PracticeCactus - Final Report

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(Word Count = 2494 words)

Introduction

PracticeCactus is a mobile app created through the Participatory Design (PD) process for use by piano teachers and their students to enhance and augment independent piano practice between weekly lessons. Support for the specific needs of both teachers and students is provided, as identified by one researcher (Heather), a group of piano students ages 7 through 17, their parents, and piano teachers. Since PD acknowledges all stakeholders on a design team, programmers (Alvin, Matt and Yuan) also have a voice in influencing the direction of the app development.

Students

Piano students are expected to practice regularly between lessons in order to develop skills, confidence, and technical proficiency on their instrument (Bloom, 1985; Ericsson, Tesch-Romer & Krampe, 1990). This can be challenging for students who describe feeling isolated while practicing, and discouraged when there is no communication with the teacher between lessons. Students also report a lack of motivation to practice regularly due to the repetition needed to achieve mastery, and the inability to perceive progress from day to day.

PracticeCactus is a mobile app which automatically detects student piano playing and displays a virtual cactus which changes mood based on how much practice occurs; this functionality addresses the students' perception that an app which reacts to their playing will lessen their feelings of loneliness while practicing (See Figure 1). Potential users were asked to think of names and eventually PracticeCactus was decided upon.

Figure 1. Students' original ideas for reactionary elements to piano practice included a dancing person, a special keyboard with light-up keys, and a pet monster which becomes healthier if you practice.

Not only are students "listened to" as they practice, but the app allows them to choose one or more parts of their practice session to record and share with their teacher. Making decisions about what to play for the teacher, and listening to their recordings before sending will foster metacognition which may lead to improvements in playing (Barry & Hallam, 2002; Hewitt, 2001; Ericsson, Krampe, & Tesch-Römer, 1993). Furthermore, sending recordings is a simple way for students to communicate with their teacher without having to wait a full week until the subsequent lesson.

Teachers

During lessons, piano teachers assign specific tasks to students, and also suggest how much practice is recommended. Teachers make educated guesses about whether students comply, but if someone does not progress as expected, it is impossible to reliably know how that student's practice habits might be implicated.

Relying on self-report data from students is problematic due to common issues with honesty, adherence, and response bias (Austin & Berg, 2006; Geringer, 1983).

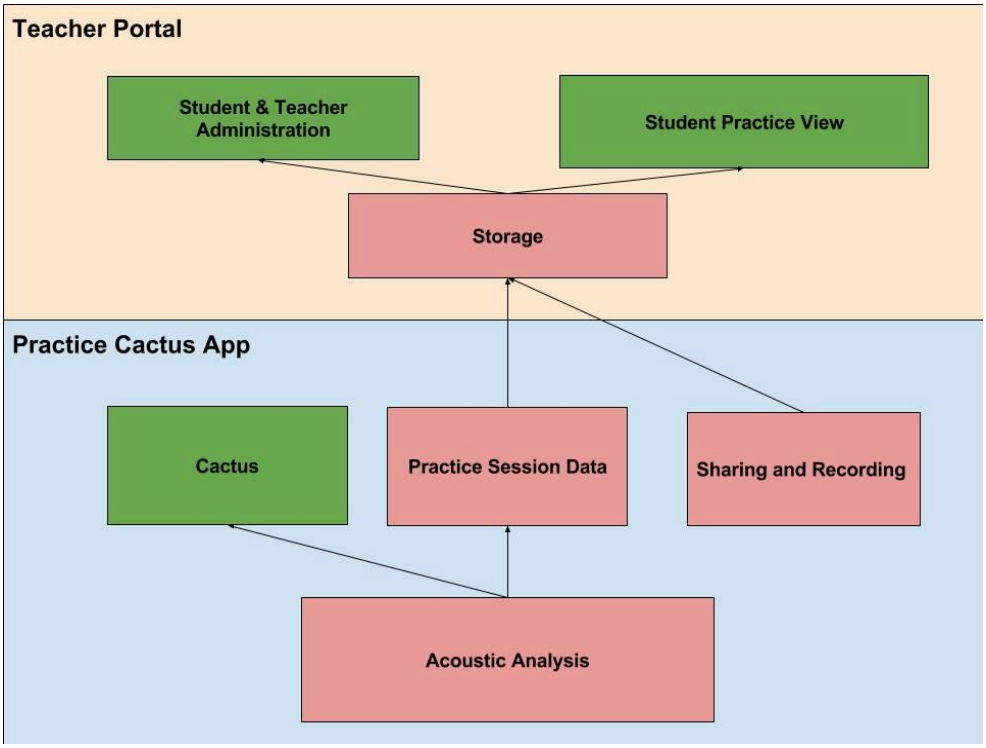
PracticeCactus includes a web portal which provides teachers with detailed information about students' practice habits. While the app is open and students are practicing, statistics about the session are collected, providing useful information to teachers. These data can inform instruction, allowing teachers to differentiate their pedagogical approach for individual students' needs (Tomlinson, 2014; Stanford & Reeves, 2005; Strickland & Strickland, 1998).

Overall Design

The PracticeCactus App

Our app is composed of four main components.

1. Acoustic Analysis Module
2. Cactus Module
3. Practice Session Module
4. Sharing and Recording Module



Acoustic Analysis. The goal of the Acoustic Analysis module (AAM) is to process audio data and provide useful information to other modules of the application. In order to ensure accuracy and speed we chose to implement the analysis largely from scratch using minimal library support. The AAM takes in raw Pulse Code Modulation (PCM) audio data from the Android AudioRecorder. After applying a discrete fast-fourier transform to the signal, the AMM calculates the relative power at specific frequencies.

Piano keys resonate at very specific frequencies and early experiments demonstrated that we were able to reliably detect an increase of power at these frequencies. The AAM is able to discriminate between piano and non-piano by looking for significant increases at frequencies corresponding to piano keys. The AAM acts as

more than a simple discriminator. We were able to incorporate multiple simultaneous note detection into the AAM with reasonable accuracy.

Architecturally, we chose to implement the AAM as a publisher in the classic pub-sub design pattern. This architecture provides loose coupling between the AAM and other modules. The AAM periodically publishes acoustic analysis events approximately 8 times per second. Other modules listen for these events and make use of the information encapsulated within.

Cactus Module. The Cactus Module is responsible for providing a friendly and encouraging user-interface to students as they practice. It consists of a controller to respond to audio analysis events and several custom views for displaying the UI.

Practice Session Data. While the PracticeCactus app is open, the Practice Session Module is listening for audio analysis events and capturing relevant practice information. In particular, the Practice Session Data module is capturing the length of the practice session, the percentage of time the student is actively practicing piano, the sound profile of the practice session, and the dominant keys played during the practice session. We implemented the module such that it requires no interaction from the user, but operates entirely in the background, allowing the student to focus on their piano practice.

Recording and Sharing. Once a student feels happy with their practice, the Record and Share module allows the student to record and submit an audio recording of their practice to the teacher portal. We designed a Recording and Sharing activity which was minimal and easy to use.

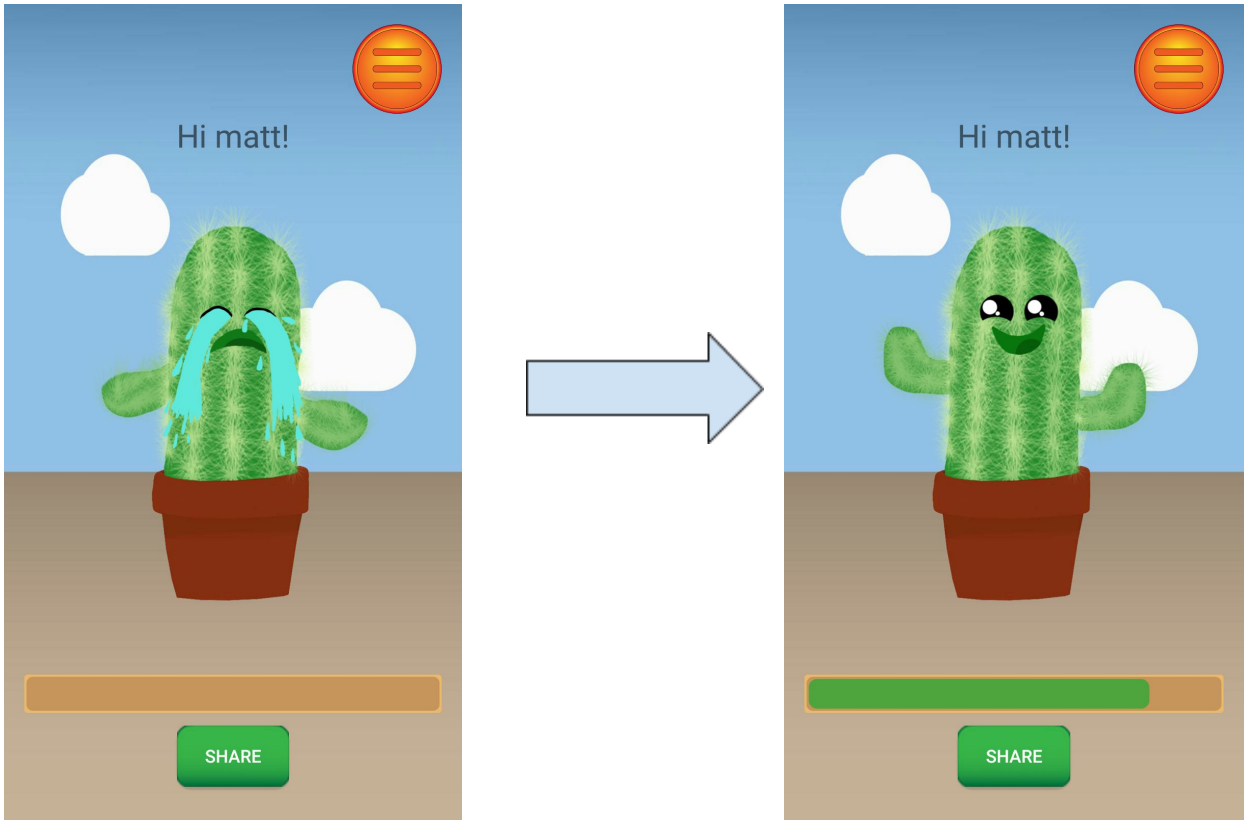
Teacher Portal (http://159.203.40.18:3000/teacher)

The teacher portal is a web application which serves as a central repository for students' practice information. In addition to storing practice session information, the server stores audio recordings that students have shared with their teacher.

Our technology stack is an Angular.js frontend, a Node.js web server, and a SQLite3 database. Node.js was chosen for its powerful I/O capabilities, for its wide acceptance in the web development community, and to keep web portal development simple by using a single programming language (javascript). Angular.js was chosen for the frontend framework because of its powerful asynchronous templating abilities. Other libraries used include Google Charts for graphing, wavesurfer.js for waveform display and recording playback, and Bootstrap for base UI styling.

Statement of Functionality

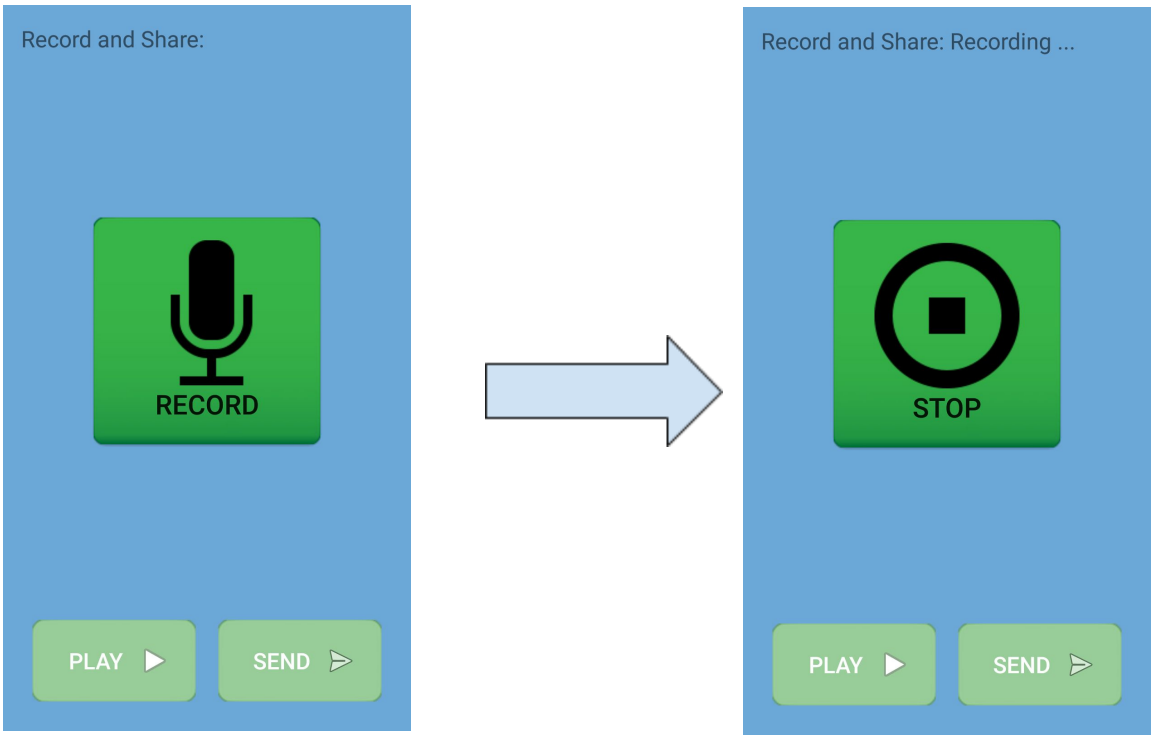
App Practice View

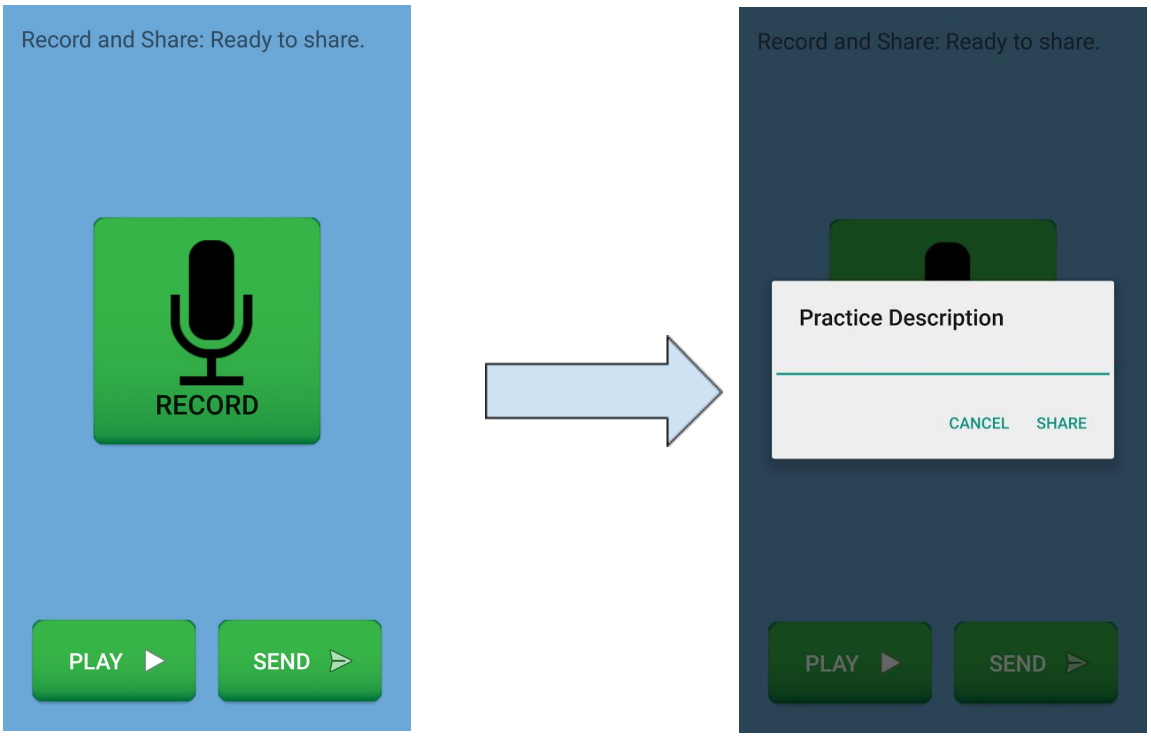


When a student opens the PracticeCactus app, they are immediately directed to the Practice View and can begin practicing the piano right away. As the student plays, the cactus mood increases. If the target session length is X minutes, X minutes of practice will increase the cactus's mood by 50%. The cactus mood undergoes exponential decay with time such that five days of inactivity causes the mood to go to zero. This behaviour was chosen in accordance with a PD session with students as well as knowledge of piano pedagogy.

Students' practice session statistics are automatically sent to the server once the app is closed. In order to minimize any distractions for the student during practice, the Practice View has only two buttons. The "Settings" button is hidden as the sun in the top-right corner, which allows teachers and students to personalize the app experience. The "Share" button at the bottom of the screen allows the student to enter the "Record and Share" activity to record a piece or technical exercise for submission to their teacher.

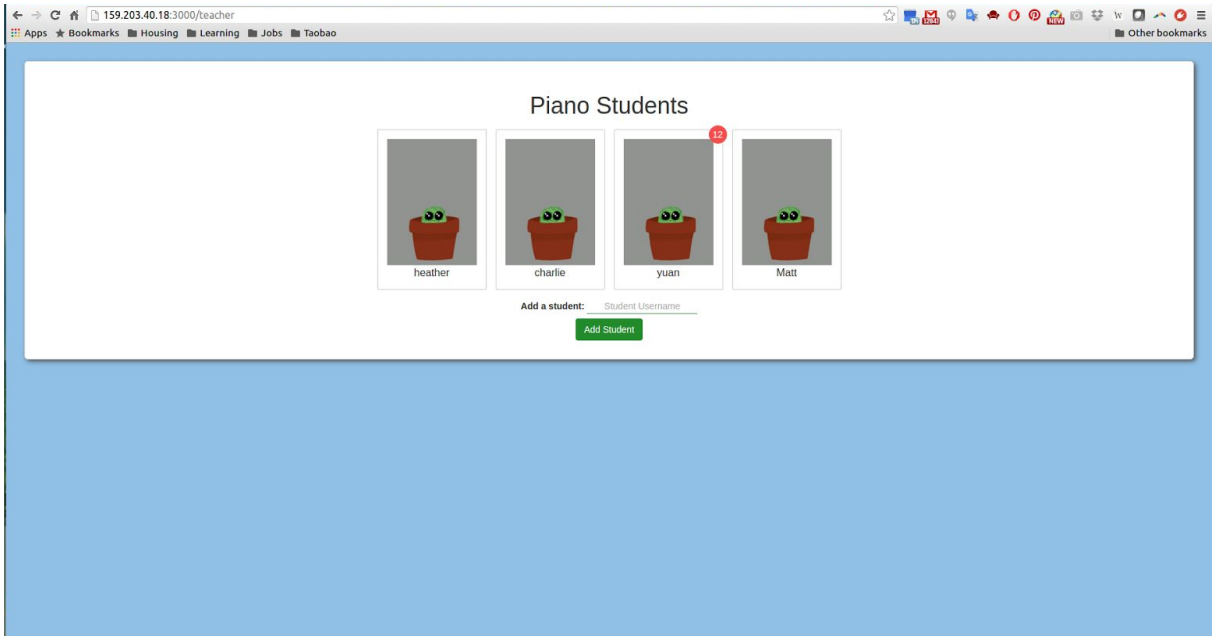
App Record and Share Activity



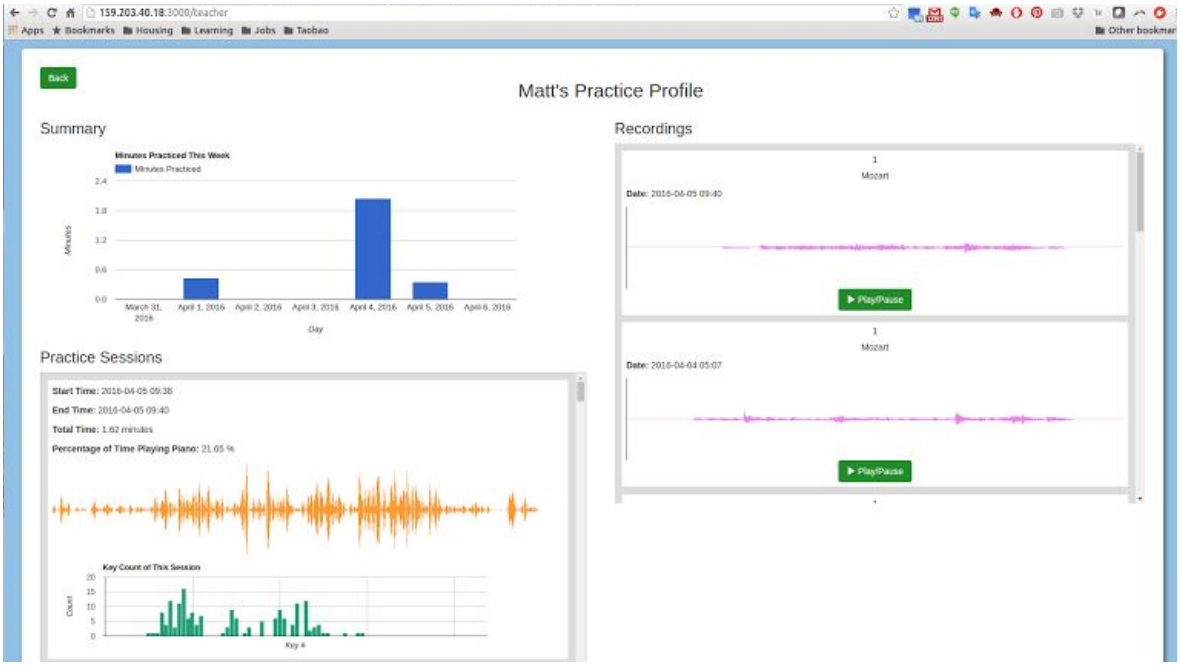


The Record and Share Activity allows students to record and share recordings with their teacher. In order to simplify the process for the student, the buttons are only visible or enabled when they are needed during the recording and sharing process.

Teacher Portal (http://159.203.40.18:3000/teacher)



After logging in, the teacher is presented with a list of their students. The teacher can see at a glance whether a student has submitted a new recording that they have not yet reviewed by the small red indicator on top of the student's icon. The teacher can also add a new student to their piano studio, and the page will be automatically refreshed to reflect this addition.



When a teacher clicks into the practice profile of a student, they are able to see critical information about the student's practice habits at a glance - a weekly practice summary (top left), a list of recordings submitted by the student (top right), and details about each practice session (bottom left). In the Practice Session section, the teacher can review detailed information about the student's practice habits during each session including the start and end time, the percentage of time the student was actively practicing piano, a visual waveform depiction of the sound profile, and a histogram displaying the number of times each piano key was played.

Key Learnings

Specialist

Ideally, all the stakeholders involved in the creation of this app would have embarked on the journey together, from the outset. However, the piano students, parents and piano teachers began the PD process before the programmers joined the design team. This required me to quickly and clearly communicate the vision which had developed over the last two years so that the programmers could feel part of the team. The PD process could have been improved through convening face to face meetings of all the stakeholders throughout the design process instead of asynchronous communication online and through mediation through me.

Programmers

From the start, we decided to work closely together, collaborating intensely on the code. One interesting point learned during the development of the app was the need to focus on user experience. Initially, we were full of ideas for features and directions to take the app in. It was a learning experience getting student feedback and focusing our efforts on their requests and needs rather than our own.

Contribution by Group Members

Specialist

Heather served as the chief negotiator among all the stakeholders on the design team, ensuring that the voices of PD participants were heard. Heather also provided valuable insight on user experience by taking design ideas directly to students and teachers and asking for their feedback. In addition, as a piano teacher herself, she was

able to provide a perspective on piano teacher culture, values and beliefs, as well as piano pedagogy and effective independent practice techniques.

Programmers

Matt, Yuan, and Alvin all worked tightly together developing PracticeCactus. Each took responsibility for portions of the app but assisted each other to fix bugs and create a cohesive application.

Yuan worked on the piano-key detection using the acoustic analysis provided by Matt. Yuan also worked on the practice session data recording, app-side data storage, the initial user-interface design for the app and fine-tuning the user-experience design for the “Record and Share” and “Settings” Activity. Yuan contributed to the team discussion for the user-experience in the app and on the web-based teacher-portal.

Alvin helped to develop the initial prototype of the audio analysis algorithm in Matlab, and then worked on storage of session records and allowing the student to submit recordings. Alvin implemented the database and the backend of the web server, setting up communication between the app and the web server, as well as the display of practice session information graphically on the front end (waveforms and graphs) and playback of recordings.

Matt worked mainly on the architectural and design features of the app. He was responsible for implementing, developing, and optimizing the base piano detection algorithm in java. Matt also designed and implemented the Cactus Module including

custom views, button design, and behaviour. Matt largely implemented the UI design for both the app and the web portal (layouts, styling, and activity dynamics).

Specialist Context

PracticeCactus can be used to collect data about student practice habits in order to answer research questions about how much time students practice, when they practice, how their practice habits correlate with achievement, and the nature of their experience using the app. Research questions about teacher use of the app could focus on how PracticeCactus is used by specific teachers in their own unique contexts, whether they find the app useful, and how the app could be developed to further support their pedagogical practice. In addition, data could be collected about what the key count data and the waveform representing student practice sessions reveals to teachers, and how these data might be useful to them.

Four of my colleagues have expressed interest in using this app with their students, for research purposes. Each would likely make use of the app in different ways, since two have traditional music studios (Indiana University, University of Toronto), one works with autistic music students (University of Ottawa), and one works in an inner city youth outreach program. I look forward to collecting the data from these differentiated contexts in order to make comparisons and draw conclusions about the effectiveness of the app for supporting both piano students and piano teachers.

PracticeCactus makes use of extrinsic motivation in the form of a responsive cactus, and through providing opportunities for students to please their teacher through

logging practice sessions of the appropriate length and nature. While extrinsic motivation has been shown to undermine intrinsic motivation, and to be ineffective in various situations, this is not the case if students have opportunities to experience autonomy and mastery (Evans, 2015; Ryan, Rigby, & Przybylski, 2006; Ryan & Deci, 2000). PracticeCactus allows students to have autonomy over which songs they practice, in which order, and for how long. While the app is "listening," it does not record the session so that the teacher can listen in. Rather, the student chooses which sections of practice they will submit to the teacher. PracticeCactus also provides opportunities for mastery since, if students practice for the requisite daily minutes to propel their cactus to the ultimate happy state, their playing will improve. A student is not simply practicing in order to see the cactus change; in the short term, this may provide motivation, but over time, improvements in piano playing which occur as a result of regular practice will foster further motivation to continue practicing.

Future Work

The app could be improved through the addition of functionality for both teachers and students. Teachers could assign practice activities to individual students, and respond to students' recorded submissions through "liking" or commenting. The cactus pictures representing students on the web portal could reflect the current mood of that student's cactus on the mobile application. This would involve continuous updating of the server state, as well as considerations of offline versus online handling of requests. The ability to set practice session length from the teacher portal side could also be

incorporated, allowing teachers to differentiate the amount of time their students practice daily in order for the cactus to reach its happiest state.

For students, the app could push practice reminder notifications if they have not practiced recently. As students practice, they could gain points and the ability to redeem those points toward customizing their cactus by choosing new pot colours or sunglasses and hats. Additional functionality could include allowing students to share their practice statistics through social media channels.

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