



Maximizing Aerobic Activity

MAX App

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Word count and penalty

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This version is available at

<https://github.com/ece1778-2020/MAX/tree/master/Documentation>

Key words

Android app; exercise; aerobic activity; stroke recovery; physiotherapy

1 Introduction

Stroke is one of the leading causes of death and disability worldwide [10]. In Canada, it is estimated that over 400,000 individuals live with the negative effects of stroke [4]. One major consequence post-stroke is poor cardiovascular fitness which affects more than 70% of stroke survivors [9].

Aerobic exercise safely and effectively improves cardiovascular fitness in individuals post-stroke [7][1]. The importance of aerobic exercise post-stroke has been highlighted by Canadian stroke rehabilitation practice guidelines [2]. In accordance to these guidelines, most stroke rehabilitation programs include aerobic training in their treatment plans [6]. However, despite initiating aerobic exercise in stroke rehabilitation, once discharged to the community, most stroke survivors are unable to engage and sustain meaningful aerobic training [5].

One reason for poor engagement in aerobic training, for stroke survivors in the community, would be the lack of guidance on how to perform aerobic exercise properly [8] and the lack of motivation to continue [3]. During stroke rehabilitation, stroke survivors receive regular and frequent feedback regarding their exercise performance. Feedback regarding whether they are exercising at the right intensity. Feedback regarding whether they are exercising for the right amount of time. Feedback regarding whether they are ready to progress. This lack of feedback can make engaging in aerobic exercise feel overwhelming. Additionally, even if they do engage in aerobic exercise initially, without the regular and frequent motivation and support from their therapist, stroke survivors also have a difficult time finding intrinsic motivation to continue and sustain aerobic exercise.

A relatively easy way to monitor an individual's exercise performance and to determine if the exercise intensity being carried out is sufficient to improve cardiovascular fitness is by measuring heart rate. For individuals post-stroke the Canadian stroke rehabilitation practice guidelines (Hebert et al., 2016) outline that stroke survivors should participate in aerobic exercise at an intensity of at least 40% of their heart rate reserve for a minimum of 60 minutes per week to obtain health benefits. Ensuring that stroke survivors exercise in this optimum heart rate range for the right amount of time is key to ensuring that cardiovascular fitness post-stroke is optimized, even post-rehabilitation.

The Maximizing Aerobic Exercise (MAX) app was therefore designed with the goal of providing personalized feedback to stroke survivors regarding aerobic exercise performance; ensuring they exercise at the right intensity and for the right amount of time. By helping users maximize the time spent in the optimum heart rate range (at least 40% of their heart rate reserve) and by providing additional motivation and guidance, the MAX app helps stroke survivors engage and sustain meaningful aerobic exercise and maximize their gains from aerobic exercise.

2 Functionality

MAX helps stroke survivors continue to safely and effectively engage in aerobic exercise by using their heart rate and their recommended optimum heart rate range for exercise to guide exercise performance feedback. This heart rate range can be automatically calculated based on the user's entered age or manually inputted based on the heart rate range prescribed for them by their physiotherapist.

For motivation, MAX allows users to set weekly exercise goals as well as weekly exercise reminders, if the weekly exercise goal has not been met. To track performance and progress, MAX also allows users to review their past sessions in graphical format so they can check to see if they are maximizing their time in the recommended heart rate range. Also, for guidance on how to progress their aerobic exercise, MAX provides exercise progression tips based on users' aerobic exercise performance history. Lastly for added motivation, MAX gamifies the aerobic exercise process by awarding badges to users when they reach important aerobic exercise milestones and allows users to share screenshots of their exercise progress.

For these features to work accurately, the app has to be paired to an external heart rate monitor. Currently MAX only supports the Wahoo TICKR Fit, but technically other sensors could be supported with minimal software modification.

Figures 1, 2 and 3 show all the parts of the app. The user experience starts on the screens depicted in Fig. 1a and 1b, where users can create a new account or log in with an existing one. This ensures all user data is stored in the cloud and their exercise data and progress is not lost in case they have to change their phones.

Fig. 2 shows all the remaining screens in the app. Fig. 2a shows the info page: a meta-page where users can read about the app and its purpose and know immediately if MAX is suitable for their goals. Fig. 2b is the first settings screen: here users can input their age and the maximum and minimum heart rate recommended by their physiotherapist, as well as their minimum goal in terms of how long they should stay in the target heart rate range per week (i.e.: between the minimum and the maximum). Fig. 2c is the second settings screen: here users can setup weekly reminders for when they are falling behind their aerobic exercise goals (see Fig. 3a), and they can also enable sound alerts to signal when they are above or below the target heart rate range, when they are unable to view their phone screen, during a session.

Fig. 2d is the dashboard screen: here users can get a reading of their current heart rate, a summary of their exercise sessions in the past week and also their currently configured minimum and maximum heart rate range. Fig 2e is the session screen: it allows users to start, pause and stop exercise sessions and it also keeps a counter with the duration of the workout. Most importantly, while a session is running the central panel gradually changes its color to let users know when they are below, in, or above the target heart rate range (yellow, green and red shades, respectively). These changes are also matched with distinct audio cues for the below and above target heart rate zone.

Also notable in the session screen is the bell icon near the top-right corner of the central panel. This bell appears whenever the user's monthly performance meets the criteria to progress to a more challenging exercise duration. After clicking on the bell users are shown messages like the one in Fig. 3b. When a session is finished, users are taken to the exercise summary in Fig. 2f, which is also accessible from the exercise log screen.

The exercise log screen shown in Fig. 2g is where users can see a graphical retrospective of their past exercise sessions. The colors in the bars on the chart match those of the session screen, making it easy for users to immediately identify the proportion of time they spent below, in, or above their target heart rate range. When a bar is clicked, users are taken back to that session's summary screen. Using pinch gestures users can zoom in and out of the chart, and they can also select a date range to restrict the time window (as shown in Fig. 2h). In the bottom of this screen there is a "share" button, which users can use to export their progress charts to social media to share their progress with their friends and family and for accountability and additional extrinsic motivation.

Finally, MAX also turns aerobic exercise into a fun, challenging and motivating game by giving badges to user who are performing well. There is a total of 9 badges that users can earn, ranging from very simple ones, like completing the first session, to very challenging, such as exercising for 60 minutes in a week in the ideal heart rate zone or exercising for the whole week only in this zone.

All parts of the app work as originally designed by the authors. The only surprise happened when working on the notification system, where all the code was originally developed using a phone running Android Marshmallow 6.0.1 as the test device, and later it was discovered that newer versions of Android changed substantially how notifications work.

Also, the sensorial feedback provided to users during sessions is sound instead of phone vibration as originally planned. In this case there was no technical limitation or challenge; sound was chosen simply because it was easier to demo it using the Zoom video conference system in our final presentation.

3 Overall Design

The overall architectural block diagram of the MAX app is presented on Fig. 4. In it, most of the blocks are contained within the user login macro-block, which indicates that most of the blocks are dealing with user specific data and creating user customized exercise sessions and feedback.

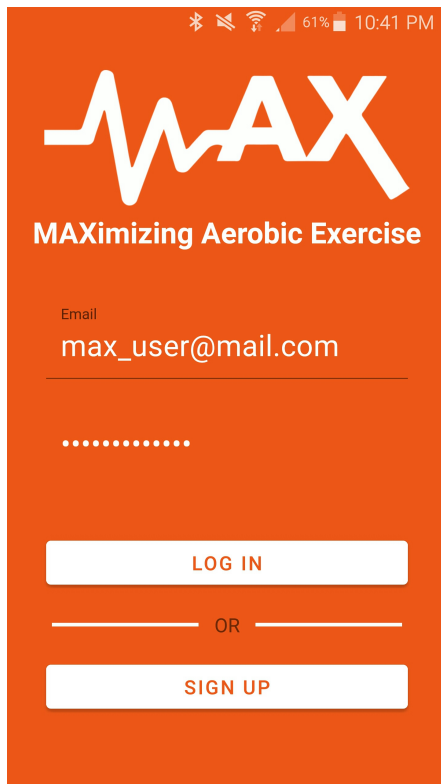
The heart rate data poller block is responsible for communicating with the external sensor. It feeds the exercise session and its alert system with heart rate data, which is also summarized and massaged by the data statistics block before it is stored. This massaged data is also fed to the bar charts in the log screen, and drives the badge reward system.

The exercise session itself is governed by the user settings, mainly the minimum and maximum heart rate thresholds. These settings are calculated based on the user age when they sign up, but they can be manually changed based on their physiotherapist's prescription or recommendation. The session also forwards the sensor data to the sensorial feedback (sound) sub-module.

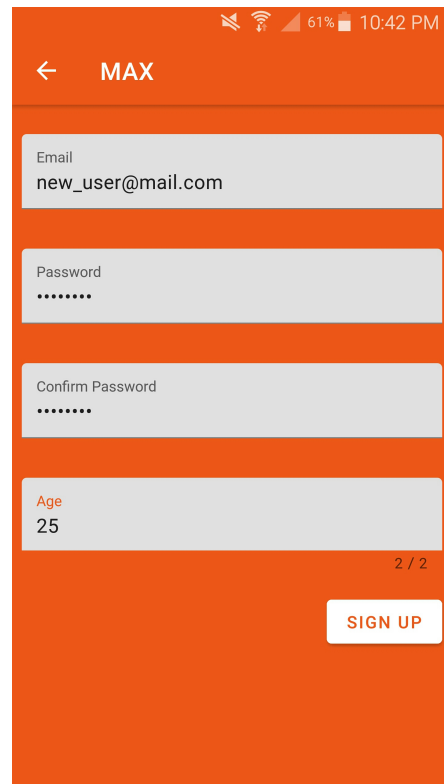
Reflecting on what we have learned with MAX, a key point to be considered in the future - specially for applications that are actually going to be deployed - is to always test them in as many different client configurations as possible. In MAX's case, we developed the whole notification system using Android Marshmallow 6.0.1 only to discover later that in subsequent versions of the Operating System the way notifications work had significantly changed. From the specialist's perspective, it was important to think through all the core functions of the app in a very detailed manner; translating physiotherapy skills and knowledge into very clear, specific and unambiguous functions that the programmers could work with.

Overall, in terms of successes that we should aim to repeat in the future, some are:

- Engage stakeholders at the start of the development process, making sure to fully understand and flesh out all the requirements;
- Keep stakeholders engaged throughout all the development cycle, making sure specifications are well understood and unambiguous;



(a) Login.



(b) Sign up.

Figure 1: MAX User Account.

- Transparency: make sure stakeholders understand technical limitations and what is (not) possible within the given schedule;
- Make sure to develop applications in gradual increments, ensuring the deliverable in the end of each cycle can be demoed;
- Communication is key. A simple conversation can avoid hours of wasted development;
- Practice demos like you would practice any other presentation.

4 Contribution by Each Group Member

The technical part of the app was developed by Felipe Clark and Ritam Haldar together. They met every day to design the app's architecture and write code. They share the ownership of the code 50%/50%.

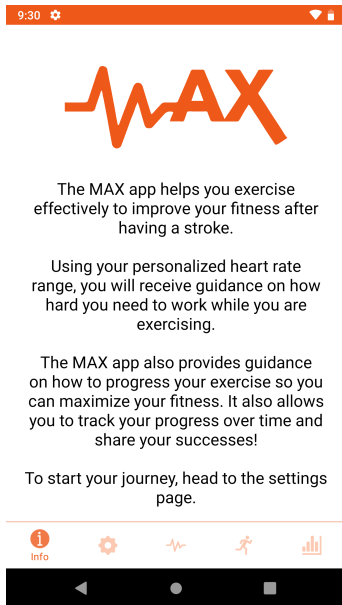
Michelle Legasto idealized the app, did the mocks for the user interface and tested all the branches on GitHub. She also coded the info page of the app.

As a group, we communicated regularly over online messaging and GitHub and met at least once a week in person or online during the coding phases and more frequently in preparation for presentations.

5 Specialist Context

MAX provides stroke survivors with a way to monitor their aerobic exercise performance and receive guidance and motivation so that they can sustain meaningful aerobic exercise in the community. As a stroke rehabilitation physiotherapist, MAX can help me educate my patients on how to effectively engage in aerobic exercise, regardless of what activity they are doing or what equipment they are using, and improve their accountability and intrinsic motivation to sustain engagement in aerobic exercise even without my constant feedback and support. I believe other physiotherapists will find MAX a useful tool in helping their patients continue to engage in safe and effective aerobic exercise beyond rehabilitation. MAX can help patients feel supported as they navigate through the rest of their stroke recovery.

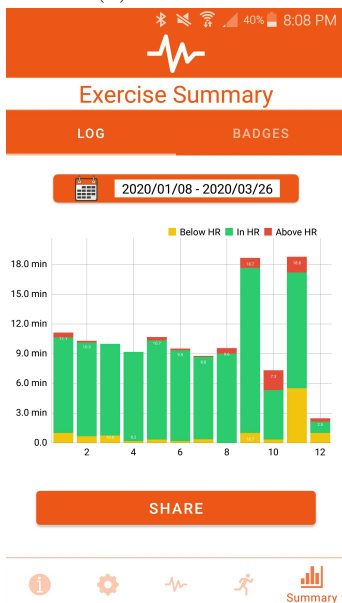
As a researcher, the focus of my PhD is to develop knowledge translation tools to optimize aerobic exercise training practices in stroke rehabilitation. Knowledge translation aims to put knowledge into practice and I



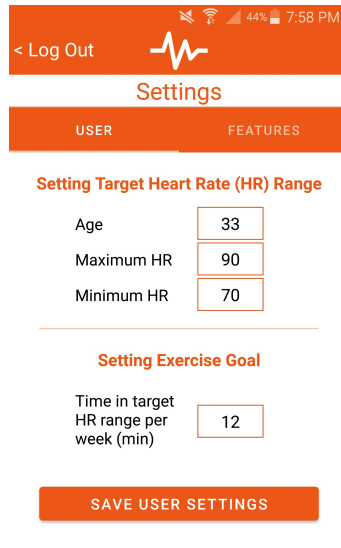
(a) Info.



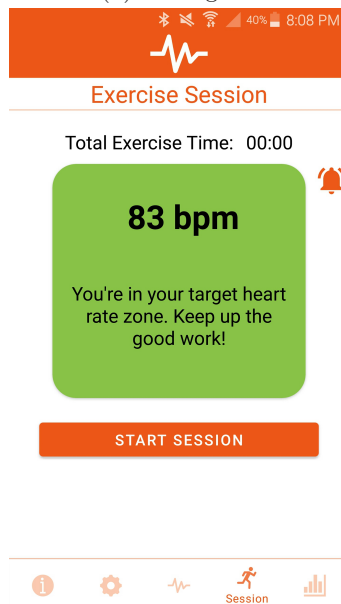
(d) Dashboard



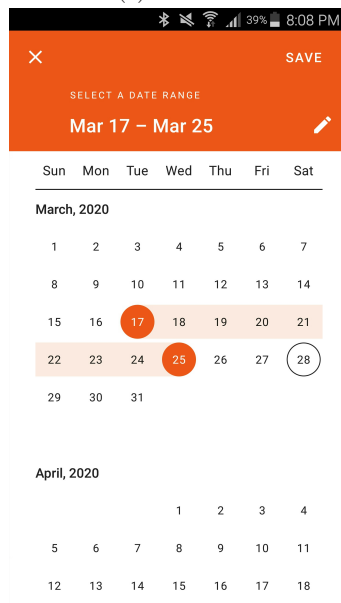
(g) Log.



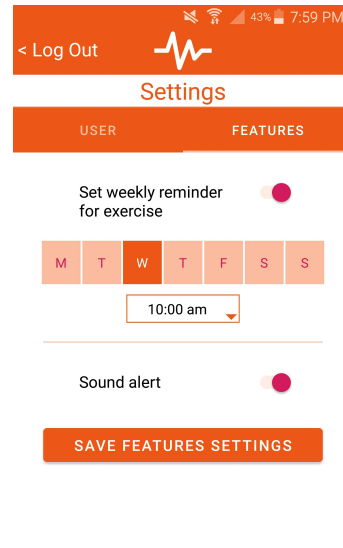
(b) Settings 1.



(e) Session.



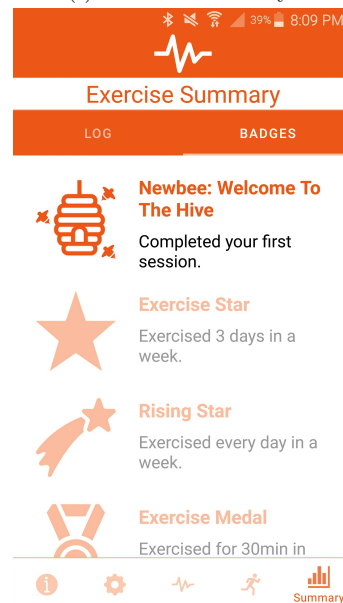
(h) Date selection.



(c) Settings 2.

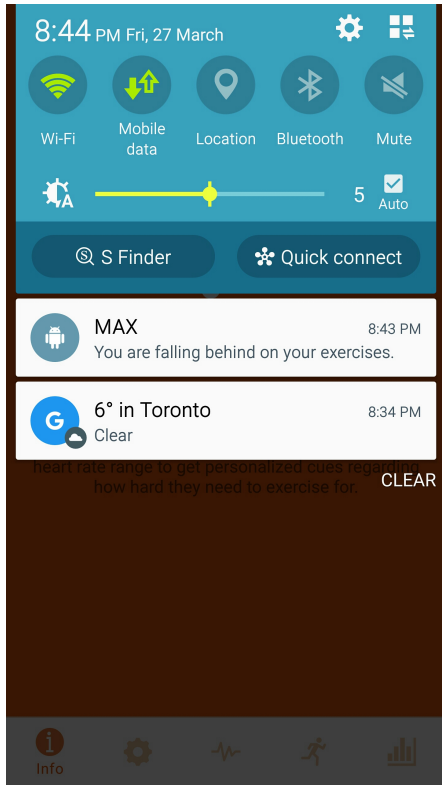


(f) Session Summary.

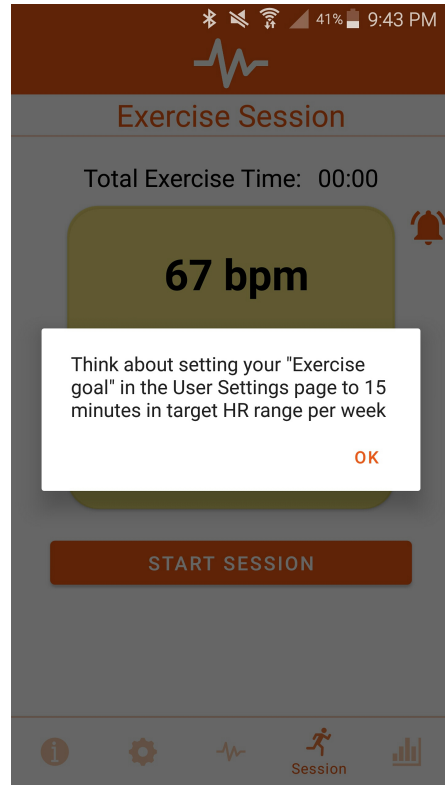


(i) Badges.

Figure 2: MAX app's screens.



(a) Reminder.



(b) Improvement Suggestion.

Figure 3: MAX Notifications.

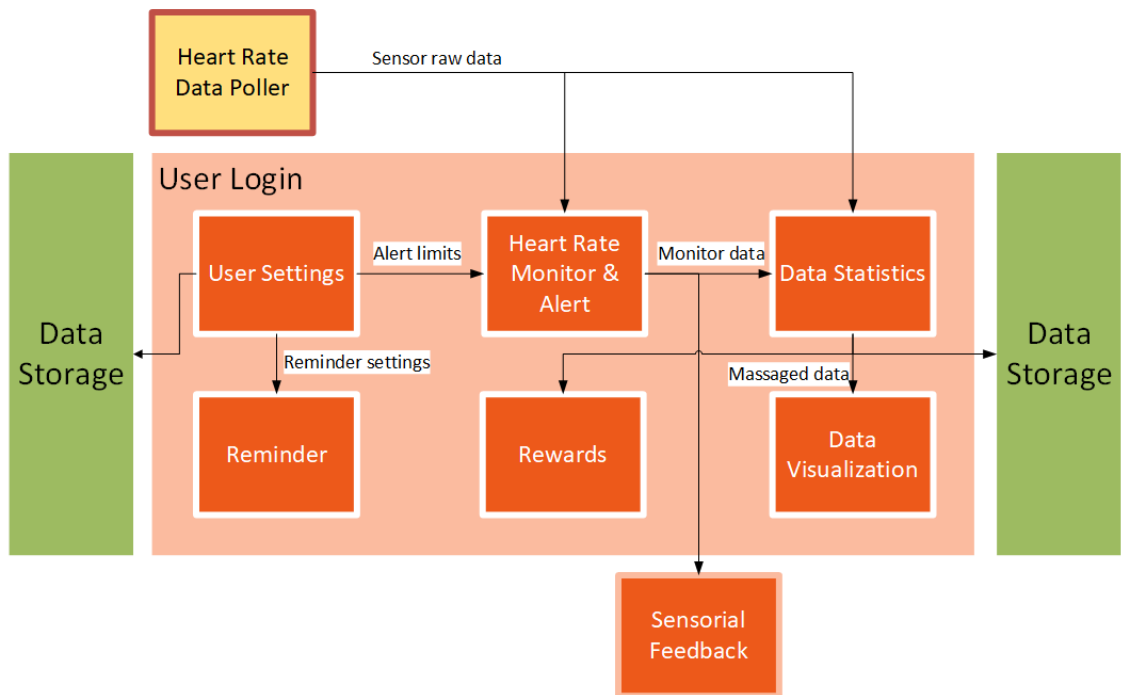


Figure 4: MAX's Block Diagram.

was very interested to see if an app could be developed to facilitate the translation of stroke best practice recommendations on aerobic exercise into actual aerobic exercise performance by stroke survivors. Now that MAX is developed, I hope to pilot test it at St. John's Rehab and see if it does facilitate the uptake of the aerobic exercise recommendations in stroke rehabilitation and beyond. I would then hope to partner with other stroke rehabilitation sites and perhaps the Heart and Stroke Foundation to move towards more widespread piloting and release.

MAX is starting point for a larger stroke aerobic exercise toolkit that will improve the ability of clinicians to prescribe appropriate aerobic exercise post-stroke and will improve the ability of stroke survivors to engage in and sustain aerobic exercise in stroke rehabilitation and beyond. Overall, MAX has the potential to significantly improve stroke survivor engagement in aerobic exercise, helping stroke survivors optimize their cardiovascular fitness and reduce the burden of stroke on individuals, their families, and the health care system.

6 Future Work

The authors believe MAX can be expanded much further, not just as an app, but also as a platform. For example, since all exercise session data is stored in a database, it should be straightforward to create a physiotherapist's portal where they can view their patients' exercise history, give more specific feedback and even update their patients' target heart rate range.

Additionally, there is a lot that can be learned from the data that MAX collects. For instance, by examining the average exercise progression of all users, physiotherapists could give their patients more specific information on their recovery trajectory. MAX could also be used by researchers to collect data on aerobic exercise activity and aerobic fitness post-stroke that could inform policy and funding decisions.

In terms of additional features for the Android app, it is desirable to implement the session's vibration feedback that the authors had originally planned (and replaced by sound alerts), and even more meaningful badges to keep users motivated.

7 Permissions

The authors of this work agree to have the following material made public:

- Video of final presentation;
- Report.

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