Development and Assessment of a Mindfulness-Based Stress Reduction Mobile Application

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Report Submitted to:
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Abstract

This project is a continuation of the 2015 Major Qualifying Project (MQP), *MBSR & College Students* (Facchini et al., 2015), the 2017 Major Qualifying Project, *Enhancing Mindfulness-Based Stress Reduction Through a Mobile Application* (Falzone et al., 2017), and the 2019 Interactive Qualifying Project, *Mobile Application Development for Mindfulness Based Stress Reduction* (Corbitt, 2020).

This project involves the development of a mobile application that aims to provide Mindfulness-Based Stress Reduction (MBSR) resources to people who are interested in mindfulness. MBSR is a meditation therapy that is often taught through an eight-week course aimed at helping people reduce their stress, anxiety, depression, and pain. People who are interested in practicing MBSR often join a course to learn breathing and meditation techniques. To disseminate mindfulness resources with greater accessibility, a mobile application will continue to be developed to aid people in practicing mindfulness.

This project can be broken up into three phases: the research, the implementation, and the evaluation. The research phase has a two-fold goal: (1) to provide an extensive background into mindfulness techniques and the need and benefits of using them; (2) to research and learn formal app development methodologies. The implementation phase is comprised of two sub-phases: (1) the development of the frontend and backend of the mobile application to include new components; (2) to modify previously developed components. The evaluation phase consists of user studies to determine the usability, user experience, and performance of the mobile application. The results of the evaluations will provide insight to the developers on the functionality of the mobile application.
Executive Summary

This project regards the development and assessment of a Mindfulness Based Stress Reduction Mobile Application (MBSR) that aims to provide MBSR resources to people who are interested in mindfulness. For some context, the conversation and importance of mental health has grown significantly in recent decades. As a result, there has been an increase in the number of people interested in mindfulness. Mindfulness is a common practice done to alleviate anxiety and depression, but has no established structure or exercises for practice. A branch of mindfulness, Mindfulness Based Stress Reduction is a meditation therapy that consists of established exercises that have been clinically proven to be effective in reducing stress, anxiety, and pain. The focus of this MQP is to continue the development of a mobile application to provide open access to Mindfulness Based Stress Reduction resources for anyone to access and practice.

This project originally began in 2015 with an MQP, *MBSR & College Students* (Facchini et al., 2015), focused on compiling a list of technologies that would aid in the recruiting, adherence, and retention of MBSR training with college students. Furthermore, this MQP produced mockups for a prototype application. Following the outcome of the 2015 MQP, another MQP was established in 2017, *Enhancing Mindfulness-Based Stress Reduction Through a Mobile Application* (Falzone et al., 2017).

The focus of this MQP was to improve upon the initial design. This MQP resulted in more robust mockups as well as market research. Following this MQP, there was an IQP in 2019, *Mobile Application Development for Mindfulness Based Stress Reduction* (Corbitt, 2020), that focused on the implementation of a prototype mobile application based on the specifications outlined in the previous MQP’s.

The visions of the app from both the 2015 and 2017 MQP’s heavily focused on the ability to stream MBSR content dynamically. This includes text, images, audio, and video. It was determined in the 2019 IQP that the prototype solution needed to be able to self-host and serve this content to the app. Additionally, an interface outside of the app itself would be necessary so MBSR content can be uploaded and managed.

A backend was created for the prototype to fulfill these requirements with three main parts. The first part is a MongoDB database, which is responsible for storing content records, account information, and other server-sided data. The second part is a Content Management
System, or CMS, that acts as the interface to manage MBSR content. Strapi, an open source headless CMS, was chosen for its extensibility. With Strapi, each content type defined gets its own REST API that can be used from any web service or consumed directly by devices. The last part of the backend is the MBSR server, a node.js server that communicates directly with the app. It relays content from the CMS, and manages other server-sided operations like account registration and authentication. Since all requests from the mobile app go to this server, any service in the backend can be modified without affecting client side API.

All three parts of the backend are containerized using Docker. A Docker Compose configuration for the backend allows for data-driven deployment, and can get everything up and running with a single command. The mobile app itself is written with React Native, a mobile framework that cross compiles JavaScript to native app code. To streamline development, the prototype in its current state only supports Android, but it would be feasible to modify the codebase in the future to support iOS devices.

The implementation portion of this MQP has two primary objectives: Perform a complete re-work of the app’s video player used to stream video content, and create new infrastructure to obtain usage information when the app is in the hands of users.

First, the original video player component was a simple webview, which is a way to render HTML5 in the app. This player worked as a proof-of-concept, but had a few problems. All HTML content under a webview is treated as a single component, so there was no way to see how users interact with the video player. The relatively small size of the video player on the phone screen also shrunk down the controls, making it hard to interact with. The react-native-video library was integrated in place of the webview to stream and render video. The react-native-video-controls library was also used to provide play, pause, volume, and fullscreen controls to the new video player. We eventually forked this library to fine tune the UI and add hooks that fire callbacks when each control is interacted with.

In addition to revising the video player, we wanted to create a way to record and send usage information while the app is used in evaluation. Originally we tried using Google’s mobile platform Firebase, but we noticed that a lot of events were being dropped in testing, and there wasn’t a simple way to export recorded events. We eventually opted to build our own native event system. The system operates from the MBSR server. Since a REST API already existed for the phone to connect to the MBSR server, it was easy to extend the API to include endpoints for
events. Events are also stored in the MongoDB database, which makes for secure storage and simple retrieval. As long as the user is able to connect to the MBSR server, not a single event is dropped either. To prepare for our evaluation, events were defined for navigation, button press, and each action that controls our video player. This system could easily be expanded upon in the future to support recording other in-app activities.

To assess the mobile application we conducted user studies to test the video player component for its usability, user experience, and performance. Following our Institutional Review Board approval, we began our recruitment of WPI students through email and social media. We provided interested participants with a link to a Qualtrics survey and a link to download a distribution of the application. The survey included an Informed Consent Form, and was then followed by several tasks involving the video player component and questions the participant can answer. The tasks participants were asked to perform involved navigating to specific screens and pressing buttons on the video player in a predetermined order. Following the execution of the tasks, participants were asked where they would place the video player UI components to make it more attractive and if the UI components worked as they expected it to. Participant responses and their interactions in the mobile application were then recorded.

In total, we had thirty participants submit the survey and 2,275 events recorded across 39 devices. From the surveys, most people agreed that the Play/Pause and Volume slider should stay in the bottom left corner and top left corner respectively. Participants were split as to where to position the fullscreen button. Regarding the functionality, a majority of participants agreed that the buttons worked as intended. From the app interaction data we learned that participants spent 5 to 10 minutes interacting with the app. Also, several participants spent time exploring other screens on the application.

Ultimately, this MQP was a learning opportunity in mobile app development and evaluation. We were able to improve existing functionality in the app, add new infrastructure, and get the app in the hands of real people for the first time. Results from our evaluation attest to the reliability of the backend, and indicate potential to further expand upon the prototype in the future. The source to the MBSR mobile application can be found at https://github.com/brycecorbitt/MBSR.

Future project work could involve the implementation of live streaming for real-time practice or expand the utilization of the account system. We believe that further research should
be performed prior to continuing development such that a clear plan for how the app will be used in production is established.
Acknowledgements

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Our project advisors, Professor Rodica Neamtu and Professor Eleanor Loiacono, for providing essential feedback and guidance through the entire process of this project, for providing us with various opportunities to make the most of our time, and for helping us to improve our professional skills. Additionally, Professor Eleanor Loiacono provided the project with funding that was used as an incentive to increase participation for the user study in our evaluation.
# Table of Contents

Abstract 1  
Executive Summary 2  
Acknowledgements 6  
List of Figures 9  
List of Tables 10  
1.0 Introduction 11  
2.0 Background 12  
  2.1 Mindfulness 12  
  2.2 MBSR 13  
    Efficacy of MBSR 14  
  2.3 The Principles of App Design 15  
  2.4 Previous Work 20  
3.0 Methodology 21  
  3.1 Analysis of Previous Work 22  
    Frontend Development 22  
    Backend Development 24  
  3.2 Creating a Priority List 26  
  3.3 Implementing Components 26  
  3.4 Evaluating the Component 27  
  3.5 Iterating the Component 27  
4.0 Implementation 27  
  4.1 Video Player 28  
  4.2 Event Logging 28  
5.0 Evaluation 31  
  5.1 Participants in User Study 31  
  5.2 Data Collection 32  
6.0 Analysis and Results 34  
  6.1 Survey 34  
  6.2 App Interaction 38  
  6.3 Component Iteration 43  
7.0 Conclusion 45
List of Figures

Figure 1: User Interface Design Process 16
Figure 2: Mockups of the MBSR Application (2015-2019) 23
Figure 3: Architecture of the MBSR App 24
Figure 4: Video Player Comparison (WebView vs. react-native-video-controls) 28
Figure 5: Screens in the application (Home, Mindfulness Exercises, Video Exercises) 31
Figure 6: Play/Pause Button Position Response Distribution 35
Figure 7: Fullscreen Button Position Response Distribution 36
Figure 8: Volume Slider Button Position Response Distribution 37
Figure 9: Component Functionality Response Distribution 37
Figure 10: Emergent Themes from the Additional Comments 38
Figure 11: Estimated locations of study participants by IPv4 address 39
Figure 12: Distributions of each event type that was recorded 40
Figure 13: Total time each participant spent using the app 41
Figure 14: Cumulative time spent on each screen 42
Figure 15: Cumulative time spent on each screen of the app across all participants 43
List of Tables

Table 1: Interaction Design Principles 17
Table 2: Visual Design Principles 18
Table 3: W3C Principles of Accessibility 19
Table 4: Neilson’s Ten Heuristics for User Interface Design 20
Table 5: Event Definitions for Logging User Interactions 29
Table 6: Recorded Fields and Descriptions for an Event 30
Table 7: User Study Protocol for Evaluating a Video Player Component 33
Table 8: Evaluation Summary and Component Iteration 44
1.0 Introduction

Mental health is an essential aspect to everyday life, and in recent decades, the conversation around mental health disorders in young adults has grown (American Psychological Association, 2019). Many studies have claimed “at least one out of every four or five young people in the general population will suffer from at least one mental disorder in any given year” (The Lancet, 2007) (National Institute of Mental Health, 2017). Mental health disorders can range from depression, anxiety, personality disorders to behavioural disorders. In recent times, the practice of mindfulness has become more recognized and has been used in mental health treatment to reduce anxiety and depression (Ninivaggi, 2018). A mindfulness based program, Mindfulness-Based Stress Reduction (MBSR), was developed in the 1970s as a method to practice mindfulness. MBSR is a meditation therapy that uses a combination of meditation, body awareness, and yoga to reduce symptoms of stress and anxiety. Often taught through a course, MBSR is intended to teach people the proper techniques to practice mindfulness so that they may continue to practice after the program. Presently, there are many eight week long MBSR courses available for people to learn the various mindfulness techniques.

This Major Qualifying Project aims to continue the development of a mobile application to provide open access to mindfulness resources for anyone to access and practice. This MQP is a continuation of the previous MQP’s MBSR & College Students (Facchini et al., 2015) and Enhancing Mindfulness-Based Stress Reduction Through a Mobile Application (Falzone et al., 2017), and the Interactive Qualifying Project (IQP), Mobile Application Development for Mindfulness Based Stress Reduction (Corbitt, 2020).

The efforts of previous projects laid the foundation for a prototype mobile application to provide reliable mindfulness resources and aid in MBSR practice. This project aims to expand access, raise awareness, and build upon the prototype to create a platform for mindfulness content.

The team will follow industry practices for Incremental Development (Amir Ghahrai, 2016). As new implementations and modifications are done to the application, user studies will be conducted asynchronously to evaluate the impact of the implemented changes. Based on the results of the user studies, modifications to the application will be made to meet user expectations. This cycle will continue throughout the duration of the project to create changes that provide certifiable impact to the user experience.
2.0 Background

In this chapter, we will establish relevant background through a literature review. Relevant background for the project will include the history of mindfulness, the practice of MBSR, principles for user interface design, and the existing work for this project.

2.1 Mindfulness

The practice of mindfulness has evolved from its roots in early Buddhism and Hinduism, and is now seen as a facet to overall wellness and self-care rather than a religious practice. Furthermore, mindfulness is a way of living as opposed to a state of mind. Mindfulness itself does not eliminate stress or other conditions but allows for individuals to become aware of the unpleasant thoughts or emotions they may be experiencing and how to manage them (Ninivaggi, 2018).

In recent decades, the practice of mindfulness has grown in popularity due to the benefits it provides and its perception as a pillar of self-care. A widely accepted definition of mindfulness is the “moment-to-moment awareness of one’s experience without judgement. While it might be promoted by certain practices or activities, such as meditation, it is not equivalent to or synonymous with them” (American Psychological Association, 2012). There are several methods to practice mindfulness including, breathing exercises, yoga, and meditation. When individuals are practicing mindfulness, often through meditation, “[they] concentrate on the internal functioning of the muscles, nerves, and blood vessels, which ultimately normalizes physiological response to the environment and reveals the importance of the moment” (Psychiatry, 2015). Moreover, researchers have theorized that mindfulness meditation promotes metacognitive awareness, decreases rumination, and enhances attentional capacities to contribute to effective emotion regulation (American Psychological Association, 2012). Thus, mindfulness meditation is a method of focusing attention on sensations, emotions, and the body.

Though Mindfulness is a broad topic and has a rich history, the concept is typically discussed today in the context of mental health. Though there are several ways to practice mindfulness, there is no single methodology or structure to practice. Due to the lack of structure around mindfulness practice, studying the benefits is more difficult. Thus, several branches of mindfulness were established with specific methodologies that have produced clinical results. Notable branches of mindfulness include Mindfulness-Based Cognitive Therapy,
Mindfulness-Based Stress Reduction, and Mindful Self-Compassion. This project will be closely looking at Mindfulness-Based Stress Reduction.

2.2 MBSR

Mindfulness-Based Stress Reduction (MBSR) was developed by Dr. Jon Kabat-Zinn at UMass Medical Center in the 1970s to help patients with chronic pain and stress related issues. The MBSR program was initially targeted towards hospital patients but has since been opened up for all people. As of 2017, more than 25,000 people completed the eight-week MBSR program (UMass Memorial Health Care, n.d.). Kabat Zinn developed the MBSR program by combining mindfulness practice and yoga into an eight-week course of group sessions and homework assignments.

The UMass Memorial eight week course is structured with a group pre-program orientation, an individual interview and eight-weekly classes. Each class is typically three hours in duration and the participants are taught how to manage their stress through various exercises. The course incorporates formal and informal mindfulness meditation. The formal meditation can include body scan meditation, gentle hatha yoga, sitting meditation, and walking meditation. Informal mindfulness meditation is the mindfulness practiced in everyday life, and can include awareness of pleasant and unpleasant events, awareness of breathing, and the deliberate awareness of routine activities. Participants are given daily assignments which include practicing formal and informal practice for extended periods of time. This course consists of thirty hours of in class contact, forty-five hours of home assignments, and three hours of group orientation (UMASS Medical School, 2014). There are certain principles established by UMass Medical School that various MBSR programs are based on. The following are the key principles of MBSR:

- Making the experience a challenge rather than a chore and thus turning the observing of one's life mindfully into an adventure in living rather than one more thing one "has" to do for oneself to be healthy.
- An emphasis on the importance of individual effort and motivation and regular disciplined practice of the meditation in its various forms, whether one "feels" like practicing on a particular day or not.
- The immediate lifestyle change that is required to undertake formal mindfulness practice, since it requires a significant time commitment.
The importance of making each moment count by consciously bringing it into awareness during practice, thus stepping out of clock time into the present moment.

An educational rather than a therapeutic orientation, which makes use of relatively large "classes" of participants in a time-limited course structure to provide a community of learning and practice, and a "critical mass" to help in cultivating ongoing motivation, support, and feelings of acceptance and belonging.

A medically heterogeneous environment, in which people with a broad range of medical conditions participate in classes together without segregation by diagnosis or conditions and specializations of intervention.

The MBSR course is highly customizable, but has several core principles that support the program and the effectiveness of the course. Moreover, a large determining factor is the dedication of the participant. A review of forty-three studies found that MBSR participants only complete about 64% of their assigned amount of work, this is roughly thirty minutes a day for six days a week (Behaviour Research and Therapy, 2017). A large importance is placed on the participants willingness to practice and commitment to adjust their lifestyle. Through the program, participants are able to realize that they are capable of self-managing and coping with various mental health issues.

Efficacy of MBSR

MBSR has been clinically seen to help patients with mental health problems such as anxiety and stress and also physical ailments like chronic pain. Moreover, MBSR is the most scientifically researched mindfulness program and is operating in over 250 hospitals (Mindful Leader, n.d.). The benefits of MBSR include, attentional control and managing rumination, mood clarity, cognitive change, exposure, control, acceptance, and relaxation. In regards to attentional control and managing rumination, MBSR helps the participant in “observing emotions in a reflective way rather than [a] reactive way”. MBSR has also been seen to alter metacognitive processes that impact mood clarity which also enhances emotional intelligence. Participants of MBSR have been seen to develop non-judgemental acceptance of negative thoughts. MBSR can work as a form of exposure therapy by “teaching participants to accept negative stimuli without producing a hyper-emotional response and improving tolerability of the discomfort”. Through the practice of meditation and hatha yoga, participants have greater control over their bodies where the participant can remain in a certain position for an extended period of
time. Participants of MBSR also gain the ability to “accept maladaptive thoughts, pain, presence of an illness and a disability in a reflective rather than reactive way”. Through various studies it has been seen that MBSR practice will help participants with chronic pain reduce muscle tension to help in relaxation (Journal of Disability Management and Rehabilitation, 2018).

One study that has similar themes to this project is, Efficacy of the Mindfulness Meditation Mobile App “Calm” to Reduce Stress Among College Students: Randomized Controlled Trial. This study looked at the initial efficacy and sustained effects of an eight week mindfulness meditation intervention. The target of this study, college students, have more common occurrences of psychological distress. The study found that the mobile application was perceived as helpful and that many participants were likely to continue using the application. It was also reported that the application was able to reduce stress, improve mindfulness and self compassion in short-term instances (JMIR Mhealth Uhealth, 2019). This positive feedback suggests that a mindfulness mobile application may be used as a cost-effective and convenient method to disseminate content, and can provide an enjoyable way to manage stress for college students.

The mindfulness application that is being developed in this MQP is using content from the website www.palousemindfulness.com (Potter, n.d.). This website was created by a MBSR instructor, Dave Potter, certified through the University of Massachusetts Medical School. Potter designed the website for people who can not take the MBSR course for financial or logistical reasons. This website provides a curated selection of content for MBSR practice. Moreover, the website uses the same curriculum and resources that are often used in in-person MBSR courses. The website organizes the content down by week and further organizes the content by videos, readings, practice sheets, and supplementary material.

2.3 The Principles of App Design

This project involves the development of a mobile application thus, the principles of app design must be considered. An aspect of mobile app development is the User Interface (UI). UI involves the interactions, aesthetics, and accessibility of an application. Users often judge an application by its interface rather than its functionality. As easily as a well designed interface can aid users in learning a new application, a poorly designed interface can lead users to make errors. A necessary step of UI design is the development of prototypes, ranging from low fidelity prototypes to high fidelity prototypes. Low fidelity prototypes can be made by creating
Wireframes to display the basic idea of the application, the various screens, and the interactions between screens. A high fidelity prototype involves the implementation of important features as well as consideration for the aesthetic. The various iterations of this project have cycled through low-fidelity and high-fidelity prototypes. A typical UI design process can be seen below.

![User Interface Design Process](image)

**Figure 1**: User Interface Design Process (*University of Maryland*, n.d.)

An aspect of UI design is interaction design, defined as “the structure and behaviour of interactive systems interaction designers strive to create meaningful relationships between people and the products and the services they use, from computers to mobile devices to appliances and beyond” (*Interaction Design Association*, n.d.). While prototyping, the interactions between various objects must be clearly mapped. Below are five principles for interaction design.
Table 1: Interaction Design Principles (Ian Gibbs, 2014)

<table>
<thead>
<tr>
<th>Principle</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consistency</td>
<td>Use of persistent elements that remain in the same location, retain the same appearance, and adhere to the same grid layouts and proportions</td>
</tr>
<tr>
<td>Perceivability</td>
<td>Interactive components should be easily identifiable, hidden interactions decrease usability and efficiency</td>
</tr>
<tr>
<td>Learnability</td>
<td>Users should be able to easily learn and remember the interactions</td>
</tr>
<tr>
<td>Predictability</td>
<td>Users should know what a interactive component does before the interaction has occurred, by using animations, video, overlays, or describing what can be done</td>
</tr>
<tr>
<td>Feedback</td>
<td>Users should understand what their current status is and what they can do next, failure to acknowledge interaction can lead to unnecessary repetition of actions, mistakes, and errors</td>
</tr>
</tbody>
</table>

The aesthetic design of a UI plays an important role in creating a theme and making an impression on users. Aesthetic is a broad term, but can include factors such as “balance, color, movement, pattern, scale, shape, and visual weight” (Interaction Design Foundation, n.d.). Designers use aesthetics to complement their application’s usability, and enhance functionality with attractive layouts. The visual components of an application are the first thing a user notices, as first impressions typically form within 50 milliseconds. (Behaviour & Information Technology, 2006). Below are five principles for visual design.
Table 2: Visual Design Principles (*Nielsen Norman Group*, 2020)

<table>
<thead>
<tr>
<th>Principle</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale</td>
<td>Using relative size to signal importance and rank in a composition</td>
</tr>
<tr>
<td>Visual Hierarchy</td>
<td>Guiding the eye on the page so that it attends to design elements in their order of importance</td>
</tr>
<tr>
<td>Balance</td>
<td>Equally distributed amount of visual signal on both sides of an imaginary axis</td>
</tr>
<tr>
<td>Contrast</td>
<td>Juxtaposition of visually dissimilar elements in order to convey that two items are different</td>
</tr>
<tr>
<td>Gestalt</td>
<td>Gestalt Principles capture the eyes tendency to perceive the whole as opposed to individual elements</td>
</tr>
</tbody>
</table>

UI design should account for the needs, experience, and capabilities of its users. Thus, designers should be aware of the user’s physical and mental limitations and should take into account that users make mistakes. Accessibility in mobile applications is important to create a more inclusive and well-rounded application. Roughly 15% of the world’s population has some form of disability, it is important to consider how an application can be used by disabled individuals (*World Health Organization*, 2018). Disabilities can be broken up into four categories, visual, physical, aural, and cognitive. The following are the four principles of accessibility established by the World Wide Consortium (W3C).


Table 3: W3C Principles of Accessibility (W3C, 2016)

<table>
<thead>
<tr>
<th>Principle</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceivable</td>
<td>Information and user interface components must be presentable to users in ways they can perceive</td>
</tr>
<tr>
<td>Operable</td>
<td>User interface components and navigation must be operable.</td>
</tr>
<tr>
<td>Understandable</td>
<td>Users must be able to understand the information as well as the operation of the user interface</td>
</tr>
<tr>
<td>Robust</td>
<td>Content must be robust enough that it can be interpreted reliably by a wide variety of user agents, including assistive technologies</td>
</tr>
</tbody>
</table>

Along with the previously mentioned design principles, there are many other sets of heuristics or established principles for user interfaces. Jakob Nielsen’s *Heuristics for User Interface Design* is inclusive of the previously mentioned principles. The principles are widely known for designing and evaluating user interfaces (*CHI ‘90 Proceedings*, 1990). Nielsen’s Ten Heuristics for user interface design are the following:
Table 4: Neilson’s Ten Heuristics for User Interface Design (Nielsen Norman Group, n.d.)

<table>
<thead>
<tr>
<th>Heuristic Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visibility of system status</td>
<td>Appropriate feedback of what’s going on in the system?</td>
</tr>
<tr>
<td>Match between system and real world</td>
<td>Any real-world metaphors and/or analogies used? If so, do they match how the real-world objects interact?</td>
</tr>
<tr>
<td>User control and freedom</td>
<td>Are users able to choose several/many paths of interacting? Are there exits for mistaken choices?</td>
</tr>
<tr>
<td>Consistency and standards</td>
<td>Consistent look &amp; feel throughout the interface?</td>
</tr>
<tr>
<td>Error prevention</td>
<td>Does the interface attempt to minimize possible user errors?</td>
</tr>
<tr>
<td>Recognition rather than recall</td>
<td>Does the system fill in known info when possible?</td>
</tr>
<tr>
<td>Flexibility and efficiency of use</td>
<td>Are there special shortcuts that experts can use for efficiency? Can users record/tailor actions to suit their needs? (advanced)</td>
</tr>
<tr>
<td>Aesthetic and minimalist design</td>
<td>Layout/interaction minimal, without extra unneeded baggage?</td>
</tr>
<tr>
<td>Help user recognize, diagnose &amp; recover from errors</td>
<td>Error messages clear to the user? They suggest a solution?</td>
</tr>
<tr>
<td>Help and documentation</td>
<td>Clear &amp; concise labels? When needed, is help available?</td>
</tr>
</tbody>
</table>

Ultimately, app design has many principles for best practice, and it is often the judgment of the developers as to which set of principles to follow. For the purposes of this MQP, the last set of principles mentioned, Nielsen’s Heuristics, are to be used by the developers to analyze the application.

2.4 Previous Work

An MQP group in 2015 performed various surveys (Facchini et al., 2015) on students to determine technologies that would aid in the recruiting, adherence, and retention of MBSR
training with college students. The group concluded that MBSR content would be best received by college students and young adults through a mobile application. The team prepared basic features for an app based on their research and provided initial mock-ups for what such a product would look like (Facchini et al., 2015, 139-140).

In 2017, a second MQP team returned to this project to build upon the initial design of a mobile application. This team conducted surveys to evaluate the 2015 MQP’s designs for a mobile application. From analyzed results, they created new mockups that incorporated the general consensus of features and changes that should be made to the application into a new design. The 2017 team also performed a heavy redesign of the app's user interface for each screen, laying out groundwork to how the app should look and feel with an emphasis on user experience (Falzone et al., 2017).

The visions of both MQP teams were first brought to life in 2019, when an Interactive Qualifying Project (IQP) designed and developed the first iterations of a prototype mobile application. From prior research and discussions with UMass Medical staff throughout development, key features were identified for implementation. The IQP also addressed points critical to supporting such features in a mobile application. As much of the app’s planned functionality relied on dynamically serving content, architecture for a backend to facilitate content management was created. Demonstrations of prototype app and the backend working concurrently were held throughout development to validate the flexibility and scalability of the platform for consumption of MBSR content.

3.0 Methodology

The goal of this project is to implement components to expand and modify the existing mindfulness application to create a more robust prototype. The mobile application is intended to be used by people to practice mindfulness related exercises, however, this project focuses on the implementation and evaluation of the application.

The mobile application at the beginning of this project was in a prototype state that served as an initial proof of concept. This project will continue the implementation by doing a need analysis to determine a priority list for components that are to be implemented. With the components implemented, users will be able to use a more functional application.
This project follows the design-based research model created by Yuxin Ma and Stephen Harmon detailed in their paper *A Case Study of Design-Based Research for Creating a Vision Prototype of a Technology-Based Innovative Learning Environment* (Ma, Harmon, 2009). This model has the following four steps: (1) Analysis of practical problems; (2) Development of solution through a mobile application; (3) iterative cycles of testing and refinement of the mobile application in practice and reflection through formative evaluation; (4) reflections and documentation to produce design principles. Based on this design-based research model, our implementation can be divided into the following objectives to simplify the development of the mobile application:

1. Analyze previous work to determine if any modifications are needed
2. Identify components to be implemented through a need analysis
3. Implement components based on the priority list previously created
4. Evaluate the mobile application through user studies
5. Iterate the components based on the results of the user studies

3.1 Analysis of Previous Work

An analysis of the prototype application was conducted to define areas that require modifying as well as identifying areas that could benefit from new implementation and features. The analysis is broken down by the frontend of the application and backend of the application.

**Frontend Development**

The frontend of an application refers to the components that the end users interact with. Decisions regarding fonts, colors, and app navigation were established during the 2017 MQP and the 2019 IQP (Falzone et al., 2017) (Corbitt, 2020). The frontend of the application has seen several changes in the past few iterations of the project through the process of creating wireframes and UI mockups to determine which aspects of the UI need to be adjusted. The mockups created through the various MQP’s and IQP can be seen below.
The app name *doyoumindful* is using the brush font Chasing Embers, which appears as watercolor. The font is distinctive and attracts attention to the logo and this becomes important for recognition. Referring back to Table 2: Principles for Visual Design, the fonts used in the application align with the principle of *Visual Hierarchy* and *Scale*. This is present throughout the application, as the different size fonts display the structure and order of importance in the application, thus producing a visual hierarchy.

The use of color in an application has many benefits, including to convey personality, set a tone, attract attention, and indicate importance. Furthermore, the color, contrast, and readability used in the application heavily impacts accessibility (U.S. Web Design System). There are many psychological properties of color thus, it is important to consider the validity and accessibility of the colors used in the MBSR app. The most prevalent colors seen in the app are purple, green, and blue. These colors are considered cool toned which can create a soothing and calming impression. Moreover, cool toned colors are linked to lowering blood pressure (*SAGE Journals*, 2014). In Table 3, W3C Four Principles of Accessibility, the colors used in the app do conform to the *Perceivable* principle which regards the use of color. The background gradient used
throughout the application is much lighter than the text color which provides contrast for users to perceive and read the text.

**Backend Development**

The prototype mobile application for the project is based on the findings published in the 2019 IQP (Corbitt, 2019). The prototype includes source code for a mobile application, as well as server-sided infrastructure to facilitate the management and serving of dynamic content. The impact of each proposed feature on both the app and the backend will require careful consideration to ensure application integrity, thus allowing for data to be secure. Below is the architecture of the application developed during the 2019 IQP.

![MBSR App Deployment Diagram](image)

**Figure 3**: Architecture of the MBSR App (Corbitt, 2019)

**React Native Mobile App**

The mobile app is written using React Native, a framework developed by Facebook that takes project code written in JavaScript and compiles it to Android Studio and iOS Xcode projects. Although support for features unique to either platform is limited, the framework’s capabilities are suitable for achieving the deliverables of the prototype app. Although builds for both iOS and Android were maintained throughout the duration of the IQP (Corbitt, 2020),
development efforts in this project will focus entirely on the Android build to maximize usability and potential.

**MongoDB Database**

The database service is the foundation of the backend that provides an outlet for storing and managing information that is crucial to the platform’s operation. It uses a document-oriented Database Management System (DBMS) called MongoDB. Although relational database’s such as MySQL and PostgreSQL are more commonly used in practice for their ability to map complex relationships between data structures, document-oriented databases can provide significant performance gains with simple structures as they scale with capacity and request bandwidth (Chickerur et al, 2015). MongoDB was chosen as the DBMS for this project due to its ability to process bulk requests (such as concurrently querying feeds for multiple users) effectively. Additionally, no restriction regarding relationship mapping between structures that come with using the dialect inhibits any existing or planned content models on the application.

**Strapi CMS Server**

A Content Management System (CMS) is used to manage content commonly used for storing information on websites. CMS servers typically provide a web portal to manage the content that is then served. This provides an easy to use interface for people who want to publish their own website with minimal web development experience. The CMS server responsible for facilitating content for the MBSR platform was created using Strapi, an open source CMS solution for self-hosted content. Instead of being bound to rendering HTML pages for a website like most CMS services, Strapi is a headless CMS, and serves its content in a JSON format that can be used across multiple applications. Entries of each content type are requested through a set of HTTP requests that Strapi generates in the form of a REST API. Because Strapi is open source, the CMS service is very flexible, and will continue to be customized by the team to best suit the needs of the MBSR platform.

**MBSR Server**

The MBSR server is the heart of the platform that bridges the backend services together and serves content to the user’s phone. Any request made from the app is sent to the MBSR server (through its own REST API), which then processes the request, gathers data to create an appropriate response, and serves it back to the user. The MBSR server also uses
Mongoose, an Object Data Modelling (ODM) library to interact with the MongoDB server to provide functionality such as account registration, login, and recovery to users in the app.

3.2 Creating a Priority List

In order to determine what the implementation of this project will entail, a need analysis was performed. A need analysis “defines deficiencies or problems and identifies causes and solutions. It can be thought of as the process of identifying gaps between what should be happening and what is happening” (Berkeley Lab, n.d.). The need analysis was done to determine where there is room to expand or improve the application and what solutions there are for each proposed deficiency. The need analysis concluded that there were seven possible areas of focus for the implementation. Below are the areas of focus from highest priority to lowest priority.

- Replacing WebViews for video streaming with native components
- Logging user interactions within the application
- Populating the application with content from Palouse Mindfulness (Potter, n.d.)
- Integrating live stream capability for meditation sessions
- Integrating search capability for all streamed content
- Persisting the app state after closing/reopening the application
- Delivering the mindfulness application in the form of a web application

From the need analysis, a few of the items on the priority list were deemed unfeasible early on. Moreover, some items on the list were removed from consideration based on the time to fully implement and evaluate them. Based on the priority list, we decided that the first component to be implemented pertains to the video player. The video player was the highest priority because at its current state the videos were rendered as WebViews, moreover the video controls were difficult to maneuver as a user. The second component to be implemented is developing an event system that logs user interactions within the application. This component is next on the priority list because logging user interactions will provide valuable information during evaluations and to analyze content engagement.

3.3 Implementing Components

In order to implement the first component, replacing WebViews for video streaming with native components, we first researched the available solutions for this. The mindfulness
application is developed in React Native. Moreover, React Native is composed of open-source component libraries that allow for efficient development. Part of the research was to see if there were any existing video player component libraries that would fill the need of implementing a native video player. Two video player component libraries were found, react-native-video-player and react-native-video-controls. Following the implementation of the two video players the benefits and drawbacks of each video player was discussed. Ultimately the react-native-video-controls component library was chosen.

The secondary component that was implemented was an event logging system, which was proposed as a way to obtain usage information directly from devices running the app. The event logging system will log interactions, within the application but also within the previously implemented video player component.

3.4 Evaluating the Component

User studies will be done to evaluate the usability, user experience, and performance of the newly implemented feature in the mindfulness application. Recruited participants will receive an email that includes a link to a distribution of the prototype app and a link to a corresponding Qualtrics survey. Within the survey, participants will be asked to perform predefined tasks and respond to questions. Following the execution of all of the tasks, the participants will be asked questions regarding their experience using the application. The survey responses will be recorded through Qualtrics. Additionally, the participants’ interactions with the app will be logged to assess timing and application performance.

3.5 Iterating the Component

We are using an incremental development model for iterating a component. An incremental development model “is a method of software development where the model is designed, implemented, and tested incrementally until the product is finished. It involves the development and maintenance” (Amir Ghahrai, 2016). This methodology allows the developers to generate working software more efficiently, provide flexibility with modifying system requirements, and allow each iteration to generate feedback.

4.0 Implementation

In this chapter, we will discuss our implementation in the mobile application. The implementation can be broken up into two stages: (1) The replacement of webviews to a native video player, and (2) The integration of a native event logging system.
4.1 Video Player

This project utilizes several React Native component libraries including, react-native-countdown-component, react-native-elements, and react-native-video-controls. The first part of the implementation regards the video player. The video player is used for the video exercises. This implementation is the replacement of the previously implemented WebView. A WebView is a component that allows an Android application to display content directly from the web. The react-native-video-controls component library includes a set of Graphical User Interface (GUI) controls that work with the existing react-native-video component. This component library also includes a back button, volume bar, fullscreen toggle, play/pause toggle, seekbar, error handling, and a timer toggle that can switch between the remaining time and the current time. Below is the side by side comparison of the video player through a WebView and the video player through react-native-video-controls.

![WebView (current) vs react-native-video-controls](image)

**Figure 4**: Video Player Comparison (WebView vs. react-native-video-controls)

4.2 Event Logging

The integrity of each part of the backend was considered during the implementation of new features into the application. While the changes made to the video player only affected the frontend, the activity logging system proposed involves sending data from the user’s phone to be recorded, and subsequently required changes to be made in the backend. Firebase, a platform created by Google for managing mobile applications, has integrated event logging that was considered to fulfill this goal. However, after successfully integrating Firebase into the app and configuring simple events, two problems became apparent that led to its removal from the project. The biggest issue was that events were dropped very often and didn’t get recorded. This
would not have been as problematic if our intention was to gain broad statistics across a user base of thousands. However, given the state of the app and the scope of our planned evaluation, it was imperative that the events recorded were as accurate and granular as possible. The second issue that arose from using Firebase was that the events it did record successfully could not be easily exported. In order to do so, the configured Firebase project must be linked to an additional Google service called BigQuery. After linking the MBSR project, however, many of the events in Firebase weren’t sent to BigQuery. There are multiple possible explanations for this, such as the fact that they were custom defined events and that Firebase only syncs data with BigQuery once every 24 hours. However, it was decided the inability to accurately record and export event data was more trouble than it was worth to integrate further into the project, and it was removed.

In light of Firebase’s tribulations, an in-house system for recording events was designed and developed from the ground up. Because the MBSR server’s purpose is to provide backend services to the app through a REST API, it was extended to support a variety of new endpoints for logging events. Infrastructure for Mongoose to store data from the MBSR server in the MongoDB instance already existed from the development of the user account system in the 2019 IQP, so it was expanded upon with new models to store each of the new event types planned.

Each event contains context to the occurring action, such as the screen an action occurred on, the X and Y coordinates of a button press, and the timestamp of when it was fired. Event listeners were implemented in the application at various points to record different actions. Below is a complete list of each event implemented, as well as the action that causes the event to fire.

**Table 5: Event Definitions for Logging User Interactions**

<table>
<thead>
<tr>
<th>Event Name</th>
<th>Fires When:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Navigation</td>
<td>User navigates from one screen to another</td>
</tr>
<tr>
<td>ButtonPress</td>
<td>A button is pressed on any screen (currently only navigation buttons)</td>
</tr>
<tr>
<td>VideoToggle</td>
<td>The play/pause button on any video is pressed</td>
</tr>
<tr>
<td>VideoSeek</td>
<td>The video progress bar is dragged on any video</td>
</tr>
<tr>
<td>VideoVolume</td>
<td>The volume slider is dragged on any video</td>
</tr>
<tr>
<td>VideoFullscreen</td>
<td>The fullscreen button is pressed on any video</td>
</tr>
</tbody>
</table>
Table 6: Recorded Fields and Descriptions for an Event

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Description</th>
<th>Event Type(s) Present in</th>
</tr>
</thead>
<tbody>
<tr>
<td>id</td>
<td>Unique identifier for event</td>
<td>All Events</td>
</tr>
<tr>
<td>type</td>
<td>String identifying event type</td>
<td>All Events</td>
</tr>
<tr>
<td>device_id</td>
<td><code>ANDROID_ID</code> to uniquely identify device</td>
<td>All Events</td>
</tr>
<tr>
<td>session_id</td>
<td>Session cookie ID for MBSR server</td>
<td>All Events</td>
</tr>
<tr>
<td>ip_address</td>
<td>IPv4 address from device</td>
<td>All Events</td>
</tr>
<tr>
<td>timestamp</td>
<td>Time event fired (sent in milliseconds, stored as <code>BSON Date</code>)</td>
<td>All Events</td>
</tr>
<tr>
<td>to</td>
<td>Name of destination screen navigating to</td>
<td>Navigation</td>
</tr>
<tr>
<td>from</td>
<td>Name of screen navigating from</td>
<td>Navigation</td>
</tr>
<tr>
<td>screen</td>
<td>Name of current screen</td>
<td>ButtonPress</td>
</tr>
<tr>
<td>button_id</td>
<td>Unique string identifier for button</td>
<td>ButtonPress</td>
</tr>
<tr>
<td>pageX</td>
<td>X coordinate of press on screen</td>
<td>ButtonPress</td>
</tr>
<tr>
<td>pageY</td>
<td>Y coordinate of press on screen</td>
<td>ButtonPress</td>
</tr>
<tr>
<td>locationX</td>
<td>X coordinate relative to press on button</td>
<td>ButtonPress</td>
</tr>
<tr>
<td>locationY</td>
<td>Y coordinate relative to press on button</td>
<td>ButtonPress</td>
</tr>
<tr>
<td>source</td>
<td>HTTP url to content being streamed</td>
<td>All Video Events</td>
</tr>
<tr>
<td>position</td>
<td>Current position in video (seconds as decimal)</td>
<td>All Video Events</td>
</tr>
<tr>
<td>duration</td>
<td>Total duration of video (seconds as decimal)</td>
<td>All Video Events</td>
</tr>
<tr>
<td>action</td>
<td>“play” or “pause” for VideoToggle</td>
<td>All Video Events</td>
</tr>
<tr>
<td></td>
<td>“start” or “release” for VideoVolume and VideoSeek</td>
<td></td>
</tr>
<tr>
<td></td>
<td>“maximize” or “minimize” for VideoFullscreen</td>
<td></td>
</tr>
<tr>
<td>volume</td>
<td>Number between 0 and 1 representing volume level</td>
<td>VideoVolume</td>
</tr>
</tbody>
</table>

The newly implemented video player will be the primary component of the evaluations. Below are three screens in the application following the implementations.
5.0 Evaluation

This previously implemented video player was evaluated using the event logging system through user studies. A user study is “any evaluation that gets users involved directly, in the lab or in the users’ natural environments” (IGI Global, 2012). The studies will evaluate the usability, user experience, and performance of the newly implemented features in the application.

Recruited participants received an email that included a link to a distribution of the app and a link to a corresponding Qualtrics survey. Within the survey, participants were asked to perform predefined tasks and respond to questions. Following the execution of all of the tasks, the participants were asked questions regarding their experience using the application. The survey responses were recorded through Qualtrics. Additionally, the participants’ interactions with the app were logged through the in-house event system to assess timing and application performance.

5.1 Participants in User Study

The participant pool for the evaluations of the MBSR application primarily consisted of WPI students. The participants were recruited through email and social media. The
advertisement for the user study promoted the chance to win a gift-card as incentive to gather more participants. Our goal was to gather thirty participants. The participants were enrolled in the user study through email, and were given a link to download the application and the accompanying survey. The survey includes an informed consent form. The full informed consent form can be seen in Appendix B. If the participant consented, the survey will ask the participants to perform several tasks and answer several questions. Otherwise, if a participant has not consented then the survey will end.

5.2 Data Collection

Participant interactions with the application were logged. For privacy purposes the data that was collected was not able to identify the participant. The type of data that was recorded includes, how many clicks it takes for a participant to reach a certain page, the time it takes for a participant to complete a task, and what pages the user accessed the most.

The data that was collected from the survey that consenting participants received includes their preferences on where specific UI components should be located in the video player, the functionality of each UI component, and any additional feedback. From this survey, participant responses will be recorded through Qualtrics. Below is the protocol for the user study aimed at evaluating the video player component. The complete protocol can be seen in Appendix C.
Table 7: User Study Protocol for Evaluating a Video Player Component

Participants are recruited through email and social media.

Recruited participants will be given a link to download the application and a link to the survey.

During the User Study:

[Informed Consent Form is presented in the survey]

[Participants confirm ‘Yes. I do consent.’ or ‘No. I do not consent.’ through the survey]

[If yes]

The participant will perform tasks and answer questions. At the end the participant will have the chance to enter an email address to enter to win a gift card.

[If no]

The survey will end and the participant will be thanked for their consideration.

<table>
<thead>
<tr>
<th>Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>From the main menu, navigate to the video exercises screen.</td>
</tr>
<tr>
<td>Select a video of your choosing in the feed, and start it by pressing the “play” button.</td>
</tr>
<tr>
<td>Tap and drag the progress bar on-screen to scrub to various points in the video stream.</td>
</tr>
<tr>
<td>Tap the “fullscreen” button on the top right corner of the video player to toggle fullscreen mode.</td>
</tr>
<tr>
<td>Drag the audio slider to adjust the audio levels of the video stream.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Included is a screenshot of the same video component in a previous iteration. Compared with this screenshot, are there any noticeable differences in the player you’ve interacted with that make the component more appealing?</td>
</tr>
<tr>
<td>Does this video player effectively accomplish the tasks that were given to you?</td>
</tr>
<tr>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>On a scale of 1 to 10, please rate your user experience in performing the instructed action.</td>
</tr>
<tr>
<td>For each of the following pieces of the video player, rate your overall user experience on a scale of 1 to 10: play/pause button, video progress bar, volume slider, fullscreen button</td>
</tr>
<tr>
<td>Is there anything about the video player that particularly appealed to your experience?</td>
</tr>
<tr>
<td>Is there anything about the video player that particularly hindered your experience?</td>
</tr>
<tr>
<td>Please provide any questions, concerns, or suggestions you may have pertaining to this component and your experience with it.</td>
</tr>
</tbody>
</table>

6.0 Analysis and Results

The testing period began on November 18th, 2020 and concluded on December 5th, 2020. The user study generated a large amount of data, both from the survey and the app interactions. To facilitate the analysis process, the survey data was exported to a spreadsheet program to produce various graphs and data summaries. App usage data from the event system was queried and stored as a JSON file, that was then read in with a Python script to create figures using the matplotlib library. Data from the surveys and app interactions required organizing and filtering to produce visualizations.

6.1 Survey

In total, there were 30 survey responses submitted and several uncompleted surveys. Only the 30 surveys that were submitted were included in the analysis. Surveys were recorded using Qualtrics and then exported to a spreadsheet program. After exporting, the data was compiled into one sheet. In order to make sense of the data, we segmented the feedback into separate sheets. Each question in the survey had its own corresponding sheet to make the analysis and visualization process organized.
There were three question types asked in the survey: multiple choice, Yes/No, and open ended. The multiple choice questions regarded the position of different video player components. The responses for the multiple choice questions were analyzed by counting the occurrences of each possible choice. The Yes/No questions were to identify if the video player component the user interacted with was functional. The responses to the Yes/No questions were analyzed by the occurrences of each answer. The open ended questions were used to gather feedback on what the users liked and disliked about the video player. The open ended responses were analyzed by sentiment, which led to several themes to emerge. Each theme that emerged was coded with a different color to organize the varying sentiments.

The first set of questions asked in the survey regarded the positioning of various video player components. The first question was, “The Play/Pause Button is located at the Bottom Left corner of the video player. If you were to redesign the video player to make it more attractive, where would you place this button?”. When asked where to place the play/pause button, 70% of respondents agreed to leave the play/pause Button in the bottom left corner. However, there were a few responses indicating the Center of the screen would be a better position. According to Nielsen’s Heuristic: Match between system and real world, the position of the Play/Pause Button is where most people would expect it to be. Furthermore, several popular video players including Google Chrome’s, position the play/pause button in the bottom left corner. The distribution of responses can be seen in Figure 6.

![Figure 6: Play/Pause Button Position Response Distribution](chart)
The second question was, “The Fullscreen Button is located at the Top Right Corner of the video player. If you were to redesign the video player to make it more attractive, where would you place this button?”. When asked where to place the fullscreen button, 57% of respondents agreed to leave the fullscreen button in the top right corner. However, 43% of responses indicated the bottom right corner of the screen would be a better position. According to Nielsen’s Heuristic: Match between system and real world, the position of the fullscreen button is where most people would expect it to be, though many did not find that true. From the responses, we can see that respondents found both of the positions to be true to what they have previously experienced with video players. The YouTube video player positions its fullscreen button in the bottom right corner, and the Hulu video player positions its fullscreen button in the top right corner, thus in the market there is no consensus where to position the fullscreen button. The distribution of responses can be seen in Figure 7.

![Figure 7: Fullscreen Button Position Response Distribution](image)

The third question was, “The Volume Button is located at the Top Left Corner of the video player. If you were to redesign the video player to make it more attractive, where would you place this button?”. When asked where to place the volume button, 60% of respondents agreed to leave the volume button in the top left corner. However, several responses indicated the bottom left and right corner of the screen would be a better position. In the additional feedback, we received comments about the necessity of volume buttons as a UI component because most modern phones have the physical volume buttons. From our analysis and discussions of the data
we concluded that it was better to keep the implemented volume button than to remove it. The distribution of responses can be seen in Figure 8.

![Volume Slider Button Position Response Distribution](image)

**Figure 8: Volume Slider Button Position Response Distribution**

The final questions were Yes/No in asking, “When you adjusted the component on the video you interacted with, did its position reflect what you would expect it to?” The component refers to the video progress bar, volume slider, fullscreen, and play/pause buttons. As we expected, a majority of responses agreed that the UI components worked as they were intended to. The distribution of responses can be seen in Figure 9.

![Component Functionality Response Distribution](image)

**Figure 9: Component Functionality Response Distribution**
In addition to the quantitative data we gathered from the survey, we also gather qualitative data in the form of short responses. Following the Yes/No questions, the respondents were asked if they had any additional feedback, in terms of things they liked and disliked about the video player. To analyze the data we marked the responses based on their sentiment, positive (likes) feedback was coded green and negative (dislikes) feedback was coded red. During our analysis, we saw several themes emerge from the feedback. From there, additional coding was done based on the content of the feedback. The distribution of themes produced from the additional comments can be seen in Figure 10.

![Figure 10: Emergent Themes from the Additional Comments](image)

### 6.2 App Interaction

From the testing period of November 18th, 2020 to December 5th, 2020, 2,275 events were recorded across 39 different devices using the newly developed in-house event system. Although the number of unique devices is accurate, it is inconsistent with the fact that only 30 surveys were submitted. Upon closer inspection, 51 events across five devices showed minimal correlation with any tasks requested of participants, and were removed from analysis. Although events from four devices that did not partake in the survey are still included, their activity did not prominently stand out enough to confidently identify them and omit them from the rest of the dataset.

In addition to the aforementioned erroneous events, it was recorded that seven participants started using the app, left it, and continued at a later point in the day. It is possible that these participants started the study and wanted to continue it later, or that they simply
wanted to try the app out more. Because the amount of time spent using the app is determined by differences of event timestamps, these participants initially appeared to have spent significantly long periods of time in the app. To reflect their usage more accurately, time differences of 60 minutes or more between two events on the same device were omitted from analysis. When a 60+ minute gap between events occurred, the timestamps of subsequent events on the devices were shifted such that all of the participant’s usage appeared to happen in one sitting.

One of the attributes recorded from the app interactions was IPv4 addresses. The IP addresses recorded were not linked to any sensitive participant data. To understand where participants were roughly located we mapped the locations of participants on a map. We produced this visualization to understand why there may have been latency related problems with several participants. The distribution of estimated participant locations can be seen below.

**Figure 11**: Estimated locations of study participants by IPv4 address

In addition to the IPv4 addresses, the event types (Navigation, ButtonPress, VideoVolume, VideoFullscreen, VideoSeek, and VideoToggle) were recorded. Based on the tasks users were asked to perform, we would expect the Navigation and ButtonPress events to be used most followed by the various video player events. From our analysis, this was true, where 36.6% of events were ButtonPress, 28.9 were Navigation, followed by the video player events.
Although the event definition for ButtonPress events mentions that the only buttons tracked are for navigation, there are more Navigation events than ButtonPress events. This is mainly because there are in fact buttons that fired ButtonPress events (namely on the Timer screen) that are not used in navigation. The notion that the ButtonPress events only fire from navigation may only be implied if the user only interacts with the VideoExercises screen. However, as the Navigation event data suggests, many participants explored other areas of the application not specified in the instructions. The distribution of the event types can be seen below.

![Event Distribution by Type](image)

**Figure 12**: Distributions of each event type that was recorded

One of the metrics we included in our event system was the time of an event being fired. To analyze the time data we calculated the time each user spent using the application and then visualized the results in the form of a histogram. There were a few users that spent more than sixty minutes using the application, those time differences were omitted from the visualization. We can see that most users spent roughly four to eleven minutes using the application. The distribution of time spent using the application can be seen below.
To further analyze the time recorded, an additional analysis was done to visualize the screens users spent the most time on. Based on the survey, the screens that the users were asked to visit include the Home screen and the Video Exercises screen. As expected, the Home and Video Exercises screens were the top two screens participants spent the most time on. From the data we learned that users spent time visiting the other screens on the application. This could mean that users may have been interested in the other features of the application. The distribution of the cumulative time spent on each screen can be seen in the bar chart below.

Figure 13: Total time each participant spent using the app
In addition to visualizing the distribution of the cumulative time spent on each screen, we also visualized each of the participants' time spent on a screen. The visualization reinforces that most participants spent between four and eleven minutes using the application. Moreover, several participants explored the applications by navigating to various other screens. The distribution of time spent on each screen per participant can be seen in the stacked bar chart below.

**Figure 14**: Cumulative time spent on each screen
Figure 15: Cumulative time spent on each screen of the app across all participants

Based on our analysis, we had several findings regarding the functionality, user experience, and usability of the application. The following are a summary of our findings:

1. The positioning of the UI video components should match the real world (Nielsen’s Heuristic)
2. The video player components (Video Progress Bar, Volume Slider, Fullscreen, and Play/Pause Buttons) worked as they were intended to
3. Issues regarding video loading/buffering/latency may be due to the distance from the MBSR server (Worcester, MA)
4. There was interest in the other screens and features of the application

6.3 Component Iteration

Following our analysis and results, we created a chart to identify areas in the application that would require changes to be made, changes not to be made, and items that were ambiguous and required more thought. The table can be seen below.
<table>
<thead>
<tr>
<th>Change</th>
<th>Not Change</th>
<th>Ambiguous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make video controls disappear slower</td>
<td>Button functionality</td>
<td>Implement Mute/Unmute or get rid of the Volume Slider</td>
</tr>
<tr>
<td>Less abrupt, more time for a user to make a decision</td>
<td>85%-90% of users stated that the buttons were functional</td>
<td>Phones already have physical volume buttons Keep the component to retain the implementation</td>
</tr>
<tr>
<td>Increase the size of the volume slider hitbox</td>
<td>Play/Pause Button location</td>
<td>Implement a fast forward/rewind button</td>
</tr>
<tr>
<td>More area and control for a user</td>
<td>The location is standard, users expect it to be placed in the Bottom left Corner</td>
<td>A few users reference popular video players that incorporate this</td>
</tr>
<tr>
<td>The Fullscreen Button location</td>
<td>Video buffering/loading speed</td>
<td>The latency of the video’s was commented on by several users in the additional feedback</td>
</tr>
<tr>
<td>Video scrubbing bar location</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Icons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Users wearable to interpret the meaning of the icons as intended</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Based on the results in the table above, the items listed in the Change column will be iterated upon to improve the application. The items were chosen based on the feasibility and the time it would take to complete the implementation. The changes to be implemented are the time it takes for the UI components to disappear in the video exercise and increasing the area of the hitbox for the volume slider.

7.0 Conclusion

From the beginning of the project in 2015, the application was intended to disseminate MBSR resources to individuals interested in mindfulness, the 2017 and 2019 projects continued in this direction. This project continues to extend this vision through the continual development of the MBSR mobile application. Thus, the final deliverable of this project is the MBSR mobile application with the newly implemented native video player and event system. The source to the MBSR mobile application can be found here and a video showcasing the application can be found here. To replace the webview, the react-native-video library was integrated to stream and render video. Additionally, the react-native-video-controls library was also used to provide play, pause, volume, scrubbing, and fullscreen controls to the new video player. The UI components allowed for more customization including larger icons and hitbox areas.

The event system was created to record and send usage information while the app is in use. The system operates from the MBSR server. Since a REST API already existed for the phone to connect to the MBSR server, it was easy to extend the API to include endpoints for events. Events are also stored in the MongoDB database, which makes for secure storage and simple retrieval. The event system was integral to the user study evaluations. Moreover, the event system provides additional value to the application by providing accurate recording of interactions that could be beneficial to content managers.

The evaluation of the mobile application was done through user studies to assess the video player component for its usability, user experience, and performance. To recruit participants for the user study, we sent emails to computer science students at WPI and posted on online forums. We provided interested participants with a link to a Qualtrics survey and a link to download a distribution of the application. Within the survey was an informed consent form and several tasks involving the video player component. The tasks participants were asked to perform involved navigating to specific screens and pressing buttons on the video player in a predetermined order. Following the execution of the tasks, participants were asked where they
would place the video player UI components to make it more attractive and if the UI components worked as they expected it to. Participant responses and their interactions in the mobile application were then recorded.

In total, we had thirty participants submit the survey and 2,275 events recorded across 39 devices. From the surveys, most people agreed that the Play/Pause and Volume slider should stay in the bottom left corner and top left corner respectively. Participants were split as to where to position the fullscreen button. Regarding the functionality, a majority of participants agreed that the buttons worked as intended. From the app interaction data we learned that participants spent 5 to 10 minutes interacting with the app. Also, several participants spent time exploring other screens on the application.

7.1 Refactoring

Multiple portions of the project’s codebase were refactored after the user study to prepare for potential future development. The Strapi CMS was updated to the latest stable release (3.5.2 as of March 2021). Additionally, a custom bootstrap script for the CMS was created such that a default administrator account is created automatically when the backend is deployed for the first time. The credentials for this account are stored in an environment file that is read on startup, so the MBSR server knows what credentials to use for authentication before the account is even created.

The Docker Compose configuration file was also updated to work across different host operating systems. Originally, the containers were configured with “host” networking mode, meaning that each service was bound to the same IP address as the host machine. As was discovered at the beginning of this MQP, host networking only works on Linux based operating systems. To accommodate for potential development on Windows or Mac OS in the future, the Docker Compose configuration was updated to use “bridge” networking mode instead. With bridge networking, a virtual network is created that each container uses to communicate with each other. Each container on the bridge network gets its own IP address that can be used to access the container from the host machine. However, if the host machine is running Windows, bridge network IP addresses can only be used by the host if the base OS of the container is also Windows (as opposed to a Linux-based container). Additionally, host machines running Mac OS are unable to access containers by bridge IP address at all. As a solution, each container in the Docker Compose configuration also has the ports it listens on bound to the host machine. This
allows for the host machine to access containers from localhost or the IP address of the host machine. Though this configuration has not yet been tested on Windows, it has been tested on Mac OS with success.

The README.md file in the project’s repository was modified to include up to date instructions on how to deploy the development environment with commands and screenshots for actions at each step. Several troubleshooting steps were also added, including the aforementioned issue regarding container access by bridge IP address from a non-Linux host.

Although the Timer screen was not a primary focus for this MQP, a new bug was discovered when recording the application for demonstration footage. This bug caused the increment and decrement (+/-) buttons on the screen to have a one press delay. That is, nothing would occur on the first press, and subsequent presses would act in response to the previous increment/decrement button press. A race condition was discovered that caused the remaining time to be updated after the countdown-component was re-rendered on screen. Callbacks for both buttons were updated such that the component is only re-rendered after the new state for the remaining time is set, which resolved the issue.

**7.2 Future Work**

Throughout the course of the project, several areas of future work emerged. Future project work could involve the implementation of live streaming for real-time practice, addressing latency in video transmission, or expand the utilization of the account system. Ultimately, we believe that further research should be performed prior to continuing development such that a clear plan for how the app will be used in production is established. Further research is required to answer the following questions:

1. Who is the target audience of the application? (college students, individuals enrolled in a MBSR course, anyone interested in mindfulness)
2. How should content be organized on the application? (by theme, difficulty of exercise, content length, upload date?)
References


https://www.nimh.nih.gov/health/statistics/mental-illness.shtml#:~:text=Mental%20illnesses%20are%20common%20in,(46.6%20million%20in%202017).


### Appendix A: Project Timeline

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<th>No.</th>
<th>TASK TITLE</th>
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<th>DUE DATE</th>
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Appendix B: IRB Approval

Worcester Polytechnic Institute
100 Institute Road, Worcester MA 01609 USA

Institutional Review Board
FWA #00015024 - HHS #00007374

Notification of IRB Approval

Date: 08-Oct-2020

PI: Corbitt, Bryce

Protocol Number: IRB-21-0045

Protocol Title: Evaluate Mobile Application for Mindfulness-Based Stress Reduction

Approved Study Personnel: Corbitt, Bryce~Patel, Pooja~Neamtu, Rodica~

Effective Date: 08-Oct-2020

Exemption Category: 3

Sponsor*:

The WPI Institutional Review Board (IRB) has reviewed the materials submitted with regard to the above-mentioned protocol. We have determined that this research is exempt from further IRB review under 45 CFR § 46.104 (d). For a detailed description of the categories of exempt research, please refer to the IRB website.

The study is approved indefinitely unless terminated sooner (in writing) by yourself or the WPI IRB. Amendments or changes to the research that might alter this specific approval must be submitted to the WPI IRB for review and may require a full IRB application in order for the research to continue. You are also required to report any adverse events with regard to your study subjects or their data.

Changes to the research which might affect its exempt status must be submitted to the WPI IRB for review and approval before such changes are put into practice. A full IRB application may be required in order for the research to continue.

Please contact the IRB at irb@wpi.edu if you have any questions.
Institutional Review Board
FWA #00015024 - HHS #00007374

Notification of IRB Approval

Date: 17-Nov-2020

PI: Corbitt, Bryce
Protocol Number: IRB-21-0045
Protocol Title: Evaluate Mobile Application for Mindfulness-Based Stress Reduction

Sponsor*: 

The WPI Institutional Review Board (IRB) approves the modification submitted on 17-Nov-2020 to the above-referenced protocol.

This modification does not extend the expiration date of your approval. The previous approval remains in effect from 17-Nov-2020 until 07-Oct-2021 unless terminated sooner (in writing) by yourself or the WPI IRB. If the research is to continue past 07-Oct-2021, you must submit a Study Renewal form to the IRB via InfoEd, at least 30 days prior to expiration.

to add a raffle for participants

Please contact the IRB at irb@wpi.edu if you have any questions.

*if blank, the IRB has not reviewed any funding proposal for this protocol
Appendix C: Evaluation Informed Consent Form

Informed Consent Agreement for Participation in a Research Study
MBSR App Usability Study Consent Form

*This Informed Consent Form will be presented through a Qualtrics Survey*

Investigators:
Bryce Corbitt (SI, bscorbitt@wpi.edu), Pooja Patel (SI, ppatel2@wpi.edu),
Rodica Neamtu (PI, rneamtu@wpi.edu)

Title of Research Study:
Evaluate Mobile Application for Mindfulness-Based Stress Reduction

Introduction
You are invited to participate in a Worcester Polytechnic Institute (WPI) sponsored research project about Mindfulness-Based Stress Reduction (MBSR). Your input is very important to this research. Participation is voluntary and you may end your participation at any time, but we hope that you will find your continued participation valuable and worthwhile. This form presents information about the study so that you may make a fully informed decision regarding your participation.

Purpose of the study:
The purpose of our usability study is to evaluate the user experience and usability of particular components in a Mindfulness-Based Stress Reduction mobile application.

Procedures to be followed:
As part of the survey you will be asked to download and install a mobile app to your Android phone or Android emulator. We provide step-by-step instructions for how to download (and install/uninstall the emulator from your computer if applicable). Through an accompanying Qualtrics survey, investigators for this research study will present you with predefined tasks to complete. Your interactions in the app will be logged. The Qualtrics survey will also ask you questions about your experience to complete after the tasks are done. This user study will take around 10-15 minutes.

Record keeping and confidentiality:
Your interactions with the app will be logged. Your survey responses will be recorded through Qualtrics. Records of your participation in this study will be held confidential. Any publication or presentation of the data will not identify you. Sensitive information will not be recorded in this study.

Your participation in this research is voluntary.
By clicking “Yes, I do consent.” below you are consenting to participate in this research. Or by clicking “No, I do not consent.” below you are not consenting to participate in this research.

*The participant will then check a box to confirm that they consent to participate in the study or that they do not consent to participate in the study. The survey will then direct the participant if they have consented, to enter their email address, area of study, and select their phone, frequency of phone use, primary purpose of phone use. Otherwise, if they do not consent the survey will end*
Appendix D: Evaluation Protocol

User Study Protocol

This user study will be used to evaluate the effectiveness of newly implemented features of a prototype application for Mindfulness-Based Stress Reduction (MBSR).

Recruited participants will receive an email including a link to a distribution of the prototype app with installation instructions, as well as a link to a corresponding Qualtrics survey. Within the survey, participants will be asked to perform predefined tasks and respond to questions. Following the execution of all of the tasks, the participants will be asked questions regarding their experience using the application. The survey responses will be recorded through Qualtrics. Additionally, the participants’ interactions with the app will be logged to assess timing and application performance. The following are potential tasks that the participant will be asked to do:

1. From the main menu, navigate to the video exercises screen.
2. Select a video of your choosing in the feed, and start it by pressing the “play” button.
3. Tap and drag the progress bar on-screen to scrub to various points in the video stream.
4. Tap the “fullscreen” button on the top right corner of the video player to toggle fullscreen mode.
5. Drag the audio slider to adjust the audio levels of the video stream.

The following are potential question areas to be covered on the survey:

1. Included is a screenshot of the same video component in a previous iteration. Compared with this screenshot, are there any noticeable differences in the player you’ve interacted with that make the component more appealing?
2. Does this video player effectively accomplish the tasks that were given to you?
3. On a scale of 1 to 10, please rate your user experience in performing the instructed action.
4. For each of the following pieces of the video player, rate your overall user experience on a scale of 1 to 10:
   - Play/Pause button
   - Video progress bar
   - Volume slider
   - Fullscreen button
5. Is there anything about the video player that particularly appealed to your experience?
6. Is there anything about the video player that particularly hindered your experience?
7. Please provide any questions, concerns, or suggestions you may have pertaining to this component and your experience with it.
Appendix E: Meeting Minutes Sample

MQP Meeting Minutes for 11/18/20

Updates:
● Recruitment Email/User Study Survey updated
● IRB Approved Amendment
● Trial Run
● Configured testing environment
● Events for video player
● Release APK finalized
● UI modifications
● Fullscreen functionality on video player

During the Meeting:
● Trial Run was done
  ○ Changes were made to survey to provide more clarity
● Discussed the events for video player
  ○ Events for the play/pause, full screen, volume, and the position in the video
● Improvements made to the application
  ○ The volume slider in the video player moved
  ○ The notification bar is now hidden in the full screen mode of the video player
  ○ Throughout the app the notifications bar is transparent
● Discussed MQP report
  ○ Will send out report re-write for Friday that includes Introduction/ Background/ Methodology
  ○ Include a section in the report that discusses the event logging
    ■ Mention how we can monitor the most viewed video, how we collect user stats, what each event is
    ■ The potential that the event logging can have insights to how users watch videos and what they are engaging with
  ○ For end of B Term have the implementation and evaluation methodology written
● Recruitment/evaluations will begin today
  ○ We will send out recruitment email/posts
    ■ If we are unable to send the email to the CS majors then we will let Professor Neamtu know
  ○ If we don’t get many responses by Friday send out a refresher

Plans for Next Week:
● No Meeting Next Week
● Maybe send out a refresher if we don’t have many participants for evaluations