Improving Outpatient Physical Therapy

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Abstract

Outpatient physical therapy loses effectiveness due to long wait times in between clinical visits. PT Helper is a system designed to combat this disadvantage in three ways. PT Helper increases the effectiveness of the patient-clinician interview conducted at the beginning of each clinical visit by presenting the physical therapist with a correlated account of a patient’s pain and activity level. PT Helper increases the likelihood of patients’ performing their assigned exercises correctly by providing a medium of instruction that cannot be lost or discarded. Finally, PT Helper encourages patients to perform assigned exercises utilizing both positive and negative reinforcement. PT Helper was developed with feedback from clinical physical therapists and evaluated by former patients, current patients, and an athletic trainer. These evaluations support the hypotheses that PT Helper is a useful tool in both increasing the efficiency of the patient-clinician interview, and encouraging patients to perform their assigned exercises correctly.
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1 Introduction

Outpatient physical therapy is dedicated to restoring the abilities of patients who have suffered significant injury. This often consists of three objectives: increasing mobility, strengthening muscles, and eliminating pain. Of these three objectives, pain is most often used as a marker of patient recovery. Pain also alerts a physical therapist to specific activities in the patient’s life that agitate his or her injury, causing the patient to heal more slowly. Thus the ability to track pain accurately is integral to physical therapists.

Unfortunately, accurately understanding when and why a patient has pain is a difficult objective. Physical therapists see most of their patients only two to three times per week, whereas pain and activity that is causing pain can occur on an hourly basis. Therefore it falls upon the patient to accurately remember each time pain occurred and communicate this and their activities to the physical therapist. This patient interview is a central diagnostic tool for the physical therapist, and is often considered to provide more helpful insights for the diagnosis than a checklist of symptoms or even a mobility test (Jenson). However, a patient interview is far from perfect. It is difficult for patients to remember certain aspects of their day, and patients lack the training to determine what details are critical to inform the physical therapist of and what details don’t matter. In addition, patient information is not always forthcoming. It can take time to properly coax the needed information from patients. The more time coaxing information out of a patient takes, the less time the physician has to diagnose and treat the problem, and the interview is not guaranteed to provide the physical therapist with the entire picture.

Another unfortunate problem that arises with outpatient physical therapy is the low frequency that rehabilitating exercises are performed. Often the typical two to three visits a week is far below the necessary amount of time spent stretching and exercising needed for optimal patient recovery. To help achieve optimal recovery time, many patients are
provided with exercises and stretches to complete at home. These patients are handed pamphlets that explain these homework exercises and told to do them regularly. As one can imagine, this leads to an infrequent and irregular exercise regimen. Patients fail to do their exercises for a variety of reasons including discomfort, limited time, and lack of motivation. This is an area of great concern among physical therapists, who have conducted multiple studies in an attempt to understand and increase home exercise compliance (Sluijs).

2 Improving Outpatient Physical Therapy

PT Helper was designed to augment physical therapy so that it could be face these challenges. The system improves a physical therapist's ability to treat his or her patients by focusing on three goals: facilitating accurate pain and activity tracking, providing exercise motivation and education, and improving communication between the patient and the physical therapist.

2.1 Facilitating Accurate Pain and Activity Tracking:

By accurately tracking a patient's pain and activity, PT Helper provides insight to physical therapists about the relationship between a patient's pain and activity. This insight allows physical therapists not only to know if a patient has been experiencing pain, but to form educated hypotheses about why that pain occurred, leading to a more specific recommendation of which muscles to focus on during therapy, what exercises to assign the patient, and what activities to prohibit so that the patient can heal.

2.2 Exercise Motivation and Education:

PT Helper is designed to motivate and educate a patient on when, how, and why they should commit themselves to at-home exercises and stretches. Motivation increases
the frequency of completed take home exercises and education decreases the probability that a patient performs their take home exercises incorrectly. Increasing the frequency of completed take home exercises strengthens a patient’s muscles and increases a patient’s mobility. Decreasing the chance of a patient performing exercises incorrectly reduces the chance of the patient injuring himself or herself and having to perform additional physical therapy.

2.3 Improving Communication

The information collected from the patient and presented to the physical therapist also helps guide the physical therapist during the routine patient interview. Instead of blanket questions such as “Have you felt any pain recently?”, physical therapists can immediately question the patient on specific instances of pain and specific days of exercise. This is the most important function of PT Helper: it increases the efficiency of the patient interview, resulting in a faster, more informative dialogue that contributes to patient treatment.

A description and evaluation of PT Helper can be found below. If correctly used, this system and its evaluation promotes a dialogue between the patients, physical therapists, and researchers that will not only help appraise this system, but also provide useful insights for future systems.

3 Previous Work

Mobile health tracking technology is in its infancy. One early innovator is the UP24, which was released in 2013 (Jawbone). PT Helper was originally designed to make use of the UP24 iOS application when tracking a patient’s activity. The introduction of the iOS HealthKit significantly altered this plan. The iOS Healthkit is a feature added to iOS software
in version 8.0. It acts as a database of health information, allowing various hardware and software products to store and read a user’s activity, caloric intake, pulse, step count, and more. This opened up new possibilities to PT Helper. Instead of requiring that a patient obtain an UP24 to track the patient’s activity, PT Helper accesses information from the iOS Healthkit. This allows patients to use a wide variety of activity trackers, including those from Fitbit, Up, Microsoft, Nike, and the new iWatch. The iPhone itself can also be used as an activity collection device with its accelerometer, though to a more limited extent.

There are a number of iOS apps that display activity information to a user: MapMyFitness is a fitness-tracking app that has incorporated the UP24 into its calorie and activity data recording (MapMyFitness), while Lose It! is a dedicated weight loss application that can be connected to the UP wristband (Weight). However, there are no current systems incorporating mobile health tracking in an effort to improve physical therapy.

There is little work in assistive technology designed to motivate physical therapy assigned exercise compliance. In 2006 Rachel Gockley and Maja Mataric conducted a study to determine under what conditions the presence of a robot could encourage exercise compliance (Gockley). While the study contained a small sample size, the conclusion, that a non-vocal robot could positively effect exercise compliance in patients, offers encouragement that assistive technology could be useful for this purpose.

4 PT Helper

PT Helper was designed utilizing feedback from the interview of three practicing physical therapists. The system is composed of three distinct modules: a secure server (PT Server) and two distinct iPhone applications: one used by the patient (Patient Portal), and one used by the physical therapist (PT Portal). Patient Portal educates, motivates, and collects data from the patient. The collected information is then sent to PT Server where it
is catalogued and saved. When a physical therapist is interviewing a patient, PT Portal collects information from PT Server and displays it in an easily understandable format.

4.1 Activity and Pain Tracking

Patient Portal receives activity information, specifically step count per hour, from the iOS Healthkit. Receiving information from Healthkit allows many different and even multiple fitness tracking devices to be used to collect data for the application. PT Portal then receives information regarding a patient’s pain from user input. This data is combined and sent to PT Server, which then sends the information to the patient’s physical therapist who views it using PT Portal. PT Portal receives patient information and displays it in a clear and condensed format. This information allows physical therapists to quickly determine where and when patient pain has occurred so that they can more quickly and accurately surmise why pain is occurring.

4.2 Exercise Education and Motivation

PT Portal allows physical therapists to assign patients homework exercises and stretches. Physical therapists can also provide instruction by attaching the URL of an instructional webpage or video to the exercise. This allows patients to perform these exercises regularly and accurately. Patient Portal allows patients to view a checklist of home exercises that they need to complete.

Patients also receive exercise motivation from Patient Portal. Exercise motivation is provided utilizing both positive and negative reinforcement. When a patient completes an exercise, he or she indicates this to Patient Portal. An exercise’s completion is viewable by the patient’s physical therapist on PT Portal. This transparency holds patients accountable to their physical therapist. If they are not doing their exercises, the physical therapist will know and provide the appropriate negative reinforcement. Patient Portal also attempts to
motivate patients with positive reinforcement called achievements. A patient receives achievements by completing general goals that encourage them to complete their exercises, use Patient Portal, and recover from injury.

4.3 Improving Communication

While it may be easier for a physical therapist to comb through patient data on a web application or a computer program, an iPhone application allows the physical therapist to view recent data while in the middle of interviewing the patient. The use of PT Portal during a patient interview provides the physical therapists with specific instances of pain, activity, and exercise compliance to ask the patient about, increasing the information gained from and reducing the time of the patient interview.

4.4 System Flexibility

In many healthcare information systems today, patient information is difficult to transfer between different physicians. In addition, systems are difficult to customize to individual clinics. PT Helper was designed in an attempt to remove these common aggravations. PT Helper provides an efficient way to transfer patient information between physical therapists and is easily customizable. Part of this customizability stems from the simplicity of the system, and part of it from the design of its functions.

5 Patient Portal

Patient Portal is a patient's interface into the PT Helper system. Patient Portal is designed to be used daily by the patient. Patients with Patient Portal can log pain that is occurring, view descriptions and a schedule of their assigned exercises, and confirm they have performed these exercises. Patient Portal is designed to encourage patients to use the
system. It provides positive reinforcement with achievements and negative reinforcement by creating accountability. Patient Portal can be broken down into four views, the *Log In and Sign Up View*, the *Home View*, the *Achievements View*, the *Exercise View*, and the *Settings View*.

### 5.1 Log In and Sign Up Views

Upon initialization of the iOS application, the *Log In View* is displayed to the patient. Figure 1 presents this view. If a patient has an account with PT Helper, the patient enters his or her username and password into the text fields. A patient should rarely visit this view. The system stays logged in unless the phone is turned off or Patient Portal is shut down by the patient. Additionally, given that the ideal use case consists of a single patient per phone there is little reason for a patient to routinely log out of the system. If a patient does not have an account, he or she can select the *Sign Up* button. This displays the *Sign Up View*. Here patients can register an account with the system. Figure 2 presents the *Sign Up View*. 
Figure 1: The **Home View**.

Here patients can log into their respective Portals, or select the *No Account? button* to create a new account.
Figure 2: The Sign Up View.

Here patients can create a new account.
5.2 Home View

Patient Portal was designed to allow a patient to quickly and easily log pain. This requires a user interface that is informative but not distracting: clearly indicating to the patient the functionality of the system without bewildering the patient with too many labels, choices, or directions. Figure 3 presents a snapshot of Home View as it can be viewed on the iPhone 6. Notice the prominent position of the Log Pain button. The position, size, and color of the button was chosen to draw the patient’s attention, ensuring that even first time patients have no trouble discovering this functionality. In fact, the size, color, font-size, and position of all buttons that make up Home View denote the importance of their respective functions. Home View breaks down the system’s functionality into three tasks: pain logging, exercise encouragement, and system maintenance. Figure 4 displays the Home View divided into these three types of functionality. Patients are expected to log pain one to three times a day; hence the Log Pain button is the largest and most prominent. The blue background Exercise and Achievements buttons in the middle of the view are exercise encouragement buttons. These allow patients to view Assigned Exercises View and Achievements View, views that they are expected to be used between one to three times every two days. Finally, the smaller Settings, Reload Data, and Log out buttons are system maintenance buttons. These perform functions that the patient is expected to need one to two times every week. This user interface subtly communicates use-case information to the patient while still maintaining a simple and non-cluttered view. The title bar of the Home View presents the patient's username, allowing patients to confirm they are correctly signed into the application. Figure 4 documents the title bar of the Home View. While it is not recommended that multiple patients use the application on the same phone (as the system collects information based on who is holding the phone and therefore cannot collect accurate information on multiple patients who utilize the same phone), presenting the
patient's username provides a small amount of multiple-user functionality. The various buttons on the *Home View* provide a variety of functions, detailed below.

![Home View of Patient Portal](image)

**Figure 3 The Home View of Patient Portal.**

The *Home View* functions as a main menu for Patient Portal.
Figure 4: Division of Home View.

Home View of Patient Portal divided into its three distinct components. The logging pain button, the exercises encouragement buttons, and the system maintenance buttons. The title bar is also highlighted.

5.2.1 Log Pain button

The effectiveness of the entire system is dependent upon the compliance of the patient. Therefore logging pain must require as little effort and time as possible. However, the more information that PT Helper can pull from the patient, the more effective it will be in assisting physical therapists. Attributes such as type, duration, location, and level of pain
can all be useful in determining why pain is occurring. Thus promoting patient compliance
and extracting information from the patient are in direct conflict with one another.
Determining the balance between these two goals was a constant struggle in development
and a major focus in evaluation of the application. After an initial discussion with a group of
physical therapists, a solution was determined: in order to balance these two conflicting
goals, the patient is only asked the type and level of pain. When selecting the Log Pain
button, the system displays a pain description window. Figure 5 demonstrates this window
in the application. At this window, a patient can select the intensity of pain he or she is
experiencing by moving the slider. The farther right the slider the more pain he or she is
experiencing. The text above the slider indicates what a specific level of pain intensity
means. Using the descriptions for the Universal Pain Assessment Tool, pain intensity is
composed of 6 levels. These levels are: “Can be Ignored”, “Interferes with Tasks”, “Interferes
with Concentration”, “Interferes with Basic Needs”, and “Bed Rest Required.” The text and
slider are color coded to make it easier to recognize a change between different levels of
pain intensity. A patient can then select what type of pain he or she is experiencing by
selecting the appropriate description under the label Pain Type. The available descriptions
are “throb”, “burn”, “sharp”, and “ache”. A patient can select all, some, or none of these
descriptors. To confirm the logging of pain, a patient selects the red Log Pain button. To
cancel the action of logging pain, a patient selects the Cancel button. It is important to note
that a patient does not need to enter information on either pain intensity or pain type. A
patient only needs to confirm pain by selecting the second Log Pain button to send pain
information to the system’s server. In PT Portal, pain logged with the default intensity of 0
appears as “Pain Intensity not Logged,” alerting the physical therapist that pain was logged
without misrepresenting the intensity level.
Figure 5 A pain description window.

When a patient selects the Log Pain button, this pain description window appears. In this window the patient can enter the pain intensity and type of pain he or she is experiencing.
5.2.2 Exercise button

The Exercise button transfers patients to Assigned Exercises View. There a patient can view all the exercises he or she has been assigned by a physical therapist. Assigned Exercise View displays these exercises in detail, informing a patient when they need to complete these exercises, the number of sets and reps they need to complete, and even offering a URL link to an instructional website or video. At Assigned Exercises View a patient can also indicate that he or she has completed, attempted, or skipped an assigned exercise. Exercise compliance information is disseminated to the physical therapist to through PT Portal.

5.2.3 Achievements button

The Achievements button transfers patients to Achievements View. In Achievements View a patient can view the names and descriptions of achievements he or she has earned. Achievements are small milestones that incentivize the patient to log pain, complete assigned exercises, and use Patient Portal in general. A patient is notified instantly if he or she has completed an achievement after performing a specific action.

5.2.4 Settings button

The Settings button transfers patients to Settings View. In Settings View a patient can assign or change the physical therapist that receives his or her information. Only one physical therapist can be assigned to a patient at a time and only the assigned physical therapist can view patient data or assign exercises. Changing the assigned physical therapist does not modify a patient’s data; it modifies the permissions of that data. This enables a patient to switch between physical therapists as frequently as he or she wants without fear of losing his or her information.
5.2.5 **Reload Data button**

Patient Portal uses the iOS Healthkit to collect information about a patient, such as the number of steps a patient took in the last hour. This information is then sent to PT Portal so that a physical therapist can correlate pain and movement data. Unfortunately, the iOS Healthkit is in its infancy, and contains a few bugs that make automatic long term monitoring of Healthkit data impractical. To solve this problem, the *Reload Data* button was created. When this button is selected, the system initiates a new instance of an automatic Healthkit monitor and collects information from the past ten days. This buttons should only be used during a clinic visit if the assigned physical therapist notices his or her PT Portal has not received information from the patient.

5.2.6 **Log Out button**

The *Log Out* button logs a patient out of Patient Portal by setting the state of the application to reflect that the patient is not logged in. This automatically transfers the patient to the *Log In View*. The *Log Out* button does not send any information to PT Server. This button stops the collection of activity information from iOS HealthKit. Upon login, activity information from the past week is sent to PT Server, allowing the system to play catch-up if a patient has been logged out for some time.

5.3 **Exercise View**

Assigned exercises are light exercises or stretches that a physical therapist deems necessary to be performed at home on days that a patient does not visit the physical therapist. The completion of assigned exercises is critical to the quick recovery of a patient. *Exercise View* is one component of a two-part process that encourages a patient to complete his or her assigned exercises. Figure 6 presents *Exercise View* on the iPhone 6. This view performs three important functions. First, it reminds patients what exercises they need to
complete each day. Second, it holds patients accountable for not completing these exercises. And third, it teaches patients how to do their assigned exercises correctly.

When a patient visits Exercise View, it displays the names of the exercises that are assigned for the current day of the week. A patient can click on these exercises to confirm to his or her physical therapist that he or she has completed them. A patient can view exercises that were due the day before in case he or she forgot to complete his or her exercises that day by selecting the Previous Day button. A patient can also view the exercises that are due the next day by selecting the Next Day button. This allows a patient to complete assigned exercises a day before if he or she realizes they will be unable to perform them the next day. However, a patient cannot view assigned exercises earlier than the day before the current day or later than the day after the current date. This accomplishes two goals: it simplifies the user interface, preventing patients from getting lost in the calendar, and it enhances the accountability placed on a patient. If a patient was allowed to view assigned exercises from many days before he or she could “cheat” right before their physical therapy appointment by going back and lying that he or she completed all their exercises from the past week. It would then appear to the physical therapist that the patient is completing all of his or her exercises. This would ultimately be detrimental to the patient’s recovery. If a patient is not performing his or her exercises, it is critical for the physical therapist to know so that they may encourage the patient to perform them or augment the assigned exercises. Thus, the system provides only a three day window for a patient to view his or her exercises and confirm completion of their exercises, meaning that a patient must open the application on their iPhone, view and confirm the completion of their exercises every three days. While this does not prevent “cheating,” it does act as a barrier against it. An alternative mechanism to preventing “cheating” could rely on the recently released iWatch and
Jawbone 3.0 (fitness trackers with heart rate collection), and is outlined in the discussion section of this paper.

**Figure 6 Exercise View.**

*Exercise View* displays the exercises a patient must complete before the end of the day. To confirm that he or she has attempted an exercise, a patient selects the name of the exercise.
5.3.1 Confirming Completion of Exercises

A patient can confirm that he or she has completed an assigned exercise by selecting the name of the exercise on Exercise View. This will present the Exercise Details Window. Figure 7 displays the Exercise Details Window. This window displays the name of the exercise, the number of sets and reps the physical therapist assigned the patient, and a URL link to a description or video of the exercise. The URL link is especially important because it provides an easy way for the physical therapist to teach the patient how to perform an assigned exercise correctly. In the current state of outpatient physical therapy this is accomplished by handing the patient a piece of paper describing each exercise. The URL link of the Exercise Details Window offers cost efficient alternative that provides the bonus benefit that it cannot be lost. If a URL link is not provided by the physical therapist then the button labeled Link to Exercise Description will instead state No Link Provided. It is worth nothing that the number of sets and reps is provided by text input of a physical therapist. Therefore if the assigned exercise cannot be measured in reps but instead in seconds, for example, it is easy for a physical therapist to modify the exercise description. Finally, the Exercise Details Window presents a patient with three buttons: The Skip button, the Attempted button, and the Completed button. A patient selects the appropriate button for the exercise and that information is transmitted to PT Server and then to his or her assigned physical therapist. The three different states an exercise can take (skipped, attempted, or completed) are reflected in the color of the exercise on the Exercise View: blue for completed, grey for attempted, and red for skipped. Figure 8 reflects this. All exercises begin
in the skipped state, thus if a patient does not interact with the iOS app, it will look to the physical therapist as if that patient skipped all of his or her exercises.

![Figure 7 Exercise Detail Window.](image)

This window provides the name of a selected exercise, the assigned sets and repetitions of the exercise, and a link to a description or video of the exercise. A patient may select one of three buttons to confirm he or she skipped, attempted, or completed the selected exercise.
**Figure 8 Color coordination.**

The color of exercise names in *Exercise View* refers to the status of said exercise: red for skipped, grey for attempted, and blue for completed.
5.4 Achievements View

*Achievements View* encourages patients to use the system by rewarding a patient for logging pain and completing his or her exercises. An achievement is a small message congratulating a patient for completing a certain milestone. The more milestones that a patient completes, the more achievements he or she obtains. This type of positive reinforcement is based of the achievements system of Microsoft’s Xbox and Stack Overflow. In Microsoft’s Xbox, players earn achievements by completing different aspects of games they have bought. In Stack Overflow, a coding forum, subscribers who are thought to have been especially helpful earn badges. Achievements in both gaming and question and answer forums have proven to be especially successful and the hope is that that success will translate to the world of healthcare. For PT Helpers evaluation, patients received achievements by logging pain a certain amount of times, completing a certain amount of exercises, and first logging into the iPhone app. However, the possibilities for achievements are limitless. Achievements could be created for walking a certain number of miles, climbing a certain number of stairs, getting a certain amount of sleep per night, etc. A separate analysis should be conducted on the benefits these and other types of achievements and how they motivate a patient. In lieu of that study, the design of achievements is built to be as general as possible, so that in future works it is easy to add different types of achievements to the system.

5.4.1 Receiving an Achievement

Whenever a patient performs an action that results in him or her completing an achievement, the *Achievement Unlocked Alert* is displayed. Figure 9 displays such an alert. This alert informs the patient that they have unlocked an achievement and that they may view it in *Achievements View*. This alert design provides immediate positive gratification for
the patient while also distracting the patient from their current activity as little as possible. A button to transfer the patient to Achievements View was initially considered, but rejected. A patient in the middle of performing an action, such as confirming he or she completed an exercise, would be frustrated or confused if they accidentally hit this button and were transferred to Achievements View, possibly confused or frustrated enough to stop using the application. Patients who wish can also disable these pop-up notifications using the Allow Achievement Alerts switch in Settings View.
Figure 9 Acheivement Unlocked Alert.

This alert is displayed to a patient when his or her actions, such as completing an exercise or logging pain, unlock an achievement.
5.4.2 Viewing Achievements

To view his or her achievements, a patient must visit Achievements View. This view provides a list of the patient's achievements, in order of most recently unlocked. Figure 10 presents a snapshot of this view. If a patient clicks on one of these achievements, the Achievement Details Window appears. This window displays the name and description of the achievement. Figure 11 presents a snapshot of this window.
In Achievements View, a patient may view all the achievements he or she has earned. A patient can view the description of a specific achievement by selecting the name of the achievement. Achievements are used to encourage a patient to use Patient Portal.

Figure 10 Achievements View.
The Achievement Details Window displays a description of the selected achievement.

5.5 Settings View

In order for a physical therapist to receive information on a specific patient, that patient must first register a physical therapist. A patient can register a physical therapist using Settings View. Figure 12 displays Settings View of Patient Portal. If a patient views the
*Settings View* and has not yet registered a physical therapist, the view will reflect that, looking like Figure 12. If the patient has already registered a physical therapist, the *Settings View* will display the name of the assigned physical therapist. This allows patients to quickly check that they have registered the correct physical therapist. If a patient wishes to change his or her assigned physical therapist, he or she can do so using the *Assign a Physical Therapist* or *Change Physical Therapist* button. Selecting this button brings up *Change Physical Therapist View*. Figure 13 presents an example of *Change Physical Therapist View*. In this view, a patient may type in the username of a chosen physical therapist to allow that practitioner to view his or her data. Only one physical therapist can be assigned per patient at a time. This means that if a patient changes his or her assigned physical therapist, the previous physical therapist will no longer be able to look at his or her data. However, switching between assigned physical therapists is quick; the action changes a single item in PT Server’s database. Therefore it can be used as often as necessary.

The *Allow Achievement Alerts* switch can be selected by a patient to allow or prevent *Achievement Unlocked Alerts*. In the event of too many achievements being added to Patient Portal, this will provide patients with a reprieve from constant alerts. A similar switch could be used to prevent or allow exercise reminders in a future iteration of the application.
A patient in Settings View can view or change his or her assigned physical therapist.
A patient may assign a new physical therapist to view their data by typing in the username of the desired physical therapist into the text field and selecting the Change PT button. If the patient inserts a username that is not in the system, PT Portal displays an error message to the patient.

Figure 13 Change Physical Therapist View.
6  PT Portal Design

PT Portal is a physical therapist’s interface into the PT Helper. PT Portal was designed to be used at the beginning and end of each clinical visit. During the beginning of the visit, a physical therapist opens PT Portal on his or her iPhone, quickly assesses the information, and then asks the patient about any relevant data points. Using PT Portal, a physical therapist can view a patient’s recent pain and activity on the same graph so that they may correlate certain activities with patient pain. They can also check to make sure a patient is completing his or her assigned exercises at home, and provide admonishment if the patient is not performing them. By using PT Portal at the beginning of the patient’s visit, physical therapists can perform a more efficient patient interview.

During the end of the visit, the physical therapists again open the application on his or her iPhone to add, remove, or edit exercise assignments for the patient. PT Portal was designed with these use cases in mind; thus the application was designed for ease of use and quickness of information. PT Portal can be broken down into four views, the Log In and Sign Up view, the Select Patient View, the Patient Pain View, and the Patient Exercise View.

6.1  Log In and Sign Up Views

Just as in Patient Portal, upon initialization, PT Portal presents Log In View. This is identical to its Patient Portal counterpart and can be viewed in Figures 1 and 2. PT Server does not treat the logging in of patients or physical therapists differently. Both are stored in the database as Users.

6.2  Select Patient View

Select Patient View functions as the home screen of PT Portal. Upon logging into the application, a physical therapist presented with the Select Patient View. Figure 14 displays
this view on an iPhone 6. In Select Patient View, a physical therapist can view a list of usernames of all patients he or she is currently attending to. By selecting one of these usernames, a physical therapist will be taken to Patient Pain View. There a physical therapist can view compiled pain and activity data for the selected patient. PT Portal was devised to be used during the first and last ten minutes of each patient’s visit. For the application to accomplish this functionality, the time to get to a patient’s information must be as short as possible. A physical therapist cannot be standing during a clinical visit searching through lists or waiting on loading views while a patient is waiting for care. Thus Select Patient View was designed to allow the physical therapist to select the correct patient and view his or her pain and activity information as quickly as possible. To prevent long load times, the patient list is loaded from the server only upon startup or when transferring from the Patient Pain View to the Select Patient View.
In Select Patient View, a physical therapist can view a list of his or her patients. The physical therapist can select the name of a patient to view that patient's pain and activity data.
6.3 Patient Pain View

*Patient Pain View* is designed to present pain and activity information in a way that allows a physical therapist to infer what actions (or non-actions) a patient takes are causing the patient pain. Figure 15 shows the *Patient Pain View*. The top half of the view presents a graph that displays the patient’s step count on the y-axis and the time of the day on the x-axis. It is important to note that the y axis represents the total number of steps that have taken place since 12 AM as opposed to the number of steps that were taken during a single hour. This simplifies the user interface (by preventing a saw-tooth like graph) and allows a physical therapist to better understand how the total activity was distributed throughout the day. A physical therapist may select the *Previous Day* button or *Next Day* button to view activity and pain information. A physical therapist can view pain and activity information up to a week earlier from the current day. While information is never deleted from the server, the application stops a physical therapists from accessing information from a time further back to prevent the physical therapist from getting lost. The cutoff was determined to be a week for two reasons: people tend to repeat activity patterns on a weekly basis and a normal physical therapy schedule includes a clinical visit at least once a week. At the bottom of the graph the day of the week the pain and activity took place is displayed. This helps ensure a physical therapist understands when pain and activity took place.
6.3.1 Pain Graph

For this application, two different methods of activity analysis were considered: step count and distance walked. Ultimately step count was chosen because it is a more
consistent measurement when dealing with multiple body types. A measurement of
distance walked is affected by the leg length and step size of the patient, while step count is
the same across patients regardless of these attributes. However, in the future iterations
many other representations of activity may be available to application developers. Because
PT Helper receives information from the iOS Healthkit, using these representations instead
of step count will be as simple as changing two to three lines of code. One especially
interesting representation that will be available to developers soon is heartbeat per minute,
which utilizes the newly available iWatch to measure a users’ pulse. Utilizing this
measurement or supplementing the current application with this measurement would
allow for an even more in depth analysis on the types of activities that are causing patients
pain by discovering activities that don’t require the patient taking steps, such as lifting or
push ups. One predicament of utilizing multiple measurements of activity is how to display
them on a graph to a physical therapist. Displaying them all on a single graph could lead to
confusion, while requiring a physical therapist to flip through multiple graphs of the same
day would be tedious. Luckily, these measures of activity should be highly related. A patient
who is taking a lot of steps is likely to have an increased pulse. A patient whose heart is
beating quickly is most likely either taking a lot of steps or performing exercises that
require him or her to be stationary. We can combine number of steps taken, changes in
pulse, and even more correlated measurements into a single measure of activity that can be
easily displayed to a physical therapist.

6.3.2 Pain Points

Red points on the graph represent times at which the patient logged pain using their
Patient Portal. To prevent cluttering of the user interface, only the most intense pain every
hour is displayed on the graph. A physical therapist may select one of these red data points
to bring up the Pain Details Window. Figure 16 displays PT Portal with this window open.
The **Pain Details Window** allows a physical therapists to view the type and intensity level of each recorded pain incident. The intensity of the pain is color coded to distinguish between varies levels of pain. In addition, the description of each level of pain is included in the window.

![Pain Details Window](image)

**Figure 16 Pain Details Window.**

The Pain Details Window displays the attributes and intensity of the selected pain.
6.3.3 Exercises Button

After reviewing a patient’s recent pain and activity, a physical therapist can also check to make sure a patient is completing his or her assigned exercises or edit the patient’s exercise regimen to correct any issues that come up. To perform these actions the physical therapist selects the Exercises Button. This presents the physical therapist with the Patient Exercise View.

6.4 Patient Exercise View

The Patient Exercise View performs two functions: It allows the physical therapist to make sure a patient is performing their assigned exercises, and it provides physical therapists with a way of creating, deleting, or editing a patient’s assignments. To perform these two functions, the Patient Exercise View consists of two modes: the recent assignments mode and the edit exercises mode.

6.4.1 Recent Assignments Mode

The recent assignments mode is composed of a list of all instances of the selected patient’s assigned exercises from the past two weeks. The list is in order of most recent, enabling a physical therapist to quickly zoom in on a day or exercises they wish to find. The list is color coordinated to match the level of completeness of each exercise: blue for completed, grey for attempted, and red for skipped. This color scheme permits the physical therapist to understand the patients past two weeks of exercise with a quick glance of the view. A skipped exercise in red immediately draws the clinician’s attention to the problem while the grey color of attempted exercises does little to distract the physician but is easy to pick out. Figure 17 demonstrates the recent assignments mode on the iPhone 6. It is critical to the system for a physical therapist to mention skipped exercises and to hold his or her
patient's accountable to the completion of theses exercises. This negative reinforcement (the admonishment of their physical therapists) encourages patients to both perform their assigned exercises and use Patient Portal. To change to the edit exercise mode, a physical therapist selects the Edit Exercises button.
The Recent Assignments mode displays a list of a patient's most recent instances of an assigned exercise. The names of the exercises are color coded to indicate if a patient skipped (red), attempted (grey), or completed (blue) them.

Figure 17 The Recent Assignments mode.
6.4.2 Edit Exercises Mode

The *edit exercise mode* is used to add, delete or edit any or all of a patient’s assigned exercises. Figure 18 presents the *edit exercise mode*. This mode consists of a list of the names of all the assigned exercises that have been assigned to the selected patient. To edit or delete an exercise, a physical therapist selects the name of the exercise that they wish to change. This brings up the *Exercise Detail Window*, populating the window with information of the exercise. To add an exercise a physical therapist selects the "+ Add Exercise" element at the bottom of the list. This button populates the table with common exercises that a physical therapist has not assigned to the specified patient. Two new categories appear in this table:

"- Cancel", which returns the physical therapist to a table of currently assigned exercises, and "+ New Exercise". Figure 19 displays this table. Selecting "+ New Exercise," or a common exercise also brings up the *Exercise Detail Window*. Figure 20 shows how the *Exercise Detail Window* appears to a physical therapist. If a physical therapist selected the "+ New Exercise" option, then all of the window’s fields are blank. However, if a physical therapist selected a named exercise, then the information of that exercise populates the window. In the *Exercise Detail Window* a physical therapist may edit the exercise name and change the sets and reps of the exercise by typing in the respective text fields. These two text fields are general text fields, meaning that a physical therapist can type anything into them and does not need to follow any sort of conventions. This is critical for the sets and reps field, because it allows a physician to use this text field even if the exercise is measured in minutes instead of sets. In fact, this general nature of the two text fields means that “assigned exercise” need not be an exercise at all. Reminders such as “Get 8 hours of sleep” or “Visit a chiropractor” can just as easily be entered into the system. While this could lead
to abuse by a physical therapist (a physical therapist assigning so many “assigned exercise” reminders that his or her patient ignores all assigned exercises) the ability for a physical therapist to customize these exercises increases PT Helper’s ability to create patient-physical therapist discussions during a clinical visit. After entering the name of the exercise and the sets and reps needed to be performed, a physical therapist may then select the days of the week the exercise must be completed by the patient by tapping the appropriate days of the week. Selected days turn blue while unselected days stay grey. Finally, a physical therapist may enter the URL of a website into the final text field. This URL is used to provide the patient with directions or an instructional video on how to perform that specific assigned exercise. Without PT Portal, physical therapists provide instructions by printing out directions on paper and handing these instructions to the patient. Changing this to providing the URL of a webpage requires little to no extra effort. Often the directions are already online. This URL field is optional, if a physical therapist does not wish to or cannot provide an appropriate URL the patient will see the message “No directions provided” on his or her Patient Portal. Upon selecting the Update button, the changes to a current exercise or details of a new exercise are uploaded to the PT Server. If a physical therapist wishes to delete an exercise from a patient’s regimen, he or she selects Delete button in the Exercise Detail Window.
In the Edit Exercise mode of Patient Exercise View, a physical therapist can view all exercises that a patient has been assigned. To edit an exercise, the physical therapist selects the name of the exercise.
If a physical therapist selects the “+ Add Exercise” element of the table, the table is populated with common exercises that have not yet been assigned to the patient. A physical therapist may choose any of these common exercises, create a new exercise by selecting the “+ New Exercise” element, or cancel their action and repopulate the table with the patient’s assigned exercises by selecting the “- Cancel” element.

**Figure 19: Common Exercises**
Figure 20 The Exercise Detail Window.

From the Exercise Detail Window, a physical therapist can edit the name, sets and reps, and URL of exercise description of a selected exercise.

7 PT Server

PT Portal and Patient Portal communicate between each other using PT Server.
Information that a patient and a physical therapist submit to the system is stored not on an individual iPhone but in a database in the server. During initial and use case testing, this server was housed in an Amazon e2c cloud services. The choice of Amazon cloud for the housing of the server does not reflect a technical assessment but rather a financial one: a year-long free trial of a micro e2c instance on Amazon Cloud is offered for first time members. The webserver itself was written using the django, a web framework written in python. Mysqlite was used as the database. This framework was then placed on the apache stack. The server configuration was chosen for quick construction and easy modification. Thus some features that might be necessary for a working version of PT Helper, especially in terms of security, were not included.

8 PT Helper Implementation

Patient and PT Portal run on iOS versions 8.0 through 8.3. iOS was selected because I had more Apple products to act as development devices. PT Helper is not compatible with devices using iOS 7 and below due to its reliance on the iOS Healthkit Store, introduced in version 8.0. Patient and PT Portal were constructed using the Swift programming language, chosen over Objective-C to reduce time debugging memory and so I could learn a new language. Both portals communicate to PT Server using HTTP protocol. Interesting implementation details are included below, more implementation information, including database implementation, iPhone global state, and custom styling, can be found in the appendix.

8.1 Post and Get Requests

PT Helper is dependent on multiple Post and Get requests in order to display information to the user. Due to the large amount of requests the system makes, two classes
were created: **PostReq** and **GetReq**. These two swift classes handle the brunt of the work required to create requests and then transform the server's reply into a dictionary. These classes contain two functions. The first of these functions is `update`. `update` takes the URL of the recipient of the request and a string specifying the data of the request. `update` then formats this into either a post or get request.

The second function is either `post` or `get`. These two functions are performed on an asynchronous thread so that the application does not stall waiting for a reply from PT Server. If a connection can't be established, they present an error message to the user, asking him or her to check their wireless settings. Once `post` or `get` have received a reply from the server, they check the item “success” in the returned dictionary. No matter what reply the server sends back, it always includes a “success” element so that `post` and `get` can determine if their request was successful. If it was, they pass the returned dictionary over to their `Processor`.

A `Processor` is another custom class that defines a function to be completed after the request has been answered. `Post` and `get` take a subclass of a `Processor` as one of their arguments. These `Processors` are called once `post` or `get` has received a reply from the server. `Processors` are critical because they allow `PostReq` and `GetReq` to access non-global variables of the views. `Processors` perform many different types of actions. The default parent class simply receives the response from the server and does nothing. However others, like `ExerciseProc`, a subclass of `Processor`, fill out the tables that can be seen by the user, like the table in *Patient’s Exercise View*. `Processors` that alter the user interface must return to the previous synchronous thread.

`Processors` and `PostReq/GetReq` dramatically increase the flexibility of PT and Patient Portal. Should a developer wish to update or change PT Helper so that it performs a different function using information from PT Server, the developer need only create a new
Processor subclass that performs this function and then plug it in to a PostReq or GetReq.

8.2 Checking for New Achievements

Achievements are awarded to patients on PT Server once the patient has fulfilled the respective requirement. Before returning a reply to Patient Portal, PT Server checks the database to determine if the request earned the patient an achievement. The function checkForNewAchievements takes as its argument the User who filed the http request and returns an integer specifying if a new achievement has been created. For each Achievement that is listed in the server, this function first determines if a UserAchievement exists that contains both the User and the Achievement. If a UserAchievement does not exist, the function then checks to see if the requirements for that Achievement have been met. If the requirements have been met, the server creates a new UserAchievement and the function returns a 4. If the patient has not earned any new Achievements, the function returns a 1. This integer is then placed in the reply message with the key “success.” Patient Portal’s GetReq and PostReq automatically check this “success” element after every request they make. If they discover that “success” is equal to 4, they create the Achievement Unlocked Alert before passing the rest of the reply message to their Processor.

8.3 Patient Pain and Activity Graph

The graph that overlays a patient’s pain with his or her activities on Patient Pain View of PT Portal is an extended version of the class LineChart created by Mirco Zeiss. The original class uses UIKit and QuartzCore to draw a line chart with selectable points given two lists of x and y coordinates. This class, though well made, was, insufficient to display the information necessary to the physical therapists. Thus it was modified extensively: two new
background storage objects were added so that the line chart could store data points of
patient pain as well as information about each of those pain data points; methods were
modified to access, delete, and edit these storage objects; points that defined the line of
activity but did not relate to patient pain were hidden and modified so that they were un-
selectable by the physical therapist; a new procedure was added to create the Patient Pain
Detail Window, and the appearance of the graph, including the lines created the points and
the labeling of the axes, was improved so that the information could be properly displayed.

8.4 Healthkit Interface

Patient Portal utilizes the iOS Healthkit to determine the number of steps taken by the
user. Healthkit presents an interesting and exciting feature of iOS because it provides a
database of health information that is collected by various different devices. Unfortunately,
as Healthkit was just recently released, developing an application that exploited the
information in Healthkit proved quite challenging. The existence of the Reload Data button
is evidence of the difficulties encountered. To make interaction with Healthkit simpler for
future iterations of PT Helper, a custom class, HKQ, was created. HKQ contains a variety of
methods and stored objects that are called throughout the life of Patient Portal.

8.4.1 authorizeHealthKit and BackgroundHealth

The first two methods called by Patient Portal are authorizeHealthKit and
BackgroundHealth. These two methods are used to obtain the necessary permissions
required to view information from the Healthkit. authorizeHealthKit checks the
permissions of a patient’s iPhone to determine if Patient Portal has the necessary
permission to view the patient’s step count. If the permissions do not exist,
authorizeHealthKit creates the default Permission Request View in an attempt to
obtain these permissions. Figure 21 displays an example of this view. If this check or
authorization is successful, backgroundHealth obtains permission from the iPhone to create a background process that continually checks the Healthkit for changes to the step count of the patient.

![Permission Request View](image)

**Figure 21 Permission Request View.**

Here a patient can allow PT Portal to track his or her step count, active calories, and walking distance. Currently, only a patient’s step count is used to track his or her activities.
8.4.2 queryColl

queryColl is called to create a background process that monitors information stored in the Healthkit. This process first sends the last five days of user activity to PT Server. It then watches in the background for any changes to a patient’s step count. If this process discovers any changes, it creates a new PostReq that sends the updated information to PT Server.

8.4.3 reloadData

Unfortunately, because the iOS Healthkit is new and contains a number of bugs, the background process that monitors the Healthkit often terminates prematurely. Initial testing revealed that this process has an average lifetime four days. In an attempt to solve this problem the reloadData function was created. This function stops and deletes the monitoring process and then creates a new one. This method is called whenever a patient selects the Reload Data button on the Home View of Patient Portal.

9 Project Timeline

PT Helper was designed, implemented, and tested within a period of nine months. The timeline was further broken down into two months spent designing the system, five months spent implementing the system, and two months spent testing and evaluating its performance. The build period was again divided into four different generations of the system, with each generation adding more functionality. The system was evaluated at each generation by former physical therapy patients to ensure it did not deviate from its intended functions. The testing period was also divided into two parts: patient evaluation and clinician evaluation. Patient evaluation involved testing Patient Portal using users who were former or current physical therapy patients. Once this analysis was complete and the
system was updated to reflect the feedback received from patient evaluation, clinician evaluation occurred. In clinician evaluation, an athletic trainer was shown anonymous data from physical therapy patients. The physician was then interviewed to determine if she felt the system was an effective means of reducing patient recovery time.

10 Patient Evaluation

After PT Helper was completed, the system underwent user testing in order to discover pitfalls in the user interface that might prevent patients or physical therapists from using the system. User testing consisted of three users. All three users experienced either care from a physical therapists or sports athletics trainer in the past five years. Each test user downloaded both Patient Portal and PT Portal and was informed of the purpose of the system. Feedback was received on two occasions: initial feedback was used to refine the user interface and flow of the applications to improve the system. Final feedback was used to evaluate the ability of the system to encourage patient exercise, relate a patient’s pain to the patient’s activity levels, and increase communication between the physical therapist and the patient.

Initial feedback was received through the test users’ preliminary questions about the working of the system and follow up discussions. The test users’ questions revealed numerous areas in which the system could be improved. A number of titles of buttons in both PT and Patient Portal were determined to be inadequate. After the follow up discussions, these buttons were renamed to more appropriately reflect their functions. It was also determined that a larger default font was required so that elderly patients would be able to use the system. The text size of buttons was increased from the default 14-point font to 28, 23, and 18-point font for buttons in different views. Colors were darkened so that highlighted choices could be better distinguished. Button position was changed in both PT
and Patient Portal to prevent accidental clicks; this was determined to be especially important of the Log Out Button. Finally, labels were added to the pain level slider in the Pain Details Window of Patient Portal so that patients would more easily understand the differences between levels of pain.

Final feedback was received from the three test users after they had each used both iPhone applications for a period of two weeks. After this time period, test users were asked to fill out a questionnaire regarding their experiences and were then interviewed based on those answers.

11 Clinician Evaluation

Clinician evaluation consisted of an in depth interview of a practicing MIT athletic trainer about the faults and merits of PT Helper. The environments of an athletic training facility and an outpatient physical therapy clinic are very similar, differing mostly in the way appointments are handled and the volume of patients treated each day (athletic trainers usually treat a substantially larger number of walk in patients and often treat multiple patients at once). Thus even though PT Helper was designed with an outpatient physical therapy clinic in mind, it could still be evaluated by an athletic trainer. In addition, the clinician evaluation was used to determine if the use of PT Helper could be extended to athletic training and other similar environments. The interview was broken down into two stages. In the first stage, PT Helper was demonstrated to the athletic trainer. This demonstration consisted of presenting PT and Patient Portal, describing different use cases of the system, and finally specifying what goals PT Helper was designed to meet. In the second stage, the athletic trainer was questioned regarding her evaluation of PT Helper, how she thought PT Helper could be applied to athletic training, and what other features she would like to see added to the system.
12 Discussion

Patient and clinician evaluation was initially proposed with the purpose of assessing the ability of PT Helper in its three main goals: improving the efficiency of patient-physician interviews, providing a better medium for assigned exercise instruction, and motivating patients to perform those exercises. Fortunately, the evaluators performed their duty and more. Each contributed not only a general assessment of PT Helper but also identified possible flaws, potential features, and interesting use cases.

12.1 The problem with lies

The most obvious of the flaws associated with PT Helper is the ability of the patient to lie to the physician about the completion of their at home exercises. While this is not a problem specific to PT Helper, as a patient can lie about his or her performance of exercises in the physician-patient interview, the ability of the patient to lie creates a dilemma for the clinician using PT Portal: Can the physical therapist trust the information the system is depicting? This may seem like a trivial nuance, but it can significantly diminish the effectiveness of PT Helper. Physicians can’t trust PT Helper completely because the information is provided by the patient and can be erroneous. When a clinician does not trust the exercise information from PT Helper, the benefits of the system start to disappear. The physical therapist must now question the patient as to the accuracy of the data, leading to potentially longer interviews than would have occurred had the clinician not used PT Helper at all.

The core of this problem is that a patient’s exercise compliance is monitored solely by the patient. To combat this challenge, patient entered information must be corroborated by other authorities. A three-axis accelerometer or heartbeat monitor would both work well as tools used to corroborate exercise compliance. Fortunately, these are sensors that are
either already available or soon will be available to the iOS Health Kit, and therefore can be used to improve the effectiveness of PT Helper. Unfortunately, even these tools cannot easily determine if a patient is performing a hamstring stretch, downward dog, or toe touch. Stretches in general are incredibly problematic, as they would require a sensor capable not only of determining the relative location and position of each appendage of the body, but also the quality of the stretch. Determining exercise compliance of patients will be a difficult challenge that physical therapy will face for quite some time.

12.2 What makes them move

Due to the difficulty in determining the exercise compliance of a patient, the ability of the system to motivate a patient to perform his or her take home exercises was examined extensively in patient evaluations. Thankfully, here PT Helper seemed to excel. The majority of evaluations indicated that the patient felt he or she would be extremely motivated to perform assigned home exercises: specifically because the physical therapist would know of his or her exercise compliance. Of course, this urge to not disappoint the physical therapist is a double edge sword. While it may push the patient to perform his or her exercises, it may also push the patient to lie about his or her compliance. However, regardless of the actions the patients take in response to the motivation provided by PT Helper, the important piece of information is the fact that the patients did feel motivated to perform these exercises.

Interestingly, while all patients mentioned physical therapist knowledge of their compliance as a major motivational factor, few spoke of achievements as motivating them at all. After an in-depth discussion with the evaluators, a few potential causes of the uninspiring nature of achievements were determined. The first of these causes is that completed achievements lacked an easily understandable value. This made different achievements incomparable. Evaluators didn't recognize a difference between the
achievement granted for completing five exercises and the achievement granted for completing twenty. There was no indication in Patient Portal that one was more valuable than the other. Thus there is little reason, at least in terms of achievement motivation, of working towards completing twenty exercises if a patient has already completed five. The two achievement systems PT Helper is based upon: Xbox achievements and Stack Overflow Badges, fix this problem in different ways. Xbox achievements include a point value, with more difficult achievements valued at more points. Stack Overflow ranks badges into bronze, silver, and gold categories, with gold badges being the most difficult to obtain. Either of these two strategies would be effective in differentiating harder PT Helper achievements from more common ones. The second possible cause of the lack of interest in achievements is the inability for a patient to see progress towards an uncompleted achievement. During evaluations, many patients suggested the addition of a method to view his or her progress towards uncompleted achievements. This progress would encourage patients who are close to completing an achievement to work harder towards that goal. As an added bonus, this would inform patients about what is required of them to complete an achievement. Currently, patients don’t know of an achievement’s existence until they have completed it. By making uncompleted achievements viewable, PT Helper would provide patients with more specific goals (i.e. complete 10 exercises) rather than the general goal of using the system. An example of this is the iWatch’s “complete the rings”, which displays how close a user is to completing his or her goal by the amount a ring is filled in. Finally, the third possible cause of the lack of motivation provided by PT Portal’s achievements is the large amount of motivation provided by exercise compliance transparency. As previously stated, many patients indicated that the ability of the physical therapist to view exercise compliance was a huge motivational factor. It is possible that the motivation provided by
this feature is so predominant that the achievements simply provide little motivation in comparison.

12.3 It’s all in your head

Another interesting pitfall exposed during the evaluations of PT Portal is that Patient Portal has the potential to cause a patient to focus too much on his or her pain. A patient who always records when he or she is feeling pain tends to more easily remember each instance of said pain. This ease of recollection is beneficial when patients are discussing pain during the clinician-patient interview. The more details the patient can remember, the easier it is for the physical therapist to assess the patient’s situation. Unfortunately, making each instance of pain easy to remember allows patients to fall victim to the availability heuristic: a situation where a patient believes that he or she is more injured and recovering slower than he or she actually is, because the patient can easily remember and point to many instances of past pain. This mistaken belief can negatively effect the recovery time of a patient by causing them to avoid activity and exercises that the patient would have performed otherwise. In essence, by causing the patient to believe that he or she is recovering slowly, forcing the patient to write down all instances of pain can increase the patient’s recovery time. This is a difficult problem to correct, especially because the negative effect could vary drastically from one patient to another. One side effect of PT Helper being separated into two iPhone applications, Patient and PT Portal, prevents a patient from always being able to view their pain and activity data. This most likely decreases the effect of the availability heuristic. A possible way to reduce this affect further is to keep track of patient milestones: notable and easily recognizable areas of improvement that can be used to measure the positive progress of a patient’s recovery. In fact, milestone tracking was mentioned multiple times as a desired additional feature to PT Helper.
12.4 Positive Thinking with Milestone Tracking

The evaluation process of PT Helper included discussions with evaluators about additional features to supplement the system. Milestone tracking was often indicated as a desired additional feature. Milestone tracking differs from achievements in two ways. The first is that milestone tracking is much more specific to each patient than PT Helper's achievement system is. Therefore milestones would most likely have to be entered by the physical therapist for each patient as opposed to being automatically included by the system. The second is the milestone tracking's primary goal is to indicate the progress of the patient's recovery, while the achievement system's primary goal is to encourage patients to use PT Helper. Milestone tracking could improve a patient's attitude towards his or her recovery and help compare the recovery timeline of two patients with similar injuries. Just as constant pain tracking encourages patients to remember instances of pain, milestone tracking would encourage patients to remember milestones that document recovery. And just as a patient who more easily recalls instances of pain might feel discouraged about his or her recovery, a patient who more easily recalls milestones might feel more confident in his or her progress. Additionally, by keeping track of milestones and comparing these milestones with the average patient with the same injury, a patient can better understand how his or her recovery is progressing. This would prevent patients from getting discouraged because of small hiccups in rehabilitation. Comparing a patient’s completed milestones with other milestones from patients with similar injuries could also assist the physical therapist in determining what exercises to assign a patient, understanding what level of pain and activity to expect from a patient, and recognizing problems with a patient’s recovery.
12.5 The Ultimate Tracker vs. Simplicity

Consistent with the desire for milestone tracking, evaluators of PT Helper often mentioned the desire for PT Helper to track not only pain and activity of a patient, but also stress, sleep, diet, health, and mood; essentially any and all environmental and biological factors that could affect recovery time. One of the main motivations for this desire is that many injuries consist not only of a physical component, but of a mental component as well. Lower back pain is specifically known to be greatly affected by an individual’s level of stress. If PT Helper could keep track of all of this information and then display this information to the physical therapist and the patient, both could make much more informed decisions about how to treat the patient’s injury. Unfortunately with current hardware, the additional features of tracking each of these factors would require a substantial increase to the patient’s input to the system. This increase in required patient input would most likely lead to dramatically lower use. While the tracking of some of these features can be solved by soon to be released products (such as utilizing the new Apple Watch to monitor a patient’s stress level through changes to the patient’s heart rate), the majority of features have little hope of becoming autonomously tracked in the next few years. Thus a developer of an assistive health tracker must decide between creating an immensely powerful application that few people will use or a much less powerful but still helpful application that more people will use. PT Helper was designed to fall into the later category. Currently, it requires user input only to mark compliance with exercises and record instances of pain, and these requirements are motivated by the physical therapist and the system itself. Adding features that track other factors of patient recovery, while increasing the diagnostic power of the system, would most likely significantly decrease the effect of the system to the general populace because of the reduction of use.
12.6 Don’t Forget

A second trade-off that was discussed during evaluation of the system was the possibility of adding exercise reminders to PT Portal. Essentially, if a patient has not yet confirmed that he or she has completed an exercise by a specific time of day, PT Portal sends a notification to the user. This would prevent patients from forgetting to perform their assigned exercises. However, if a patient has exercises assigned to them each day of the week, this notification could quickly frustrate the patient. During evaluations, the patient evaluators were split on how they felt about exercise notifications. Some felt that they would prefer to have notifications in case they forgot to perform an exercise, while other stated that they would most likely delete the application from their phone if they received more than three notifications a week. In light of the possibility of losing users and in hope that regular visits to the physical therapy clinic were enough to remind a patient to perform his or her exercises, notifications about forgotten exercises were initially rejected.

A possible solution to this problem is the inclusion of an Allow Exercise Reminders switch, similar to what is done with Achievement Unlocked Alerts. This would allow patients to customize Patient Portal to suite their needs: enabling some to rely on the application to remind them of incomplete exercise assignments, while preventing others from avoiding the app because of a single feature.

12.7 It’s all About Tolerance

Another interesting feature proposed during evaluations is pain normalization. Each injury a physical therapists treats is different, as is each patient. One difficult challenge that physical therapists face when treating a patient is determining how to correlate a patient’s statements about his or her pain intensity with progress of the patient’s recovery. The solution to this problem requires two pieces of knowledge. The first is how painful a specific
type of injury is likely to be. Physical therapists learn this through training and experience. The second is the specific patient’s pain tolerance. Pain tolerance can vary drastically among different patients. Some scream in pain from stretching hamstrings while others treat broken bones as slight inconveniences. Because PT Helper reports a patient’s pain intensity, evaluators felt that the ability to normalize the pain information to an average pain tolerance scale would increase the functionality of the system. Such a feature could be created by comparing a patient’s pain information with information from other patients with a similar injury and then clustering patients based on pain tolerance. However, the feature would most likely require so many reports of instances of pain from the patient that by the time the system is ready to categorize the patient, the physical therapist has already formed an estimate of how the patient handles pain. While it would be an interesting project to pursue, especially in instances where a patient changes physical therapists but still has the same injury, the feature would most likely be too slow to be helpful in the majority of cases.

12.8 Applications in Athletic Training

One of the main foci of the clinician evaluation was to discover if PT Helper was applicable to areas outside of physical therapy clinics. One such area is sports athletic training. The merits and disadvantages posed by using PT Helper for athletic training were discussed during an evaluation and follow up interview with a current MIT athletic trainer. From this evaluation, it was deduced that although PT Helper could not be used in the same way as it was designed to be used in physical therapy, it could provide assistance to athletic trainers during records keeping, before an athlete’s first appointment, and when diagnosing a hard to evaluate injury.
One of the largest differences between athletic trainers and physical therapists is the scheduling of appointments. Physical therapists often only interact with patients during scheduled clinical visits. There are very few walk-in patients. Because they normally deal with scheduled appointments, physical therapists usually have 30 minutes to an hour alone with a single patient. In contrast, Athletic trainers most often deal with walk-in athletes. These walk in athletes generally all come to be treated during the same time period: right before or right after practice. This means that athletic trainers rarely get to spend the same amount of time focused solely on one athlete that a physical therapist does with one patient. Often athletic trainers are interviewing one athlete as they perform a physical examination or manipulation of another. That’s not to say athletic trainers don’t make appointments with injured athletes, they do, but the vast majority of the athletes they treat are walk-ins. This hectic schedule prevents the athletic trainer from being able to review an athlete’s data in PT Portal when most patients come to receive care. Finally, athletes rarely carry their phone with them during their most intense periods of activity.

However, this does not preclude the use of PT Helper in all instances of athletic training. In the evaluation of the system, it was determined that PT Helper would be useful in specific areas of the athletic training environment. The first of these areas is record keeping. Instead of PT Helper keeping track of what exercises a patient does at home, the evaluator expressed interest in utilizing PT Helper to track exercises an athlete is assigned to complete in the athletic training room. Because athletic trainers are often moving from one patient to the next, there is normally little time to make sure an athlete is completing all of their assigned exercises. PT Helper would confirm that the athlete is aware of all the exercises he or she is supposed to perform. PT Portal would also be able to assist athletic trainers in the instance of patient scheduled appointments. It would especially be useful for an injured athlete’s first scheduled appointment, giving an athletic trainer a much richer
picture to diagnose the athlete's injury. Finally, PT Helper would be useful for detecting injuries that are difficult to diagnose such as stress fractures, which require historical pain data to distinguish between fractures and bad bruises. The use of PT Helper during a period of uncertainty would provide athletic trainers with the information necessary to make the right diagnosis.

12.9 Applications to Single User

Another interesting use case that was considered during evaluation was the single user environment: where a patient downloads both PT Portal and Patient Portal in order to track his or her pain and activity information. The biggest shortcoming to using PT Helper in this instance is that a patient must download and use two different iPhone applications. This use case also removes what many evaluators felt was the main incentive for the patients to complete assigned exercises: the ability of the physical therapist to view exercise compliance. However, it is worth nothing that many patient evaluators felt that the ability to self-track pain, activity, and exercise information was worth the negative side effects. They pointed to two specific instances where this use case could occur: when physical therapy was unreachable due to financial or other causes, and when a patient was uncertain of the necessity of physical therapy. In both occurrences, evaluators felt that PT Portal provided useful assistance.

12.10 Extending PT Helper

With so much discussion of the possible extensions to PT Helper, the ease of adding these and other features must also be evaluated. PT Helper was designed with the ability to extend the system in mind. One great example of this is the way many different objects in the database of PT Server are stored. For example, instead of instances of activity having a dedicated step count column, they have a data column. Step count is inserted into a
dictionary that is then placed in the data column of activity. This allows new developers to extend instances of activity to things that don’t include step count. Average heart beats per minute, number of push-ups completed, or number of hours practicing a team sport could all be stored as an activity instance. And because the graph in Patient Pain Log View of PT Portal is a generalized graph, all three activities would be displayed in PT Portal with no extra work. The use of generalized instances throughout the database of PT Server allows the extension of PT Helper in this and many other different directions.

The inclusion of the iOS Healthkit also drastically increases a developer’s ability to upgrade PT Helper. iOS Healthkit allows developers to retrieve information from any health device that is connected to their phone. This means that PT Helper could be easily modified to utilize data from not only the accelerometer of the patient’s iPhone, but the patient’s fitness tracker, the patient’s Watch, and even input from the patient about their daily activities. The ability of PT Helper to easily interface with the iOS Healthkit provides easily accessible data to a new developer.

12.11 General Evaluation of PT Helper

While evaluators of PT Helper provided many insights into possible shortcomings and extensions of the system, the general reaction to PT Helper was overwhelmingly positive. Patient evaluators agreed that the system would encourage them to complete assigned exercises they might not have done alone. They claimed that this motivation was due to two attributes of the system: the ability of a physical therapist to view exercise compliance and the exercise description link that took patients to a video or webpage with detailed instructions of a specific assigned exercise. Patient evaluators also felt that they would use the application to record when they felt pain. The required user input to log pain was deemed worth it. Patient evaluators mentioned that because pain often distracts them
from their current activities, they would be even more likely to stop what they were doing and enter intensity information into Patient Portal. This conclusion points to the possibility of increasing user input to reveal more information about the patient’s pain in future versions of the system. Patient evaluators confirmed that PT Helper would remind them of past pain and encourage them to have a more active discussion with their physical therapist about their activities. They also found the description of pain intensity levels to be helpful in determining what level of pain they were feeling.

The clinician evaluator felt that the pain and activity graph would be very useful in increasing the efficiency of patient appointments: specifically in helping her generate questions to ask the patient about his or her injury. The evaluator, though concerned about patient dishonesty, liked the ability to view a patient’s exercise compliance and confirmed that she would have no problem admonishing a patient for not completing assigned exercises. The evaluator commented that the terms used to describe different aspects of pain worked well because they were distinct from one another.

The user interface was well received by the majority of evaluators; each felt that the functions of both portals were understandable and intuitive, though a few opposed the color scheme of the applications. Consistent with the design of PT Helper, evaluators labeled the ability to track a patient’s pain and activity as the most critical function of the application, with providing motivation to perform exercises as the second, and providing instructional information of exercises as the least important function.

13 Future Work

In future iterations of Patient Helper, it would be useful to install a Touch ID login into the system. A patient should rarely log in and out of the device, thus a Touch ID login would
prevent him or her from forgetting his or her password to Patient Portal. A pulse monitor, milestones, and point-based achievement system would also increase the applications of the system. In addition, a study concerning the expenses and revenue of the initiation and upkeep of PT Helper in a clinic environment would provide further evaluation of the system.

14 Contributions

Under the direction of Peter Szolovits in the department of Electrical Engineering and Computer Science of Massachusetts Institute of Technology and with assistance from physical therapists of Physiotherapy Associates in San Diego California, I developed PT Helper: a system designed to improve outpatient physical therapy. PT Helper works to reduce patient recovery time in three ways. PT Helper improves the efficiency of the patient-clinician interview by highlighting specific instances of a patient’s pain and activity that the clinician can ask about. PT Helper increases the effectiveness of assigned home exercises by providing a better medium of exercise instruction. Finally, PT Helper delivers motivation for a patient to perform his or her assigned exercises utilizing both negative and positive reinforcement. PT Helper was evaluated by former and current physical therapy patients as well as a current MIT athletic trainer. Utilizing this feedback, I provided a detailed analysis on the design of the system, benefits and pitfalls of the system in different use cases, and possible extensions to the system. It is my hope that this analysis will encourage further discussion and development of health tracking systems in the domain of physical therapy.
15 Acknowledgements

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16 Appendix

This index provides a more detailed examination of the implementation of PT Helper. Included is a description of the tables of the database in PT Server, custom models used to create windows and color schemes, the global state used in both iPhone applications, and login and logout procedures.

16.1 Data Base Tables

1. **User**: Any user of the system.

   1) **is_pt**: A Boolean that indicates if the user is a physical therapist or not. Only physical therapists can be assigned patients.

   2) **password_hash**: A string that stores the hash of a user's password to be checked when a user attempts to log in.

   3) **name**: A string that stores the username of the user.

   4) **email**: The email of the user. Currently this is not being used by the system. However, it is stored in preparation for a future expansion that adds the ability to retrieve forgotten passwords.
5) **session_key**: A 1000 character string that is generated each time a user logs in and is used to verify that user who initiated the session by logging in is the same user making requests.

6) **session_ip**: A string storing the ip of the user who logged in. This is currently tracked, but the system does not yet enforce the user to use the same ip during the entire session.

7) **exercise_number**: An integer storing number of assigned exercises the user has successfully completed. This is used to determine a user’s achievements.

2. **Pair**: Stores the information regarding which physical therapist is register to receive information for which patient. Only the physical therapist that is registered to receive a patient’s information can access that information. Only one Pair per patient may exist.

   I. **assigned_pt**: The User who is the registered physical therapist

   II. **patient**: The User who is the patient.

3. **Pain**: Stores the details of each instance of logged pain from every patient. The time an instance of pain takes place is represented by two different attributes. The time attribute stores what date the pain took place, while the hour attribute stores what hour of the date it occurred (0 – 23). This separation of hour and date makes it much easy to create a graph of pain that occurred.

   I. **patient**: The User who logged the pain

   II. **time**: A string containing the date in which the pain occurred in mm-dd-yyyy format.

   III. **hour**: An integer representing in which hour the pain occurred in military time (1 for 1 – 2 am, 5 for 5 -6 am, etc).
IV. **data:** A string containing information regarding the pain, such as intensity and pain type. Because this data is stored as a string, it is simpler to change what it contains for future iterations.

4. **Activity:** Stores an instance of activity for every patient. While Activity is currently only being used to store the step counts of each user during specific time periods, it has the ability to be expanded to store almost any type of activity. Like Pain, the time an Activity took place is represented by two attributes, time and hour.

   I. **patient:** The User who performed the activity.

   II. **time:** A string containing the date in which the activity occurred in mm-dd-yyyy format

   III. **hour:** An integer representing in which hour the activity occurred.

   IV. **data:** A string containing information about the activity. This information is stored as a string to allow for expansions of the system.

   V. **type:** The type of activity that is being recorded. The purpose of this attribute is to be used in functions that must deal differently with different types of activities.

5. **Exercise:** Stores all information regarding each exercise that is assigned by a physical therapist to a patient.

   I. **patient:** The User who is assigned the exercise.

   II. **days_assigned:** A string that stores information regarding which days the exercise must be completed. To save space, this is a string of a seven digit binary number, where each index of the number corresponds to a day.

   III. **name:** A string storing the name of the exercise.

   IV. **reps:** A string storing the sets and reps of the exercise.
V. **lastFiveTimes:** A string of a dictionary that it used to compute the last five
days the exercise has been assigned, and whether or not the patient
completed the exercise.

VI. **first_day:** A string storing first day the exercise is assigned.

VII. **link_to_url:** A string storing the URL of the exercise description.

6. **Achievements:** Stores all information regarding each type of achievement.
   I. **name:** A string storing the name of the achievement.
   II. **description:** A string storing a description of the achievement.

7. **UserAchievements:** Stores User Achievement pairs.
   I. **user:** The User who unlocked the Achievement.
   II. **achievement:** The Achievement that the User unlocked.
   III. **date:** The date that the Achievement was unlocked

16.2 iPhone Global State

While most of a user’s information is stored on the system server, Patient Portal and
PT Portal do store some global state to keep track of which user they are interacting with.
This state is housed in the NSUserDefaults, a class for interacting with persistent memory of
an application. Three variables are stored using this class: **isLoggedIn**, an integer used to
determine if a user is currently logged into the system, **session_key**, a 100 character string
that is sent in all logged-in requests to identify the user to the system server, and
**username**, the username of the user. In addition, Patient Portal also stores **isHealthQuery**, an integer used to determine if a Healthkit query is currently monitoring the iPhone’s
Healthkit and **viewAchievements**, an integer used to determine if **Achievement Unlocked**
Alerts should be displayed to the user. PT Portal also stores current_patient, a sting that stores the username of the patient whose data a physical therapist is currently viewing.

16.3 Logging in and out of the system

When a patient or physical therapist using his or her respective Portals logs into the system, the Portal notifies the server by calling the login function. This function checks to make sure that the Portal has the correct password, using the password_hash it has stored for the user, and then generates and supplies the user with a new session_key. This key is stored on the iPhone and used in later interactions to identify the user to the server. Once the session_key is saved. The global-variable isLoggedIn is set to 1, transferring the user to either Home View in Patient Portal, or Select Patient View in PT Portal.

16.4 Custom Windows

iOS includes AlertViews, small pop-up windows that are used to inform the user when an event has occurred. An AlertView was used for the Achievement Unlocked Window. However, for the majority of pop-up windows AlertView was difficult to customize and unable to easily perform the functions required of PT Helper. On those occasions, a custom window was created. Custom windows provide the customizability of a new view but are also able to access their parent view’s attributes, making them ideal for items such as the Pain Details Window of Patient Portal or the Edit Exercise Window of PT Portal. Custom windows are composed of many other classes, such as custom colors, button objects, label objects, checkbox objects, and text field objects.

16.5 Colors and Server IP

To make ensure that colors are consistent throughout the applications, both Patient Portal and PT Portal contain the CustomColor class. This class stores all colors used in the
application and allows other objects to quickly color the user interface. Along the same vein, the IP address of the system server is stored in the class Connect. Both CustomColor and Connect were created so that values that often change in development could be edited in one line.
17 Works Cited


