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Use of Adaptive Mobile Applications to Improve Mindfulness

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USE OF ADAPTIVE MOBILE APPLICATIONS TO IMPROVE MINDFULNESS

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Computer Engineering

By

Wiehan Boshoff
B.S.C.E., Wright State University, 2016

2018
Wright State University
I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY Wiehan Boshoff ENTITLED Use of Adaptive Mobile Applications to Improve Mindfulness BE ACCEPTED IN FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF Master of Science in Computer Engineering.

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ABSTRACT

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Mindfulness is the state of retaining awareness of what is happening at the current point in time. It has been used in multiple forms to reduce stress, anxiety, and even depression. Promoting Mindfulness can be done in various ways, but current research shows a trend towards preferential usage of breathing exercises over other methods to reach a mindful state. Studies have showcased that breathing can be used as a tool to promote brain control, specifically in the auditory cortex region. Research pertaining to disorders such as Tinnitus, the phantom awareness of sound, could potentially benefit from using these brain control strategies as the auditory cortex is suspected of being the region in the brain responsible for the production of symptoms associated with Tinnitus. Mobile Applications have become an increasingly popular tool, due to their accessibility, that can be used to promote mindfulness, and as a result help patients cope better with Tinnitus. Using applications to guide patient’s breathing patterns could be a more desirable and effective method to attaining a more mindful state. This study explores the effectiveness of such an application, and how the application can modified to be adaptive towards each individual user. Two questionnaires, Attentional Control Scale (ACS) and Mindful Attention Awareness Scale (MAAS), are used to measure self-reported attentional control and mindfulness. The results obtained from the questionnaires along with number of times the application was used, were used to determine which features, and whether using the application more times, had an effect on a participant’s mindful score. Machine learning regression trees and ANOVA was used as part of the analysis, but due to lack of data, concrete conclusions on whether using the application more times has a better affect on a participant’s mindfulness could not be established. That said future work will include a larger more diverse dataset which could allow us to make more accurate conclusions about this study.
## Contents

1 Introduction and Motivation ..................................................... 1  
1.1 Motivation .............................................................................. 2  
1.2 Research Objective ................................................................. 3  

2 Background .............................................................................. 4  
2.1 Attentional Control Scale (ACS) ............................................. 4  
2.2 Mindful Attention Awareness Scale (MAAS) ............................. 6  
2.3 Decision Trees ....................................................................... 6  
2.4 Research Questions ................................................................. 10  

3 Methodology ............................................................................. 12  
3.1 Aim 1: Assess Strategies for Neuroplastic Brain Control .......... 12  
3.2 Open and Closed Card Sort Analysis ....................................... 13  
3.3 Aim 2: Design and Implement an Easy to Use Training Regimen for Neuroplastic Brain Control ..................................................... 15  
3.4 Smartphones Applications for improving Mindfulness and Tinnitus Management ................................................................. 17  
3.5 Design Guidelines ................................................................... 18  
3.6 Design of the Application .......................................................... 20  
3.7 Design Evaluation .................................................................... 30  
3.8 ACS and MAAS Data Collection .............................................. 32  
3.9 ACS and MAAS Data Collection - Pilot Study (Heuristic Evaluation) ...................................................................................... 33  
3.10 Classification Tree Analysis ..................................................... 33  
3.11 ANOVA Analysis .................................................................... 35  

4 Results and Discussion ................................................................. 36  
4.1 Results ..................................................................................... 37  
4.2 Discussion .............................................................................. 49  

5 Conclusion and Future Work ....................................................... 50  
5.1 Conclusion .............................................................................. 50  
5.2 Future Work ............................................................................ 51  

Appendices .................................................................................. 52  

List of Figures

2.1 An example of a decision tree model. ........................................... 9
3.1 Closed Card Sort Responses - Bar Plot ........................................ 14
3.2 Brain Control Strategy Responses - Word Counts .......................... 15
3.3 Landscape Analysis of Android Tinnitus Management/Mindfulness Applications .................................................. 16
3.4 Honeycomb Model .................................................................... 19
3.5 Initial Startup Screen ................................................................. 20
3.6 Home Screen ........................................................................... 20
3.7 Internal Storage Files .................................................................. 21
3.8 User Navigation File Content ...................................................... 21
3.9 Do Not Disturb Warning Screen .................................................. 23
3.10 Do Not Disturb Access Screen .................................................... 23
3.11 Airplain Mode Warning Screen ................................................... 24
3.12 Tutorial Screen 1 ....................................................................... 25
3.13 Tutorial Screen 2 ....................................................................... 25
3.14 Tutorial Screen 3 ....................................................................... 25
3.15 Tutorial Screen 4 ....................................................................... 25
3.16 Tutorial Screen 5 ....................................................................... 26
3.17 Exercise Screen ......................................................................... 28
3.18 Earphones Absent Screen ........................................................... 28
3.19 No Distractions Screen ............................................................... 29
3.20 No Distractions Screen 2 ............................................................. 29
4.1 ACS vs App Uses vs MAAS .......................................................... 37
4.2 ACS Question 6 .......................................................................... 38
4.3 ACS Question 12 ......................................................................... 39
4.4 ACS Question 16 ......................................................................... 40
4.5 Complete Decision Tree ............................................................... 41
4.6 Number of Times Using the Application vs MAAS - Scatter Plot .... 42
4.7 Subset Decision Trees One and Two .............................................. 43
4.8 Subset Decision Trees Three and Four .......................................... 44
4.9 Subset Decision Trees Five and Six ............................................... 45
4.10 Subset Decision Trees Seven and Eight ........................................ 46
4.11 Decision Tree MAAS Predictions
List of Tables

3.1 User Experience Honeycomb Model Survey . . . . . . . . . . . . . . . . . 30
3.2 User Experience Honeycomb Model Survey Results . . . . . . . . . . . . . 31

4.1 App Uses vs MAAS - Analysis of Variance . . . . . . . . . . . . . . . . 47
4.2 App Uses vs MAAS - Means for Oneway Anova . . . . . . . . . . . . . 47
4.3 App Uses vs MAAS - Ordered Difference Report . . . . . . . . . . . . . 47
4.4 App Uses and ACS vs MAAS - Analysis of Variance . . . . . . . . . . . 48
4.5 App Uses and ACS vs MAAS - Effect Test . . . . . . . . . . . . . . . . 48
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1

Introduction and Motivation

During our lifetime our brain has the ability to reorganize itself and induce novel responses by changing neural connectivity in response to stimulus, injury, or disease. This concept is known as neurplasticity. The functionality of a person’s brain is affected by their thoughts, experiences, actions, emotions, and behaviors. That means using your conscious mind you can make changes in your brain that last, which might have enduring benefits [19]. Mindfulness exercises have been shown to have the capacity to influence this process, as they can be used as neuroplastic brain control techniques [15]. Neuroplastic brain control is simply the process of voluntarily changing the way your brain functions.

There are varying definitions of mindfulness. One of which is “paying attention in a particular way: on purpose, in the present moment, and nonjudgmentally” [8]. Another way of explaining it is that mindfulness is the state of retaining awareness of what’s happening at this instant. Mindfulness has proven to have a number of positive effects on individuals. One of the most notable is stress reduction [11]. Research has indicated that mindfulness
is opposingly interconnected to stress at the trait level [8]. In other words, people who are more mindful undergo less stress, and are more inclined to handle stress better than people who are less mindful. It is also found that mindfulness is opposingly associated to stress at the within-person level. This means practicing mindfulness daily can potentially reduce daily stress [8]. Stress reduction along with some of the other benefits of mindfulness such as relaxation, and improved state of alertness could especially be helpful in disorders such as Tinnitus. Tinnitus is regarded as the phantom awareness of sound which includes a variety of perceived noises, but also not limited to: ringing, buzzing, and in some cases hissing [15].

1.1 Motivation

This study is aimed to explore the effectiveness of using mindfulness techniques in mobile applications, to help participants increase their mindfulness level.

   Previous work relating to a Mindfulness Based Stress Reduction (MBSR) study found that Tinnitus symptoms and neuroimaging changes in functional connectivity have been lowered after 8 weekly, 2-hour MBSR sessions, and a single 3 hour retreat. The content of the sessions included instruction in meditation, movements, as well as exercises to promote mindfulness. Peelle et al., determined that MBSR comes forth as being a helpful approach to reduce the symptoms of Tinnitus in patients. The study points out that MBSR is economical, noninvasive, and takes advantage of the brains neuroplasticity which might produce enduring benefits [11].
As mentioned, there have numerous approaches to create methods and tools that lower the costs associated with Tinnitus, as well as increase the effectiveness of management of the underlying symptom. Multiple research studies have demonstrated that Tinnitus treatment delivered via the internet suggests to be effective, particularly pertaining to time, and costs to receive treatment [8]. Due to the accessibility of smartphone applications, they are becoming increasingly popular as a means of improving mindfulness.

According to the American Tinnitus Association more or less 20 million people are faced with oppressive Tinnitus in their daily lives, and furthermore it’s speculated that about 2 million individuals are faced with acute tinnitus that affects the quality of their lives in a devitalizing manner [15].

1.2 Research Objective

The overall goal of this study is to explore and determine the effectiveness of using mindfulness in mobile applications:

(a) The first aim of this research study is to assess which strategies for neuroplastic brain control was self-reported to be most effective in increasing mindfulness

(b) The second aim is to design and implement an easy to use training regimen for neuroplastic brain control.

(c) The third and last aim of this study is to explore the use of an adaptive training regimen for increasing mindfulness.
2

Background

In this chapter we will explain the different Questionnaires that was used in the study to collect data, and the machine learning techniques used to process that data in order to make an effective evaluation.

2.1 Attentional Control Scale (ACS)

Attentional Control Scale (ACS) scores are used to reflect an individual’s ability to control their attention voluntarily. The questionnaire includes 20 questions such as, ”It is difficult for me to coordinate my attention between the listening and writing required when taking notes during lectures.” The full list of questions is included in Appendix A. ACS has been applied to research models where independent differences in the ability to control attention as a source of resilience or vulnerability. In these research models, the ability to control attention decreases elements that have an effect on emotional, neurophysiologic, and behavioral results [20].
ACS has been demonstrated to be a useful tool in measuring self-reported attentional control. Williams et al. (2017) state that self-reported attentional control has been used in studies involving functional neuroimaging, association connection activation of rACC and low self-esteem, and defensive effects of attentional control. It was found that attaining higher scores on the ACS meant better emotional regulation in reaction to fear. ACS scores have also help indicate negative association in the relationship of positive affect and social anxiety. ACS scores have also suggested a relationship between fear of public speaking and speech performance, as well as a relationship between insomnia and negative feelings [20].

Another study, with respect to the relationship between ACS and attentional control, suggests that evidence is appearing that anxiety and depression can be lessened by initiating in mindful based exercises that includes attentional control training by introducing meditation-like activities [9]. ACS will be used in this study to try and determine if, and what features of the ACS questionnaire has an affect on an individual’s mindfulness level. Participants will fill out the ACS questionnaire, participate in a mindful based exercise via a mobile application, then have their mindfulness level measured. So in order to analyze a individual’s mindfulness we studied the Mindful Attention Awareness Scale (MAAS) which is discussed in the next section.
2.2 Mindful Attention Awareness Scale (MAAS)

One of the means to measure mindfulness is with the Mindful Attention Awareness Scale (MAAS). It is a 15-question survey where each individual question is rated from 1-6 on a Likert scale. 1 indicates ”Almost Always”, and 6 ”Almost Never”. An example of one of these questions would be, ”I rush through activities without being really attentive to them” The complete set of questions is available in Appendix B. The approach the questionnaire takes is to ask participants in the present moment how often they run into experiences of not being attentive to what is happening around them.

Osman et al. (2016) state that there were positive correlations with MAAS scores and other mindful- and mindlessness measures. They also found negative correlations with assessments scores of depression, anger, and stress. Negative correlations between MAAS and assessments scores of self-monitoring, and social appeal, were also reported [10]. Another study conducted on the relationship between mindfulness and psychopathology, also states that normal subjects showcase greater mindfulness than participants with clinical symptoms of both depression and/or anxiety, by measuring mindfulness with MAAS [1].

2.3 Decision Trees

Machine learning classification algorithms is the process for choosing a hypothesis from an arrangement of choices that best fits an arrangement of perceptions. The first thing to note about classification algorithms is that the model needs to be trained with a set number
of inputs and their corresponding output labels. The accuracy of the classification algorithm can be determined by setting aside a set number of input samples from the training set. Running these inputs through the model will give you an estimation of how well the classifier can predict the output of the given input [6].

Decision Trees is a type of classification model. They are easy to understand, suitable for variable selection, and decently robust on smaller datasets. Decision Trees are usually composed out of nodes that represent decision nodes or terminal nodes. Their branches allow you to go one of two ways from the current node to another. Decision trees used for machine learning classification or regression, takes a row of data (categorical features), and begins at the root, and then visits each following node till the terminal node is reached. The root node of the Decision Tree divides the dataset using the input feature that represents the top dividing metric assessed for all subtrees in the dataset resulting from this divide. The terminal node is reached once the dividing metric is at the maximum or minimum of the learning function. This is useful as you can determine from inspecting a decision what input features have the greatest affect on the output labels [6], [7].

Decision Trees have been used to evaluate numerous datasets, and have proven to be successful to accurately predict outcomes from a variety of specified feature data [3], [13], [17]. A study pertaining to differential diagnosis of eating disorders was able to predict healthy patients with 100% accuracy, patients with bulimia with 78.72% accuracy, and anorexia with 86.36% accuracy [3]. Another study pertaining to a Decision Tree approach to assess Posttraumatic Stress Disorder(PTSD) was able use decision trees and predict the
PTSD with 94.2% accuracy using Clinician-Administered Posttraumatic Stress Disorder Scale (CAPS) results [17]. Moreover a study exploring how viable Decision Trees can be, when used to diagnose breast cancer, from breast FNAC results, has showed that the C4.5 algorithm (one of the most popular algorithms to build decision trees) can produce accurate results. In the study Sarka and Nag was able to predict outcomes from the dataset with 96.71% accuracy [13].

Open source machine learning and data mining software are available, that allow users to quickly set up machine learning models for testing. Orange is but one of these software platforms that includes visual representations of the models that you can build. These models can be trained, tested and analyzed to better understand the data that you are working. Orange was developed and continues to be maintained by the Bioinformatics Laboratory of the Faculty of Computer and Information Science at the University of Ljubljana [6]. Figure 2.1 below is a representation of how a Decision Tree model would be set up in Orange with training data, test data, and visualization tools.
The Tree model inside Orange can be used as both a Regression Tree or a Classification Tree. Regression Trees are used when the target value is continues or numeric in nature. Classification Trees are used when the target value is categorical in nature. For this study the Decision Tree model in Orange will act as a Regression Tree, as our target variable will be MAAS scores, which are continues values.

We’ve mentioned some of the advantages of Decision Trees, but it is also important to note that Decision Trees are prone to over fitting if the data set is very large. This could be due to the fact that when a decision tree is built all features of the dataset are considered. An alternative to Decision Trees is Random Forests. A Random Forest takes a subset of rows at random and selects a particular number of features at random as well to build a decision tree. A collection of subset decision trees then build up the random forest. If many trees
are used to build up a random forest, sooner or later all of the features in the dataset will be included. This method helps reduce error caused by variance and by bias. So for accuracy random forests almost always works better.

For the purpose of this study we chose to use a Decision Tree model oppose to a Random Forest, as a single decision tree is more comprehensible, trains much more quickly, is easier to interpret, and easier to explain.

2.4 Research Questions

In this study we are going to analyze the effect that a mindfulness application has on MAAS scores. We want to be able to answer each of the following questions for each objective of this study.

Specific research questions pertaining to the first aim includes:

Which neuroplastic brain control strategy, was self-reported to be the most effective method for increasing mindfulness?

Specific research questions pertaining to the second aim includes:

Does the mindfulness application fit the User Experience Honeycomb Model?

Specific research questions pertaining to the third aim includes:

Does the Mindfulness Application help achieve better results in the MAAS scores obtained after using the application?

H0: There is no significant difference between MAAS scores that were taken without using the application prior to taking the survey, and MAAS scores taken post application.
use.

H1: Participants that use the application will yield better MAAS results, then that of participants that don’t use the application prior to taking the survey.

Does some features from ACS have a greater effect on the outcome of a participant’s MAAS score?

H0: No features from ACS has a significant impact on the scores obtained from MAAS or all features from ACS have similar weight towards the outcome of the MAAS survey.

H1: Some features from ACS have a bigger contribution than others towards the results obtained from MAAS.

Can a Decision Tree model predict the MAAS score of a participant using their ACS data and the number of times they used the application?

H0: The Decision Tree does not accurately predict the MAAS score of a participant using their ACS data and the number of times they’ve used the application prior to taking the MAAS survey.

H1: The Decision Tree does accurately predict the MAAS score of a participant using their ACS data and the number of times they’ve used the application prior to taking the MAAS survey.
Methodology

In this section we conduct various forms of analysis and methods, to determine techniques that could potentially be used for neoplastic brain control. We also showcase the process that was used in order to come up with, design, and implement, an easy to use training regimen for neuroplastic brain control. This section also explains how data will be collected and evaluated.

3.1 Aim 1: Assess Strategies for Neuroplastic Brain Control

This section along with the following section covers the first aim of this study, which is to assess which strategies for neuroplastic brain control was self-reported to be most effective in increasing mindfulness. The mind can be set up for deeper meditation by performing various breathing exercises. Meditation and yoga breathing have the ability to activate the
parasympathetic nervous system and generate transformed states of consciousness. Scientific studies have indicated that visualization, meditation, and breathing improve stress-related cognitive and physical disorders [2].

To assess which strategies for neuroplastic brain control might be most effective, Functional Magnetic Resonance Imaging Nofeedback Training (fMRI-NFT) can be used. fMRI-NFT is where continues BOLD (Blood-oxygen-level dependent) signals are measured from regions of interest in the brain, processed, and showed to a participant in real time. Dr. Matthew Sherwood and colleagues, found that fMRI-NFT can be used to teach primary auditory cortex self-regulation with directed attention strategies. The study included ten healthy patients, each having to do 5 fMRI-NFT sessions. Four simple directed attention strategies were suggested before a participants scan session, that they can use to try and lower a bar plot on a screen that represents the subjects’ primary auditory cortex activity. That said subjects were allowed to use any brain control strategy they preferred. An interview was conducted with each participant, after each session, where the brain control strategies was logged, that the participants said worked best to lower the bar plot on the screen [15]. See Appendix C.

3.2 Open and Closed Card Sort Analysis

An Open Card Sort was conducted on the brain control strategy responses obtained from Dr. Sherwood and colleagues’ fMRI-NFT study. Open Card Sort is where participants are required to take content or a set of responses and organize them into groups that makes
sense to them. The participants then have to name each of the newly created groups in such a way that they feel best describes each group [18]. Experts in human factors methods were asked to categorize each of the responses into one of four categories. Once all responses were categorized, the students had to give an appropriate label to each category.

From the Open Card Sort we determined that Breathing, Math, Counting, and Music were the most popular categories mentioned. A Closed Card Sort was then conducted in a classroom of six graduate students, where each response had to be placed into one of the four established groups. Closed Card Sort is simply where participants are asked to take content or a set of responses and organize them into pre-defined categories [18].

It was found that 64.29% of responses were placed in the Breathing category, 12.5% in Math, 7.86% in Counting and 15.35% in Music. This indicates that Breathing was the most popular method for neuroplastic brain control in the study.

![Closed Card Sort Responses - Bar Plot](image)

Figure 3.1: Closed Card Sort Responses - Bar Plot
The same brain control strategy responses were used to count the frequency certain words occurred in the dataset. Figure 3.2 indicates that breathing occurred the most times. Sound, math, counting, breath, and exhale were also among the top twenty words that most frequently occurred in the dataset.

![Brain Control Strategy Responses - Word Counts](image)

Figure 3.2: Brain Control Strategy Responses - Word Counts

3.3 **Aim 2: Design and Implement an Easy to Use Training Regimen for Neuroplastic Brain Control**

This section, as well as the next four sections, addresses the second aim of this study, which is to design and implement an easy to use training regimen for neoplastic brain control. Mobile devices have become accessible, affordable, and is suspected of being an effective way of promoting mindfulness via applications. It is suggested that there will be approximately 2.87 billion smartphone users by year 2020 [16]. From the open and closed card sort analy-
sis we were able to determine that breathing was a very popular means of neuroplastic brain control in the study conducted by Dr. Sherwood and colleagues. Figure 3.3 is a landscape analysis of 6 Android applications, where the names of the applications are represented in the first row, and the features present in the application are represented in the first column. Even though breathing is considered a popular mindfulness technique, if we look at the landscape analysis shown in Figure 3.3 it shows that only 2 out of the 6 applications incorporate breath control strategies, which indicates that breath control as a mindful exercise might often be overlooked. Guided breath control strategies via Mobile Applications could be an effective portable method for assisting in neuroplastic brain control that could have enduring benefits.

Figure 3.3: Landscape Analysis of Android Tinnitus Management/Mindfulness Applications
3.4 Smartphones Applications for improving Mindfulness and Tinnitus Management

A smartphone application using tailor-made notch music has received some light, as a result of its capability to reduce Tinnitus noise and Tinnitus related activity around the auditory cortex. A control group-based study indicated that the application, incorporating tailor-made notched music, drastically relieved the patients tinnitus loudness perception. Mal-adaptive auditory cortex alterations, the suspected cause of Tinnitus, has been suggested to be improved due to tailor-made notched music as it lowers the cortical activity of the center frequency by lateral inhibition [4]. The application showed to improve subjective Tinnitus in certain patients, as was revealed by the reduced Tinnitus Handicap Inventory (THI) score in the research study [4].

Another Application called the TrackYourTinnitus (TYT) App involved the measurement of Tinnitus symptoms in 24 people over a period of two weeks at four different, random points in time during the day. The results obtained from the study suggested that even though the participants Tinnitus was measured frequently over the two-week period, it had no negative influence on the perceived Tinnitus distress, measured by the THI. This is an indication that moving participants attention on Tinnitus multiple times a day doesn’t make their Tinnitus worse by any means. The framework used for this study is based of ecological momentary assessment (EMA), which allows for systematic assessments of the moments of various Tinnitus severity. EMA presented quite a few benefits for Tinnitus
assessment including [14]:

- Minimization of retrospective bias.
- Assessment over a longer period can expose dynamic processes and temporal relationships.
- Assessment in daily life situations can introduce measurements of Tinnitus with higher ecological validity.
- Integration of additional sensor data allows for objective measurement of contextual and biological variables.
- Availability and Affordability (cost effective assessment tool).

One of the more popular applications, ReSound, includes a variety of techniques to help patients cope with their Tinnitus. The applications main focus is sound therapy but also includes guided meditation, breathing exercises, multisensory stimulation, and imagery [12]. Although there are benefits to each technique, it is difficult to determine which is best suited for a patient faced with Tinnitus, as Tinnitus is perceived differently by different individuals.

3.5 Design Guidelines

The user interface needs to be designed to be simple, easy to use, and straightforward. In order to create a user experience that is effective we can use the User Experience Honey-
The User Experience Honeycomb model is a helpful tool that is used across industry and explains the various facets of user experience design relating to the component being built. The model was created by Peter Morville and is used to extend the developer or designer’s assessment beyond just the usability factor of an application, and helps them understand the need to establish priorities. It has been widely used since 2004 and has been applied as a tool, and framework, as well as translated, canonized, and featured [5]. In order to fit the User Experience Honeycomb model the application needs to be useful, desirable, accessible, credible, findable, usable, and valuable. A visual representation of the model can be seen if Figure 3.4.
3.6 Design of the Application

On startup of the application the user is prompted for a user id shown in Figure 3.5. User ids are required to log various users in-app navigation, for example, how much time a user spends on certain screens, how much time the user spends doing the exercise, when a user did the tutorial, etc. This could be a helpful means of determining why a user was successful in the exercise or not, and what adjustments are needed to use the app more affectively. Once a user has specified their user id, the main screen of the application will open. The users id will be shown in an id field as shown in Figure 3.6.

If its the users first time using the app, a new file will be created in the Documents folder
in internal storage of the device as shown in Figure 3.7. All in-app data will be stored into files inside this folder, where each respective file is named in the following format: user id - App Data.txt. If a user logs into the app again with the same user id, the data collected for that session will be appended to the existing users file as shown in Figure 3.8. Later the app could be expanded to send these types of files to a server instead of saving it to internal storage. This can help with regards to improving the application as it shows the behavior of each individual user as they navigate through the application.

![Internal Storage Files](Figure 3.7)

![User Navigation File Content](Figure 3.8)

If a user opens the app for the very first time after installation, the user will automatically be taken to the tutorial screen once they press the start button. This will only automatically happen once after installation, as once the user logs in again, it is assumed
that they have already completed the tutorial and aren't required to go through it again. That being said the tutorial screen will be accessible once the user reaches the next screen which will be discussed later in this section.

Before the user is able to reach the exercise screen a few things is required from the user in order for the exercise to be as successful as possible. Notifications can be annoying and distracting, so they are required to be switched off while the exercise is to be performed. In order to do this the user needs to leave the app, go into system settings, and turn off notifications manually for other apps. This is due to the fact that only system apps have the freedom of turning off notifications from various apps. This is tedious and inconvenient for the user to do every time they want to use the app, so the solution to this problem is simple.

Once the start button is pressed the user is prompted to give the app DO NOT DIS-TURB permission as shown in Figure 3.9. If the user clicks on the YES button they will automatically be redirected to the page shown in Figure 3.10. which will allow the user to give the necessary permission. This will only be required by the user once, after which the app will always have permission to switch the phone to silent mode automatically.
Once the user has given permission, simply pressing the back button will redirect the user to the main screen again. Switching the phone to silent mode only fixes half of the problem though, so it is also required for the user to switch the phone into airplane mode before continuing. The user will be prompted the message shown in Figure 3.11 if airplane mode is not switched on. Most android devices can toggle airplane mode on and off by opening the the notification panel of the device. The notification panel is easily accessible by swiping down from the top of the screen.

The combination of switching the device to silent mode and air-plane mode will reduce the number of distractions significantly when the breathing exercise is performed. It assures that no cellular service is available which in turn prevents calls, messages, and notifications.
from other apps. Silent mode also prevents various sounds from the phone which in turn helps minimizes the total distractions while using the app.

As mentioned earlier, once the user presses the start button for the first time after the application was installed, the tutorial screens shown in Figure 3.12 - 3.16 will automatically be displayed. If the user chooses to view the tutorial screens again, they can be accessed by pressing the tutorial button located on the exercise screen shown in Figure 3.17. Tutorial screens are necessary for the user to completely understand how all the components work,
and how the exercise is completed.
Figure 3.16: Tutorial Screen 5

On the top-right hand corner of the exercise screen, shown in Figure 3.17, a volume bar is available to adjust the loudness of the white noise being played back during the exercise. The playback sound is a 10khz lowpass white noise waveform audio file that the user will listen to while performing the exercise. This is required to block out any background or ambient noise while the application is in use. The waveform file was obtained from Dr. Sherwood and colleagues which was used in the study mentioned earlier that suggested breathing as a neuroplastic brain control strategy worked best.

On the top-left hand corner the breaths per minute can be adjusted, that allows the user to specify their target breathing rate. The exercise will begin by expanding and contracting the bubble over a two second interval for 30 intervals. After each interval, the cycle of expansion and contraction increases by 0.2 seconds until the target breathing rate is reached.
Once the 30 cycles are completed the exercise will end. Because Tinnitus is perceived by the individual and differs from patient to patient, the app is designed to allow the user to adjust components inside the app, like volume and breathing rate. This is done so that the user can perform the exercise to settings that is suited for the individual.

Buttons and interactive components are designed to give haptic feedback (vibrate) once pressed. This gives the illusion that a user is pressing on a physical component. The color shading of buttons is designed to make buttons seem round and more appealing to the user. Once a button is pressed not only does it give haptic feedback, it also changes to a brighter color to indicate to the user that they are pressing down on the button. If the user releases the button, the buttons action is performed.

Once the start button is pressed on the exercise screen, the user will be warned as shown in Figure 3.18 in case earphones are not attached/connected to the phone. This is done to warn the user that if earphones arent connected, the loud white noise sound will be outputted through the phones built in speakers. Some users might use the app in an area where other people arent present and wouldnt want to disturb them as they perform the exercise.
To ensure that the user is solely focused on the exercise the application allows the user to switch the screen to the state shown in Figure 3.19. This is done by pressing and holding down on any part of the exercise screen. All the components are hidden except for the green bubble, and the background is switched to black. This eliminates any distractions on the screen and allows the exercise to be performed as efficiently as possible. Tapping and holding on any part of the screen again will return the screen to its original state. If a user needs to exit the screen immediately tapping on the screen once will showcase the navigation bar at the bottom of the screen as shown in Figure 3.20, then the user can simply press the back button to redirect to the main screen.

The application is also designed to always display, in other words the phone will never
lock or turn off its display when someone uses the app. This is critical as the exercise takes a couple of minutes to complete, and the application shouldn’t become inactive halfway through the exercise. During the use of the application, simple continuous noise may be administered at or below 90dB (decibels) via headphones attached to the mobile device. This is due to the fact that sound output greater than 100dB can cause damage to a participants auditory network. As mentioned before the purpose for this noise is to simulate the affects of Tinnitus as the user tries to reach a mindful state with the exercise.
3.7 Design Evaluation

In order to see if our application’s design provided an effective user experience, two surveys were conducted. The first was a User Experience Honeycomb survey that asked participants to rate on a scale of 1 to 7, where 1 is “Strongly Disagree” and 7 is “Strongly Agree”, if the application met the useful, desirable, accessible, credible, findable, usable, and valuable criteria of the User Experience Honeycomb model, see Table 3.1.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Strongly Disagree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Useful</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
</tr>
<tr>
<td>Desirable</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
</tr>
<tr>
<td>Accessible</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
</tr>
<tr>
<td>Credible</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
</tr>
<tr>
<td>Findable</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
</tr>
<tr>
<td>Usable</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
</tr>
<tr>
<td>Valuable</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
</tr>
</tbody>
</table>

Table 3.1: User Experience Honeycomb Model Survey

The survey was conducted on 5 graduate students from Wright State’s Interactions and Modeling Lab. Table 3.2 shows how well the application met the specified criteria of the model. The score was calculated by dividing the total of each of the responses, of each category, by 35 (7 x 5 student responses) multiplied by a 100 to get a percentage score.

From the survey results we are able to determine that the application fit the User Experience Honeycomb Model fairly well. That said it is important to note that although the application was able to do well in the Usable, and Credible category, there is still room for improvement in the Useful, Desirable, Accessible, Findable, and Valuable categories.
Table 3.2: User Experience Honeycomb Model Survey Results

The second survey that was conducted is the System Usability Scale survey. This survey was completed by the same students, and is shown in Appendix D. The System Usability Scale (SUS) is a simple, ten-item scale giving a global view of subjective assessments of usability. The accumulative SUS score represents a composite measure of the overall usability of the system being studied, in this case the mobile application. To calculate the score, first we have to sum up the score contributions from each item. Each item’s score contribution will range from 0 to 4. For odd items the score contribution is the scale position minus 1. For even items, the contribution is 5 minus the scale position. We then multiply the sum of the scores by 2.5 to obtain the overall value of the application’s usability. The end score will be a score out a 100.

After calculating the scores of each participants, the average System Usability score was 90.5% which suggests that the applications usability factor is really good.
3.8 ACS and MAAS Data Collection

The third and last aim of this study, which is to evaluate an adaptive training regimen for increasing mindfulness will be divided into two phases, Pilot Prototype Evaluation, and Full Subjects Evaluation. Participants will be recruited from Wright State University and surrounding communities. A total of three sessions is required by all participants. Every subject will be asked to complete the ACS questionnaire prior to using the application. Following the ACS questionnaire, the participant will use the application either zero, two, or four times. The experiment will be completely randomized to eliminate learning effect, using the counterbalanced measures design method, and once the participant has finished using the application, they will be asked to complete the MAAS questionnaire. Up to 60 subjects may be enrolled during the study, and all subjects will have to meet the following criteria in order to participate in the experiment:

Inclusion Criteria

- Between 18 and 50 years of age inclusive.
- Able to read and write in English.
- Normal or corrected to normal vision.
- Have signed the consent form for the study.
- Able to complete all training sessions within one week.

Exclusion Criteria
- Serious unstable medical or mental illness.
- History of brain cancer or other brain disease.
- Medical contraindication to any element of the study procedure.
- Have not read and signed the informed consent form.
- Hearing loss > 40dB.

3.9 ACS and MAAS Data Collection - Pilot Study (Heuris-tic Evaluation)

Due to time constraints, the initial IRB protocol for the study was not able to be accepted in time. This required a Pilot study to be conducted, that included six participants each having to do six sessions of app training. The same guidelines were followed where each participant was required to fill out the ACS questionnaire, use the application either zero, two, or four times, then take the MAAS survey after using the application. The experiment was also completely randomized to eliminate learning effect, using the counterbalanced measures design method.

3.10 Classification Tree Analysis

The newly obtained data is most likely not going to be enough to fully train a Decision Tree model, but it will still allow us to answer some of our research questions as well
as give an indication where we could adjust approaches in our study, in order to make more concrete and accurate conclusions once more data is collected. The data can be used to train a Decision Tree model using supervised learning. Supervised learning is the process of training a classification algorithm where both the input and output data are provided to the learning algorithm. The algorithm analyzes the training data and constructs an inferred function. This function can be used for mapping new input values. This not only provides a means of determining what features in the ACS contributes most towards a user's mindfulness level, it also provides a means of determining what subset of potential users, if any, will benefit most. If the participants predicted score is low, the participant will be prompted to do the exercise more than once. Depending on the mindfulness level we can adjust the usage of the app for the individual. Participants might be classified into a very low, low, medium, high, and very high mindfulness-level groups, and each group does the exercise a certain number of times, where a very low mindfulness score will require you to do the exercise the most times. The very low mindfulness group is classified to have an accumulative MAAS score of 1-2, low mindfulness group will be 3-4, medium mindfulness group will be 5-6, high mindfulness group will be 7-8 and very high mindfulness group will be 9-10. Scores are calculated by taking the combined total score of the participant divided by 90 (the sum of the maximum value of all questions) multiplied by 10. This will give the participant a score out of 10. A proposed strategy to try and measure the accuracy of how well such a model could work is to set aside 10-20% of the data samples for testing. Note, this 10-20% of the data is not used to train the model. If the classifier predicts the MAAS
scores accurately, we can determine that using a participants ACS results can be used to predict the mindful score of the participant measured with MAAS.

If we use the number of times a participant has used the application as an extra feature in our dataset, we can then determine the dividing factor of the number of times using the application has on the outcome of a participants MAAS score. One proposed method is to let a participant not use the application but take the surveys on day one of testing. Let the participant use the application twice on day two of testing alongside the surveys, and four times on day three of testing alongside the surveys. Using a Decision Tree classifier, we can then determine how much of an effect, the number of times using the application, has on the participants mindfulness level. As mentioned earlier the experiment will be completely randomized to eliminate learning effect. The Counterbalanced Measures Design approach will be used to ensure proper randomization of the experiment.

3.11 ANOVA Analysis

We can also determine if multiple uses of the application have an effect on the MAAS score. This can be done with Anova where MAAS is the dependent variable, and the number of times the application is used, is the independent variable. We can run samples that include only participants that used the application zero and two times, samples that include only participants that used the application two and four times, and samples that include only participants that used the application zero and four times. We can also do an Anova on the combined effect of app uses, and ACS, on MAAS.
Results and Discussion

A 3D scatter plot of App Uses vs ACS vs MAAS is shown in Figure 4.1. It is difficult to determine if there are trends present when ACS and App Uses are considered together when compared to MAAS scores, as there are no sensible cluster formations in the data points from the Pilot study. The data points are grouped by color according to number of times the app was used. Zero app use data points are colored gray, two app uses are colored orange, and four app uses are colored red.
4.1 Results

From the Pilot study we are able to determine that Question 6 is greatest dividing factor of achieving a better mindful state, see Figure 4.2. Participants who answered that they almost never or sometimes get easily distracted if there are people talking in the same room, while reading or studying, showcased higher mindful levels than that of participants that often or always get easily distracted if there are people talking in the same room, while reading or studying.

Figure 4.1: ACS vs App Uses vs MAAS
If look at the left subtree of Question 6 we can see that Question 12 was the second highest dividing factor to achieving a higher mindful state, see Figure 4.3. Participants who almost never find it difficult to coordinate their attention between the listening and writing required when taking notes during lectures, showcased higher mindful levels than that of participants that sometimes, often, or always find it difficult.
At the right subtree of Question 6, it is shown that Question 16 was also a high dividing factor to achieving a higher mindful state, see Figure 4.4. Participants that almost never have a hard time coming up with new ideas quickly received a lower mindful score than participants that sometimes, often, or always find it difficult.
The dividing factors indicate the attributes of the dataset that had the greatest effect on participants’ MAAS scores. When we inspect the whole tree constructed from the data obtained in the Pilot study, shown in Figure 4.5, we notice that the number of times using the application was not a high dividing factor of achieving a higher mindful state. The scatter plot showcased in Figure 4.6 indicates that the correlation coefficient value of the regression line is very low. If the correlation coefficient value is close to zero it indicates
that there is not good relationship between the variables. This is why the number of times using the application, was not a suitable diving factor in achieving a higher mindful state. This could be caused due to the fact that there is too much variance in the data points with respect to how many times the application was used. That being said if more data points were present, in a more diverse population, a more accurate assessment of how much an effect using the application will have in the results obtained from the MAAS survey. Using more data points on a more diverse population might even showcase that other questions in the ACS could have a greater effect on the MAAS results attained after using the application.

Figure 4.5: Complete Decision Tree
To make sure that features with the highest dividing factor are consistent across data partitions, another analysis was done using a Random Forest. In Figures 4.7 through 4.10 we see that Question 6, Question 12, and Question 16 consistently show up as among the highest diving factors in a subset of 8 Decision Trees from the Random Forest.
Figure 4.7: Subset Decision Trees One and Two
Figure 4.8: Subset Decision Trees Three and Four
Figure 4.9: Subset Decision Trees Five and Six
Figure 4.10: Subset Decision Trees Seven and Eight
Running a One way Anova test on the number of times using the application as the independent variable and the MAAS score as the dependent variable we can see in Table 4.1 that the p-Value is 0.8065, which is much greater than our alpha value 0.05. This means that there is no statistical significance present in the dataset obtained from the Pilot study relating to the number of times the app was used and the MAAS score obtained.

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>F Ratio</th>
<th>Prob &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>App Uses</td>
<td>2</td>
<td>0.18125</td>
<td>0.090625</td>
<td>0.2167</td>
<td>0.8065</td>
</tr>
<tr>
<td>Error</td>
<td>29</td>
<td>12.1275</td>
<td>0.41819</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Total</td>
<td>31</td>
<td>12.30875</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4.1: App Uses vs MAAS - Analysis of Variance

Table 4.2 shows us that the mean values of each respective level are very similar, which justifies why we saw such a low correlation coefficient in Figure 4.6.

Table 4.2: App Uses vs MAAS - Means for Oneway Anova

We can also see from Table 4.3 that the p-Values are all greater than 0.05, which indicates there is no statistical significance in samples of only 2 and 4 app uses, samples of only 4 and 0 app uses, and samples of only 0 and 2 app uses, with the MAAS score obtained.

Table 4.3: App Uses vs MAAS - Ordered Difference Report
Running a One way Anova test to see whether there is a combined effect from ACS and App Uses on the MAAS score obtained, Table 4.4 indicates that there is no statistical significance present, as our p-Value is much greater than our alpha value of 0.05.

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>F Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>5</td>
<td>0.525889</td>
<td>0.105178</td>
<td>0.2321</td>
</tr>
<tr>
<td>Error</td>
<td>26</td>
<td>11.782861</td>
<td>0.453187</td>
<td>Prob &gt; F</td>
</tr>
<tr>
<td>C. Total</td>
<td>31</td>
<td>12.30875</td>
<td></td>
<td>0.945</td>
</tr>
</tbody>
</table>

Table 4.4: App Uses and ACS vs MAAS - Analysis of Variance

Looking at Table 4.5 it’s clear that neither App Uses, ACS, and the combined affect of ACS and App Uses showed a statistical significance in the MAAS score obtained as our p-Values are all greater than our alpha value of 0.05.

<table>
<thead>
<tr>
<th>Source</th>
<th>Nparm</th>
<th>DF</th>
<th>Sum of Squares</th>
<th>F Ratio</th>
<th>Prob &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>App Uses</td>
<td>2</td>
<td>2</td>
<td>0.19028428</td>
<td>0.2099</td>
<td>0.812</td>
</tr>
<tr>
<td>ACS</td>
<td>1</td>
<td>1</td>
<td>0.13520381</td>
<td>0.2983</td>
<td>0.5896</td>
</tr>
<tr>
<td>ACS*App Uses</td>
<td>2</td>
<td>2</td>
<td>0.32804326</td>
<td>0.3619</td>
<td>0.6998</td>
</tr>
</tbody>
</table>

Table 4.5: App Uses and ACS vs MAAS - Effect Test

When a decision tree model is trained, where 15% of the data is excluded for validating the classification of the tree, we can clearly see from Figure 4.11 that the tree was unable to accurately predict any of MAAS scores using the ACS data and app uses from the testing dataset. The left column is the predicted score after the inputs are presented to the tree, and the right column is the actual MAAS scores. The tree is unable to classify accurately because a much larger dataset is required in order to build a classifier that can accurately predict outputs.
4.2 Discussion

From the evaluation we were able to determine that some features of ACS had indeed have a greater effect on the outcome of MAAS scores. That being said we were unable to determine if ACS features, and using the application a set number of times, could be used to predict a participant’s MAAS score, due to lack of data. A much larger diverse dataset is required in order to train an effective classifier. We were unable to determine if using the application at all was a contributing factor towards achieving a higher mindful score measured with MAAS, due to too much variation in the data points with respect to the number of times the application was used by participants. This could have been caused by collecting data from a small population. If a much larger dataset was used we could make better justifications whether using the app is a contributing factor in the MAAS score obtained. We also determined that from the Pilot study data, the combined effect of ACS and app uses did not show a statistical significance in the MAAS score obtained.
5

Conclusion and Future Work

5.1 Conclusion

In order to make accurate conclusions if, and by how much, using the application has an effect on a participants’ MAAS score, a larger more diverse dataset is required. Having a population of 60 participants that only participate in three application training sessions might produce a dataset that is less correlated, as well as a dataset with less variation with respect to the number of times the application was used versus the MAAS score obtained. Using a larger more diverse dataset might also showcase other features of ACS as the greatest dividing factor. That said from the Pilot study we were able to determined that Questions 6, Question 12, and Question 16 were the some of the top dividing factors of achieving a higher mindful state. Having a larger dataset will also allow us to effectively train and test how well our model can predict the MAAS score of a participant using their ACS data and the number of times they’ve used the application.
5.2 Future Work

The Decision Tree model has proven to be a useful tool to extract features that have the greatest influence on the desired output. Once we are able to run the study with more participants we might be able to extract the core features of ACS that has the greatest influence on a participant’s MAAS score. This will allow us to build a classifier and incorporate it into the application. A participant can then fill out for instance only the top contributing factors from ACS, the application will then predict the MAAS score of the participant, and adjust variables inside the application to extend and shorten the participant’s session based of the predicted score. A participant with a low predicted score will for instance have the exercise extended to 90 breathing cycles, where a participant with a high score will have to do 30 cycles. This could maximize the effectiveness of the exercise, and will allow the application to potentially be used as a portable method for improving neuroplastic brain control with guided breathing techniques. This might have enduring benefits on the neuroplasticity of the brain, which might improve depression, anxiety, and even disorders such as Tinnitus.
Appendices
A

Attention Control Scale Questionnaire
Attentional Control Scale

Subject ID

The purpose of this questionnaire is to assess your concentration and attention during normal activities. Please select the answer that applies to you for each statement.

It's very hard for me to concentrate on a difficult task when there are noises around.

- almost never (1)
- sometimes (2)
- often (3)
- always (4)

When I need to concentrate and solve a problem, I have trouble focusing my attention.

- almost never (1)
- sometimes (2)
- often (3)
- always (4)

When I am working hard on something, I still get distracted by events around me.

- almost never (1)
- sometimes (2)
- often (3)
- always (4)
My concentration is good even if there is music in the room around me.
- almost never (1)
- sometimes (2)
- often (3)
- always (4)

When concentrating, I can focus my attention so that I become unaware of what’s going on in the room around me.
- almost never (1)
- sometimes (2)
- often (3)
- always (4)

When I am reading or studying, I am easily distracted if there are people talking in the same room.
- almost never (1)
- sometimes (2)
- often (3)
- always (4)

When trying to focus my attention on something, I have difficulty blocking out distracting thoughts.
- almost never (1)
- sometimes (2)
- often (3)
- always (4)

The purpose of this questionnaire is to assess your concentration and attention during normal activities. Please select the answer that applies to you for each statement.

I have a hard time concentrating when I'm excited about something.
- almost never (1)
- sometimes (2)
-
When concentrating I ignore feelings of hunger or thirst

- almost never (1)
- sometimes (2)
- often (3)
- always (4)

I can quickly switch from one task to another

- almost never (1)
- sometimes (2)
- often (3)
- always (4)

It takes me a while to really involved in a new task.

- almost never (1)
- sometimes (2)
- often (3)
- always (4)

It is difficult for me to coordinate my attention between the listening and writing required when taking notes during lectures.

- almost never (1)
- sometimes (2)
- often (3)
- always (4)

I can become interested in a new topic very quickly when I need to.

- almost never (1)
- sometimes (2)
- often (3)
It is easy for me to read or write while I’m also talking on the phone.

- almost never (1)
- sometimes (2)
- often (3)
- always (4)

I have trouble carrying on two conversations at once.

- almost never (1)
- sometimes (2)
- often (3)
- always (4)

I have a hard time coming up with new ideas quickly.

- almost never (1)
- sometimes (2)
- often (3)
- always (4)

The purpose of this questionnaire is to assess your concentration and attention during normal activities. Please select the answer that applies to you for each statement.

After being interrupted or distracted, I can easily shift my attention back to what I was doing before.

- almost never (1)
- sometimes (2)
- often (3)
- always (4)

When a distracting thought comes to mind, it is easy for me to shift my attention away from it.
It is easy for me to alternate between two different tasks.

- almost never (1)
- sometimes (2)
- often (3)
- always (4)

It is hard for me to break from one way of thinking about something and look at it from another point of view.

- almost never (1)
- sometimes (2)
- often (3)
- always (4)
Mindful Attention Awareness Scale

Questionnaire
Mindful Attention Awareness Scale (MAAS)

Day-to-Day Experiences

Instructions: Below is a collection of statements about your everyday experience. Using the 1-6 scale below, please indicate how frequently or infrequently you currently have each experience. Please answer according to what really reflects your experience rather than what you think your experience should be. Please treat each item separately from every other item.

<table>
<thead>
<tr>
<th>Item</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>I could be experiencing some emotion and not be conscious of it until some time later.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>I break or spill things because of carelessness, not paying attention, or thinking of something else.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>I find it difficult to stay focused on what's happening in the present.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>I tend to walk quickly to get where I'm going without paying attention to what I experience along the way.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>I tend not to notice feelings of physical tension or discomfort until they really grab my attention.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>I forget a person's name almost as soon as I've been told it for the first time.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>It seems I am “running on automatic,” without much awareness of what I'm doing.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>I rush through activities without being really attentive to them.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>I get so focused on the goal I want to achieve that I lose touch with what I'm doing right now to get there.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>I do jobs or tasks automatically, without being aware of what I'm doing.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>I find myself listening to someone with one ear, doing something else at the same time.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>I drive places on 'automatic pilot' and then wonder why I went there.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>I find myself preoccupied with the future or the past.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>I find myself doing things without paying attention.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>I snack without being aware that I'm eating.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>
C

fMRI-NFT Subject Responses
<table>
<thead>
<tr>
<th>SUBJECT</th>
<th>SESSION</th>
<th>DATE</th>
<th>Q1: How well did you understand the instructions and procedures?</th>
<th>Q2: How well do you think you performed in the training?</th>
<th>Q3: What mental/cognitive strategies did you use during neurofeedback training?</th>
<th>Q4: What was your level of comfort during the procedure?</th>
<th>Q5: Additional notes</th>
<th>Interviewer</th>
</tr>
</thead>
<tbody>
<tr>
<td>E101</td>
<td>3</td>
<td>2/3/2017</td>
<td>PERFECTLY</td>
<td>GOOD 9/10</td>
<td>FOCUS ON BREATHING, BE NORMAL DURING RELAX</td>
<td>COMFORTABLE 8/10</td>
<td>NONE</td>
<td>JP</td>
</tr>
<tr>
<td>E101</td>
<td>1</td>
<td>2/16/2017</td>
<td>ALL THE WAY</td>
<td>WELL</td>
<td>FOCUS ON BREATH</td>
<td>COMFORTABLE</td>
<td>NONE</td>
<td>JP</td>
</tr>
<tr>
<td>E101</td>
<td>2</td>
<td>3/11/2017</td>
<td>GOOD/PERFECT</td>
<td>WELL</td>
<td>FOCUS ON BREATHING DURING TASK; FOCUSED ON SOUND - NOT BREATHING DURING RELAX</td>
<td>COMFORTABLE</td>
<td>NONE</td>
<td>JP</td>
</tr>
<tr>
<td>E101</td>
<td>4</td>
<td>2/7/2017</td>
<td>FULLY</td>
<td>GOOD</td>
<td>FOCUS ON BREATHING DURING TASK; RELAX (SENSORY, WRESTLING (WORKED BEST, EMBRACING NOISE))</td>
<td>COMFORTABLE</td>
<td>NONE</td>
<td>JP</td>
</tr>
<tr>
<td>E101</td>
<td>5</td>
<td>2/16/2017</td>
<td>PERFECT</td>
<td>WELL</td>
<td>FOCUS ON BREATHING DURING TASK; RELAX (SENSORY, WRESTLING (WORKED BEST, EMBRACING NOISE))</td>
<td>COMFORTABLE</td>
<td>NONE</td>
<td>JP</td>
</tr>
<tr>
<td>E103</td>
<td>1</td>
<td>2/17/2017</td>
<td>2ND EVERYTHING FINE</td>
<td>2ND/THIRD DID WELL (NOISE &amp; THERMOMETER BAR) STROOP UNCLEAR</td>
<td>LST (MATH, UNSUCCESSFUL), BREATHING (LONG BREATH AND EXHALE SLOWLY), BREATHING WAS BEST</td>
<td>EARBUD TIGHTER B/C OF HEAD MOTION</td>
<td>THOUGHT SOUND WAS FOR EVERY DISPLAY</td>
<td>ED</td>
</tr>
<tr>
<td>E103</td>
<td>2</td>
<td>2/22/2017</td>
<td>VERY WELL</td>
<td>PRETTY GOOD</td>
<td>BREATHING (CONTROLLING EXHALE); MATH DOESN'T WORK!</td>
<td>OK</td>
<td>NONE</td>
<td>JP</td>
</tr>
<tr>
<td>E103</td>
<td>3</td>
<td>3/27/2017</td>
<td>NONE</td>
<td>PRETTY GOOD</td>
<td>FOCUS ON BREATHING</td>
<td>EXCELLENT</td>
<td>NONE</td>
<td>JP</td>
</tr>
<tr>
<td>E103</td>
<td>4</td>
<td>2/28/2017</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E103</td>
<td>5</td>
<td>3/1/2017</td>
<td>FINE</td>
<td>WELL, STROOP VOLUME TOO LOUD</td>
<td>AUD - BLUR OUT EVERYTHING BUT DOTTING, EXHALE AIR, STOP TO LOWER, ECHALE TO RAISE</td>
<td>FINE</td>
<td>MOTION CORRELATED W/ FEEDBACK</td>
<td>MS</td>
</tr>
<tr>
<td>E106</td>
<td>1</td>
<td>2/8/2017</td>
<td>VERY WELL</td>
<td>WELL</td>
<td>BREATHING SLOW + RYTHMICALLY</td>
<td>B/10 - WARM BLANKET</td>
<td>N/A</td>
<td>JP</td>
</tr>
<tr>
<td>E106</td>
<td>2</td>
<td>2/15/2017</td>
<td>VERY WELL</td>
<td>WELL, BETTER ON 1ST</td>
<td>RHYTMCIC BREATHING</td>
<td>GOOD</td>
<td>NONE</td>
<td>JP</td>
</tr>
<tr>
<td>E106</td>
<td>3</td>
<td>2/17/2017</td>
<td>VERY WELL</td>
<td>DID WELL</td>
<td>RHYTMCIC BREATHING YES/BEST</td>
<td>GOOD</td>
<td>NONE</td>
<td>ED</td>
</tr>
<tr>
<td>E106</td>
<td>4</td>
<td>2/20/2017</td>
<td>GOOD</td>
<td>1. RHYTHMIC BREATHING; 2. COOKING</td>
<td>FIRST TIME WAS NOT GOING WELL SO CHANGED</td>
<td>GOOD</td>
<td>N/A</td>
<td>JP</td>
</tr>
<tr>
<td>E106</td>
<td>5</td>
<td>2/24/2017</td>
<td>VERY WELL</td>
<td>PRETTY GOOD</td>
<td>FOCUSED ON BREATHING DURING LOWER (WORKED BEST); PICTURING FACES (HT OR M/SS)</td>
<td>PRETTY GOOD</td>
<td>MAY HAVE USED WRONG BUTTONS FOR STROOP TASK; CONFIRM</td>
<td>ED</td>
</tr>
<tr>
<td>E110</td>
<td>1</td>
<td>3/6/2017</td>
<td>FINE</td>
<td>OK, IFFY</td>
<td>NOT UNCOMFORTABLE HEADPHONES WERE TIGHT</td>
<td>N/A</td>
<td>MS</td>
<td></td>
</tr>
<tr>
<td>E110</td>
<td>2</td>
<td>3/7/2017</td>
<td>GOOD</td>
<td>BETTER</td>
<td>DEEP BREATHING, FOCUS ON BREATH</td>
<td>N/A</td>
<td>MS</td>
<td></td>
</tr>
<tr>
<td>E110</td>
<td>3</td>
<td>3/10/2017</td>
<td>FINE</td>
<td>BETTER THAN FIRST TIME, ABOUT THE SAME AS SECOND, DIFFERENT B/C QUIET</td>
<td>DEEP BREATHING DURING LOWER (DEEP BREATHING HELPS GO TO SLEEP); NO OTHER</td>
<td>FINE, HEADPHONE USE CHANGES</td>
<td>SOUND LEVELS inconsistant compared to 1st and 2nd sessions</td>
<td>ED</td>
</tr>
<tr>
<td>E110</td>
<td>4</td>
<td>3/13/2017</td>
<td>FINE</td>
<td>PRETTY GOOD</td>
<td>LOWER (ZONE OUT, &quot;SLEEP&quot;), BREATH DEEPER, WATCHED ARROW; RELAX (LISTENED)</td>
<td>FINE</td>
<td>N/A</td>
<td>MS</td>
</tr>
<tr>
<td>E110</td>
<td>5</td>
<td>3/20/2017</td>
<td>FINE</td>
<td>PRETTY GOOD</td>
<td>LOWER (DEEP BREATHING (FEELING OF IT)), RELAX (NOTHING)</td>
<td>FINE</td>
<td>N/A</td>
<td>MS</td>
</tr>
<tr>
<td>E111</td>
<td>1</td>
<td>3/15/2017</td>
<td>100%</td>
<td>OKAY</td>
<td>DEEP BREATHING FOR RELAX, LOWER (MATH, ADDITION THEN MUL.T.), EMOTIONAL/EXCITING MEMORIES, GYMNASTICS</td>
<td>REALLY COMFORTABLE</td>
<td>N/A</td>
<td>MS</td>
</tr>
<tr>
<td>E111</td>
<td>2</td>
<td>3/20/2017</td>
<td>GOOD</td>
<td>BETTER</td>
<td>LOWER (COUNTING, DEEP BREATHING Not thinking about it, LISTENING)</td>
<td>10 OUT 10</td>
<td>N/A</td>
<td>MS</td>
</tr>
<tr>
<td>E111</td>
<td>3</td>
<td>3/27/2017</td>
<td>COMPLETELY</td>
<td>7 OUT 10</td>
<td>LOWER (COUNTING (U/D), MULT, DISTRACTION), RELAX (BREATHING, LISTEN TO SOUND, MEDITATE)</td>
<td>COMFORTABLE</td>
<td>N/A</td>
<td>MS</td>
</tr>
<tr>
<td>E111</td>
<td>4</td>
<td>3/28/2017</td>
<td>GOOD</td>
<td>NOT SO WELL</td>
<td>LOWER (COUNTING (MATH), DISTRACTION), RELAX (MEDITATION, BREATHING)</td>
<td>COMFORTABLE</td>
<td>N/A</td>
<td>MS</td>
</tr>
<tr>
<td>E111</td>
<td>5</td>
<td>3/30/2017</td>
<td>UNDERSTAND</td>
<td>SO-SO</td>
<td>COUNTING PULSE RATE; FOCUS ON FINGER TIPS; HOLD BREATH TO FEEL HEART; WORKED BEST (FOCUS ON PULSE WORKED BEST, EMBRACING NOISE)</td>
<td>COMFORTABLE</td>
<td>N/A</td>
<td>MS</td>
</tr>
<tr>
<td>E114</td>
<td>1</td>
<td>3/13/2017</td>
<td>WELL 9 OUT 10</td>
<td>5 OUT 10 NOT SO GREAT</td>
<td>2 OUT 10</td>
<td>NO HEADPHONES</td>
<td>N/A</td>
<td>MS</td>
</tr>
<tr>
<td>E114</td>
<td>2</td>
<td>3/15/2017</td>
<td>GOOD, BETTER</td>
<td>GOOD 7 OR 8 OUT 10</td>
<td>LOWER (FOCUS ON SENSES NOT ON BAR (SENSORY, WRESTLING (WORKED BETTER)))</td>
<td>BETTER 10 OUT 10</td>
<td>N/A</td>
<td>MS</td>
</tr>
<tr>
<td>E114</td>
<td>3</td>
<td>3/20/2017</td>
<td>GOOD</td>
<td>REALLY GOOD</td>
<td>LOWER (FOCUS ON BREATHING (SAYING RISING/FALL W/ BREATHING)); RELAX (FOCUS ON SOUND)</td>
<td>10 OUT 10</td>
<td>N/A</td>
<td>MS</td>
</tr>
<tr>
<td>E114</td>
<td>4/3/2017</td>
<td>10 OUT 10</td>
<td>8 OUT 10</td>
<td>LOWER (FOCUS ON BREATHING, TELLING BAR TO GO DOWN, VISUALIZED LARGE NEG BAR); RELAX (FOCUS ON SOUND)</td>
<td>10 OUT 10</td>
<td>N/A</td>
<td>MS</td>
<td></td>
</tr>
<tr>
<td>-------</td>
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<td>-----------</td>
<td>---------------------------------------------------------------------------------------------------</td>
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<tr>
<td>E114</td>
<td>5/3/2017</td>
<td>100%</td>
<td>6 OR 7 OUT 10 (OVERALL 7 OUT 10)</td>
<td>LOWER (FOCUS ON BREATHING, PICTURE BAR LOWER); RELAX (LISTEN, HARD TO STOP BRAIN)</td>
<td>10 OUT 10</td>
<td>N/A</td>
<td>MS</td>
<td></td>
</tr>
<tr>
<td>E117</td>
<td>1/3/2017</td>
<td>VERY WELL</td>
<td>DECENT 7 OUT 10</td>
<td>LOWER (END) DEEP BREATHING (EXHALE/INHALE) (BEST); CHEM CONVERSION PROBLEM; RELAX (CLEAR MIND)</td>
<td>6 OUT 10</td>
<td>N/A</td>
<td>MS</td>
<td></td>
</tr>
<tr>
<td>E117</td>
<td>2/3/2017</td>
<td>VERY WELL</td>
<td>6 OR 7 OUT 10</td>
<td>LOWER (FOCUS ON HOW PARTS OF BODY FELT); RELAX (WATCH BAR, KEEP EYES OPEN)</td>
<td>7 OR 8 OUT 10</td>
<td>N/A</td>
<td>MS</td>
<td></td>
</tr>
<tr>
<td>E117</td>
<td>3/3/2017</td>
<td>VERY WELL</td>
<td>ABOUT A 6 OR 7 OUT OF 10</td>
<td>LOWER (MATH, STOICHEIOMETRY); RELAX (NOTHING)</td>
<td>7 OR 8 OUT OF 10</td>
<td>ROTATIONAL MOTION IN THETA L/R; NFT1 MAY NOT BE ACCURATE, PRESENTATION CRASHED</td>
<td>ED</td>
<td></td>
</tr>
<tr>
<td>E117</td>
<td>4/4/2017</td>
<td>VERY WELL</td>
<td>7 OR 8 OUT 10</td>
<td>LOWER (FOCUS ON HOW BODY FELT; MATH PROBLEMS); RELAX (CLEAR MIND; VISUALIZE BAR GOING UP)</td>
<td>6 OR 7 OUT 10</td>
<td>N/A</td>
<td>MS</td>
<td></td>
</tr>
<tr>
<td>E118</td>
<td>1/3/2017</td>
<td>GOOD</td>
<td>6 OUT 10</td>
<td>LOWER (MENTAL MATH, PLAYING A SONG ON GUITAR (WORKED BETTER)); RELAX (FOCUS ON SOUND, EMPTY MIND)</td>
<td>5 OUT 10</td>
<td>N/A</td>
<td>MS</td>
<td></td>
</tr>
<tr>
<td>E118</td>
<td>2/3/2017</td>
<td>COMPLETELY</td>
<td>POORLY</td>
<td>RELAX (FOCUS ON SOUND, COUNT, TAKE DEEPER BREATHS); LOWER (THINK ABOUT PROBLEMS/PROJECTS, PLAYING MUSIC)</td>
<td>4 OUT 10</td>
<td>N/A</td>
<td>MS</td>
<td></td>
</tr>
<tr>
<td>E118</td>
<td>3/3/2017</td>
<td>TOTALLY</td>
<td>NOT GREAT</td>
<td>LOWER (SPACING OUT, LET THOUGHTS PASS); RELAX (FOCUS ON SOUND/BAR)</td>
<td>5 OUT 10</td>
<td>N/A</td>
<td>MS</td>
<td></td>
</tr>
<tr>
<td>E118</td>
<td>4/3/2017</td>
<td>GOOD</td>
<td>OKAY, NOT GREAT</td>
<td>LOWER (MEDITATING, NOT DWELLING, LET THOUGHTS PASS BY); RELAX (FOCUS ON BAR/SOUND)</td>
<td>FINE</td>
<td>N/A</td>
<td>MS</td>
<td></td>
</tr>
<tr>
<td>E118</td>
<td>5/3/2017</td>
<td>COMPLETELY</td>
<td>OKAY 7 OUT 10</td>
<td>LOWER (REALLY DEEP BREATHS AND COUNTED); RELAX (IMAGINED WAVE SOUND ON BEACH)</td>
<td>FINE 6 OUT 10</td>
<td>N/A</td>
<td>MS</td>
<td></td>
</tr>
<tr>
<td>E119</td>
<td>1/3/2017</td>
<td>OKAY, NFT 10 OUT 10</td>
<td>10 OUT 10</td>
<td>LOWER (RELAX, CALM DOWN, MEDITATION, BREATHING); RELAX (THOUGHT OF MUSIC, PUMPED UP AT PARTY, MIND WANDER)</td>
<td>PRETTY COMFY</td>
<td>N/A</td>
<td>MS</td>
<td></td>
</tr>
<tr>
<td>E119</td>
<td>2/3/2017</td>
<td>BETTER THAN LAST 9 OUT 10</td>
<td>10 OUT 10</td>
<td>MATH STUFF (LIKE THE TEST, CALC)</td>
<td>7 OR 8 OUT 10</td>
<td>TEST TODAY AFTER CLASS</td>
<td>MS</td>
<td></td>
</tr>
<tr>
<td>E119</td>
<td>3/3/2017</td>
<td>10 OUT 10</td>
<td>9 OUT 10</td>
<td>LOWER (CLEAR HEAD (DAZE)); RELAX (EXCITED FOR THE WEEKEND)</td>
<td>FINE 6 OUT 10</td>
<td>N/A</td>
<td>MS</td>
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</tr>
<tr>
<td>E119</td>
<td>4/3/2017</td>
<td>GOOD</td>
<td>BETTER 7 OUT 10</td>
<td>LOWER (MEDITATION (CALM DOWN, BREATHING, HR)); RELAX (EXCITED ABOUT STUFF)</td>
<td>OK, FINE</td>
<td>N/A</td>
<td>MS</td>
<td></td>
</tr>
<tr>
<td>E119</td>
<td>5/3/2017</td>
<td>GOOD</td>
<td>6 OUT 10</td>
<td>LOWER (CLEAR THOUGHTS, DAZING OFF); RELAX (RELAX AND WATCH BAR, MIND WANDER)</td>
<td>FINE</td>
<td>N/A</td>
<td>MS</td>
<td></td>
</tr>
</tbody>
</table>
D

System Usability Scale Survey
System Usability Scale


1. I think that I would like to use this system frequently
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]

2. I found the system unnecessarily complex
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]

3. I thought the system was easy to use
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]

4. I think that I would need the support of a technical person to be able to use this system
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]

5. I found the various functions in this system were well integrated
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]

6. I thought there was too much inconsistency in this system
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]

7. I would imagine that most people would learn to use this system very quickly
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]

8. I found the system very cumbersome to use
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]

9. I felt very confident using the system
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]
   [ ] [ ] [ ] [ ] [ ]

10. I needed to learn a lot of things before I could get going with this system
    [ ] [ ] [ ] [ ] [ ]
     [ ] [ ] [ ] [ ] [ ]
     [ ] [ ] [ ] [ ] [ ]
     [ ] [ ] [ ] [ ] [ ]
     [ ] [ ] [ ] [ ] [ ]
References


[16] Statista. "Number of smartphone users worldwide from 2014 to 2020 (in billions)"
number-of-smartphone-users-worldwide/


