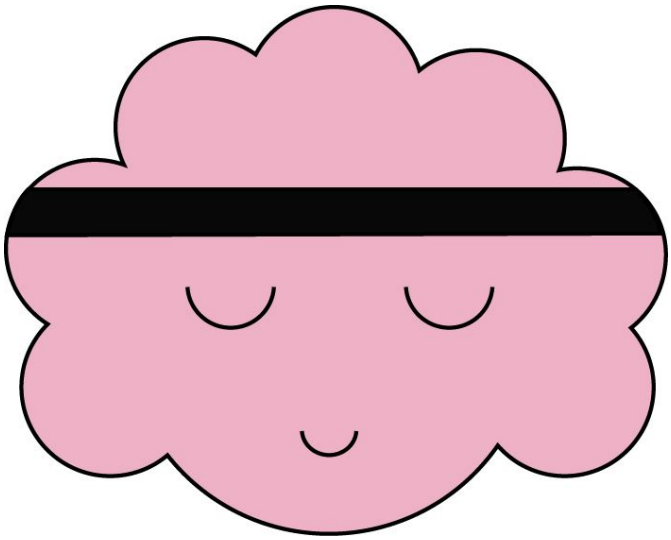

M3 (Mindful Meditative Minds)

ECE1778 Final Report

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Creative Applications for Mobile Devices

University of Toronto

1. Introduction

The goal of the Mindful Meditative Minds (M3) application is to link older adults' (60 years or older) success in mindfulness meditation to their performance on mental tasks. Older adults will complete cognitive tasks (high-level executive functions) before and after completing a module of 10 meditation sessions. During meditation, the Muse Headband will be used to collect and measure alpha brainwaves (associated with being calm and in a meditative state) [1]. Feedback on the effectiveness of mindful meditation will be provided to older adults by comparing the alpha waves produced during meditation to the calibrated values collected prior to meditation. Higher alpha during meditation relative to calibration will be linked to being in a "calm" state.

In mindful meditation, the trainee is instructed to close their eyes and focus on the present moment. If/when the mind wanders, they are told to acknowledge the shift in focus and then gently bring their attention back to the breath and the present moment without judgement. Research shows better mental performance among mindful meditators in higher-level executive functions (ignoring distraction, shifting attention), because - through being mindful - meditators are repeatedly practicing the ability to ignore internally and externally generated distractions to focus on the "now" and are constantly shifting their attention back to the current moment, when their mind wanders [2]. Higher level executive functions have been shown to decline with age [3,4]; however, older adults who practice mindfulness meditation have better executive functioning (e.g., shifting attention) as compared to controls [5].

Given the association between meditation and mental abilities, we built the M3 app to encourage mindfulness meditation in older adults by provided them with an easy to use home-based app that demonstrates how their own mental performance is impacted by continuous mindful-based mediation practice.

2. Overall Design

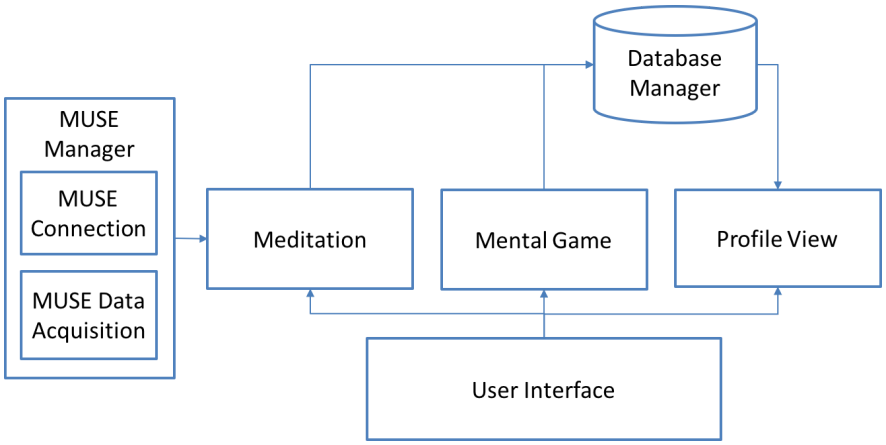


Figure 1: M3's block diagram

User Interface: contains sign-up and sign-in page for previous and new users to keep their session data. If a new user is detected, a walkthrough is invoked to explain the flow of the app. All of the components of the app can be accessed from this module.

Meditation: requests for data from Muse Manager for a complete meditation session. First, the module will connect to a paired Muse headband then perform signal quality check for reliable data. Then audio guides user through calibration to capture the brain's active state at that time. Lastly, audio guides user through meditation to capture the brain's meditative state. Feedback on session performance is displayed at the end.

Muse Manager: handles all of the communications with the Muse headband. Available Muse APIs are used here to establish connection with the headband and gather data.

Mental Game: measures the distractibility of the person. It contains stroop task, which uses accuracy and reaction time to quantify distractibility. The module must be completed as soon as a user signs up to gather their baseline data and becomes unavailable. After 10 sessions of meditation, this module becomes available again.

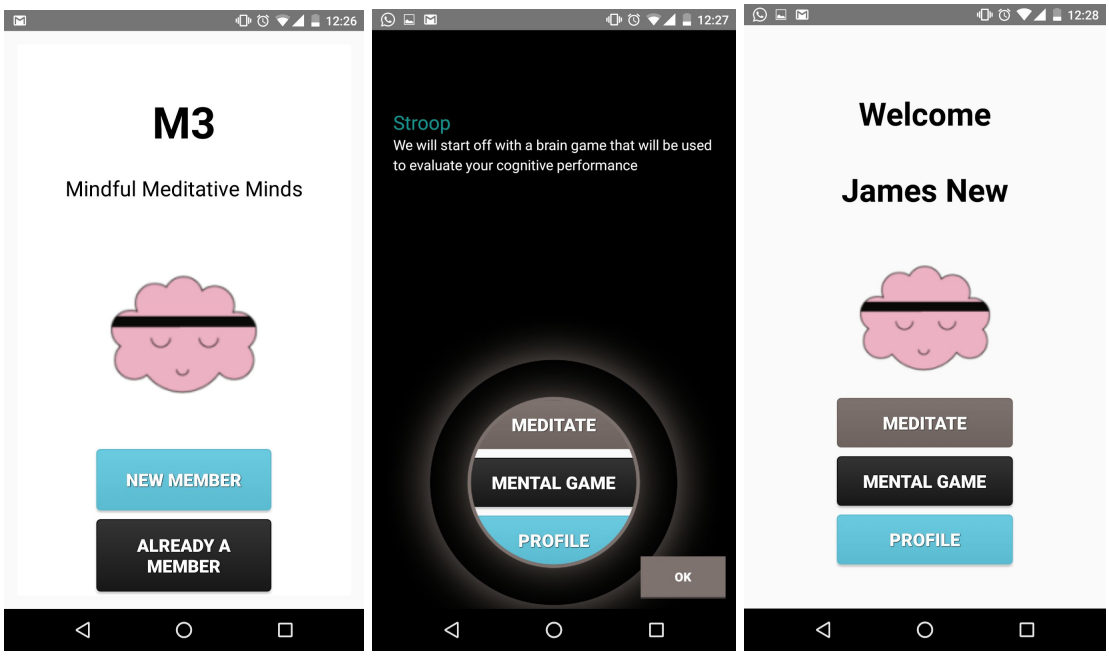
Profile View: displays database information to users to track their progress in summarized graphs. Also allows users to view their past performance in meditation and mental game.

Database Manager: SQLite database is used to store all relevant data in M3

3. Statement of Functionality

3.1 User Interface

The first screen the user sees when he/she opens the app, the user is prompted to sign up or sign in. The app will gather user information on their name, age, and contact info, which will get stored locally. Once the log-in is completed and if a new user is detected, a spotlight feature will walk the user through the three major functionality of our app. This is required to facilitate the correct usage of our app since the mental game must be completed before meditation is started.



(a) Login Page (b) Guided Walkthrough (c) Main Menu

3.2 Meditation

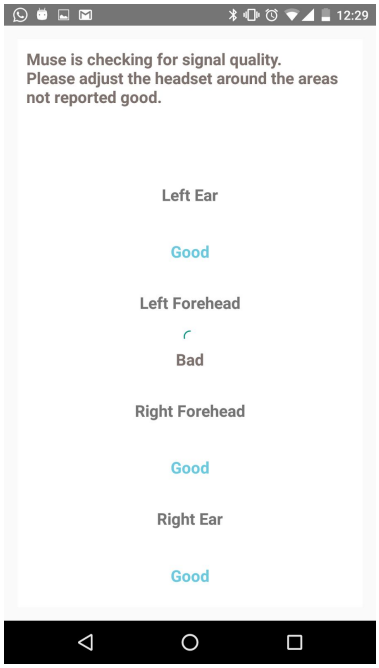
The meditation module first automatically connects to the Muse headband, performs signal quality check, calibrates, then starts meditation. First, we try to establish a connection to a Bluetooth paired Muse headband. If it is connected, then a visual feedback is given and the app proceeds to next step, otherwise the app will prompt the user to try to reconnect.

After the headband is connected, we check for signal quality to confirm that a good physical connection has been established and that the alpha wave data we collect is clean. In other words, we make sure that data integrity of acquired data during calibration and meditation is reliable. When the Muse headband can consistently detect good signal quality, we proceed to calibration. Note that while the Bluetooth connection is easy to

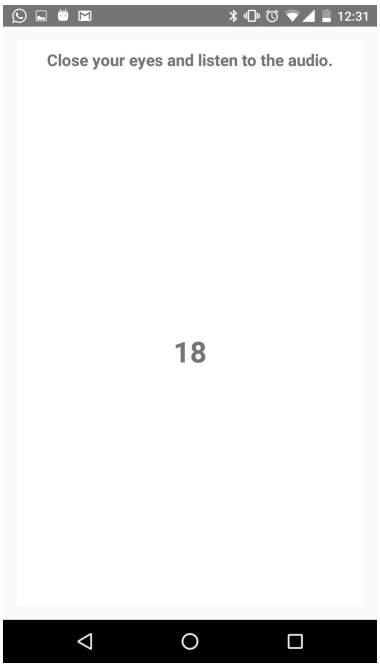
establish, getting quality data is a major hurdle since it depends on the user's positioning of the headband and the sensor contact[1] to the skin.

When the user gets past the previous stage, a 20 second calibration ensues. An audio cue will guide the user to think of items in a category, which will capture the brain's active state. The average of the alpha values during calibration is what we referred to as the calibrated value. The expected value is low since alpha values are associated with being in a calm state whereas the users are guided to be in active state during calibration. This is done before every meditation session since human brain's internal activity fluctuates throughout the day.

Finally, during meditation, another audio cue will guide the user through the meditation session. In this part the user will be asked to focus on his/her breath. This has a calming effect, which effectively allows the user to generate higher alpha values - associated with good meditation. In the end of the session, we present the user with a graph of alpha values over the time of meditation. We then use this to calculate the percentage the user was in the calm state. To decide whether a person was in calm state, the alpha value captured during meditation is compared to the calibrated value.



(d) Signal Quality Check



(e) Meditation Countdown

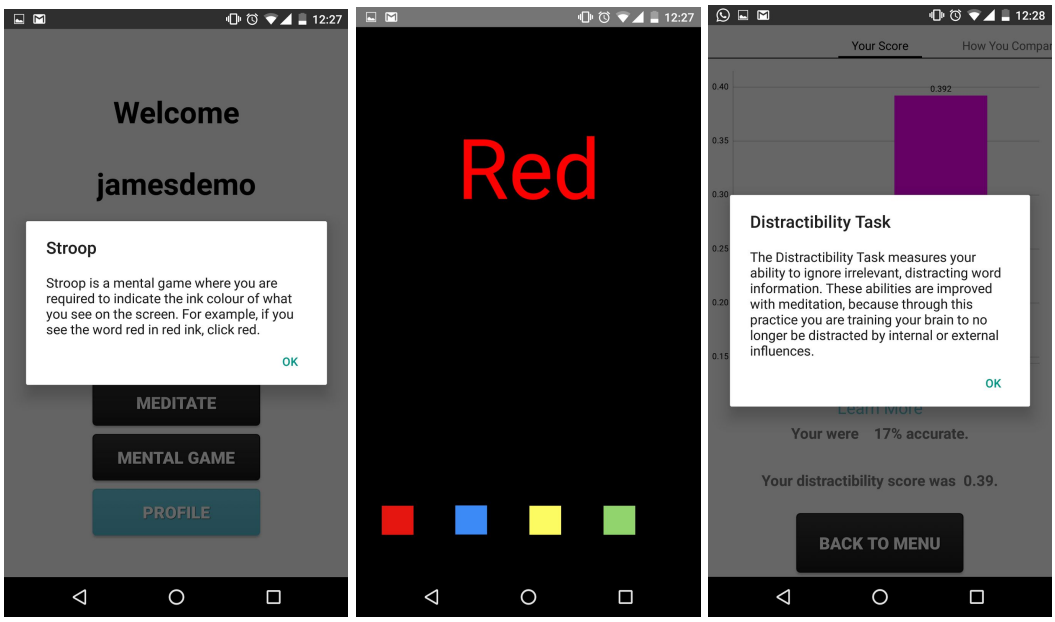
(f) Performance Graph

[1] We later found that Muse recommends clean skin with lotion can help expedite this process; however, it was still not reliable enough to connect within a minute during our actual demonstration.

3.3 Mental Game

The mental game module will ask the user to perform a brain game, stroop, referred to as distractibility task in our app. This measures one's ability to ignore distractions by displaying a color in word with different ink color and asks the user to identify the ink color rather than the word. While the user performs the task, the reaction time and correctness is measured. After the task is completed, the user is given a feedback of their "distractibility score" and accuracy. Distractibility score uses the reaction time to determine its value. The user is also able to compare his/her result against their peers, and the percentiles of the user's score is shown.

Although the comparison of user's result against the peers was built, it did not function as intended. We wanted to use the data Andrea garnered from her research to compare with the user's performance. However, the pie chart that we integrated failed to display properly when the 100th percentile is reached. We speculated that we did not use the API as intended, and decided to spend our efforts on other parts of the app.



(g) Stroop Task Intro (h) Stroop Task (i) Distractibility

3.4 Profile

The profile module allows users to access 3 types of data. In the first section the user sees 2 graphs. First, a bar graph shows the past distractibility task results. This graph is intended to show a change in performance of the same task from when the user first performed the task. Second, a line and a bar graph shows the past meditation session data. The bar graph indicates the percentage the user spent in the calm state and the line graph shows the total aggregated amount of alpha values captured during the session. Ideally, the user should see an increase in the blue bar and decrease in the pink bar in the first graph and an upward rising trend in the line and bar graph in the second graph.

In the second and third section, reached by swiping left or right, a dropdown menu is used to display specific distractibility score results and meditation data.

(j) Overview in Profile (k) Past Distractibility Info (l) Past Meditation Info

3.5 Flow of App

The app is intended to be used once a day to promote regular meditation. If a user plays the mental game and meditates 10 times on the same day, the user will not see an improvement in their post mental game performance. We did not implement this feature since the testing would take quite some time.

3.6 Software Libraries

- google-gson (https://github.com/google/gson)
- MPAndroidChart (https://github.com/PhilJay/MPAndroidChart)
- Apache Commons Math (http://commons.apache.org/proper/commons-math/download_math.cgi)
- Showcaseview (https://github.com/amlcurran/ShowcaseView)

4. What We Learned

Our group's frequent meetings and clear outline of weekly goals helped us manage the project well. Everyone equally participated in discussions of ideas and features without dismissing anyone's idea.

In terms of project management, we realized the importance of a flowchart that illustrates the clear flow of the app. In our first meeting, we only outlined a block diagram rather than a flow chart. In hindsight, we believe that if we created, improved, and updated the flow chart as the project progressed, we would have had a more clear understanding of how each modules should be implemented.

Reflecting on working with Muse headband, we should have put drastically more effort in checking the signal quality before moving onto other aspects of our project. We did not realize how sensitive the headband can be to placement and movements. This resulted in repeated crashes of our app during the development process.

Lastly, we believe that sharing information about open-source libraries early with the specialist could be very beneficial. When our specialist realized what they are, she was able to visualize the difficulty of certain tasks.

5. Contribution by Group Members

Andrea

- Generated the idea to create an app that connect mindful-based meditation practice to mental performance in older adults.
- Created and recorded the voice-over content for the calibration and meditation sections of the app.
- Provided guidance and suggestions on structuring performance feedback across time (mental game and meditation) in a graphical form that was both accurate and easy to understand.
- Created Moqups and the flow diagram to illustrate the sequence of events experienced by older adults as they used the app.
- Offered suggestions and guidance as requested and during weekly group meetings.

Jin Hee

- Muse Manager: Created the manager to use available Muse API to communicate with the headband.
- Database Manager: Established the SQLite database and functions for accessing data for various purposes of the app.
- Meditation: Implemented connection and signal quality check to ensure data integrity and data acquisition during calibration and meditation and stored it in database.
- User Interface: Sign-up and sign-in feature implemented. Worked on overall consistency of buttons, fonts, and graph appearances.

Jonas

- Mental Game: Implemented the distractibility task with score analysis, storing, and displaying using the graphing API, as well as implementing the percentile vs. peers graph.
- Profile View: Created the numerous graphs to show the overall results of meditation and the mental game, enabled the user to view historical result.
- User Interface: Implemented the Showcaseview to guide users through the usage of the app, incorporated numerous styles to create the theme for the M3 app

6. Specialist Context

The External Specialist has a PhD in Psychology with a specialization in Cognitive Aging. She is interested in exploring approaches to enhance mental functioning in older adults, and has experience collecting and analyzing brainwave data.

The M3 app makes a novel contribution to the cognitive aging space, because it is the first app of its kind to connect brain game performance to meditation efficiency within a single application. Prior to M3, individuals could only participate in research that evaluated the impact of mindfulness meditation on brain game performance - in a laboratory setting across several weeks. In this context, older adults are unable to get their individual performance, because research findings are always presented as group averages. Although there are many brain game and meditation apps that exist separately, M3 fills a gap in the market by combining these two areas of interest within a single app. Older adults are now able to see the benefits of meditation on their personal mental performance from the comfort of their own homes.

The M3 app also has potential of becoming a valuable research resource in the field of cognitive aging, because of the rich source of data it collects. The combination of profile based information (age and gender), brain game performance, as well as frequency and quality of meditation practice has the potential to offer powerful insight into how the benefits of meditation on mental performance changes as we progress through the aging process. By tracking individuals over time, we can begin to explore what factors moderate the relationship between mindfulness and mental performance, and determine how to optimize this association with increasing age.

7. Future Work

Future work will be done on the app in several ways:

a. Add more mental games. In addition to a measure of ignoring distraction (Stroop), additional games that assesses other abilities know in literature to be impacted by mindfulness meditation, including shifting attention (Trails A/B) will be included.
b. Add more meditation modules by offering older adults a series of 10-session mediation modules, each with a different objective. For example, one module will focus on "appreciation" and another one will focus on mental "balance".
c. Integrate a social component to motivate users through competing against their peers. In particular, older adults will be able to compete against others in the network (via cloud servers) on brain game performance as well as mediation efficiency (i.e., alpha). Older adults will also be given the option to post their performance to social media, if desired.
d. Provide more meaningful and personalized feedback. In particular, when an older adult has completed 10 sessions of meditation and the subsequent brain games, they will be informed about how much better or worse they did, e.g., "We can see you did not meditate regularly, every day. This may explain the limited benefits you saw in your mental game performance. Meditation - like physical exercise - has the biggest effect when practiced everyday."
e. Add achievement badges that can be gained when certain milestones are reached
f. The M3 app will be further developed to add a research opt in section. When an older adult agrees to be a part of research, their data will be stored in a cloud or server/online database so that it can be aggregated and analyzed by researchers.

We agree to have the video and our report posted. The External Specialist is planning on continuing work on the M3 app, but has agreed to open sourcing the source code.[2]

[2] Word Count: 2447 words, excluding References, Title Page, and Statement of agreement above

8. References

[1] Kovacevic N, Ritter P, Tays W, Moreno S, McIntosh AR. 'My Virtual Dream': Collective neurofeedback in an immersive art environment. PLoS ONE. 2015 Jul; 10(7): e0130129. doi: 10.1371/journal.pone.0130129

[2] Gallant SN. Mindful meditation practice and executive functioning: Breaking down the benefit. Conscious Cogn. 2016 Feb; 40: 116-130.

[3] Hasher L, Zacks RT, May CP. Inhibitory control, circadian arousal, and age. In: Gopher D & Koriat A, editors. Attention and performance XVII: Cognitive regulation of performance: Interaction of theory and application. Cambridge: The MIT Press; 1999. p. 653-675.

[4] Fisk JE, Sharp CA. Age-related impairment in executive functioning: Updating, inhibition, shifting, and access. J Clin Exp Neuropsyc. 2004 Oct; 26(7): 874-890.

[5] Moynihan JA, Chapman BP, Klorman R, Krasner MS, Duberstein PR, Warren Brown K, et al. Mindfulness-based stress reduction for older adults: Effects on executive function, frontal alpha asymmetry and immune function. Neuropsychobiology. 2013 Jun; 68: 34-43.