PhysioTrack
INFO 5/4871: Personal Health Informatics, Spring 2022

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Abstract

This project focuses on self-tracking injury and pain through video documentation on a mobile health application. The team researched and modeled different aspects of the mobile health application, including pain tracking (location and scale), video recording upload area, and access to shareable results. Users can log their pain, physical therapy activities, medications, and access resources about their injury. This study sought to generate insights into users' pain tracking needs, especially in the context of chronic pain. Our proposed application, PhysioTrack, provides a platform for users to log their injuries and pain and, optionally, upload media related to physical therapy exercises. The features of PhysioTrack intend to navigate the tensions between clinicians and self-tracked patient data by using simple scales and objective data (multimedia). The application provides patients with a simplified electronic health record, a referenceable log, and simple metrics to discuss pain management and injury recovery.

CCS CONCEPTS • Human-centered computing~Human computer interaction (HCI) • Applied computing~Life and medical sciences~Health informatics

Additional Keywords and Phrases: Physical Therapy, Self-Tracking, Pain, Mobile Health Tracking, Video Tracking

ACM Reference Format:

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1. Introduction

From managing injury recovery and chronic pain to improving mobility—physical therapy is an effective treatment option. Each member of our team drew on their experiences with physical therapy in order to create a prototype for a mHealth application for users engaged in physical therapy as a treatment for chronic pain and other similar injuries. Additionally, the app will give users the ability to get instant feedback from their physical therapists on form or other constructive feedback. Tracking improvement and getting input from providers while not in a session are essential aspects that haven't been introduced to the physical therapy community yet.

During one section of the Personal Health Informatics class, some of our members researched the presence of technology in the current physical therapy environment. We wanted to explore the ways in which we can improve upon self-tracking in domains such as physical progression and pain management. These improvements aim to better help patients understand the scale of their pain and progress, as well as being able to give a more detailed log to their therapist, ultimately resulting in better care. Team members were collectively interested in enhancing how we manage pain data and treatment options during the self-tracking experiment we performed in class. The type of software arrangement that would be implemented into the prototype aims to bridge the gap within this area.

The use of technology in health care is increasingly becoming more prevalent; however, many of these new technologies are not present in our current environment. We hope to introduce new concepts and features for patients to use on their mobile smartphones while also giving them the ability to discuss progress and performance with their providers. Furthermore, we want to contribute insight to progression tracking for physical therapists and patients.

2. Background/Related Work

For those who are injured, manage chronic pain, or aim to avoid surgery and maximize movement, physical therapists can help attain their goals of health. These symptoms impact people's performance, productivity, and overall quality of life. The treatments are designed specifically for the person's challenges, needs, and objectives and are available to people of all ages and abilities. In physical therapy, therapists empower people to take an active role in their treatment (Beresford, 2022). For patients, working with their therapist and the other providers in a medical background can allow them to receive the best care.

Machine learning and computer vision are emerging as an effective tool to assess movement in sports health and performance. There has been tremendous investment in using computer vision and advanced machine learning health analytics to track athlete performance and recovery in professional sports. Physiotrack intends to bridge the gap between the tools available to athletic organizations and the tools used by physical therapists.

One of the earliest iterations of such a technology came from the Chelsea football club in the UK. Their analytics include a semi-automated video recording of performances on the pitch to track player progress. Computer vision is capable of classifying most movements with 70-90% accuracy, but complex motions such as jumps and direction changes sometimes require further analysis from humans. Chelsea and Prozone began their research in the 90s and have effectively created a computer vision suite that works from a single angle on the pitch to assess each player's performance, even referee and ball tracking (Xinke, 2019)

Vondrak et al (2008) propose a 3D tracking system based on physical simulation of body components using Newtonian physics. Body part collision and extension limitations prevent impossible movements. Difficulties in quantifying “normal” or full ability motion limits by the information available from the subject. Quantifying improvement is impossible without an initial baseline for comparison. Using a 3D model inferred from this study, researchers can cope with incomplete information regarding the subject's full health capabilities. Operating a rag doll simulation, similar to those used in the gaming industry, can greatly assist in approximating progress for physical therapy patients. However, this technique is computationally complex and can have difficulty scaling to different body types.

Alabbasi et al (2015) encountered a similar problem in their attempt to design a program for Kinect V2 on Windows that can compare a training regimen to a pre-recorded baseline. In their study they found that using a pre-trained system such as the Kinect proved to be more effective than creating a full tracking system themselves, due to the lower setup and training complexities. Kinect uses a depth camera paired with a traditional RGB camera to map and track human movement for video games, although the technology has found more success recently for research projects and corporate uses. The researchers in this study were able to pair the Kinect SDK with Unreal Engine 4 to easily program and record training exercises. The user’s avatar stands next to another, showing the correct (ie; pre-recorded) movements in comparison to their own. (Fig 5, Alabbasi et al) Any wrong movements turn the user’s avatar red. In order to calculate correct and incorrect positions, the researchers found that measuring angles between joints was sufficient. As such, a limited range of movement is allowed. This allowance is reflected in our prototype as a gray bar overlaying the flexibility scale (Fig. 14). Range of movement normalcy is represented according to a healthy range of movement for the demographic using the app, per the user’s own input.

For the purposes of our study, using a kinect sensor will introduce complexities and costs that are not attractive for end users. Therefore, utilizing the multitude of depth sensing technologies present on current smartphones, such as Face ID and LIDAR on Apple's iPhone and iPad platforms, could prove to be just as effective as Kinect. Otherwise, computer vision using a traditional 2D RGB image plane from any camera, trained to identify individual joints, can be reasonably accurate, as seen in the 2019 study by Xinke et al.

Further research proved that the requirement of a health specialist's presence during recovery can induce difficulty in the recovering party for a number of reasons. For patients recovering from a stroke, a 2021 study by Kashi et al. found that "*One explanation for why compliance rates are low is that patients undergoing rehabilitation are not able to assess their own functional state and their performance without the therapist.*" (Kashi et al. 2021). This finding was echoed in prior research into PHI, and introduced considerations that led to the development of this app prototype. The research from Kashi et al. looked to automate recovery progress data collection for recovering stroke patients, using a variety of motion capture sensors to track user's movements to be assessed by a trained neural net. Certainly, using a full mo-cap suit introduces a significant barrier to accessibility for the purposes of our project, so marrying the findings of the Kashi et al. study with a motion tracking model derived from computer vision seen in prior research is the intent of our design study. Alongside this proposal, a full suite of progress and personal health informatics tracking methods, designed to benefit both the therapist and user alike, are proposed as a solution to the constraints revealed in our literature review process.

3. Design Proposal and Rationale

To address the lack of self-tracking technologies in the physical therapy domain, we concluded that an app would be the best and most sufficient answer to our problem. In order to come to this conclusion, we used background information and prior experiences to design PhysioTrack. This practical and easy-to-use mobile application allows users to log pain, access condition resources, and record videos of physical therapy exercises that their physical therapist can also see. The reasoning behind this is that physical therapists often assign patients exercises to work on at home, which can lead to various injuries if not performed correctly.

When the user first opens PhysioTrack, they are greeted by their name and an inspirational quote that changes every day. The home screen on the app (Figure 1) also allows the user to view their recent logs and multimedia. By selecting the '+' icon, users can choose to log pain, physical therapy, or general health notes (Figure 2). Users can view their account information, tracking habits, health-related trends, and resources for common conditions by selecting the flyout menu (Figure 3).

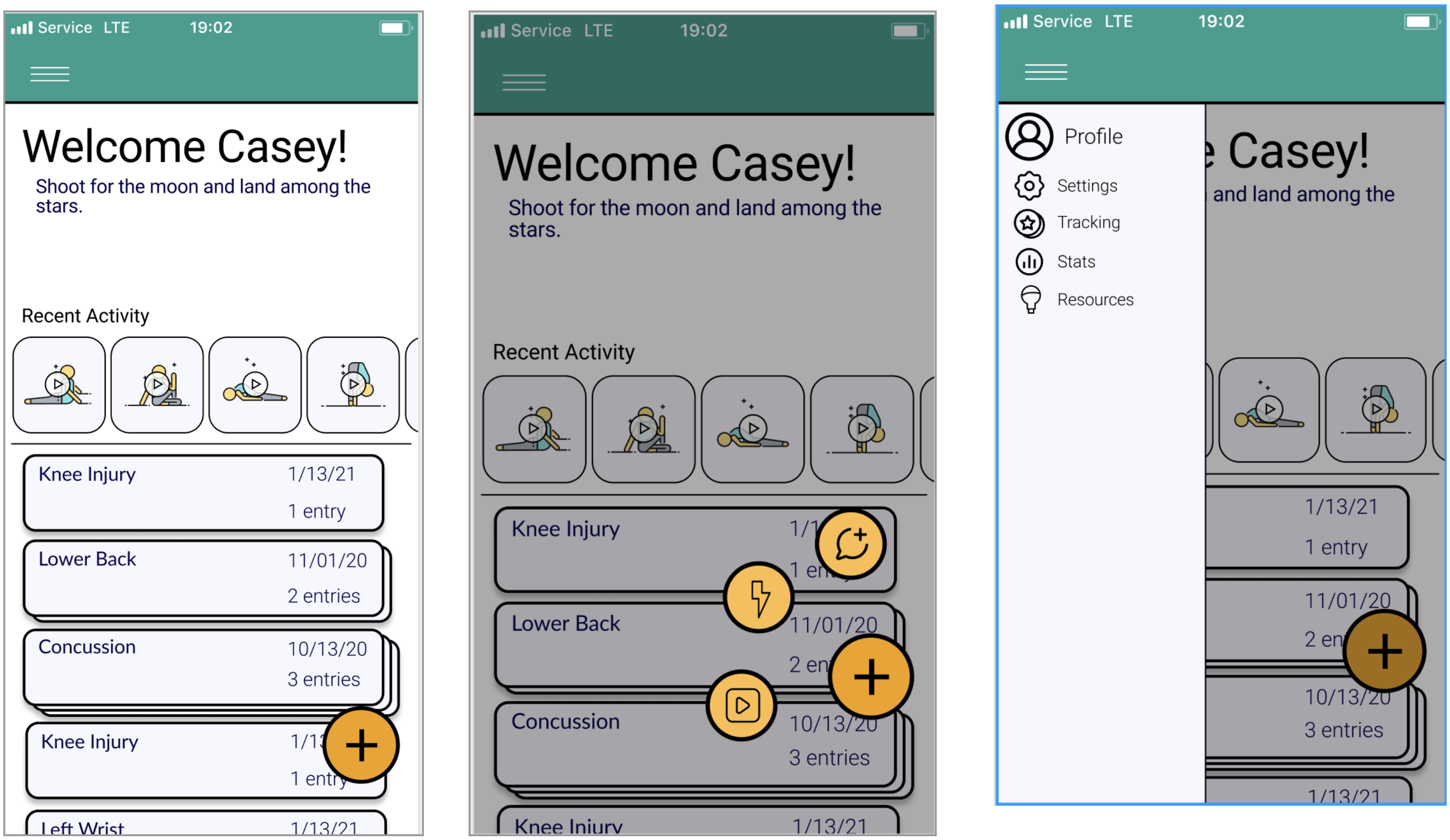


Figure 1 (left): PhysioTrack homescreen; Figure 2 (center): log and add notes, pain rating, or video; Figure 3 (right): fly out menu.

The message bubble represents any notes the user may want to add to the app, whether daily activities, medications taken, or any other thought they feel needs to be recorded somewhere.

Next, the user is able to add their pain to a daily log by clicking on the **lightning bolt**. After clicking on this, the user is prompted to select the date they are logging information (Figure 4). By clicking 'Continue,' the user can then select where exactly their pain is on their body by clicking the red '+' button on the figure (Figure 5). The next screen prompts users to describe their pain by selecting from a list of types of pain (Figure 6). To complete the new log, the user will rate on a scale of 1–10 the intensity of the previous selection of pain types they are experiencing (Figure 7). In addition to their ratings, they can add the amount of sleep they got and the amount of activity that may contribute to their current pain levels. After clicking ‘Add to Log,’ the patient’s full log will appear (Figure 8).

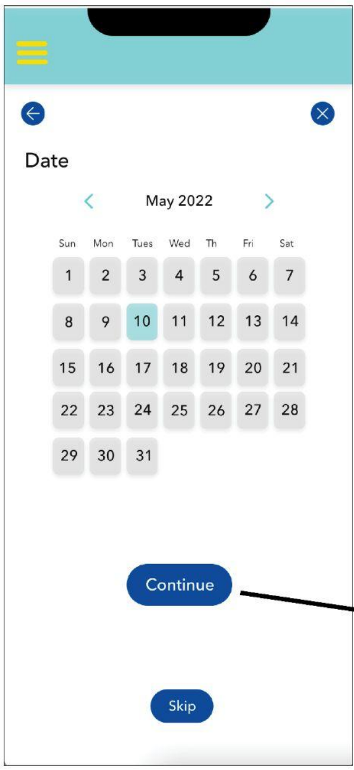


Figure 4: select date of pain that is being logged.

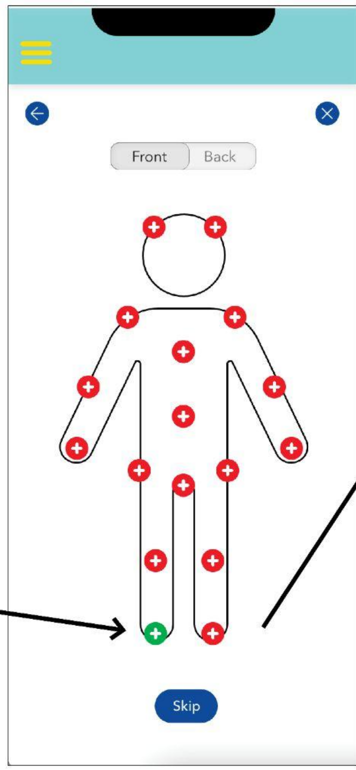


Figure 5: choose an area of where the pain is occurring, either front or back of the body.

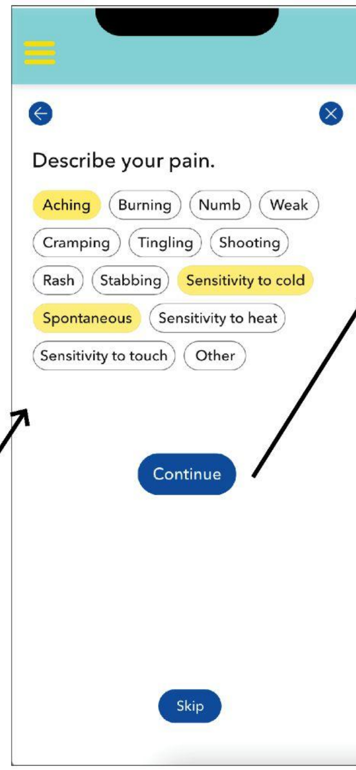


Figure 6: user chooses different types of pain.

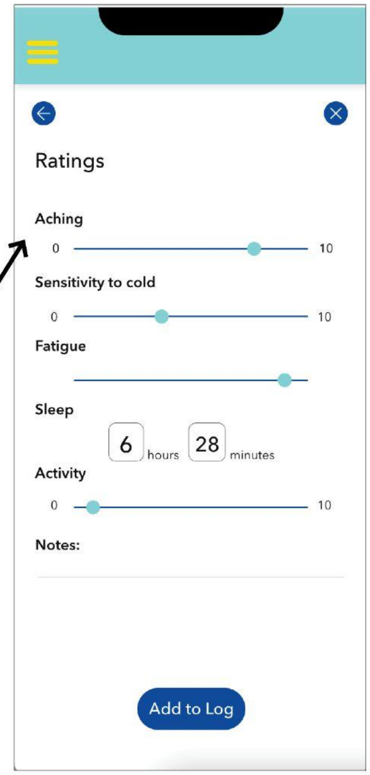


Figure 7: user rates these types of pain on a scale 1-10 and can include other possibly beneficial information.

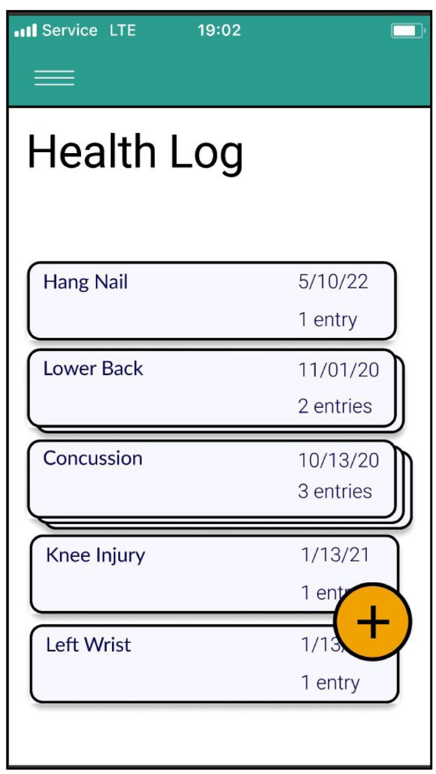
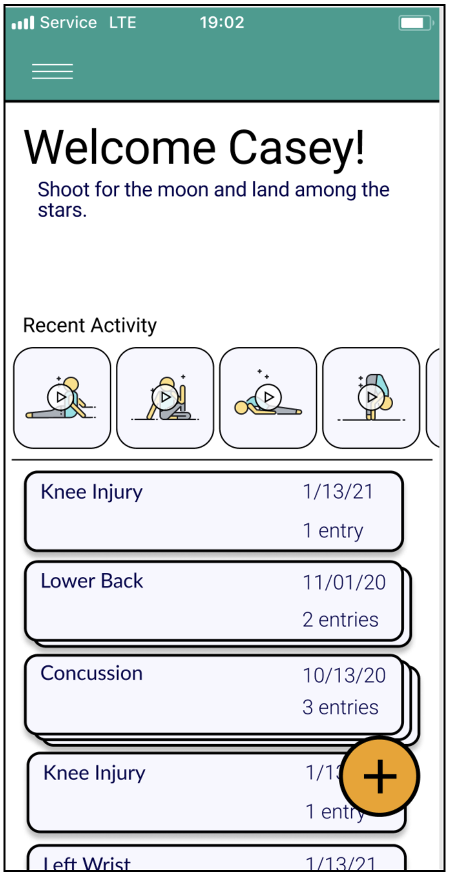
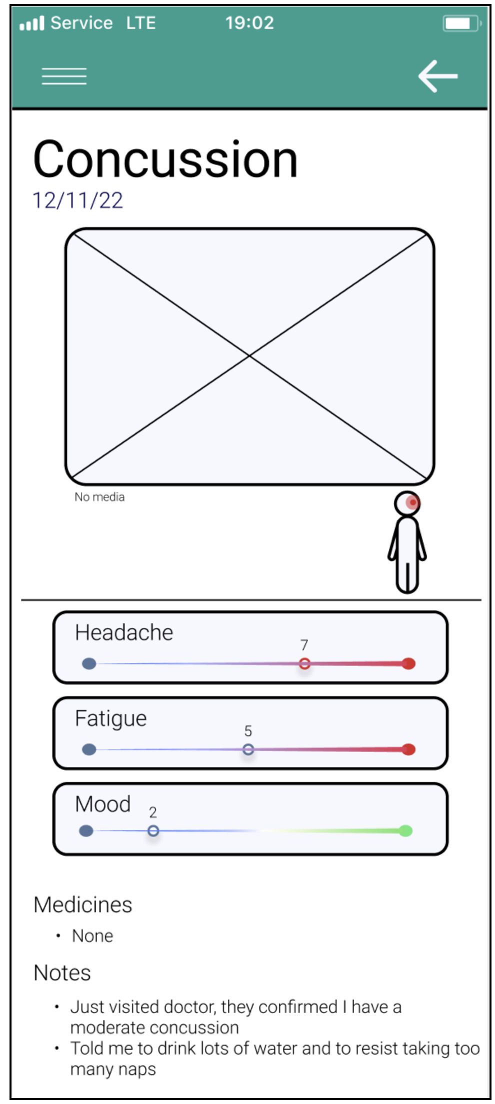


Figure 8: the full health log of patient's entries including pain, notes, and videos.

Users have the option to add entries to existing injury logs. Injury logs are visualized in Figures 9 & 10, in which users select an injury log with multiple entries. Each entry was logged on different dates, as the user's concussion symptoms progressed. Figure 11 illustrates the '(12/11/2022)' entry in the concussion log, in which the user confirmed their headache caused by a fall suffered while skiing is, in fact, a concussion diagnosis. The user included notes from their



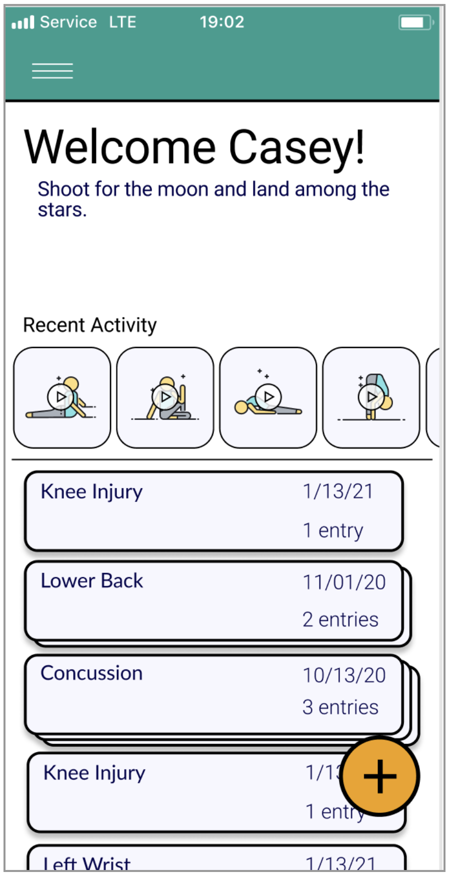


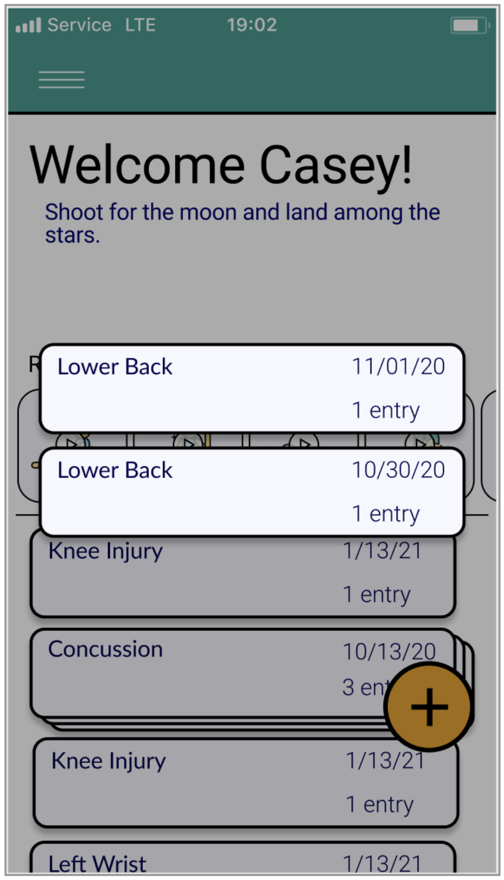
doctor's visit (in addition to symptom tracking).

Figure 9 (left): Physiotrack homescreen, Figure 10 (middle): concussion log entries; Figure 11 (left): finalized individual entry.

The frames below display a similar flow, illustrating how a user selects the '(11/01/2020)' entry for their 'Lower Back' log (Figure 13). Figure 14 shows the multimedia uploaded by a user engaging in a PT exercise. Under the footage, the machine vision software outputs a strength score and a mobility score. The shaded regions represent healthy ranges for the user's age and body type. The user will be able to view their progress under the 'Stats' tab (Figure 3), plotting their strength and mobility scores (for each injury) over time.

Additionally, in this frame, the user records two medications they are currently taking. By co-recording all of this information, doctors can access objective data about the efficacy of medicinal and therapeutic regimens in managing pain.





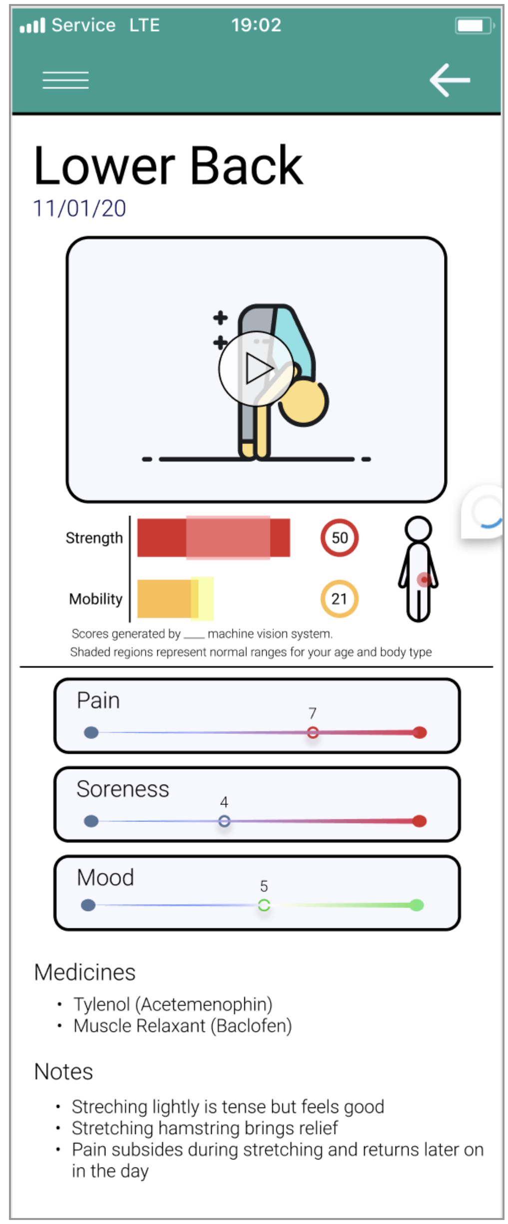


Figure 12 (left): Physiotrack homescreen, Figure 13 (middle): lower back log entries; Figure 14 (right): finalized individual entry.

PhysioTrack also gives patients (the users) the ability to record themselves performing their at-home exercises, which are then available to the patient's physical therapist to view in order to give their patient constructive feedback and praise. To record and add a video, the patient will click on the '+' at the bottom right of the homescreen. When the three bubbles pop up, they will choose the bottommost one with the icon of a play button with a box around it (Figure 2).

The phones camera will immediately show up, prompting the user to record a video of themselves performing an exercise (Figure 15). Next, the video will play to ensure the user is satisfied with their video (Figure 16). If not, there is an option to retake the video altogether. Lastly, the user can describe their video and add other helpful information such as date logged/taken, the specific exercise that was performed, the level of difficulty the exercise was, and any relevant information or notes (Figure 17). By pressing ‘Continue,’ the user will then view their entire log (Figure 8).

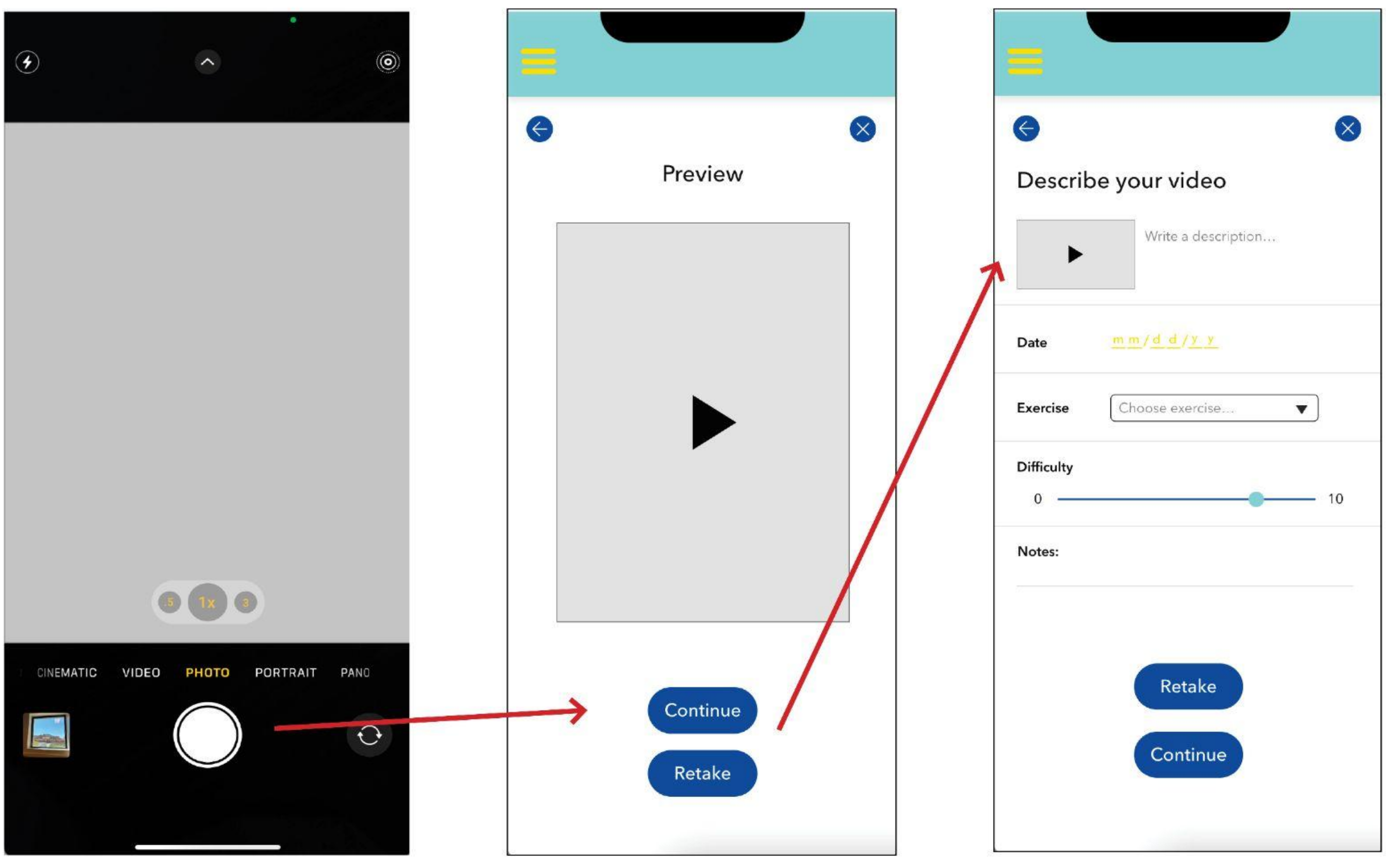


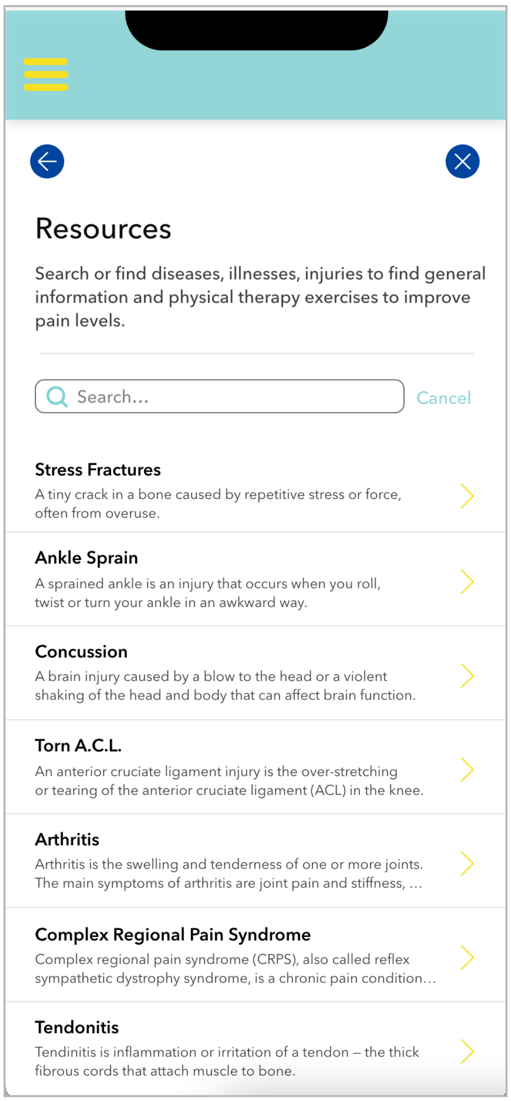
Figure 15: camera interface opens

Figure 16: preview video before continuing to log details

Figure 17: add a description of the exercise, the exercise name, the date performed, difficulty, and any relevant notes.

The last feature of PhysioTrack appears in the flyout menu as ‘Resources.’ This feature allows users to read and access condition resources such as what is the condition, symptoms, treatments, and more. Here users can find other possible treatments besides physical therapy that they can discuss with their clincian and physical therapist. There are two parts to the resources feature: one being able to scroll or search for conditions, the other being the information page.

When the resources tab is first clicked, patients will have the option to either scroll and look for a certain condition while also being able to see what other conditions they can educate themselves on. User can also simply type in the search bar whatever condition they are seeking to find information for. After selecting a condition, users are presented with paragraphs of basic information on the subject.



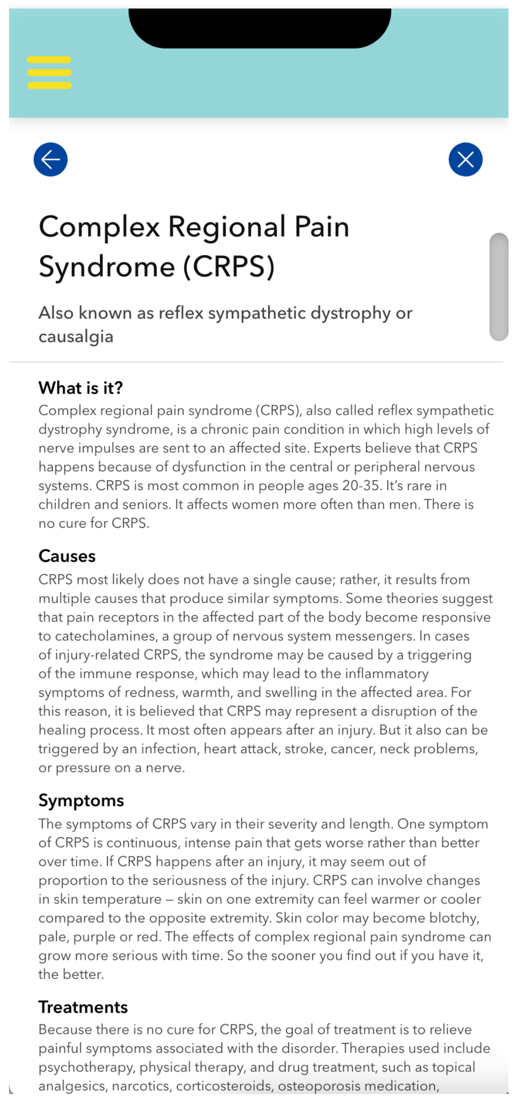


Figure 18 (left): Resources landing page; Figure 19 (right): condition information such as basic facts and treatments.

4.1 Limitations

Our team faced some limitations and challenges while designing a prototype for a self-tracking application. Our first challenge was the overall timing of this project, as we created a concept that needed more time for iterations and development, mainly including the actual video capture portion of our design. Another limitation is that we could not get user testing completed for feedback leading to the continuous iteration of the design within our time of development. Within our design, we needed to overcome challenges to move forward in implementing a working prototype. This included a difference in idea and quantifying metrics, as well as aesthetics. The team solved these challenges by discussing the design on a broader scale and focusing on details. Likewise, determining adequate scope for a project of this nature proved to be difficult. As a prototype, our design specifications were sufficient, but implementing a computer vision algorithm beyond a prototyping phase would require a large amount of user testing and data collection that was not feasible given our timeline. As such, our background and research section reflects future design possibilities.

This app aims to remove some of the more fundamental barriers to good physical therapy accessibility by bringing pain and PT tracking and health informatics to the handheld smartphone. Of course, technology limitations present themselves as an inherent barrier to access for this platform, as not everyone can access a smartphone. However, despite this, we decided to use a mobile platform for this project due to their relative ubiquity in the United States and Europe. Other concerns include time and effort restraints on the user's end, learning and using an app such as our proposal can be daunting, and it is important to reduce annoyances and design barriers present in such an application. Therefore, user testing is of utmost importance for this design process, and any further work done in this study should carefully consider the needs and limitations of any user that may choose to use the app. For instance, the computer vision model must be designed to allow for multiple camera angles, distances, and quality levels, as it cannot be assumed that each user has an equally prime recording environment. Some users may choose to utilize the app in a gym, or around other people. Likewise, it is important to consider the breadth and diversity of patients' injuries in both the UI design and computer vision subsystems.

This project reinforced the overall idea that health informatics can be a daunting task. Still, through research, the collaboration of ideas, and commitment to design, we created a prototype that we believe could be propelled to the next stage of fidelity.

Conclusion

People who manage chronic pain, and those who engage in periodic physical therapy need tools to track their progress and the efficacy of their regimens. Doctors can also benefit from self-tracked data but prefer to focus on more objective metrics like medicine dosage and pain levels. Patients can benefit from this data over time but can prefer other metrics, such as exercise, mood, and various other symptoms. Our mobile application, PhysioTrack, supports both the patient's and clinician's needs.

For patients tracking chronic pain, it is beneficial for them to log various possible factors and notes throughout the day or week. PhysioTrack gives patients the ability to do so by logging their types of pain, whether that be one or multiple causes, and the option to rate them on a scale. When a patient logs their pain, they are prompted to enter the date, location of pain, and rate their pain so that both the patient and clinician have accurate details of the event for future recollection. In addition to this, patients are able to input their medications, any medications they have taken throughout the day, or medications that may have improved or worsened their symptoms. This information is crucial when it comes to discussing possible treatments with a clinician because it provides documentation of what worked and what did not.

For patients engaging in periodic physical therapy, it can be helpful to objectively track a patient's progress in their exercises and stretches via video footage. Progress can be gradual, and it is heartening to know that progress is being made; therefore patients and physical therapists can view their past videos at any time. We focused on collecting the types of data (self-report + multimedia) that could be compared across time so that users could visualize their progress. Additionally, PhysioTrack's machine vision system can be used to quantify progress, reaffirming feeling stronger or more in control. Usability testing would be required to assess the machine vision's efficacy and its effect in situations where its outputs are at odds with the user's beliefs.

ACKNOWLEDGMENTS

Thanks to Professor Steve Voida for instructing Personal Health Informatics!

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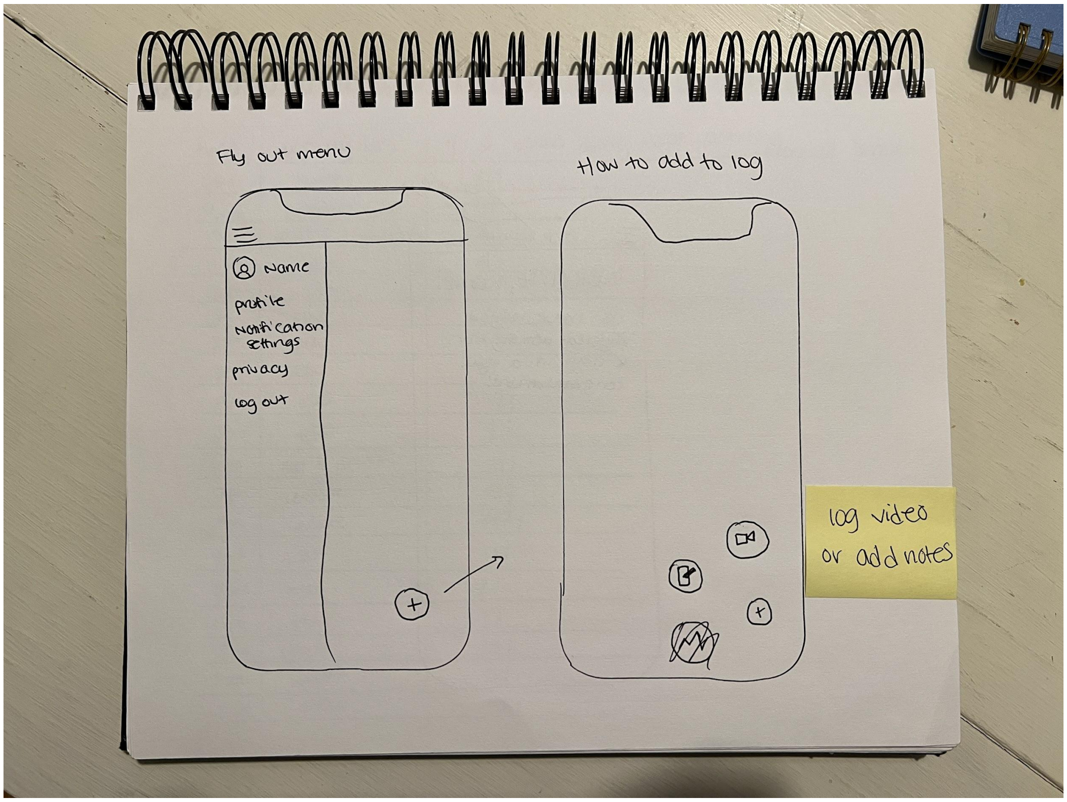
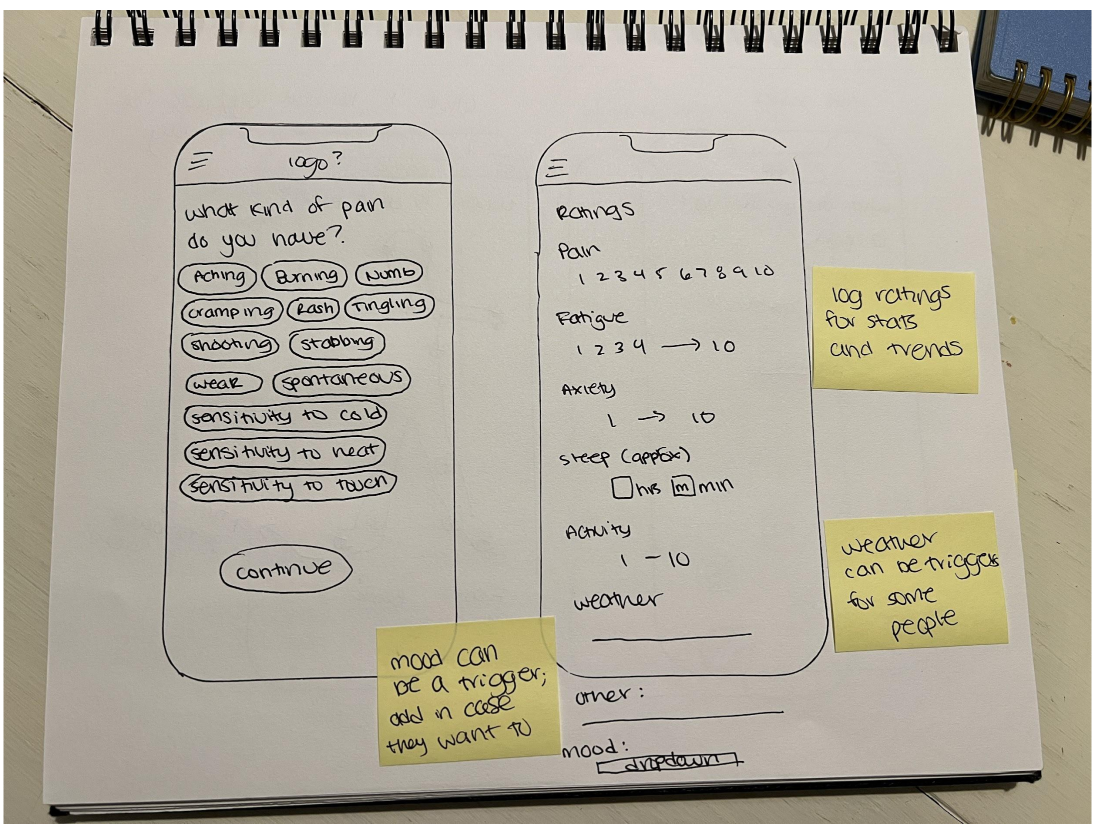
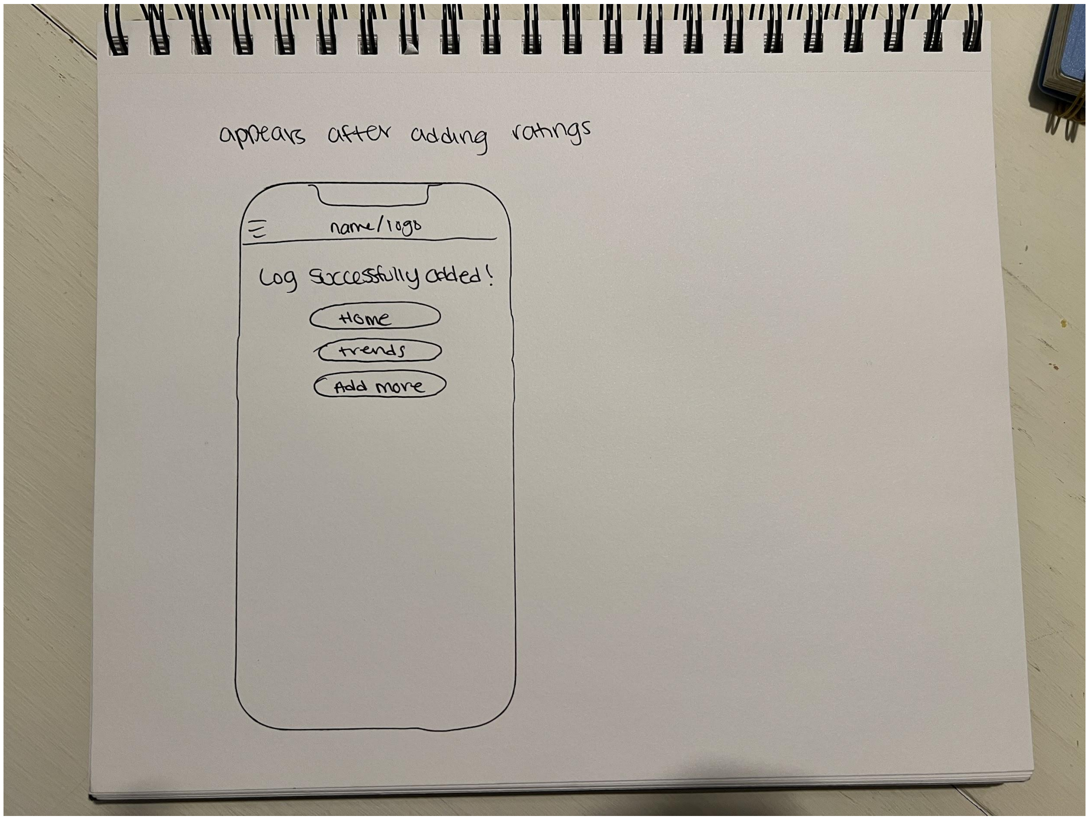
A APPENDICES

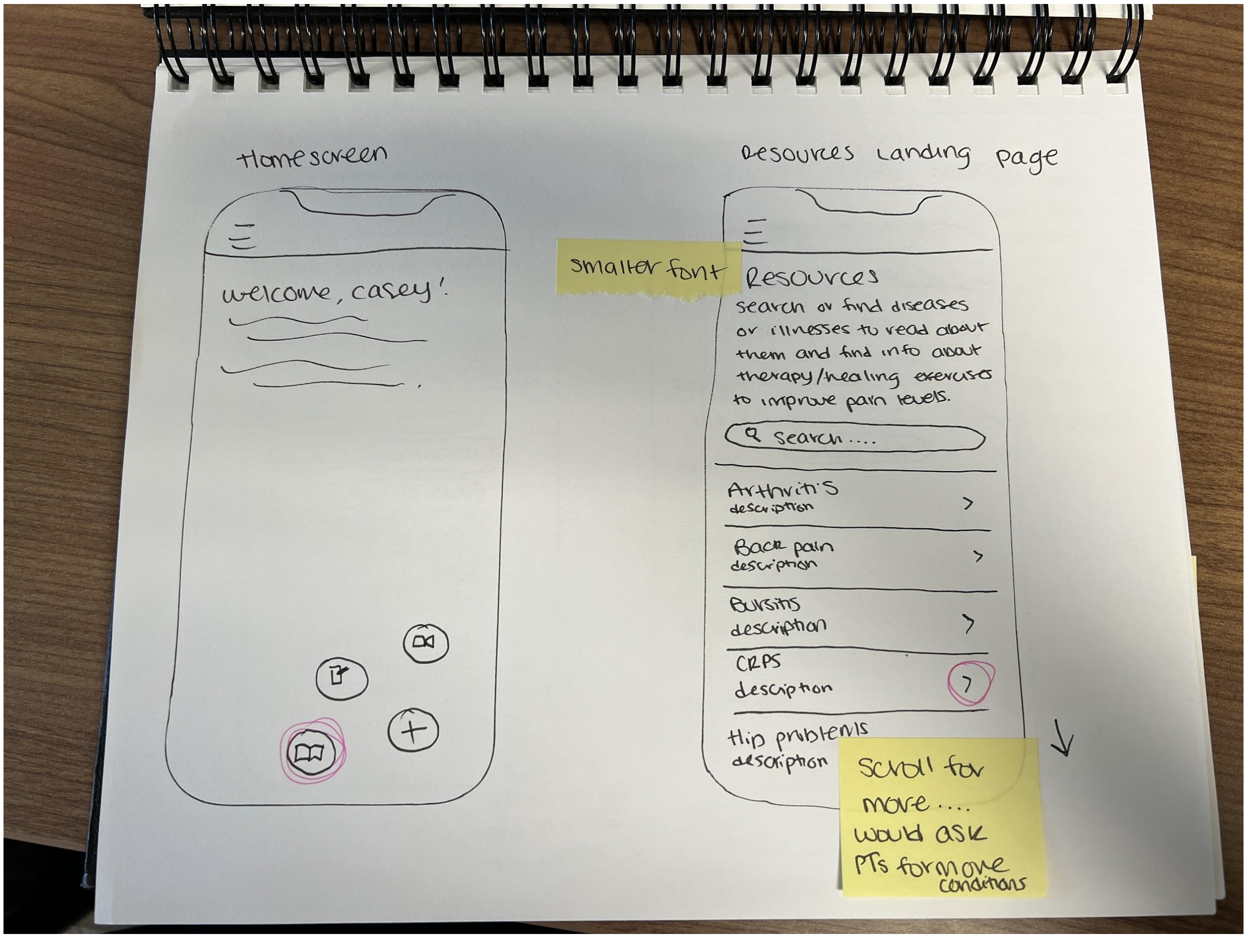
A.1 Preliminary Design

Attached in our appendix are any sketches for the prototype and design resources we used.

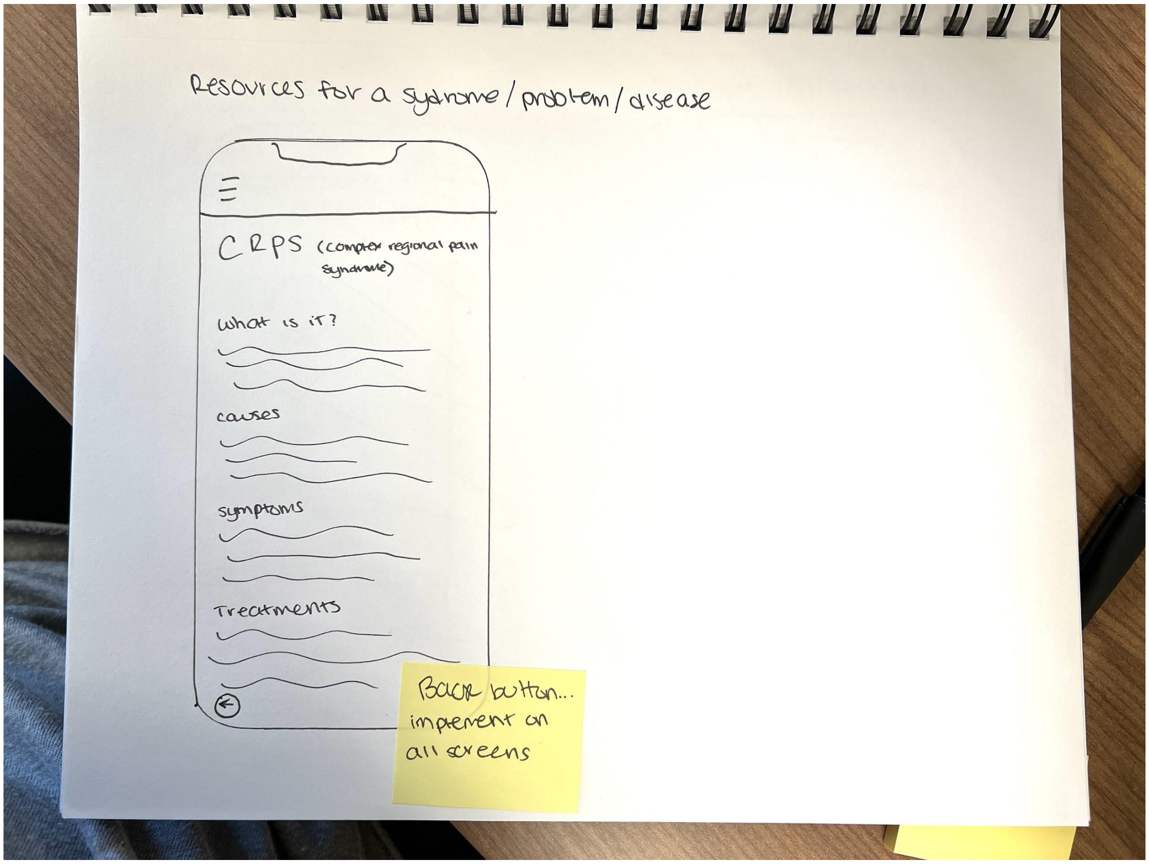

Fly out menu
How to add to log
Name
profile
Notification settings
privacy
log out
log video or add notes


logo?
what kind of pain do you have?
Aching
Burning
Numb
cramping
Rash
Tingling
shooting
stabbing
weak
spontaneous
sensitivity to cold
sensitivity to heat
sensitivity to touch
continue
Ratings
Pain
1 2 3 4 5 6 7 8 9 10
Fatigue
1 2 3 4 → 10
Anxiety
1 → 10
sleep (approx)
hrs
min
Activity
1 – 10
weather
other:
mood:
dropdown
log ratings for stats and trends
weather can be triggers for some people
mood can be a trigger; add in case they want to

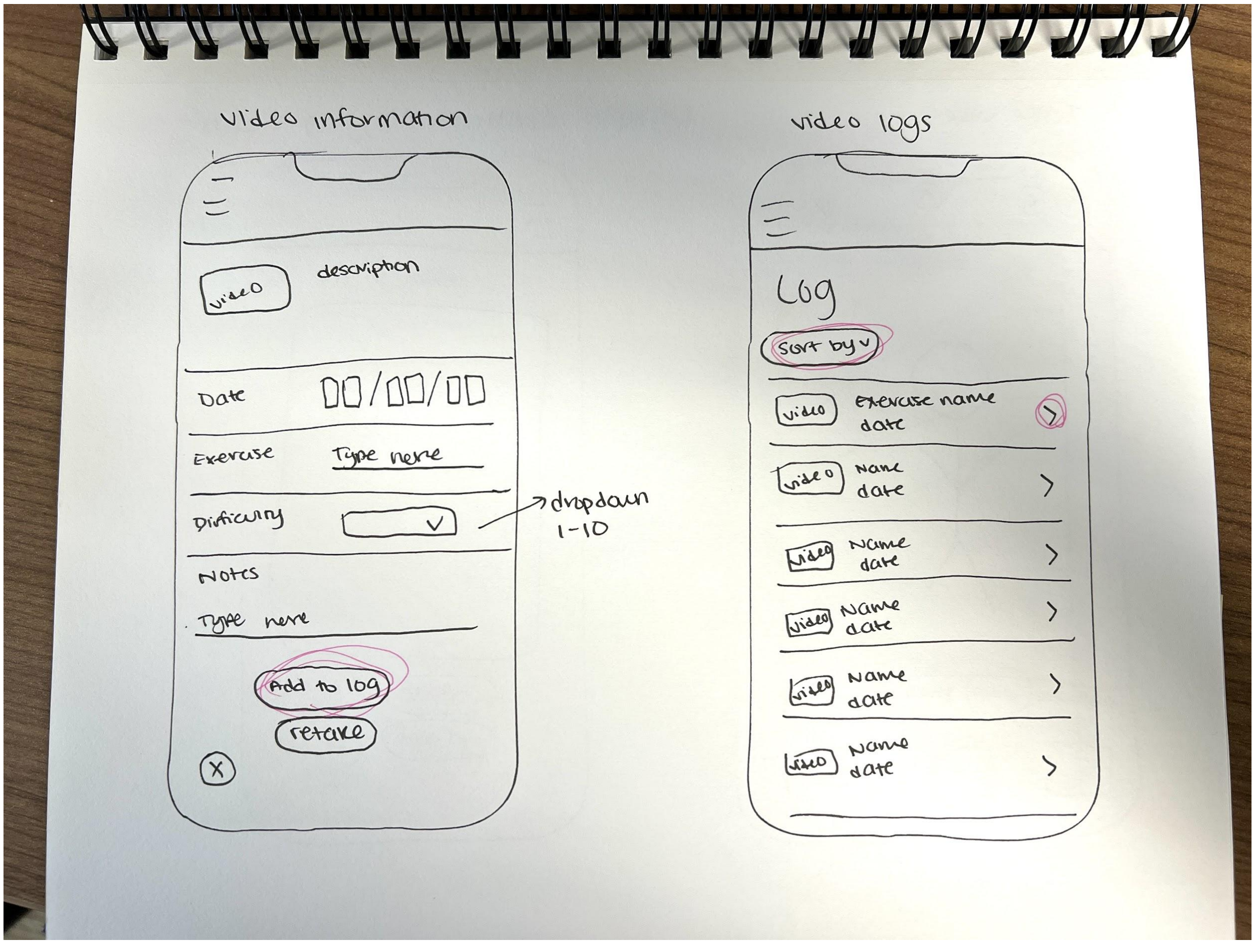

appears after adding ratings
name/logo
Log successfully added!
Home
trends
Add more


Homescreen
welcome, casey!
Resources Landing page
smaller font
Resources
search or find diseases or illnesses to read about them and find info about therapy/healing exercises to improve pain levels.
search ....
Arthritis
description
Back pain
description
Bursitis
description
CRPS
description
Hip problems
description
Scroll for more .... would ask PTs for more conditions


Health Log
Knee Injury
1/13/21
1 entry
Lower Back Pain
11/01/20
2 entries
Concussion
10/13/20
3 entries
Knee Injury
7/10/20
1 entry


Resources for a syndrome/problem/disease
CRPS (complex regional pain syndrome)
what is it?
causes
symptoms
Treatments
Back button... implement on all screens


Homescreen → video sequence
Welcome, Casey!
Logged videos



A.2 Peer Evaluation Form

[Final Project Peer Assessment Form]