is authenticated, does a user session already exist?

If the user session already exists, add the connecting device to the existing session. Does the user session have a primary role assigned to a device? If not, set the role of the device to primary in the session and send a response to the new device with the primary role and all other devices that a device had been assigned a primary role. If yes, set the role of the device to secondary in the session and send a response to the new device with the secondary role.

If the user session does not exist, create a new session, add the connecting device to the session, set the role of the device to primary in the session and send a response to this device with the secondary role. This way, we ensure that only one primary role is assigned as new devices connect.

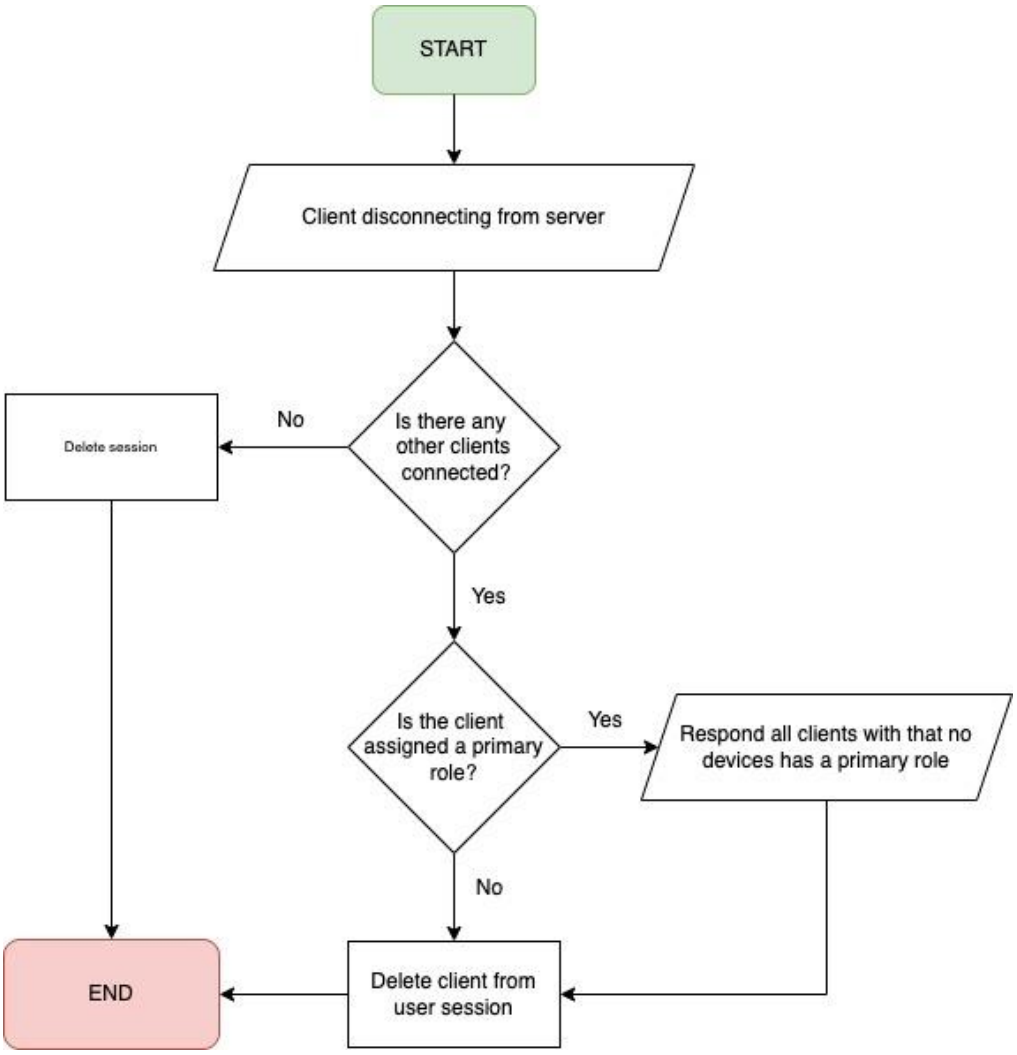


FIGURE 6.3 FLOW CHART DIAGRAM OF DISCONNECTING DEVICES

In figure 6.3 the flow chart diagram shows how the procedure of disconnecting clients works on the server side. When a client disconnects from the web application or loses connection to the server, the first thing to check is if there are any other clients connected. If there are none, delete the session and end the procedure. If there are other clients, check if the client is assigned a role of primary. If so, respond to all other devices that no devices have a primary role, delete the client from the user session, and end the procedure. If the client is assigned a role of secondary, just delete the client from the user session without responding to the other devices and end the procedure as they do not affect the client with the primary role.

The idea is that if it happens that the client with the primary role disconnects, all other clients that might be connected will be prompted to be assigned the new primary role or connect a new device. This ensures communication between devices regarding assigned roles goes smoothly.

6.2.3 ACTIONS

As almost all actions within the application must provide feedback on all the other devices, the server must know how each action should be treated. The server will handle each action by the clients within the user sessions by processing which functions to run depending on the action performed. The functions could update the user session, save data to a database, or distribute data to other devices in the user session.

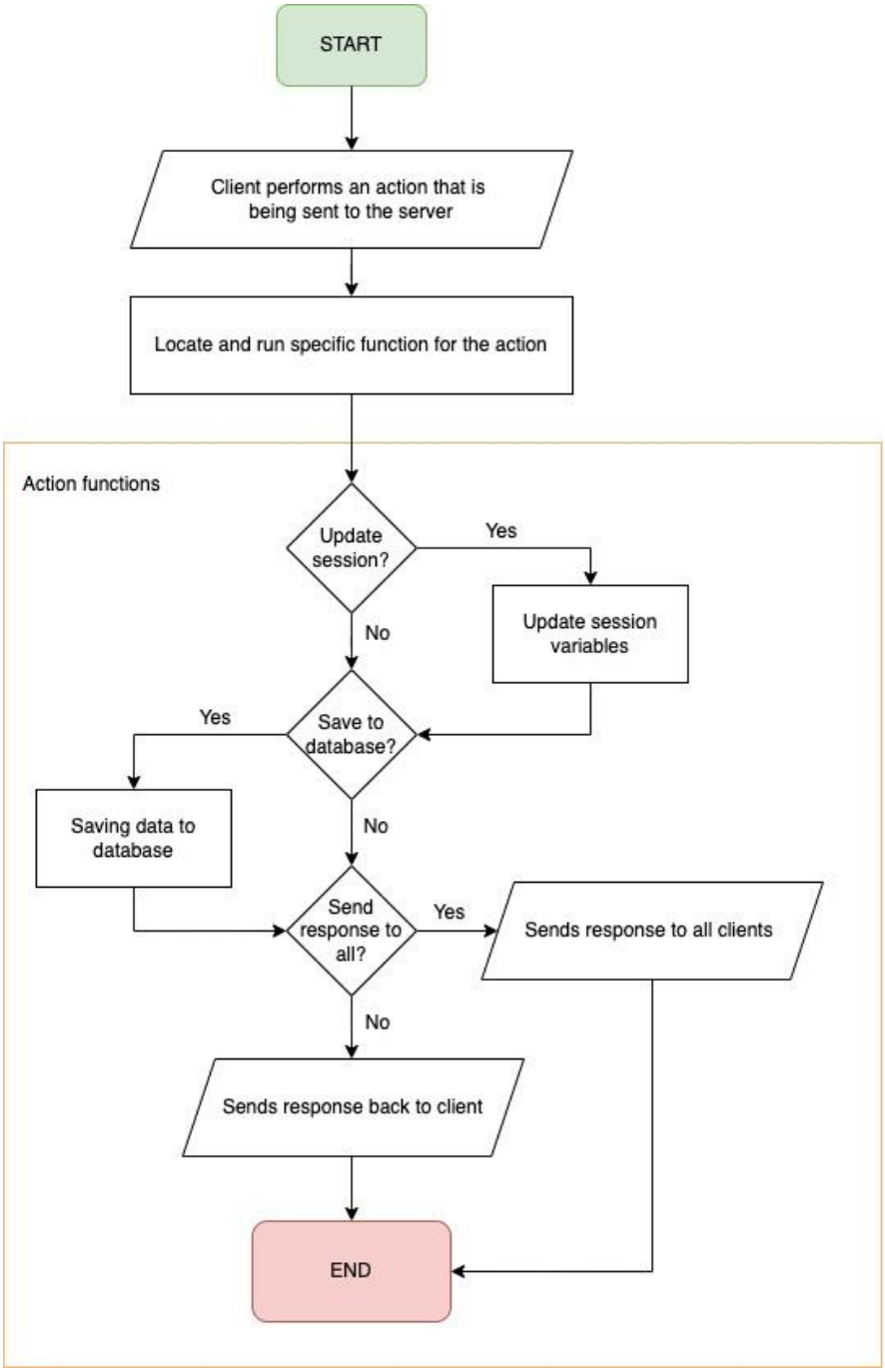


FIGURE 6.4 FLOW CHART DIAGRAM OF ACTIONS

In figure 6.4 you will see a flow chart diagram of actions performed by client users that is being processed by the server. Not all actions require processing on the server, but most do due to the application state. This chart shows the general process of each function the server makes use of depending on the action performed by the client. They all have different background processes and goals, but the chart will explain the general processes shared by the functions.

It starts off by having the server receive an action that had been performed by a client. All clients are already identified and are part of a user session. The server then locates the function built for that specific action and runs the function. Inside the function it goes through different processes, but each function performs one or more big operations such as updating the user session, saving data to a database, or sending a response back to the client or clients. These three big operations are usually done after processing the action.

6.2.4 General Infrastructure

The infrastructure is mainly built upon the client management and actions performed by clients. Each user session stored in the server has many variables that describes the state of the current user session. The list of clients connected to the user session defines how many devices needs to be kept up to date with the state of the user session. The different actions performed by a client heavily affect the state of the user session as existing and connecting clients must maintain the same state. The variables of each user session also describes if a primary role has been assigned, if the client with the primary role currently has a project open along with the entire project state that will be regularly updated to keep all existing and new clients up to date with the state of the user session.

The infrastructure of the application will not be explained on a detailed level here as the next sub-chapter will describe how the application works. This will give an insight into how the infrastructure described so far affects the overall application.

6.3 Web application

As mentioned in the note at the beginning of this chapter, the second functional prototype looks vastly different from what was designed in the high-fidelity prototype. The functionalities of the application and the wireframes are mostly the same for the functional prototype and the high-fidelity prototype. We will go through each functionality and the primary / secondary roles of the application and explain how they work. Because of how much development time it has taken to create these three components, some less important functionalities from the high-fidelity prototype were discarded.

The functional prototype consists of three major components to make it work: a web application, a server, and a database. These all work together to create a cross-device interactive drawing application that also allows users save their projects to a database. These components have each their own hosting service to allow them to be accessed from anywhere on the globe. The web application was hosted at DomeneShop because this was easy to set up and cheap to rent. The server was hosted on Heroku with a paid plan to be granted an SSL certificate, which is required by Auth0 to work due to security reasons. The database was hosted on MongoDB as it was easy to use and offers a suitable free plan for hobby projects. These are all connected using tokens to identify and validate each other. The server and database components are required to make the web application work.

What was seen in the high-fidelity prototype and the development of the prototype might differ slightly because there are open-source packages out there that allow easy implementation of certain features. They might look and function differently, but ultimately aim for the same goals. Each functionality will be described below.

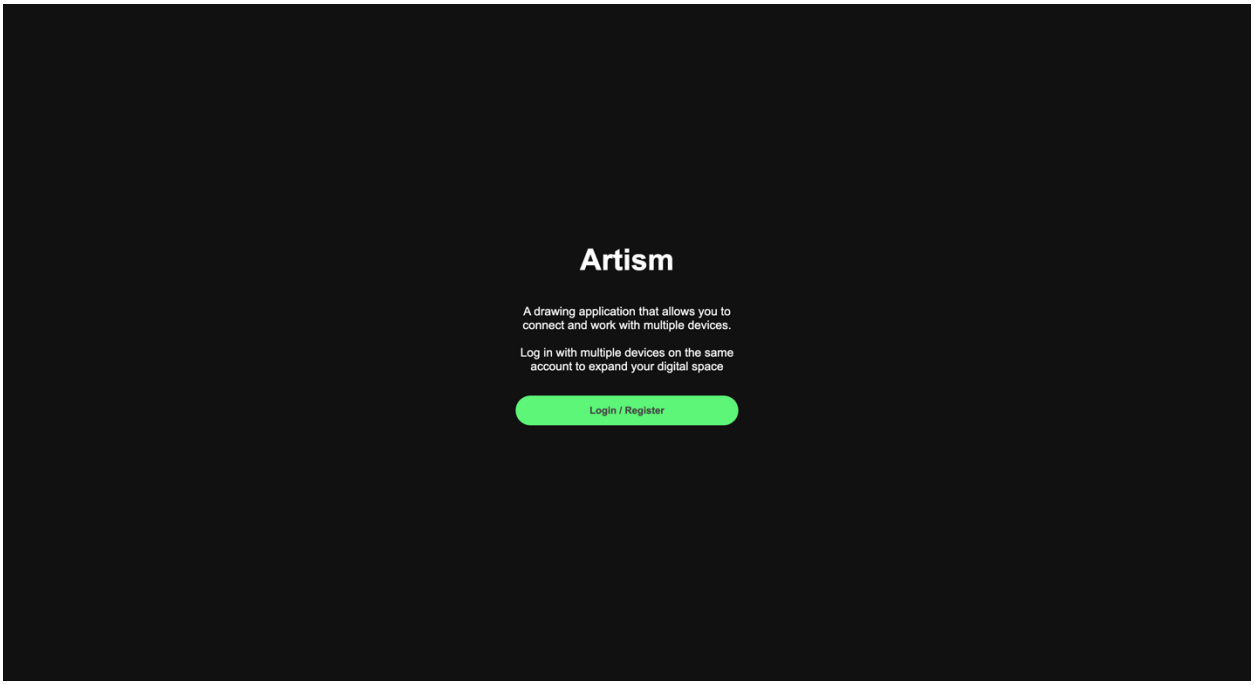


FIGURE 6.5 SCREENSHOT OF THE LOGIN SCREEN

In figure 6.5 you can see the login screen. Here, you no longer create or login to an account, but clicking the green button that says login or register will take you to an external Auth0 authentication page that will be described in the next section.

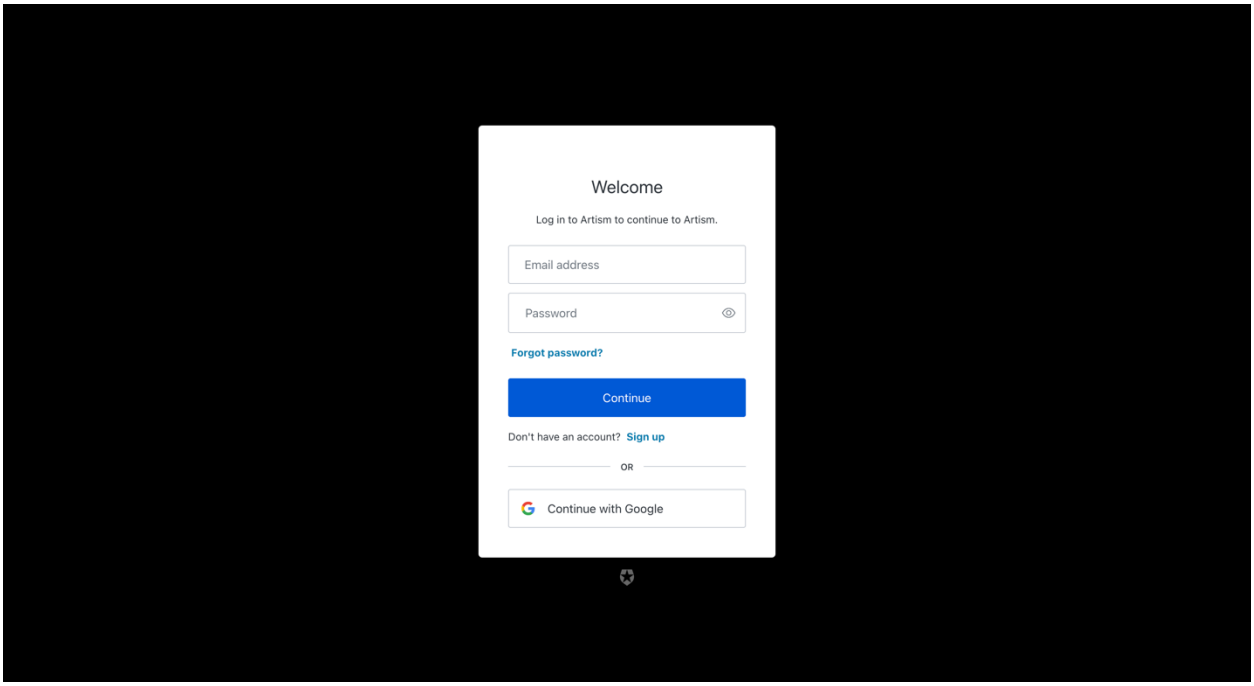


FIGURE 6.6 SCREENSHOT OF THE AUTH0 AUTHENTICATION PAGE

In figure 6.6 you will see the Auth0 authentication page. You can either log in or register by entering an email and password, or by using your google account. Once authenticated, you will be taken back to the web application and if the redirect works successfully, you will be taken to the gallery page described in the next section.

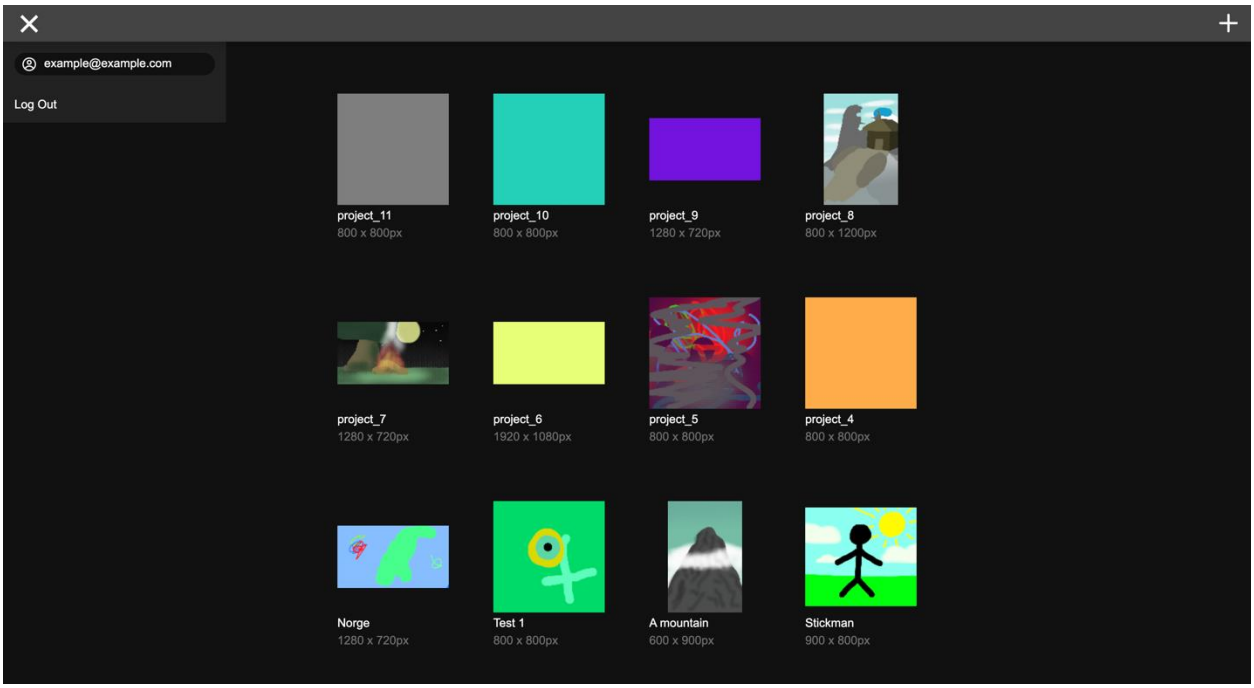


FIGURE 6.7 SCREENSHOT OF THE GALLERY WITH THE MENU OPEN

In figure 6.7 you will see the gallery in which your projects will be displayed. Here each project is displayed with a preview, a title, and the pixel size in width and height. On the top left the menu is already open, showing the user's email address along with a log out button that will take you back to the login page. On the top right you can see a white cross. This button means to create a new project which will be described in the next section.

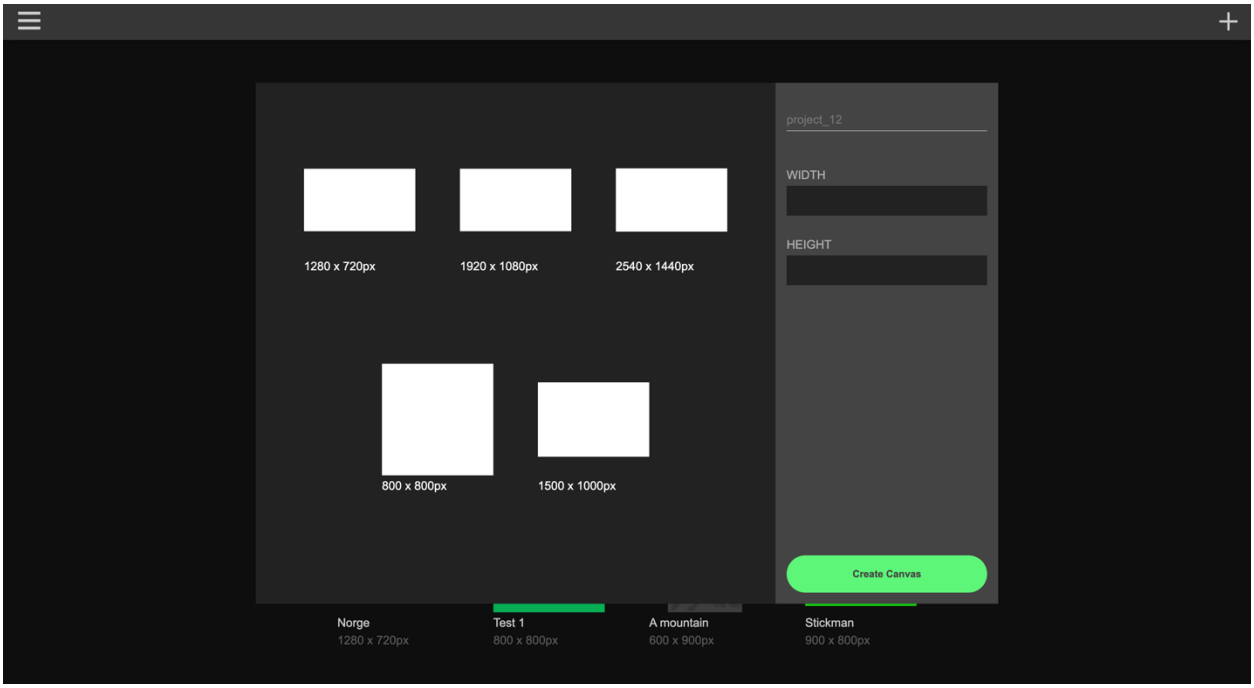


FIGURE 6.8 SCREENSHOT OF THE GALLERY WITH A CREATE NEW CANVAS POPUP OPEN

In figure 6.8 you will see a create a new canvas popup that appears in front of the gallery page. Here you can select between five different size presets, and on the right, you can input a project name, custom width, and custom height. In the bottom right corner, you can press the green button to create the project and enter the working area which is described in the next session.

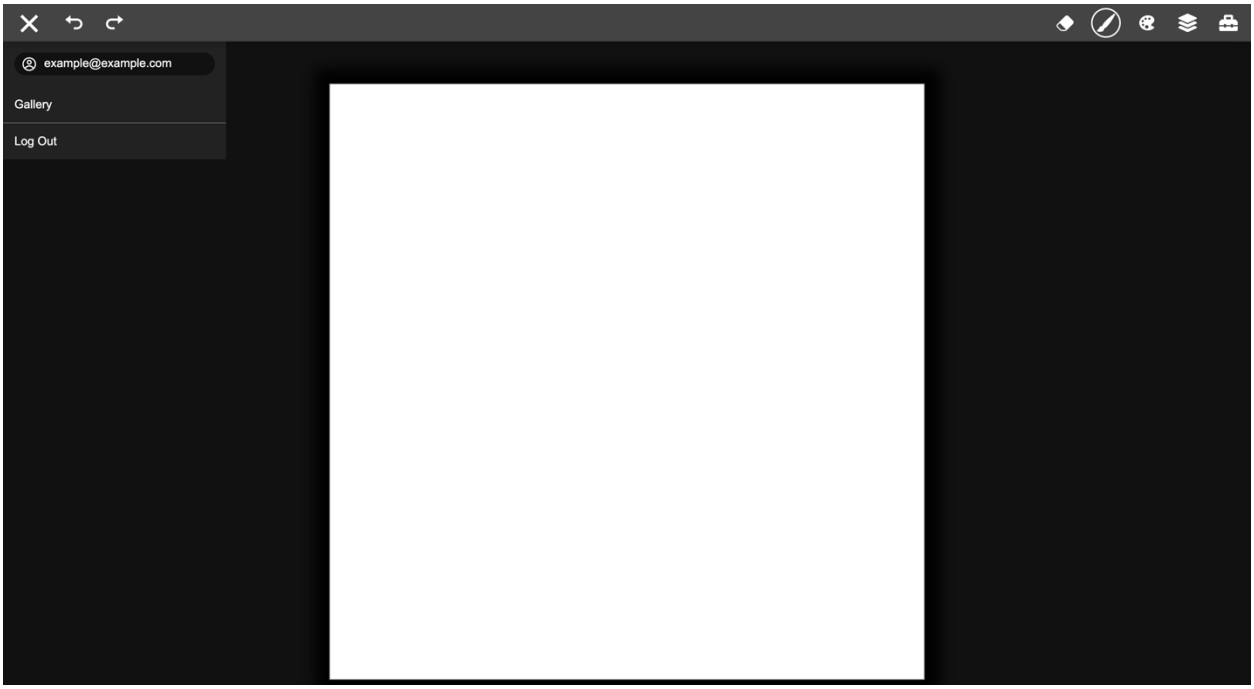


FIGURE 6.9 SCREENSHOT OF THE CANVAS WITH THE MENU OPEN

In figure 6.9 you will see the canvas page after creating or selecting a project to work on. On the top left corner, you will see the menu open. Here you can see an additional option which is a button that will take you back to the gallery. The white box in the middle is the canvas, ready to be drawn on. In the header you will see a variety of buttons to make use of. From the left you have the menu, undo, redo, eraser, brush, color, layer, and toolbox.

The undo and redo buttons are functions that activate once you press on them. Undo is the arrow that points to the left that when you click on it, it will reverse the last action you made, whether it be draw or to add / delete a layer. Redo has an arrow that points to the right that when you click on it, it will reverse any undo actions you have previously done. Each time you draw on the canvas or add / delete any layers, the redo history will be erased to keep the undo history intact.

If you happen to be drawing on a touch device, you can make use of finger gestures to move and zoom in and out of the canvas. This is done by using two fingers by moving them around, or by pinching in or out. There are other solutions available for devices that do not have touch input, but these will be described later.

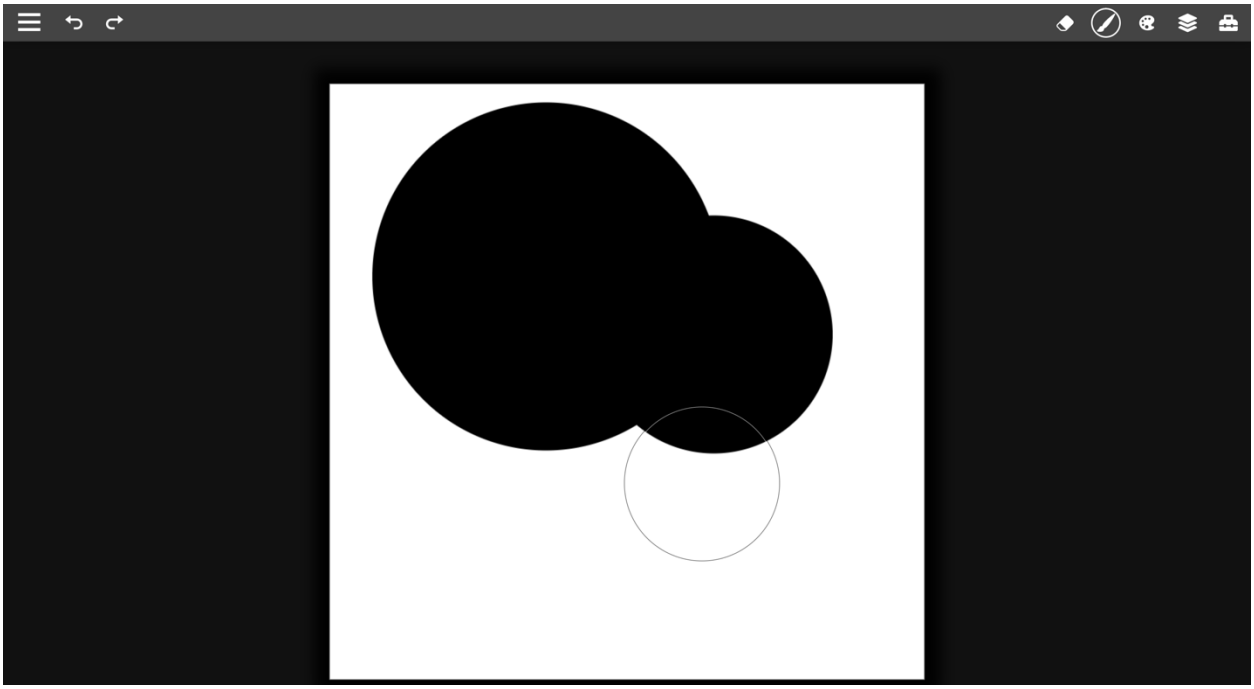


FIGURE 6.10 SCREENSHOT SHOWING A CIRCLE WITH WHITE AND BLACK EDGE BELOW THE TWO BLACK DOTS

In figure 6.10 you will be seeing some shapes being drawn on to the canvas. Beneath the two black circles you can see a white and black outlined circle. This acts as an indicator as to where and how much area the brush will cover once you draw on it. This helps to predict how much of the area will be targeted, increasing precision.

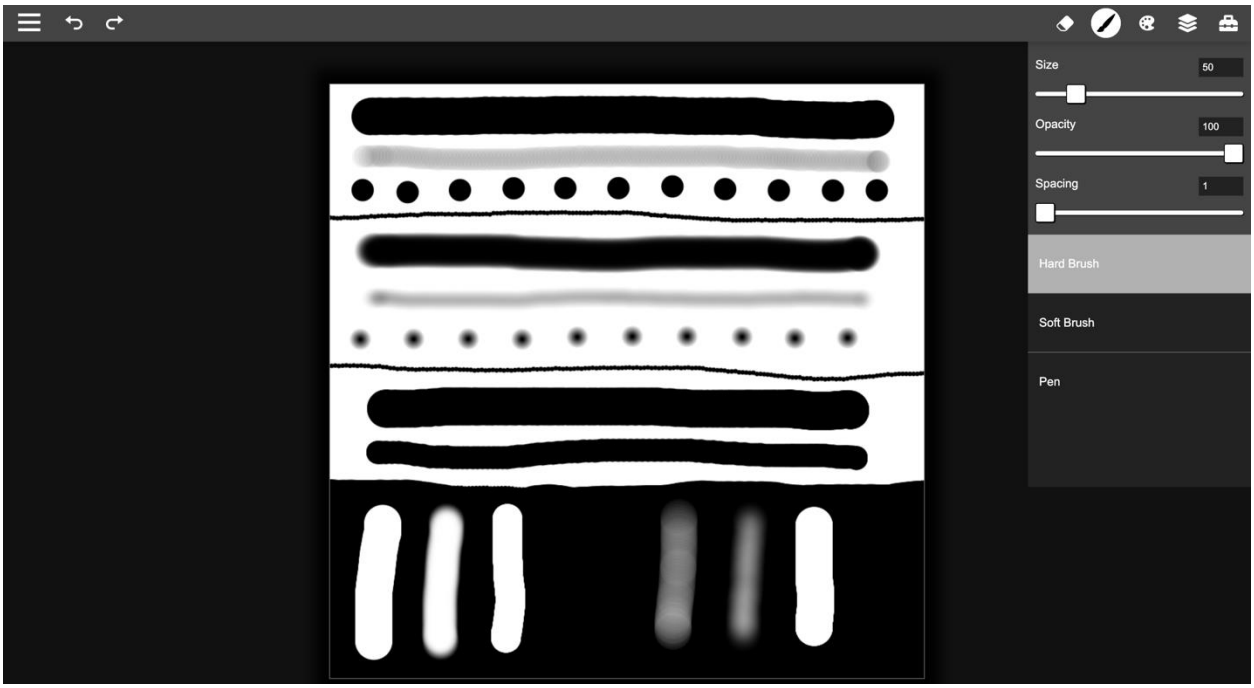


FIGURE 6.11 SCREENSHOT SHOWING THE USE VARIOUS BRUSHES, SETTINGS, AND THE USE OF AN ERASER

In figure 6.11 you will see a pattern of drawn shapes on the canvas along with the brush settings window open on the right side. In the brush settings window, you have three different setting options as well as three types of brushes. The canvas has been drawn on to show each of these in use. The flow setting shown in the high-fidelity prototype had been replaced with spacing due to difficulties implementing such function. Only three types of brushes had been implemented due to the complexity of creating brush types.

The top three strokes have been made using the hard brush. The first one has a larger size. The second has a lower opacity. The third has increased spacing. The next section has three more strokes, but they have all been drawn using the soft brush, creating a more faded effect on the edge. The last section has two strokes with different sizes drawn by the pen because the pen only has a size setting. The black box at the bottom showcases how the eraser removes the drawn black from the canvas. The left side uses the hard brush while the right side uses the soft brush.

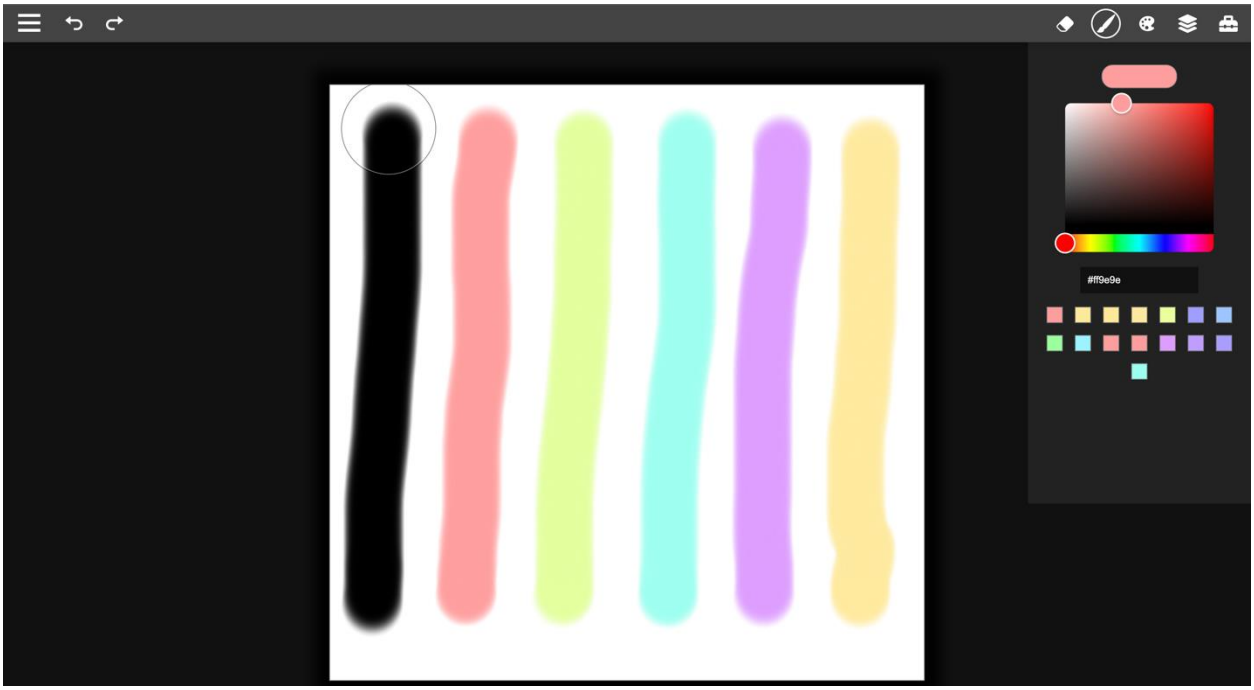


FIGURE 6.12 SCREENSHOT SHOWING THE USE OF VARIOUS COLORS

In figure 6.12 you can see a variety of colors being drawn on to the canvas and that the color window on the right side is open. In the color window you have a preview of the color on the top, a brightness selector underneath with a hue color slider. Underneath the hue color slider, you have an input field for hexagon color values that change upon selecting a color from the brightness selector, hue color slider, or the color history which updates upon each color change. Once a color has been selected, new drawings on the canvas will make use of that color.

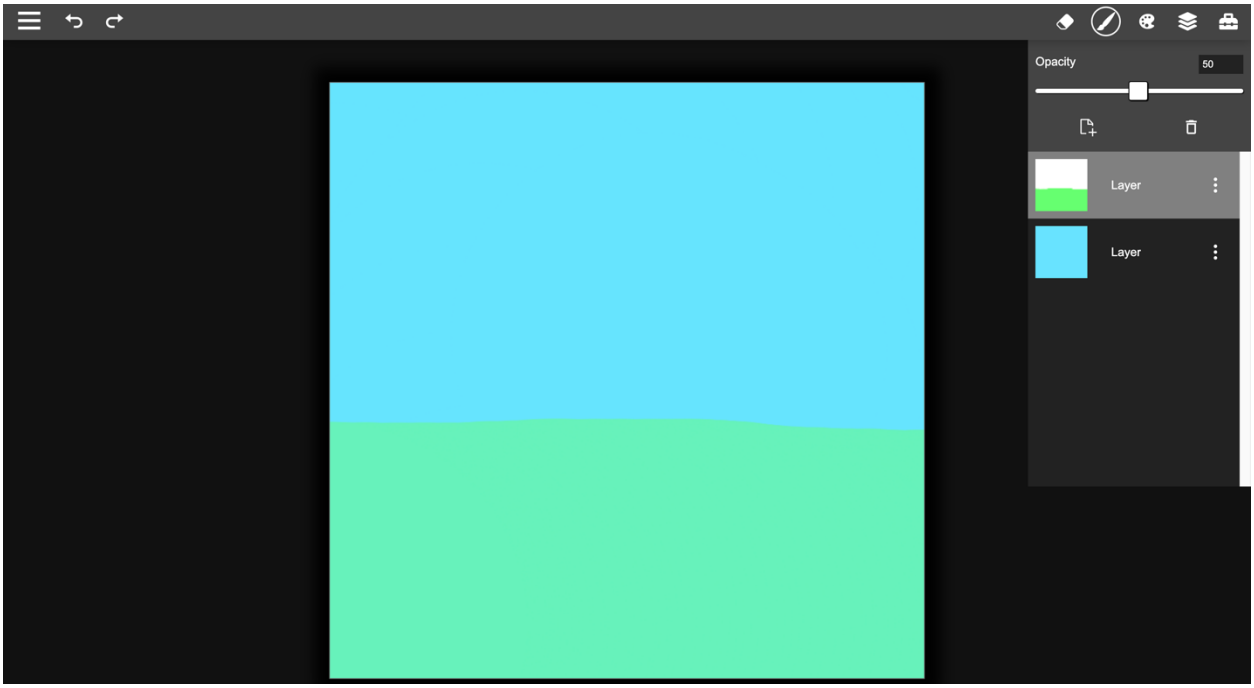


FIGURE 6.13 SCREENSHOT SHOWING THE USE OF THE LAYER SYSTEM

In figure 6.13 you can see a green and a blue color on the canvas along with an open layer window on the right. There are currently two canvas layers in the list. The bottom one has been drawn entirely blue while the upper one has been drawn partially green. These are stacked up on the canvas starting with drawing the layer with blue first, then draw the layer with green on top. You can change the order in which these are drawn by holding and moving the three dots on the right side of the layer in the list and drag it up or down. If you were to drag the blue layer up, then the green layer would be put on the bottom of the list, meaning it will be drawn first before the blue layer. This would mean that since the blue layer is drawn the last on the canvas and fills the entire canvas, you will not be able to see the green layer on the canvas.

As you might notice on the canvas, the green layer is not as green bright as the preview shown in the list of layers. This is because on the top of the layer window you have an option for adjusting the opacity. This means reducing the opacity would make the layer more transparent. In this case, the green layer only has a fifty percent opacity meaning it would be drawn on to the canvas with a fifty percent transparency.

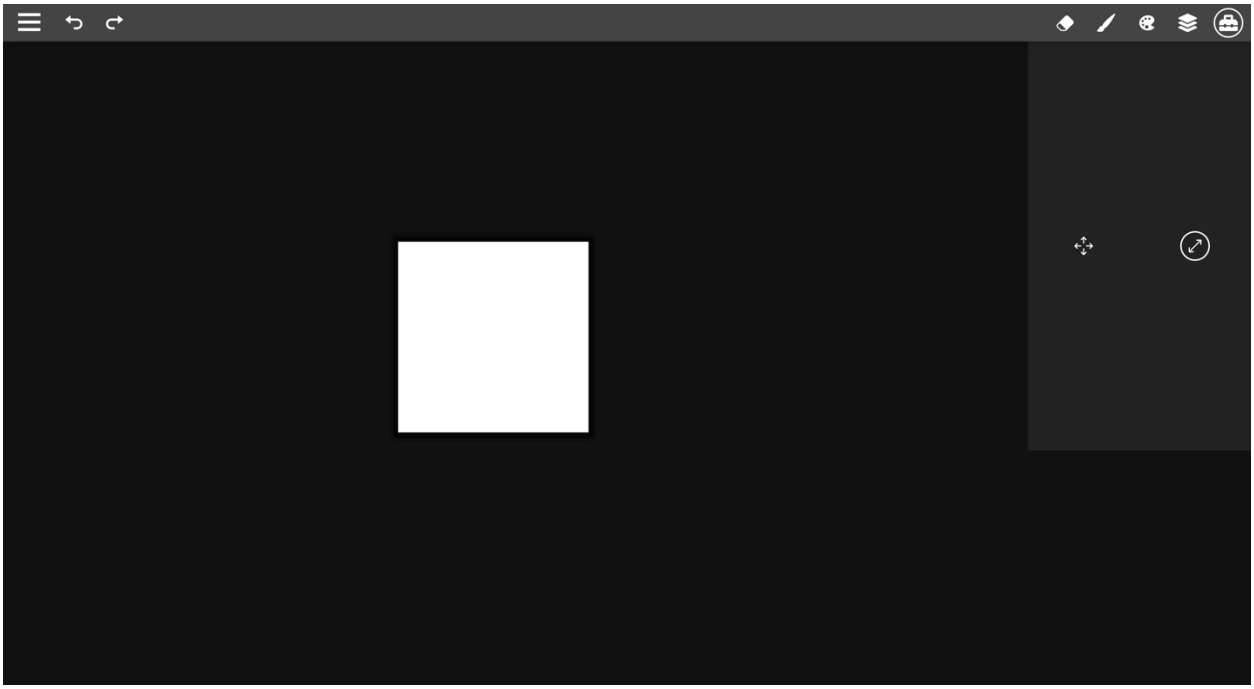
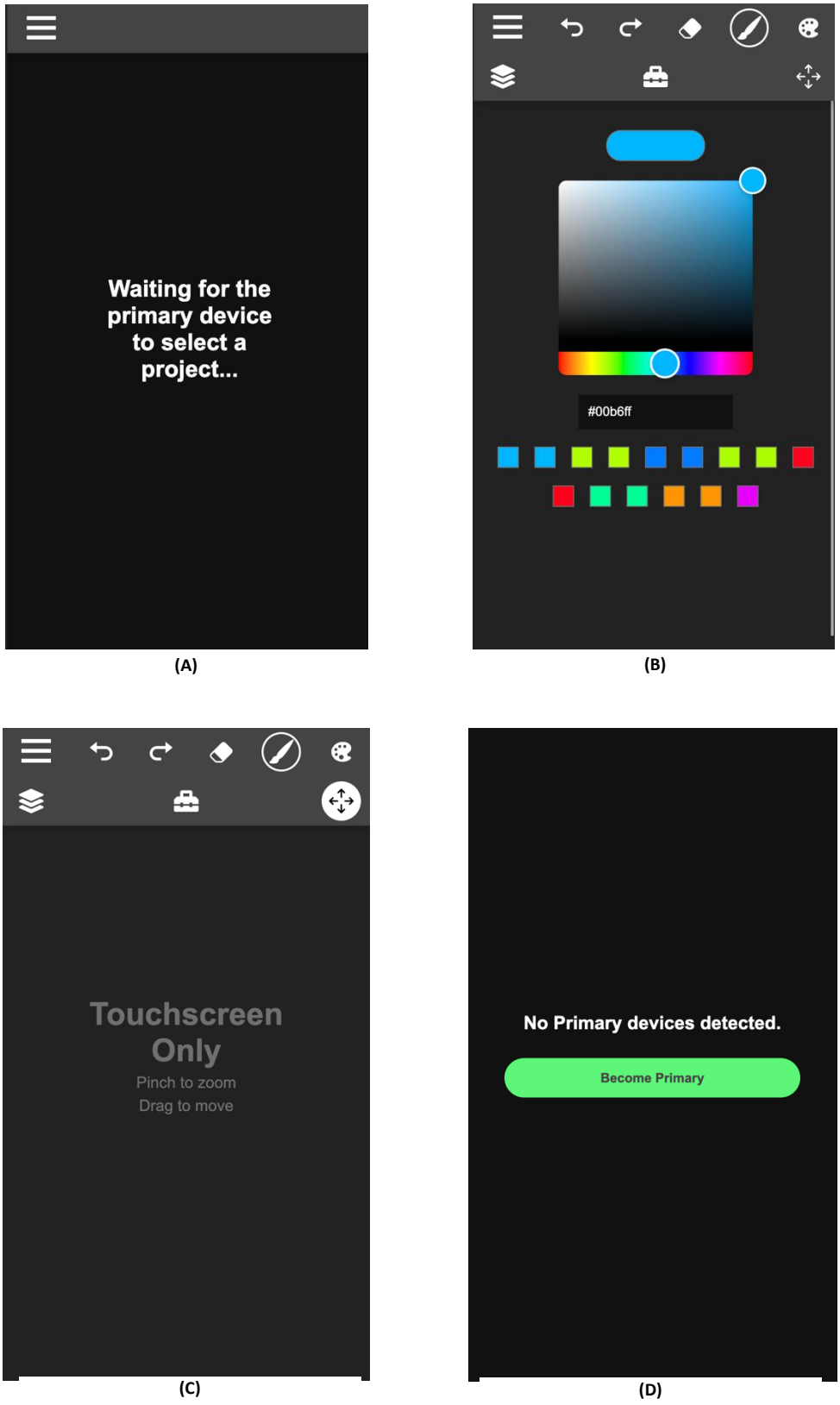


FIGURE 6.14 SCREENSHOT SHOWING THE USE OF THE TOOLBOX OPTIONS ZOOM AND MOVE

In figure 6.14 you can see a white canvas appearing smaller and positioned a bit to the left. This has been done using a move tool and a zoom tool which are available in the toolbox window on the right. The move tool can be used by clicking and dragging the canvas around. The zoom tool can be used by clicking and dragging on the canvas up to zoom in and down to zoom out. This is intended to be used by devices that do not support touch input such as mouse and keyboard. Due to development time, only these functions were prioritized in the prototype.



(A) (B)

(C) (D)

FIGURE 6.15 FOUR SCREENSHOTS DISPLAYING DIFFERENCES ON DEVICES WITH SECONDARY ROLES

In figure 6.15 you will see four different screens on a secondary device. These do not hold the canvas but the functionalities the application has to offer. In figure A, the screen indicates that the primary device has yet to select a project. In figure B, you can see the open color window showing an example as to how each window will appear. In figure C, you have an extra functionality meant for secondary touch devices that can be used to move and zoom the canvas on the primary device. The finger gestures work the same as on the primary device. In figure D, all secondary devices have received information that the device with the primary role has been disconnected and a new device with a primary role must be chosen. If you press the green button saying become primary on one of the secondary devices, that device will become the new primary device. A new connecting device will also automatically become the new primary.

6.4 Cross-Device Setup Examples

Cross-device interaction requires two or more devices to function. Opening the web application on only one device is the traditional way of working, where everything is locked in the one device you have. There is no limit as to how many devices you can connect to the web application, so you could for example have three cellphones, two tablets, and two computers each holding different functionalities of the application. Expanding the digital workspace this much might be too clustered, require more setup, and require many devices that most people don't have. A realistic number of devices would be between two to three, as it was mentioned earlier in this thesis that around 36% of Americans have a cellphone, tablet, and a computer. [2]

This sub-chapter will provide some examples with pictures that show how one would go about setting up a cross-device interactive environment. These should provide insight into how different environments affect how one would make use of the functionality.

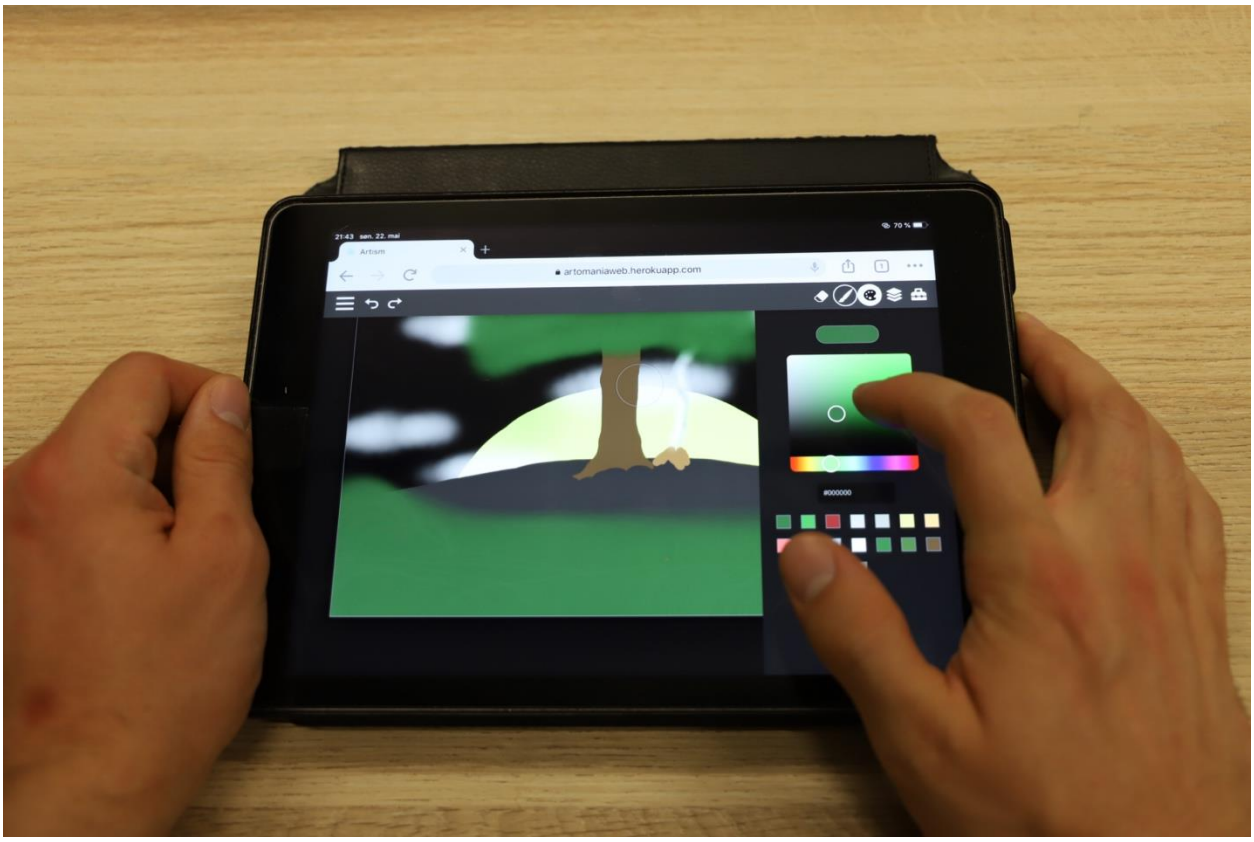


FIGURE 6.16 PICTURE OF A SINGLE DEVICE USING THE WEB APPLICATION

Figure 6.16 shows a single device environment for the sake of showing how using this application used traditionally would look like. Here, you can see the application being used only on one iPad. Working on one device requires you to both handle the settings and drawing on the canvas in the same space. This involves additional user interactions to open different windows to change the brush settings, color, layer, or toolbox. Opening these windows results in windows appearing on top of the canvas as well as requiring a press outside of the window to close it.

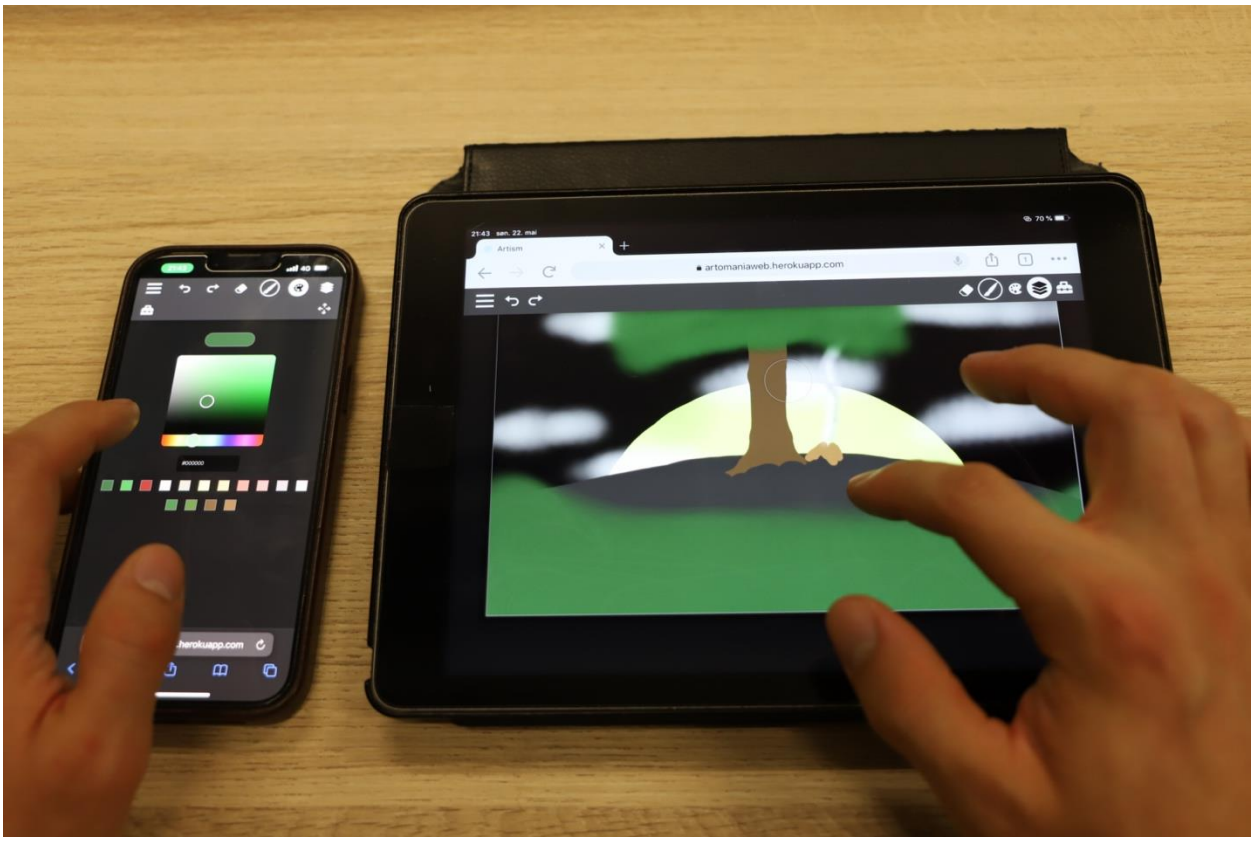


FIGURE 6.17 PICTURE OF TWO DEVICES USING THE WEB APPLICATION

Figure 6.17 shows a cross-device environment in which an iPad and a cellphone are being used. Here, the iPad has a primary role while the cellphone has a secondary role. As shown, the cellphone is being used to control the colors of the brush but can switch to other windows by simply using the buttons in the header.

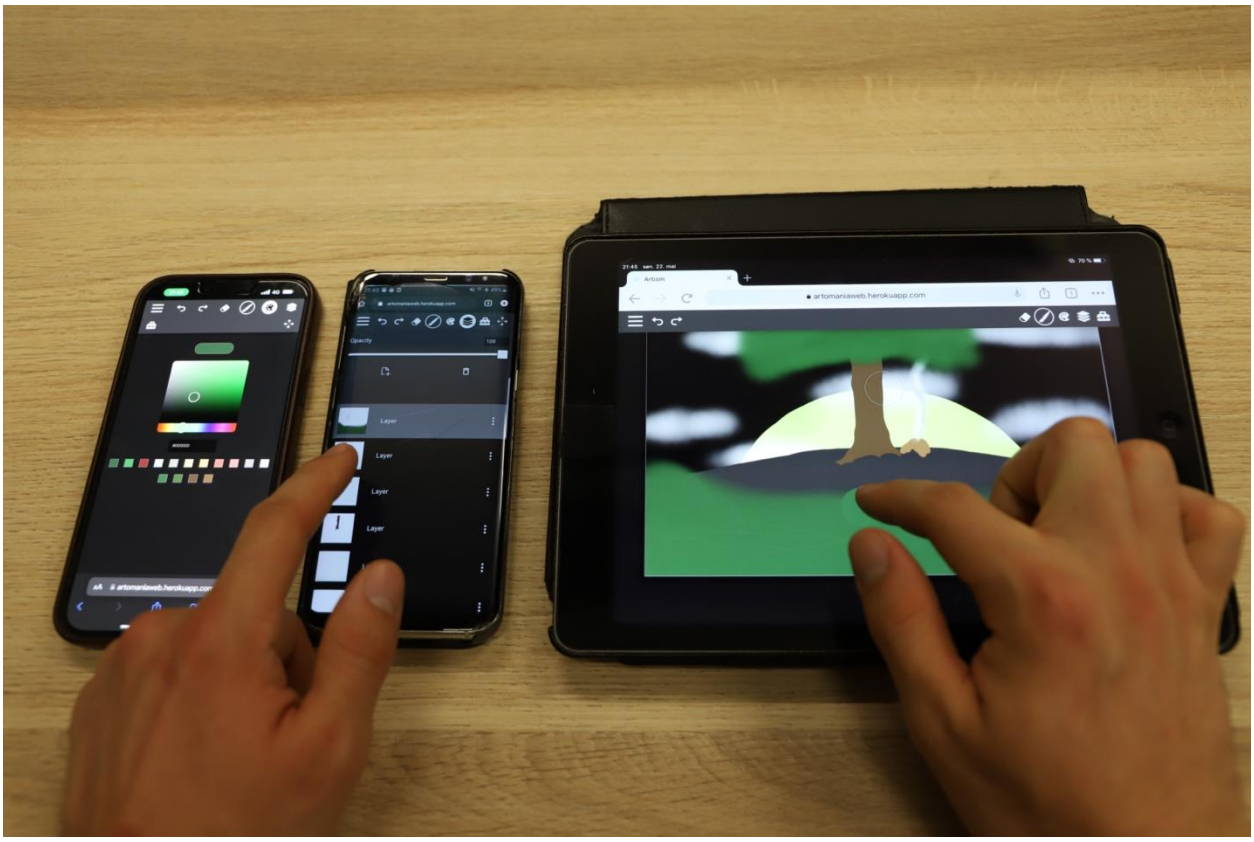


FIGURE 6.18 PICTURE OF THREE DEVICES USING THE WEB APPLICATION

Figure 6.18 shows a cross-device environment in which an iPad and two cellphones are being used. Here, the iPad has a primary role while the two cellphones have a secondary role. The left cellphone is used to control the colors while the right one controls the layers.

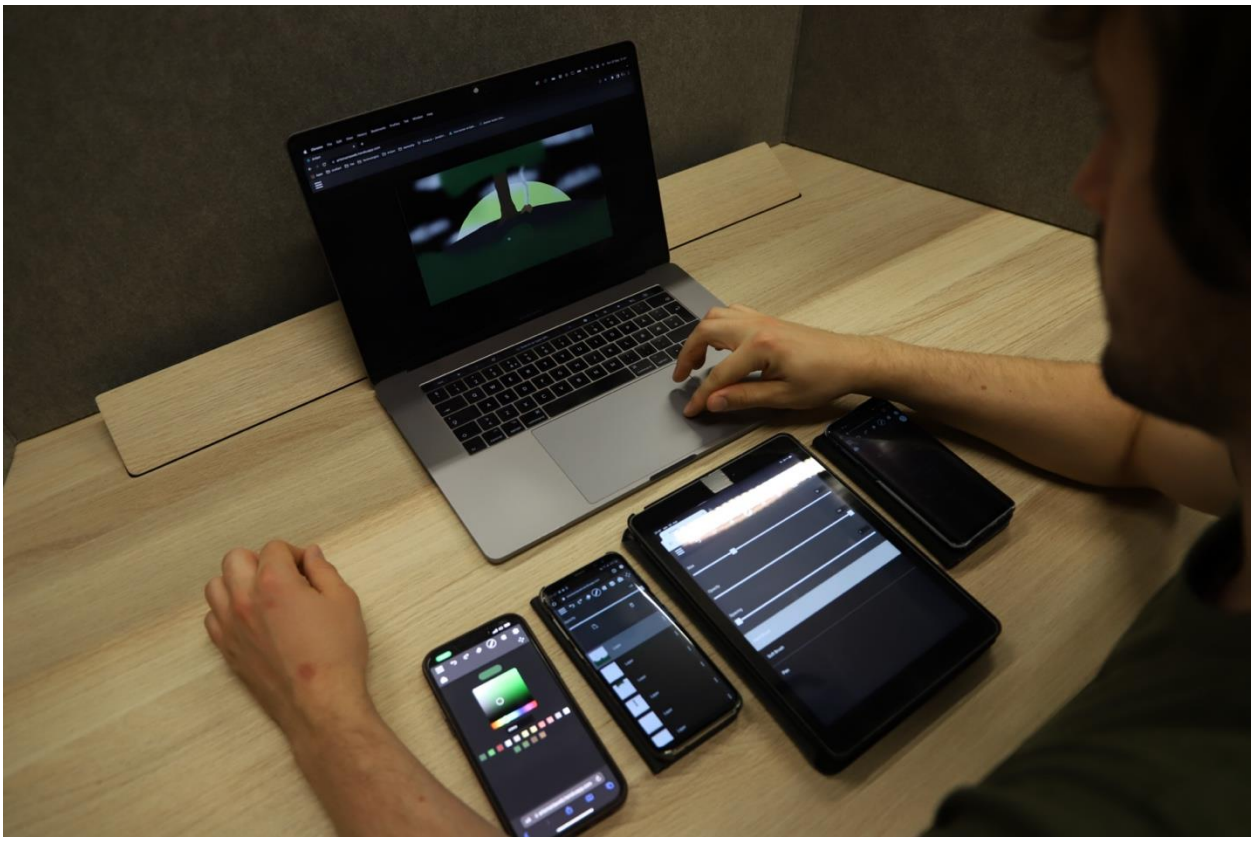


FIGURE 6.19 PICTURE OF FIVE DEVICES USING THE WEB APPLICATION

Figure 6.19 shows a large cross-device environment in which a computer, an iPad, and three cellphones are being used. This time, the computer has the primary role while the others have secondary roles. Of the four handheld devices at the bottom, the first one controls color, the second controls layer, the third controls brush settings, and the fourth uses finger gestures to move and zoom the canvas on the computer.

This kind of setup has more devices than people normally carry around, but this example just shows that it is possible to connect these many devices.

6.5 Future Development

In this section a description of possible implementations and changes will be discussed in case of adaptation in the future.

Downloadable application instead of a web application would introduce some problems, but it would also solve some problems with web applications such as these. With downloadable applications, you would have to download it on every device you would want to use in a cross-device environment, but it would solve some issues that web applications struggle with today. There are multiple popular web browsers being used today, and they are constantly changing. These browsers treat code differently, so several functionalities that were made in this functional prototype had to be made differently because one of the browsers would not support it properly. When you move away from web applications on to downloadable applications, you don't rely on these constant changes and different browsers supporting functionalities differently.

Personalization to allow users to fully manage the layout of their application so that they can tailor it to their own needs. This would be for example to place the header on the left, right, or even bottom instead of the top. Another would be to create two or more sections in which multiple windows can be shown at once.

Bluetooth instead of using the internet to transmit data between devices would solve multiple issues with networking. If the user does not have a network signal, or one of the devices is unable to connect to the internet, one could make use of Bluetooth between devices to allow the cross-device interaction to work. This could also make it possible for the application to be run offline.

Canvas preview to allow the whole canvas to be viewed on one of the devices if the user wishes to. This could be useful if the user has zoomed in on the canvas to focus on specific spots and still wants to see the whole canvas.

Haptic feedback is an area that can be explored within a cross-device interactive working environment and could improve or introduce new ways to interact with the system.

CHAPTER 7: SUMMARY AND EVALUATION

This chapter takes us through the evaluation process of the functional prototype and the results from conducting the evaluation. The study structure will also be described and how the analysis was done explained.

7.1 PILOT STUDY

Several pilot studies were conducted to create not just the ideal study structure for the best data gathering, but also for testing and making sure the functional prototype is functioning as intended. By conducting these pilot studies, major changes were made to the functional prototype to prevent the prototype from being annoying to work with for the participants. Big changes were also made to the original study structure as it was not just 90 minutes long, but overly complicated for the participant, which showed that the data gathered were too affected by these factors.

The study structure was simplified for the main study and shortened down to 30-45 minutes from 60-90 minutes. The study structure had earlier included the Nasa TLX paired comparison procedure for a between-rater variability, but the pilot studies had shown that this proved to be time consuming and complicated for the participant to answer. The background information given to the participants was also overly complicated and had no positive effect on the study. The interview questions were simplified, and some questions were removed due to not eliciting sufficient relevant information in the pilot study.

7.2 STUDY STRUCTURE

Conducting an evaluation on a functional prototype that will be used to create a response on the research question “How does a cross-device interactive application affect workload among digital artists in creative media production?” requires a well thought study structure to gather the right data using the right methods. Three methods were used together in the evaluation process to help provide relevant data for the analysis.

Appendix B shows the final study structure used for the evaluation of the functional prototype. The data had to be comparative, so both cross-device and single-device setups had to be evaluated and compared. As Nasa TLX would be used to measure workload after a task and it only provides quantitative data, an interview was also conducted to gather the participants’ qualitative opinions and feedback on the study.

The evaluation followed a single-subject research AB design. The A did not contain any changes and used a single-device environment. The B changed from a single-device environment to a cross-device interactive

environment. There are several single-subject research designs to make use of such as ABA, ABAB, or ABC, but AB proved to be the best fit for this study as A was already known to the users and would be compared to B, and that the duration of the study would be drastically lowered as participants would be performing drawing tasks and answering a Nasa TLX afterwards. [25]

It was decided to go with a within-subject study design meaning each participant tests all the conditions compared to a between-subject study design that only exposes the participant to one condition. It was first decided to go with between-subject study design so a single-subject AB and BA design could be conducted, which allows comparing if the order in which the conditions were presented showed any difference. [26] But because it proved difficult to locate enough participants for this kind of comparison and that it would still be possible to compare A to B using the Nasa TLX and an Interview, it was decided to go with this structure.

The study itself started off with an introduction informing the participant about the functional prototype, the study, the goal, that the study is anonymous, and that the participant could ask any questions at any time. Once that was done, we moved on to the web application and the participant was given login details that used the assigned participant number. Once logged in, the participant was shown a guide that described the purpose and functionality of the application.

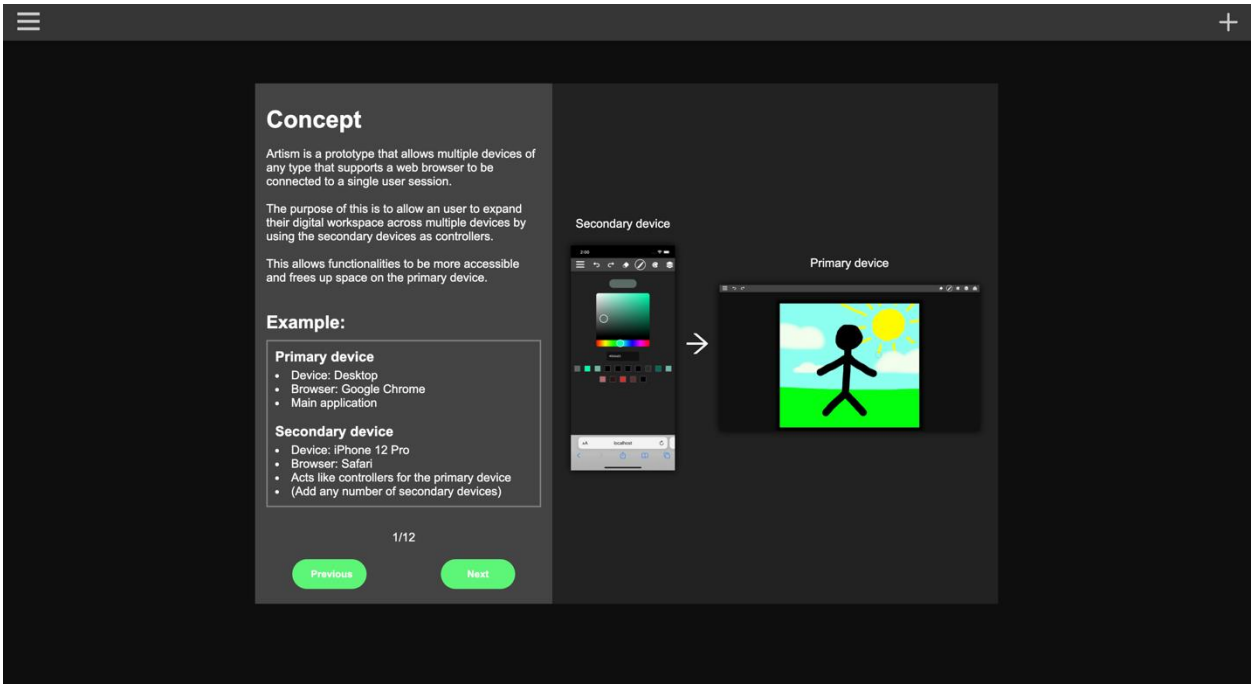


FIGURE 7.1 SCREENSHOT OF THE BEGINNING OF THE GUIDE INSIDE THE DRAWING APPLICATION

Each participant went through twelve slides in which each described the purpose of the application and the various functionalities it offered as shown in figure 7.1. After completing the guide, the participant was asked to explore the application for up to five minutes using a single device to get comfortable with the application. After getting to know the application, the participant was given a drawing task using a single device to complete within six minutes. The keywords given were sky, cabin, water, and mountain. Once the six minutes was up the participant would answer a Nasa TLX form to evaluate the workload, he/she experienced during the task.

After answering the Nasa TLX, the participant was given a few minutes to cool off if needed, before moving on to the next drawing task. This time the participant was to create a cross-device environment using two or more devices before exploring this way of working with a drawing. For the sake of not having the participants automatically switch back to the habits of using only one device to manage the functionalities, the device with the canvas had all the buttons in the header removed except from the menu, forcing the participant to use the other devices with secondary roles. After up to five minutes of exploring for the participant to become comfortable with the setup, the participant would go through the same process of the drawing task and answering the Nasa TLX form, but with different keywords. The keywords for this task would be night sky, bonfire, smoke, and tree.

After going through the two drawing tasks followed up by a Nasa TLX form, a few questions were asked in an interview regarding the study and their opinions on it.

7.3 Locating Participants

Conducting a study with participants that meet specific requirements can require a time-consuming search if you do not have a network of people who might know suitable potential participants. And even if you do, it can prove difficult if they are not rewarded for their participation, as they should not know you personally. If you make use of participants that you know personally it can cause a halo effect that creates biased data, as they might become overly engaged compared to the general population or have a more positive attitude towards the study. [27]

> "The halo effect refers to the tendency to allow one specific trait or our overall impression of a person, company, or product to positively influence our judgment of their other related traits." [27]

An attempt was made to find potential participants through personal network, professional work, Facebook groups, and forums. As the study was up to 90 minutes long, I received feedback that it was too long. After making major changes to the study, it was shortened to approximately 40 minutes. The next

attempt to locate potential participants was more successful as two people participated, but it was still ineffective as I required around six participants to create some pattern in the data gathered. My last attempt included providing a 20$ gift card to compensate for the participants' time. I figured it would prompt my personal and professional network to be more willing to ask around as one would be rewarded for the participation, and it worked. Six participants were found in the end that

7.4 ANALYSIS

Once enough participants have completed the study and the data has been stored, it must be sorted and analyzed so that the data can turn into reason. The gathered data does not involve complicated analytical tools to analyze as the Nasa TLX only has six values for each drawing tasks coming from the six scales, and the interview is a structure done that makes it simple to group answers and distinguish unique answers.

Analyzing the Nasa TLX form was as mentioned straightforward, by calculating the average of each of the six scales for the task completed on a single-device and performing the same calculation for the task completed on multiple devices. As the interview was structured, it was a simple task to group data together to create general responses while taking unique responses and analyzing them individually for discussion.

CHAPTER 8: DISCUSSION

This chapter discusses the analyzed results from the evaluation process. The analyzed data will be compared to identify patterns and responses relevant for responding the research question.

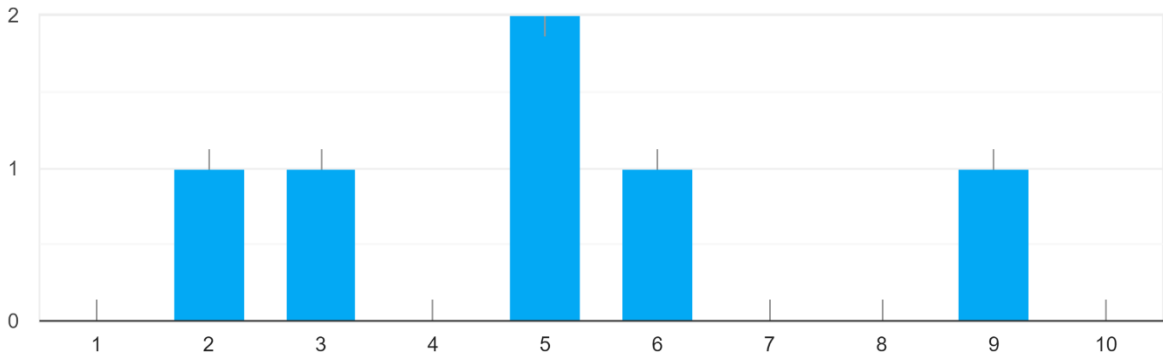
It was observed during the evaluation study that participants would approach the study differently, which could affect the study. The participants had different experiences and styles regarding drawing that could affect their approach to the drawing tasks. The order in which the single-device and multi-device tasks were given could also affect their experience, making it either more or less comfortable to work on. There were also two groups of device setups that were used by the participants. One was an iPad and a cellphone, and the other was a computer screen with a drawing tablet connected to it and a cellphone. This could potentially affect how they perceived the workload they experienced, and the responses given in the interview.

When the participants were asked during the interview if the keywords were equally demanding, all but one said yes. The dissenting participant thought the second task was a bit more comfortable to work with. All participants felt familiar with the app and the functionalities quickly, mostly due to the research done on popular drawing applications and the inspiration the functional prototype took from them. Getting used to the cross-device interaction had a slightly deeper learning curve, but all participants quickly learned how to make use of it.

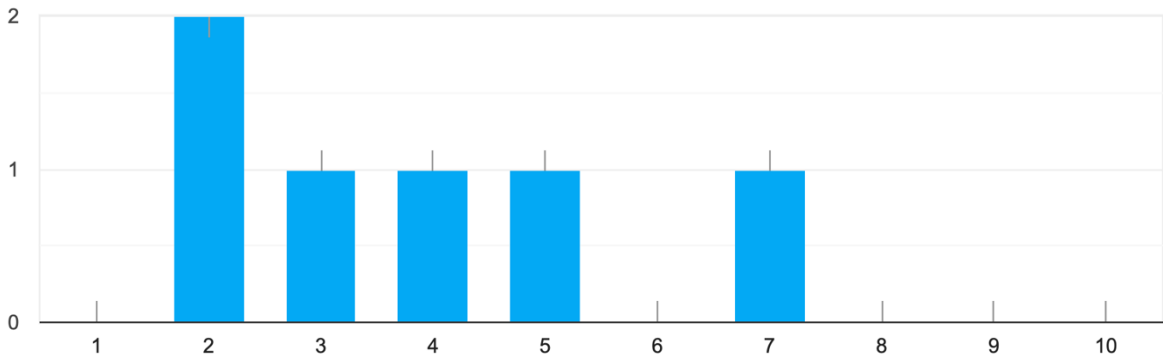
Although the participants had been told that a functional prototype with limited functionalities and possible bugs could occur, it might have affected how they responded to the Nasa TLX due to some experiencing breaking bugs, forcing them to reload the application. They were however given more time to compensate for this.

The Nasa TLX was used for both the task performed on a single device and that performed on multiple devices. Data gathered from conducting the Nasa TLX was divided into these two groups to see potential differences in workload from using a single device and multiple devices. Each of the six scales is discussed and the results shown from each group. The interview that was conducted at the end of the study will also be used to determine how the data gathered from the Nasa TLX will be perceived. The six scales go from low to high, meaning the lowest is 1 and the highest is 10 unless specified otherwise.

Mental demand – How mentally demanding was the task?



(A)

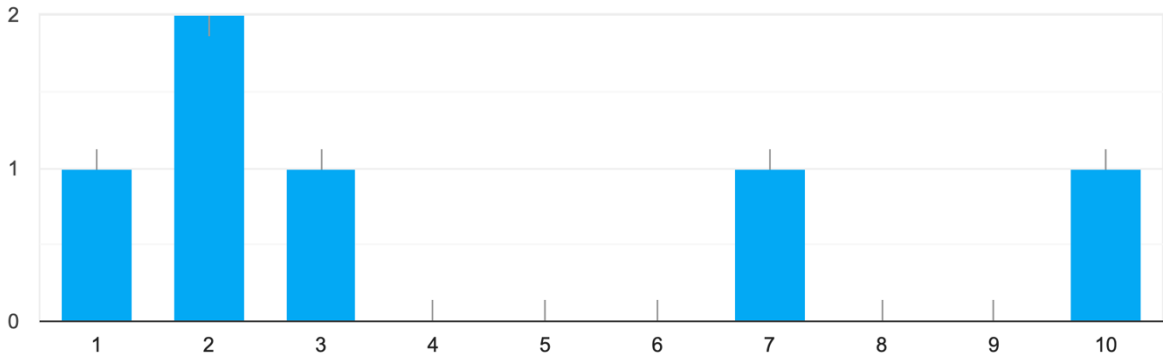


(B)

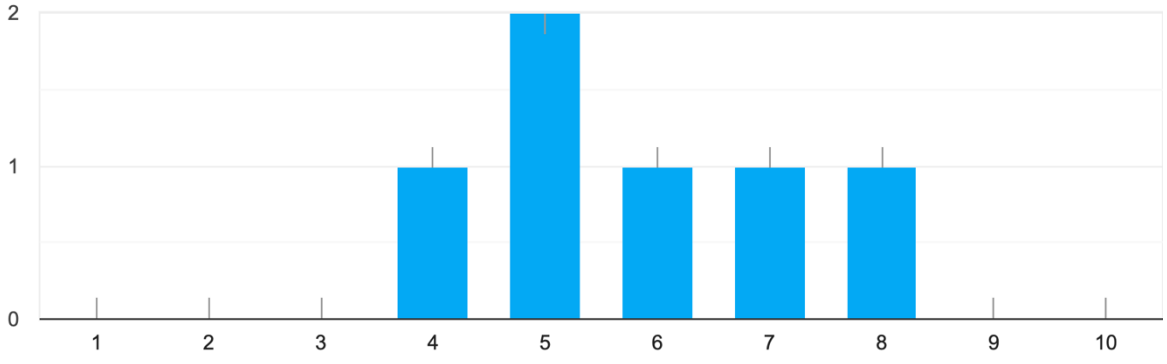
FIGURE 8.1 SINGLE-DEVICE (A) AND MULTI-DEVICE (B) MENTAL DEMAND CHART

Figure 8.1 shows results from evaluating mental demand in which figure A focuses on a single-device and figure B focuses on multi-devices. The mental demand that was experienced by each participant was more scattered on the single-device task, while the multi-device showed an overall lower mental demand.

Physical demand – How physically demanding was the task?



(A)

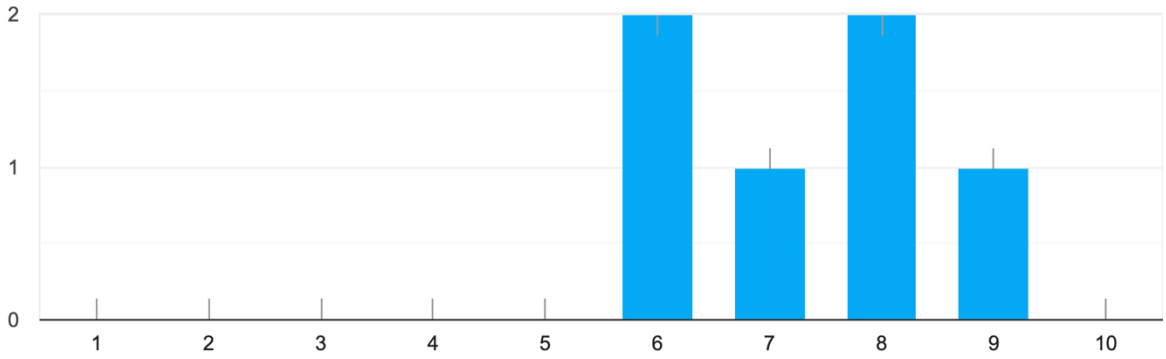


(B)

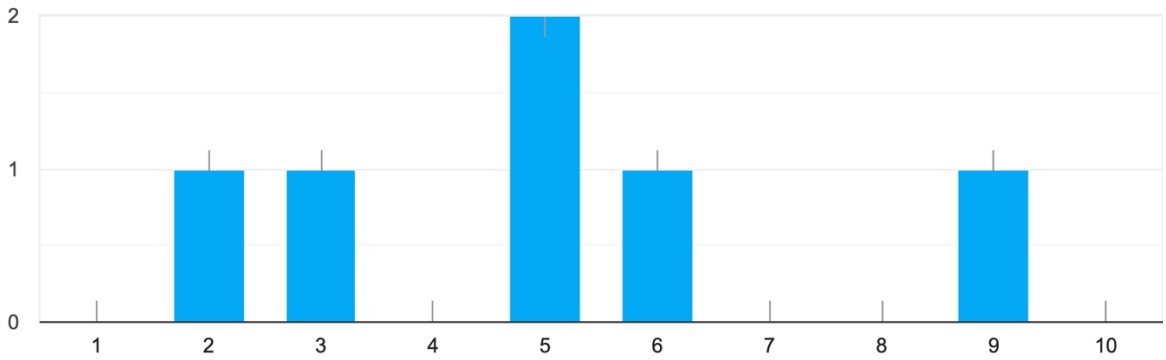
FIGURE 8.2 SINGLE-DEVICE (A) AND MULTI-DEVICE (B) PHYSICAL DEMAND CHART

Figure 8.2 shows the results from evaluating physical demand, in which figure A focuses on a single-device and figure B focuses on multi-devices. The physical demand that was experienced by each participant was more scattered on the single-device task, while the multi-device showed an overall higher physical demand.

Temporal demand – How hurried or rushed was the pace of the task?



(A)



(B)

FIGURE 8.3 SINGLE-DEVICE (A) AND MULTI-DEVICE (B) TEMPORAL DEMAND CHART

Figure 8.3 shows results from evaluating temporal demand, in which figure A focuses on a single-device and figure B focuses on multi-devices. The temporal demand that was experienced by each participant was higher on the single-device task, while the multi-device showed an overall lower temporal demand.

Performance – How successful were you in accomplishing what you were asked to do?

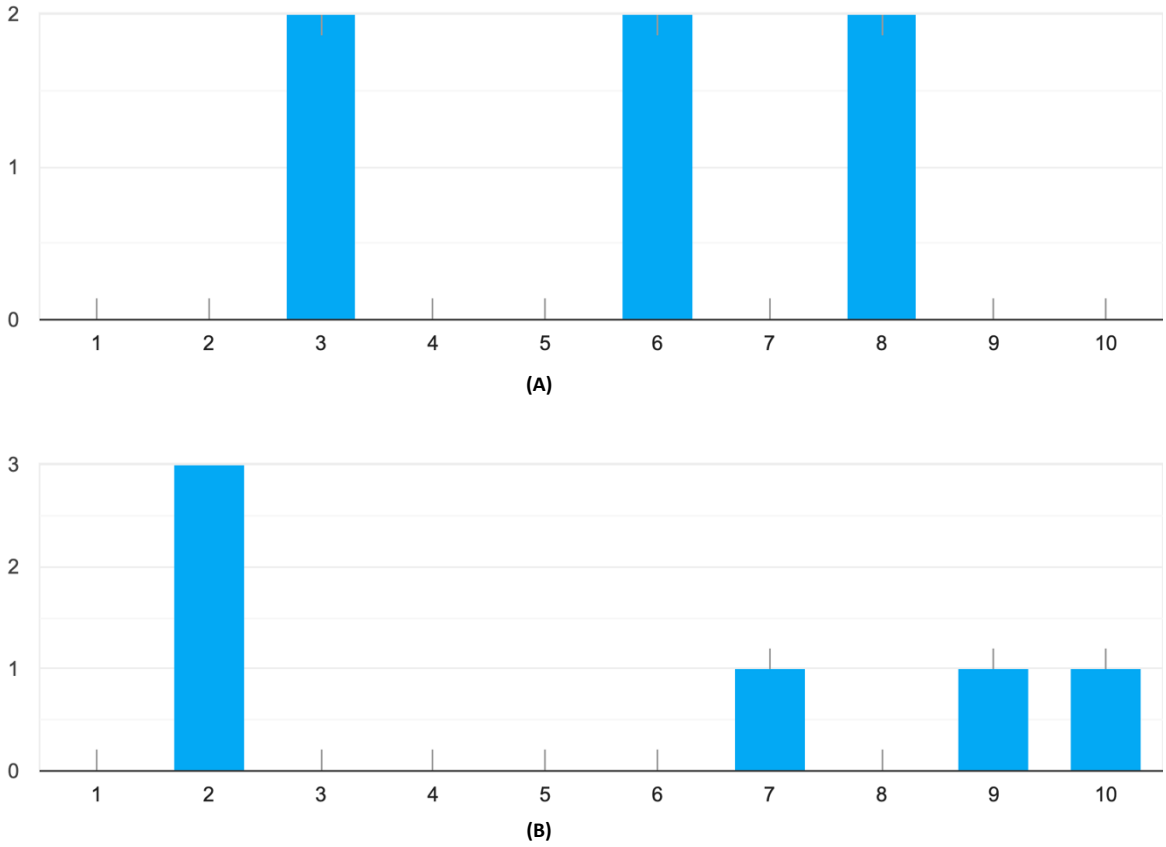
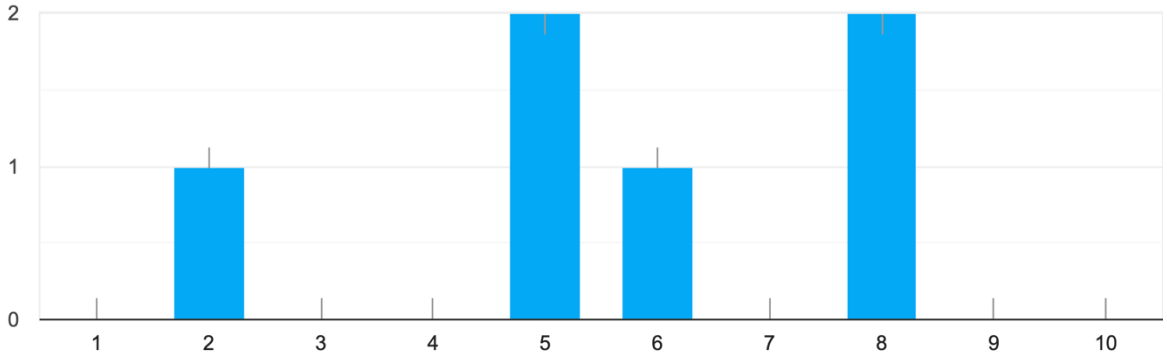


FIGURE 8.4 SINGLE-DEVICE (A) AND MULTI-DEVICE (B) PERFORMANCE CHART

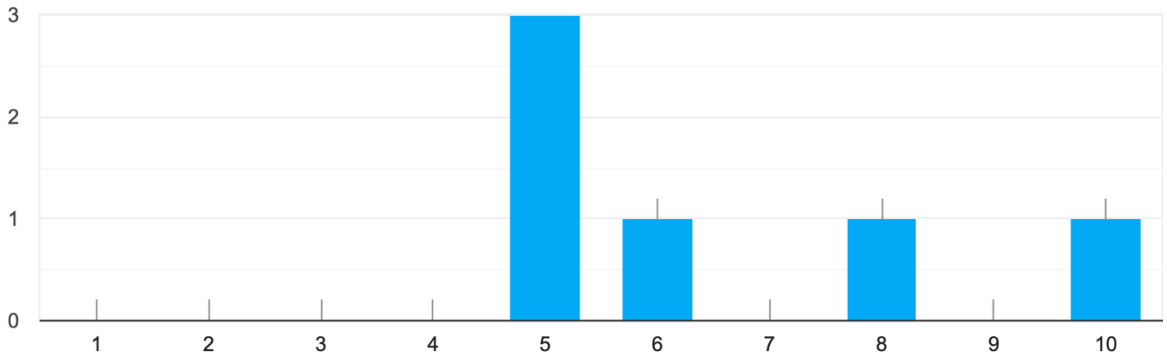
All scales have endpoint descriptors that go from low to high, but the performance scale does the opposite by changing the endpoint descriptors to perfect and failure. If a user thinks they were successful in accomplishing the task they were asked to do, they will place the scale on the higher side. Because perfect is on the left side instead of the right as the high endpoint descriptor is on the right, this change might not have been spotted by some participants as shown in the unique responses from the results. Overall, the interview together with the responses indicate there were no major issues in being able to complete the tasks.

Figure 8.4 shows results from evaluating performance in which figure A focuses on a single-device and figure B focuses on multi-devices. The performance that was experienced by each participant was more centered on the single-device task, while the multi-device showed a more scattered result which results in a similar result.

Effort – How hard did you have to work to accomplish your level of performance?



(A)

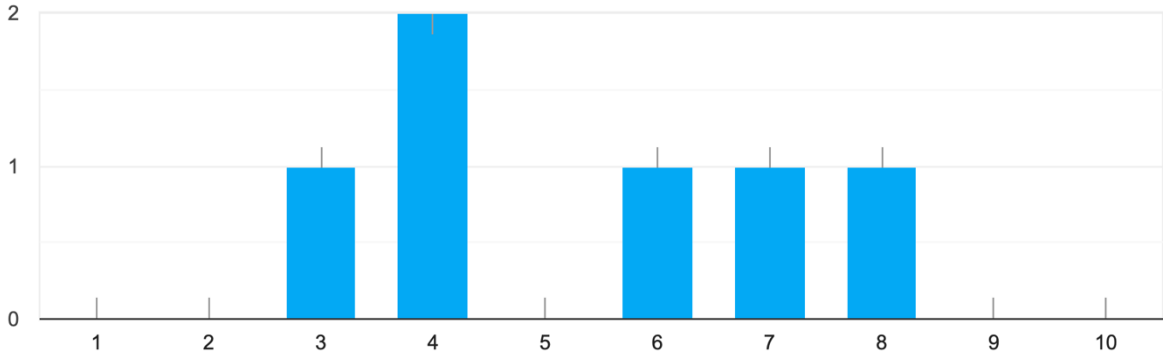


(B)

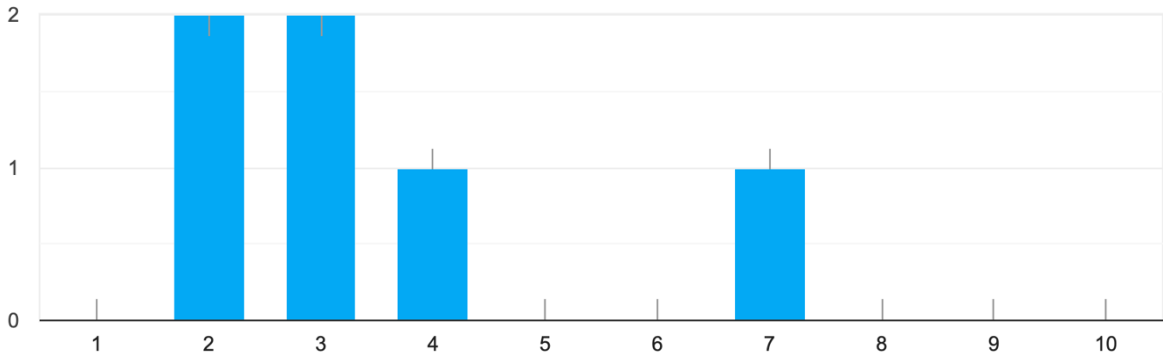
FIGURE 8.5 SINGLE-DEVICE (A) AND MULTI-DEVICE (B) EFFORT CHART

Figure 8.5 shows results from evaluating effort in which figure A focuses on a single-device and figure B focuses on multi-devices. The effort that was experienced by each participant was overall lower on the single-device task, while the multi-device showed an overall slightly higher effort.

Frustration – How insecure, discouraged, irritated, stressed, and annoyed were you?



(A)



(B)

FIGURE 8.6 SINGLE-DEVICE (A) AND MULTI-DEVICE (B) FRUSTRATION CHART

Figure 8.6 shows results from evaluating frustration, in which figure A focuses on a single-device and figure B focuses on multi-devices. The frustration that was experienced by each participant was overall higher on the single-device task, while the multi-device showed an overall lower frustration.

How does a cross-device interactive application affect workload among digital artists in creative media production? (RQ)

The six scales and the results from each of these as presented above vary from one to another. A closer inspection on the two participants with a computer and cellphone setup shows that there were no notable differences for either single-device or multi-device setup compared to the tablet and cellphone setup. The two participants did however have very different results on all points, which could have been influenced by how the setup was organized. It was mentioned in the interview that one had some issues getting used to moving the eye from the computer screen down to the cellphone to adjust settings, which could have prompted a difference. It was also mentioned by those that made use the tablet and cellphone setup that

during the learning curve, they had accidently used the pen which would only work on the tablet on the cellphone to attempt to change the settings.

The results show that the mental and physical effort was higher when making use of multi-devices, but that the frustration and temporal levels went down. In the interview all participants found the cross-device setup to be more comfortable and organized or wanted to experiment more to see if it would work for their workflow. Performance was similar for both single-device and multi-device and no participants commented on the performance being better or worse. Most preferred not to make use of more than two devices due to workspace complexity, battery being drained on multiple devices if traveling, and distraction if a personal cellphone would be used due to calls, social media, and notifications.

These results indicate that cross-device interactive drawing applications have the potential to be more comfortable and organized for users. This should be applicable to other types of applications within creative media production as well because they should be able to make use of a similar distribution of controls across devices. This study shows that a cross-device interactive environment can help create comfort and a more organized workspace for creative media artists who work with digital drawing. As the study shows that people in general wishes to experiment more with cross-device interactive environment to see if it works for their workflow.

Despite cross-device interactive environments having the potential to be used in a professional setting, it still lacks to this day guiding principles as to how such systems would work on the design as well as the system. The lack of research done on cross-device interactive workspaces shows that this thesis can be used as an important source of information on how to move the research forward.

CHAPTER 9: CONCLUSION

In this study I have investigated the cross-device interactive functionality within a drawing application to find the possible advantages and disadvantages of having a single digital artist work on multiple devices.

I have conducted research for gaining knowledge about basic functionalities a drawing application should have. Several design solutions were presented and tested. A big part of this project was to develop a functional prototype to be used for data gathering regarding workload and feedback on the functionality.

For future research it would be a good idea to get expert technicians to explain what complications can occur when developing such systems and why they have not been used in any products today. It would be wise to perform a larger study with an application that does not have limited functionalities such as this

functional prototype and to conduct a long-term study that participants will use over time, because it might require adaptations to accept new functionalities that have such a big impact on how one would work.

SOURCES

[1] Jaruzelski, B. (2013). How Digital Tools are Transforming Innovation. *Wired.* Available at: https://www.wired.com/insights/2013/11/how-digital-tools-are-transforming-innovation/ [Accessed 11.06.2020].

[2] Anderson, M. (2015). Smartphone, computer, or tablet? 36% of Americans own all three, *Pew Research. Center*, Nov 25. Available at: https://www.pewresearch.org/fact-tank/2015/11/25/device-ownership/ [Accessed 14.04.2020].

[3] Johansen, S. (2020). Multiscreen for productive applications and its effect on professionals.

[4] Houben, S *et al*. (2017). Opportunities And Challenges For Cross-Device Interactions In The Wild. Available at: https://interactions.acm.org/archive/view/september-october-2017/opportunities-and-challenges-for-cross-device-interactions-in-the-wild [Accessed 20.04.2022].

[5] Saleem, J. Weiler, D. (2018). Performance, workload, and usability in a multiscreen, multi-device, information-rich environment. *PeerJ Computer Science* 4:e162. Available: https://peerj.com/articles/cs-162/ [Accessed 27.05.2020].

[6] Woźniak, P. Schmidt, B. Lischke, L. Franjcic, Z. Yantac, A. Fjeld, M. (2014). MochaTop: Building Ad-hoc Data Spaces with Multiple Devices. *CHI EA '14: CHI '14 Extended Abstracts on Human Factors in Computing Systems*, April 2014, pp 2329–2334. Available: https://dl.acm.org/action/doSearch?AllField=mochatop [Accessed 20.05.2020].

[7] Grudin, J. Poltrock, S. (2016). The Encyclopedia of Human-Computer Interaction, 2nd Ed. *Interaction Design foundation.* Available at: https://www.interaction-design.org/literature/book/the-encyclopedia-of-human-computer-interaction-2nd-ed/computer-supported-cooperative-work [Accessed 26.05.2020].

[8] Rowland, C. (2015). Chapter 5. Cross-Device Interactions and Interusability. *Designing for the internet of things by O'reilly Media, Inc.* Available at:

https://www.oreilly.com/library/view/designing-for-the/9781491971468/ch05.html [Accessed 27.05.2020].

[9] (Anon.). (n.d). What is User Experience Design? Available at: https://www.interaction-design.org/literature/topics/ux-design [Accessed 27.05.2022].

[10] Muslihat, D. (2018) Agile Methodology: An Overview. *Zenkit Blog.* Available at: https://zenkit.com/en/blog/agile-methodology-an-overview/ [Accessed 26.05.2020].

[11] Indeed Editorial Team. (2021). What Is Comparative Analysis and How Is It Used? Available at: .https://www.indeed.com/career-advice/career-development/comparative-analysis [Accessed 22.04.2022].

[12] Taei, P. (2018) The 8 Types of Thinking Maps and How They Help Visualize Ideas. Medium, *Marketing & Growth Hacking*. Available at: https://blog.markgrowth.com/the-8-types-of-thinking-maps-and-how-they-help-visualize-ideas-e51053fe4983 [Accessed 20.05.2020].

[13] Hordina, M. (2019). Functional Prototyping in App Development. Available at: https://www.linkedin.com/pulse/functional-prototyping-app-development-aleksandra-parshakova/ [Accessed 09.05.2022].

[14] Komninos, A. (2020). 7 UX Deliverables: What will I be making as a UX designer? *Interaction Design Foundation.* Available at: https://www.interaction-design.org/literature/article/7-ux-deliverables-what-will-i-be-making-as-a-ux-designer [Accessed 28.05.2020].

[15] Ibragimova, E. (2016). High-fidelity prototyping: What, When, Why and How?, *Prototypr.io UX design 101.* Available at: https://blog.prototypr.io/high-fidelity-prototyping-what-when-why-and-how-f5bbde6a7fd4 [Accessed 20.05.2020].

[16] Olsen, J. Kellogg, W. (2014). Ways of Knowing in HCI.

[17] Baxter, K. Courage, C. Caine, K. (2015). Understanding Your Users: A Practical Guide to User Research Methods.

[18] George, T. (2022). Types of Interviews in Research. Available at: https://www.scribbr.com/methodology/interviews-research/ [Accessed 15.05.2022].

[19] (Anon). (n.d). NASA Task Load Index. Available at: https://digital.ahrq.gov/health-it-tools-and-resources/evaluation-resources/workflow-assessment-health-it-toolkit/all-workflow-tools/nasa-task-load-index [Accessed 15.05.2022].

[20] NASA. (n.d). Nasa TLX: Paper/Pencil Version. Available at: https://humansystems.arc.nasa.gov/groups/tlx/tlxpaperpencil.php [Accessed 15.05.2022].

[21] Ross, J. (2017). Conducting Qualitative, Comparative Usability Testing. Available at: https://www.uxmatters.com/mt/archives/2017/03/conducting-qualitative-comparative-usability-testing.php [Accessed 05.05.2022].

[22] Wikipedia. (n.d). Clip Studio Paint. Available at: https://en.wikipedia.org/wiki/Clip_Studio_Paint [Accessed 25.06.2020]

[23] Wikipedia. (n.d). Autodesk Sketchbook Pro. Available at: https://en.wikipedia.org/wiki/Autodesk_SketchBook_Pro [Accessed 01.06.2020]

[24] Wikipedia. (n.d). Procreate (software). Available at: https://en.wikipedia.org/wiki/Procreate_(software) [Accessed at 17.06.2020]

[25] Wikipedia (n.d). Single-subject research. Available at: https://en.wikipedia.org/wiki/Single-subject_research [Accessed at 09.05.2022].

[26] Budiu, R. (2018). Between-Subjects vs. Within-Subjects Study Design. Available at: https://www.nngroup.com/articles/between-within-subjects/ [Accessed 25.05.2022].

[27] Perera, A. (2021). Why the Halo Effect Affects How We Perceive Others. Available at: https://www.simplypsychology.org/halo-effect.html [Accessed 30.05.2022].

APPENDIX

APPENDIX A: LOW-FIDELITY AND HIGH-FIDELITY PROTOTYPE PILOT STUDY

Low-Fi & High-Fi Prototype

Pilot Studies

Have the participants use a desktop/laptop with one prototype and a smartphone/tablet for the second prototype. The participant will go through each screen on each device slowly, but the participant controls the pace.

Interface

What score would you give the design?

What are your thoughts on the design?

What are your impressions on how one navigates through the application?

Does the application seem structured or unstructured somehow?

Did the windows such as layers/colors/brush/menu make sense?

Functionality

What are your impressions on the functionalities such as layers/colors/brush/menu? Does it feel like something is missing?

How do you feel the learning curve of this application would be?

Cross-Device

What did it feel like to have a smartphone/tablet next to the computer/drawing tablet that held some functionality of the application?

Did the distribution of the application on multiple devices feel like it would require some time to get used to?

Is there anything that comes up in your mind to make it easier to get used to?

How did you feel about the way you connect and manage the devices?

Overall

What score would you give this prototype in its current state?

Anything else you would like to say about the prototype?

APPENDIX B: QUALITATIVE COMPARATIVE USABILITY TESTING STUDY STRUCT

Multi-device Study

Participant number
000

Email	Password
000@study.com	Welcome!

Introduction

- Thank you for participating in the study that is part of my master's project.
- I will give explanation about the project, what the study is about, what the goal is, and what we will be going through for the next 30-45 minutes.
- If you have any questions during this study, don't be afraid to interrupt me at any point.

Abstract

I have created a functional prototype of a drawing application that I would like you to experiment with today. Before we dig deeper into the application, I would like to explain a bit about the study and what the data will be used for.

Study

The aim of this study is to gather data that will be used to create a response on a research topic regarding workload using drawing applications.

Note that this is a prototype, so it only provides the most basic drawing tools. It is only expected that you explore this functionality and how you feel that this way of working would affect your workload compared to the traditional way.

Data

When it comes to the type of data that is collected and how it will be used, no personal data will be collected, and no video or audio will be recorded. You will be given a participant number that identifies this study session. The data will only be used for answering the research question.

Study structure

Nasa TLX Google Form: https://forms.gle/T7baVupxYgdLGwpX8

Single and Multi-device Overview	
Single-device	Multi-device
• 6 minutes • Keywords: Sky, cabin, water, mountain • 1 device permitted	• 6 minutes • Keywords: Night sky, bonfire, smoke, tree • Up to 5 devices permitted (minimum 2)

Study Structure (tasks)
• Single-Device practice • Single-Device task • Nasa TLX survey • Break 3 minutes • Multi-device practice • Multi-device task • Nasa TLX survey • Break 1 minute • Interview

Pre-preparing the user

- Have the participant locate available devices

Pre-interview

- Which devices did you manage to locate?
- Which device will you be using for drawing?
- Which browsers do you have on your different devices?
- Which device and drawing application do you use for your work?
- Do you sit in a calming environment? Is it comfortable?

Study guide

- Website
- Login Details
- Read through guide
- Select single device in gallery
- Create new project for testing
    - Explore up to 5 minutes
- Create new project for task
    - Complete task within 6 minutes
- Answer Nasa TLX
    - Explain Nasa TLX
    - Enter participant number
    - Enter number of devices
    - Answer questions
- Select multi-device in gallery
- Create new project for testing
    - Explore for 5 minutes
- Create new project for task
    - Complete task within 6 minutes
- Answer Nasa TLX
    - Enter participant number
    - Enter number of devices
    - Answer questions

Interview

- Were the keywords equally demanding? If not, how so?

- How would you describe the learning curve of getting to know the interface and the tools available?

- How would you describe the learning curve of using multiple devices?

- If you were to have more devices at hand, how do you imagine it would affect your work?

- Do you see yourself experimenting more with multi-devices if this functionality was implemented in your preferred drawing application?

- Do you imagine you would face any difficulties if you were to use this functionality from now on?

- Anything else you would like to add?

End

Thank you for participating in this study! If you have any questions, feel free to contact me on this phone number or this email.