RehabMe
Semester Report

Interactive In-home Rehab Exercise Solution

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Acknowledgements

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RehabMe Semester Report
ELEC 419 - Innovation in Mobile Health

I. Introduction

Physical rehabilitation is essential to the recovery of a wide range of injuries and diseases including sports injuries, stroke, and parkinson's disease that affect millions of people every year. There are 1.9 million sports injuries treated in the ER in 2012 alone[1], and more than 200,000 ACL injuries annually in the US[2]. Physical rehabilitation helps patients with these injuries and diseases to regain physical abilities, such as balance and strength of certain part of their body.

During the rehabilitation period, which usually lasts from 4 weeks to 3 months, depending on the injury condition, patients are expected to perform a set of simple exercises daily. Due to insurance constraints, however, most patient only visit rehab facilities once or twice a week As a result, patients perform most of their rehabilitation exercise at home. Therefore, the quality of in-home exercise separates an excellent recovery from an OK recovery. However, many patients do not perform their in-home rehab exercises. One therapist believes only 15% to 25% of her patients perform the assigned rehab exercises at home.

We are able to discover several reasons for this phenomenon by interviewing both therapists and patients. Some patients do not understand the importance of in-home exercises and lack motivation to perform them. Some patients find the traditional exercise instruction sheets confusing and intimidating. Currently, therapists have no way to track patients in-home exercise at all and could end up being blamed for the lack of recovery progress even if they have done everything right.

II. Costumer discovery

We conducted more than a dozen interviews with 4 physical therapists, 6 student athletes, and 3 rehabilitation researchers. One of our most important initial hypothesis is that the form of

in-home exercises is crucial to patient recovery, and therefore we were considering incorporating motion tracking devices into our project. However, most therapists think that simply getting their patients to think about the exercises is a big step forward and precise form, such as accurate motion tracking, is not nearly as important. We present in this section two phases of our hypothesis, and how we came from our initial idea to the minimum viable product we currently have.

1. **Hypothesis phase I**

Based on the assumption that we were going to make a product that involved hardware for motion tracking, and software for recording and presenting data, we came up with the following hypothesis, and whether they were validated or rejected through interviews. Green check mark means the hypothesis is validated, and red cross means the hypothesis is rejected. These indications stay the same for the entire section.

<div align="center">List of Hypothesis</div>

✓	A number of rehab activities involve balance and physical movements.
X	Rehab patients could be assisted by sensors and sensory feedbacks when attempting rehab that requires balance.
X	Our product would be targeting low-cost, in-home rehab equipments

What we found is that most of the rehab exercises are relatively simple. Some of them does not require any movement; instead, they require the patients to stretch or hold a position for a duration of time. This means that even though we might use sensors to provide feedback for a few rehab exercises, our product would be limited to only those exercises that require motion, and would not be applicable for other exercises that require less or even no motion. We have also found that because the exercises are simple, patients can perform exercises by assistance of a chair, a table or a wall. More complicated exercises will be performed in the hospital, where advanced equipments will assist them in doing the exercises. Therefore, we believe that there is no need for the patients to purchase additional equipments to assist their in home rehab exercises, even though these equipments might be of low cost.

2. **Hypothesis phase II**

According to the above findings, we decided to abandon hardware as part of the solution, and switched direction to focus on a software solution. We formed another set of hypothesis, and conducted more interviews to validate them. The hypothesis for the second phase, and whether they were validated or rejected, are listed in the table below.

List of Hypothesis

✓	Patients forget to perform in home rehab exercises because instruction sheets are difficult to read and are easily lost.
✓	Therapists would like to see how their patients are recovering at home, even if the patients self-report their progress, which might not be entirely trusted.
✓	Rehab progress can be evaluated by some simple metric, and can be displayed visually
✓	Patients would like to track the rehab progress, even if the tracking process may not be automatic
✓	Patients will remember to do their in home rehab exercises if they are reminded by our app, or other reminding methods. They will not likely to ignore them.

This time, we were able to gather some very good results from interviews. The first two validated hypothesis gave us an idea to design an improved version of the instruction sheet that is intuitive, interactive and can be accessed almost everywhere, and at the same time allow therapists to give feedback to the patients when the patients are at home. The other validated hypothesis gave us an idea of some additional useful features that we could include in our solution. All combined, the hypothesis confirmed our idea to design a software solution that can best assist patients' in-home rehabilitation. We choose iOS as our platform for the software application. More details of our minimum viable product is explained in the next section.

III. the Minimum Viable Product

Based on findings from our interviews, we decided to create **RehabMe** — the interactive in-home rehabilitation solution that helps patients achieve the best possible recovery. Our primary goal is to, on the one hand, provide interactive exercise instructions for patients to replace traditional exercise sheets, and on the other hand, help therapists track patients' in-home

exercise progress and better evaluate their performance. Our application connects patients with their therapists and there are two parts of our MVP — mobile application and cloud application.
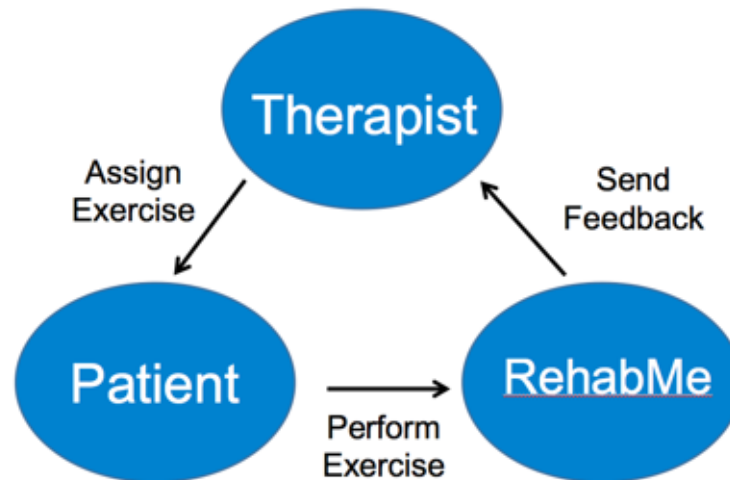
Therapists assign desired exercises through our cloud application. Assigned exercises are then presented as a deck of cards in our mobile application for the patients. Patients can perform assigned exercises in any order they wish. Patients simply swipe left if they wish to skip an exercise or perform it later; or swipe right after completing an exercise. Instead of reading through wordy instructions for a particular exercise, patients can simply watch a video to learn the exercise. The application also utilizes built-in timer to assist patients with holding exercises and sends out notice to remind patients to perform their exercises. After finishing their daily work, patients are asked to rate the difficulty of their exercise.

Our cloud application receives all the exercise data from mobile application and visualizes it in color coded scheme. The therapists then receive a weekly report on the performance of their patients, and can therefore make better decisions for the next step of rehabilitation.

IV. Technical Details

Figure 4.0 shows a high level system flow diagram for our application. The mobile application itself is self-contained, meaning that the smartphone is the only requirement to operate our app. Selected usage data are sent to Parse, our choice of cloud platform, and website

queries data from the cloud platform and visualize the data. Details are explained in the subsections below.

Figure 4.0 System flow diagram of RehabMe

1. RehabMe Mobile

Figure 4.1 shows a control flow of RehabMe mobile app. Each block represents one interface, or view controller (the following subsections will use this term instead of interface) by iOS terms, that users will see and do operations on. Details of the diagram are explained below, with figures in Appendix I.

1) The first time entrance to the app requires the user to either register or log in to use the app (Figure 4.2). We also provide a Facebook login so that users can create an account using their Facebook login information.

2) The app begins with the exercise card deck view controller. Here, all the exercises are represented by cards. Each card contains the name of the exercise, how many times and how long it should be performed, along with a picture illustration of the exercise, as can be seen in Figure 4.3.

3) There is a button "start" under each card. When pressed, the app enters the card detail view controller that displays the detailed instructions of the exercises (Figure 4.4). There are three buttons on the bottom: a "timer" button, a camera icon button, and a "done" button.

    i. When the user is ready for a particular exercise, the user hits the "timer" button, which brings the app to the timer view controller that shows a countdown clock, as can be seen in Figure 4.5. The time duration of the countdown clock depends on the time required for a particular exercise, typically 30 seconds. The user is expected to perform

the exercise until the timer hits zero. Tapping the screen brings the user back to the exercise detail view controller.

ii.   When the user needs to take a video of himself or herself doing the exercise so the user will not forget how to perform the exercise, the user can hit the camera icon. If there is no video recorded for this exercise, the app will ask for permission to use the phone camera (Figure 4.6). Afterwards, the user can record the video when he or she is ready. After recording, the user can either discard the video, or use it, as indicated by the two buttons on the button of the screen (Figure 4.7). The recorded video will be associated with the exercise. When there already exists a video associated with the exercise, the video will start playing immediately. The top left button brings the app back from the video to the card detail view controller.

iii. The last button in card detail view controller, the "done" button, brings the user from the card detail view controller back to the card deck view controller, which is an indication that the user has completed the exercise.
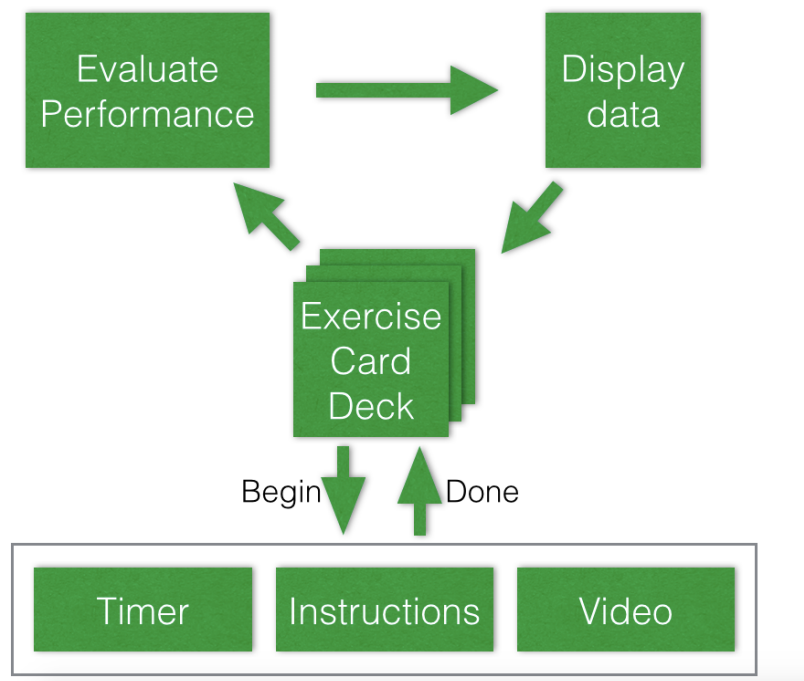

Figure 4.1 Control flow of RehabMe Mobile

4)   When in the card deck view controller, the user has two options to enter the next card (exercise) by swiping left or right the current card. Swiping left is to "discard" the current

card, which means that this exercise is not performed. On the other hand, swiping right means that the exercise is completed (Figure 4.8). The user is expected to either swipe the card again, or perform the exercise by going through steps explained previously in 1). When all exercises are completed, i.e. all the cards are swiped, the app enters the rate performance view controller (Figure 4.9), which provides the user with the opportunity to rate the difficulty level of all the exercises. Note that the user cannot rate each exercise individually; the user is expected to evaluate the whole set of exercises, which are the cards he or she just swipes through, and rate the overall difficulty he or she feels. The user will drag the circle on a scroll on the center of the screen. The left side of the scroll means maximum difficulty indicated by a thumb-down, and the right side of the scroll means minimum difficulty, indicated by a thumb-up. Once the user has completed the rating, he or she needs to hit submit, and the app enters the display data view controller.

   5)   Display data view controller is the last view controller before re-entering the home screen, which is the card deck view controller. The visualization makes use of the number of exercises performed per day to make a chart for the performance for the past 5 days (Figure 4.10). The score is calculated by the number of exercises performed in total for the past 5 days. A motivational quote is shown on the top of the screen. It can be clearly seen how the user is performing for the past few days by making use of simple usage data. After that, the user needs to hit the menu button on the top left corner of the screen to navigate back to the home screen, which is the card deck view controller. The menu bar (Figure 4.11) also provides quick access to multiple view controllers, such as performance (display data view controller), videos and exercises. In video view controller, user can watch all the videos he or she records, and delete them if he or she so desires. Similarly, exercise view controller stores all the exercises with their respective detailed information. User can customize the information, or add new exercises.

   2. RehabMe Cloud

This part of the product completes the feedback loop by visualizing patients' performance data on our website, rehabme.us. Screenshots are displayed in Appendix II.

   The following data is automatically sent to the server from the mobile app:
   • Date and time each exercise is performed, and the duration of the performance
   • Name and the number of the exercise performed or skipped

• User self reported difficulty level of each performance

Besides, the server also host information for all exercises. We do this because we envision that in the future, therapists can select certain exercises from an exercise database and send them to the patients. Therefore, patients do not need to have all the exercises stored on their phone. Instead, all the exercises will be stored on the server, and only a selected few exercises will be downloaded to the mobile app. This provides great flexibility for therapists to personalize exercises for their patients as well as saves storage space on the patients' phone.

We choose Parse as our cloud server, because it provides complete SDK and numerous examples that allow fast prototype. We only need to include the SDK in Xcode project, and with only a few lines, the data are sent to the server, and can be manipulated and visualized easily on the Parse server.

In order to organize the data to provide information that therapists and patients will understand by instinct, we organize the the above mentioned performance data into a table to show the patient's performance of a particular exercise on a certain date(Figure 4.12). Columns represent dates and rows represent exercises. Data in each cell represents the number of a particular exercise the patient performs on a particular date. The table is color coded. Red means bad performance, yellow means OK but needs improvements, and green means good performance. The color of row names and column names is determined by a simple algorithm:

i.   If the total number of exercises performed for a date

    i.i. exceeds 15, then that date cell is green;

    i.ii. is between 5 and 15, then that date cell is yellow;

    i.iii. is below 5, then that date cell is red.

ii.   If the total number of a certain exercise performed

    ii.i. exceeds 10, the the exercise name cell is green;

    ii.ii. is between 5 and 10, then the exercise name cell is yellow;

    ii.iii. is below 5, then the exercise name cell is red.

The color provides patients and therapists an intuitive way to quickly pinpoint on which dates, and for which exercises, the patient is not doing well. The therapists can then ask specific questions during the next meeting with the patient at the rehab institute, and give more useful feedback to help the patients better recover.

The website contains a dropdown menu. When clicked, the menu will show the table. Currently there is also a demo explanation inside the dropdown menu. The menu is also color coded, in a way that if there exists a cell that is red in the table, the menu will be red. The idea is that the therapists will see a lot of patients, and they only need to focus on those patients that are shown as red on the menu, and expand the menu to see the detailed performance. We believe this saves the therapists a lot of time, while still providing insights into patients' performance. Also note that the information is strictly controlled; each patient will only see their own performance data, but not other patients'. Therapists, however, will be able to see all of their patients performance data.

We create the website, rehabme.us to display host the table. JavaScript functions on the website query data directly from Parse, and organize the information in HTML table elements. Therefore, the website is updated in real-time: whenever the user completes an operation, the data shown on the website will be modified instantly by refreshing the page.

V. Results

We validated our product with potential users to get feedback on the current features and to get suggestions on possible additional features. We started the validation process once we have the very first prototype of our product, which is just a deck of cards that you can swipe left or right. We then perform the two validations to modify our product based on what we have discovered during the validation process.

Our potential users will be patients going through rehabilitation process, and therapists that oversee and assist the patients. Our aim in this validation is mainly to get ideas on the functionalities of our product, i.e. what features to add, and what features to improve. We presented our product to in total 2 therapists and all the patients we have interviewed. We then made changes to our product, and presented the changed version to our potential users once again to validate the changes. These seem to be minor changes, but we believe will be significant improvement on the user experience. Some changes and additional features are listed below.

    1) We heard that users complain that there is no way to exit the timer on some situations, i.e. when they suddenly receive a phone call when they are in the timer screen. They would like an option to exit the timer and enter it again when such situation is encountered. So we modify the timer screen so that when in timer view controller, user

can hit anywhere on the screen to exit the timer view controller. Previously, the user will be locked on this view controller until the timer is ended.

  2) We heard that users would like more flexibility to personalize the exercises. There is a separate screen for all exercises. The users can view the exercises on one screen, make changes to them, or add their own customized exercises.

  3) We heard that users would like clearer indication of the difficulty level of their workout. So we changed the rating to a scroll bar with thumb-down on the left side, indicating difficult, and thumb-up on the right side, indicating easy. The user can scroll from left to right and choose how difficult they feel for the exercises he or she just performed. Perviously we used 5 stars to indicate difficulty level, and it is not clear whether 5 stars mean difficult exercises or easy exercises.

  4) Therapists said that just getting patients think about the exercises is a great step in making them do the exercises. We therefore added push notifications that patients as well as therapists can customize to send a notification to patients at certain time of the day to remind them to do the exercises when they haven't yet done so.

We were also able to confirm some features we already have that our potential users liked. The timer, video taking functionality, the data visualization, the motivational quote, and the card deck that shows all exercises, have been confirmed to be useful when patients as well as therapists played with the app.

We then would like to perform A/B test. We'd like to work with therapists, so that they will use our application for half of their patients, and see if there is improvement for this group of patients compared to the patients who are not using our application. In this way, we will really know the effectiveness of our application. In summary, in the current stage, we validated existing features and added or modified them based on feedback from our potential users.

VI. Future Work

Human factor is a very important and indispensable component in our application. In the product prototype we have designed so far, we built the framework that effectively addresses the hypothesis we have validated during the customer discovery process. Under the framework, we use a deck-of-card like interface with useful features such as timer and video taking to replace traditional exercise instruction sheet, and website to visualize useful data sent from the app to the

server for therapists to remotely understand their patients. In addition to all the features we have built, we would like to enable interaction among people, so that the app is not only much more fun to use, but also provides additional motivation for people to perform their in home rehab exercises. Therefore, we propose the following next steps:

1. **Build the reword system**. Giving our users rewards based on certain usage data has been proven to be an effective way to increase app usage[3]. In our app, we plan to implement the following three functionalities to complete the reward system:

    i) <u>Digital badges</u>. The app issues digital badges based on the three categories of users' data: the length of a streak (how many days in a row does the user perform the exercises), the number of exercises performed, and the time spent on the exercises. A badge will be issued based on the streak and on the two scores. We will set certain milestones, such as 5 day streak, 50 sets of exercises completed, 100 minutes spent on exercises, etc.. When the user hits a certain milestone, he or she will receive a badge. We will include information on why the badge is earned ("Congratulations! You have just completed the 50th set of exercises.") and when the badge is issued, because studies show that these information adds to the credibility motivation for the user[4].

    ii) <u>Messaging system</u>. We will enable even more interactivity between therapists and patients by a messaging system. With instant message functionality, therapists have the ability to send encouraging words, or friendly reminders, to the patients, based on the patients' performance that the therapists can view on the website. This functionality allows patients to receive feedback from therapists in real time, so that they get a sense of accomplishments when the therapists praise them on good performance, or they work on their exercises when the therapists remind them of not performing exercises for the day. Either way, we believe that the messaging system is a good way to connect therapists and patients, and to help patients better perform their in-home exercises.

    iii) <u>Social network</u>. We will allow users to share their achievements on social networks. It has two benefits: firstly, users get extra motivation for doing their home rehab exercises by sharing their achievements to their friends, and secondly, more people will know about our application and try it themselves.

Therefore, social networks not only help users recover better, but also help us attract more users.

2. Integration with HealthKit, ResearchKit. The advantage of building the application on iOS device is the possibility to integrate with apple's HealthKit and ResearchKit. These two kits provide API for medical data, and have various data visualization and research tools. By integrating HealthKit, we open the gate for the user to combine the data from our app with data from other health related applications the user might use to get a thorough landscape of the user's health and recovery conditions. Similarly, by integrating ResearchKit, we create opportunities for researchers and doctors to make use of the usage data generated by our application for research purposes. With the advancement of big data analysis, we hope that our app, with the integration of ResearchKit and descent number of users, will allow scientists to discover better rehab methods that may further enhance a patient's recovery.

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Appendix I - Figures for RehabMe Mobile
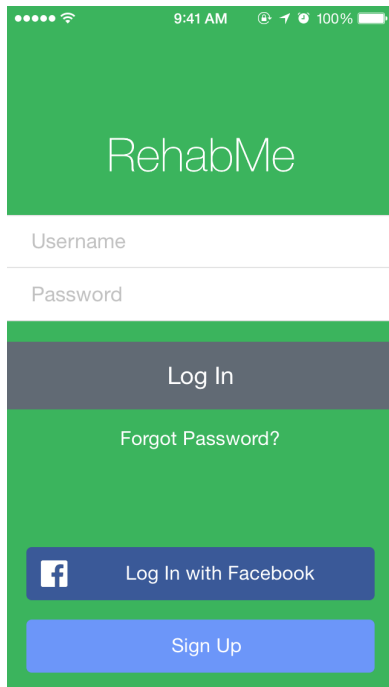
Figure 4.2 Login screen
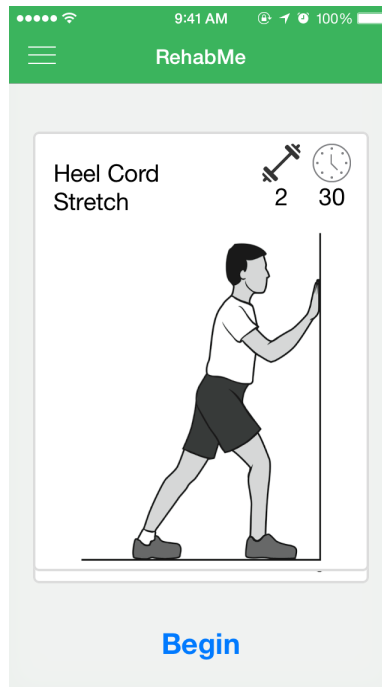
Figure 4.3 Card deck
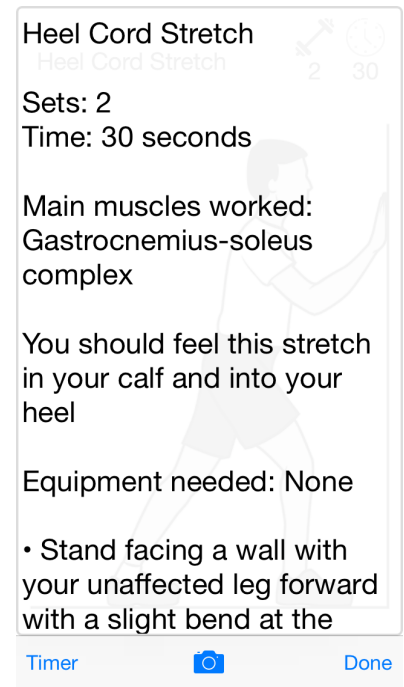
Figure 4.4 Card detail

Figure 4.5 Timer
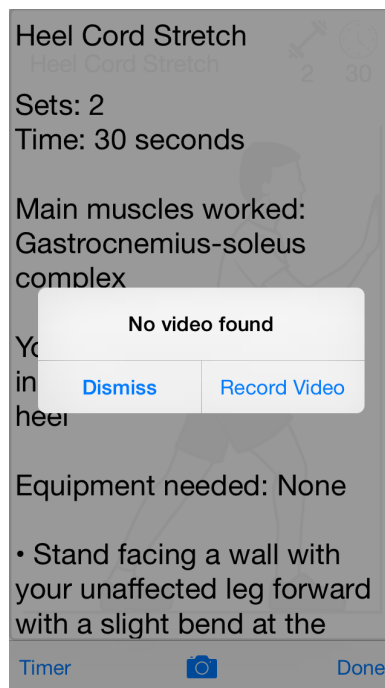
Figure 4.6 Video recording

Figure 4.7 Video playback
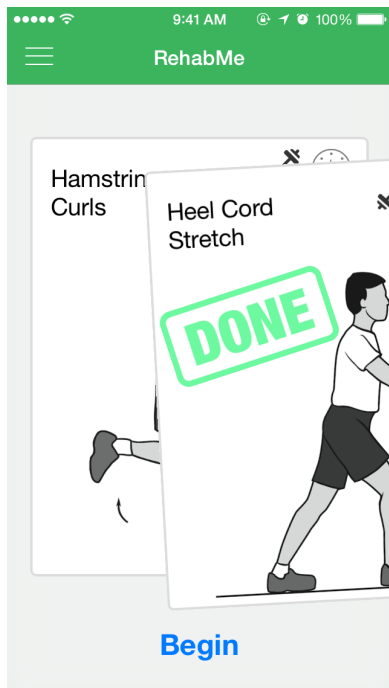
Figure 4.8 (a) Swipe right
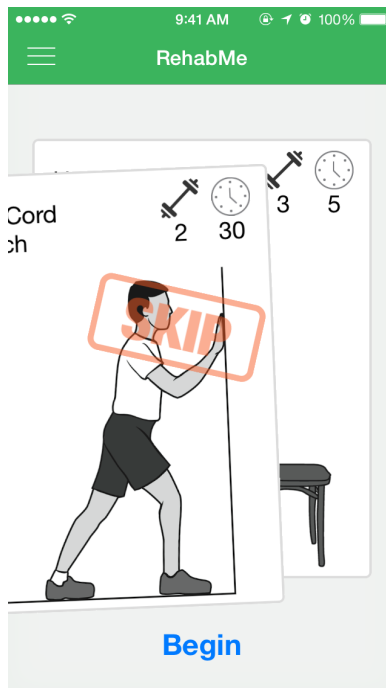
Figure 4.8 (b) Swipe left
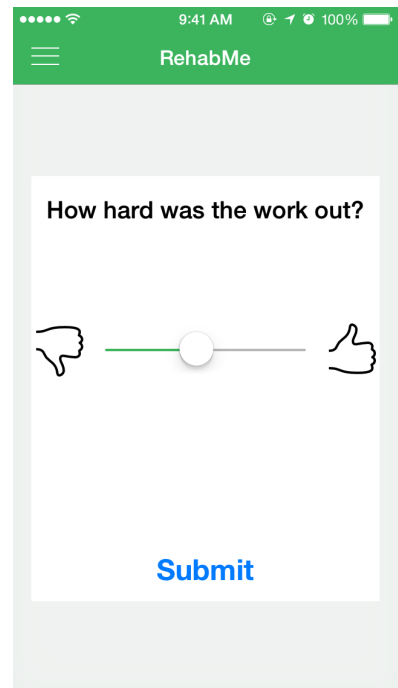
Figure 4.9 Rate performance

Figure 4.10 Display data
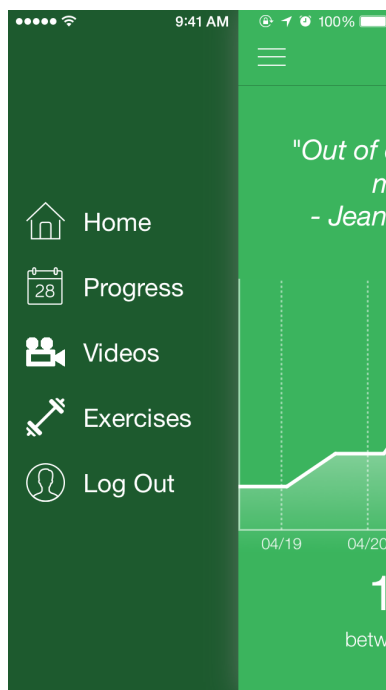
Figure 4.11 Menu bar

Appendix II - Figures for RehabMe Cloud

Exercises	Dates			
	Wed Apr 08 2015	Mon Apr 20 2015	Wed Apr 22 2015	Thu Apr 23 2015
Heel Cord Stretch	0	1	5	1
Hamstring Curls	0	1	5	2
Half Squats	0	1	5	1
Supine Hamstring Stretch	0	1	2	2
Standing Quadriceps Stretch	0	1	2	1
Calf Raises	0	1	4	1
Leg Extensions	0	1	2	1
Straight-Leg Raises	0	1	2	1
Straight-Leg Raises (Prone)	0	1	2	1
Hip Abduction	0	2	4	1
Hip Adduction	0	0	0	1
Leg Presses	0	1	0	1

Figure 4.12 Color coded table

Figure 4.13 Expanded menu view

Figure 4.14 Login screen