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Designing a Mobile Application to Support the Indicated Prevention and Early Intervention of Childhood Anxiety

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ABSTRACT
This paper presents the design of an mHealth application for prevention and early intervention of childhood anxiety. The application is based on REACH, a preventative-early intervention protocol for childhood anxiety. This paper describes the multidisciplinary design process, sharing lessons learned in developing an effective mHealth application. This mHealth application is unique due to participant age, preventive-early intervention focus, and utilization of mobile technology in a situated manner. A design process inspired by user-centered leveraging key informant interviews was used to identify application features, including game based strategies and an animated motivational avatar. Validation was performed through external review and a usability study performed with target end users of the application. Results suggest overall satisfaction, ease of use, and increased motivation.

Categories and Subject Descriptors
D.2.2 [**Software Engineering**]: Design Tools and Techniques – *Evolutionary prototyping, and user interfaces.*

General Terms
Design, Human Factors, Verification

Keywords
Youth Anxiety Prevention, mHealth, User-Centered Design.

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1. INTRODUCTION
Mobile health applications (mHealth apps) span a wide spectrum of health-related issues and treatment approaches, such as health monitoring (physiological or self-reported), protocol adherence through reminder communications, and (psycho)education [15]. Interestingly, the ubiquitous and familiar nature of smartphone devices creates the potential for mobile health (mHealth) applications targeted to youth "at risk" for anxiety disorders or meeting criteria for anxiety disorder diagnoses. In fact, mHealth for anxiety disorders may be of unique importance because most parents do not seek help for their anxious youth, effect sizes from anxiety programs are generally modest and need to be potentiated, and there is a pressing need for sustainable and streamlined intervention efforts that have "real world" utility [2][3][13]. In addition, targeting anxiety disorders is of public health significance because these are among the most prevalent psychiatric problems in children with rates ranging from 5% to 10% and as high as 25% in adolescents. Anxiety disorders also cause significant impairment, typically fail to spontaneously remit, and are prospectively linked to clinical depression and problematic substance use for some youth [13].

Although the popularity of mHealth apps is exploding, few lessons have been shared regarding the user experience design for such innovations. Building on randomized control trial (RCTs) studies and theory, this research focuses on the design process for adapting aspects of an empirically informed child anxiety disorder intervention to a smartphone platform. Thus, this work is significant due to the domain (anxiety), the nature of the intervention (preventative-early intervention), the use of an app to increase protocol efficiency, and the integration of concepts from innovative design technology (gaming, notifications, user experience design) to improve outcomes.

Focusing on the anxiety protocol, it is important to note that considerable strides have been made to develop evidence-based treatment and prevention armamentaria targeting youth anxiety with almost every protocol employing the same cognitive and behavioral procedures (Fisak et al., 2011; Silverman et al., 2008) .

REACH for Success (REACH hereafter) is a school-based cognitive-behavioral protocol designed for 4th and 5th graders for the indicated prevention and early intervention of childhood anxiety and related problems. REACH uses procedures found to be efficacious in RCTs, including in our own 3 RCT [8][9][12]; however, there are several features that set REACH apart. Most relevant to this paper is data suggesting that the classic design of evidence-based prevention programs (including programs like FRIENDS [1]) is simply not feasible or sustainable in schools (e.g., there are too many sessions, sessions are too long, manuals are too cumbersome and not organized for real world-implementation, too much training is required, and preparation is too time consuming). In contrast, REACH was created from our evidence-based exposure-based cognitive-behavioral protocols as a practical intervention that can build a foundation for sustainable large-scale diffusion. That is, REACH was streamlined into 6 sessions (instead of the typical 12-15), each 20-30 minutes in length (rather than the typical 60 to 90 minutes), and uses an easy-to-follow manual (each session is condensed into one page front and back while FRIENDS, for example, has an 89 page manual). One concern with REACH, however, is that such a streamlined protocol may result in a lower dosage of the active change ingredients and fewer opportunities for youth to practice coping skills because there are fewer sessions and less practitioner feedback time. This concern is justified as a recent child anxiety treatment study evaluating an 8 session adaptation of the 16 to 20 session Coping Cat program yielded lower youth response rates suggesting that difficulty practicing the skills was a major impediment to recovery [11].

A purpose of this research was to design an mHealth platform to accompany the REACH 6 session school-based preventative early intervention protocol. Specifically, the goal was to develop an mHealth app that: (a) provides on-demand opportunities for skill practice, (b) uses notifications relevant to skill practice to improve compliance, (c) offers tools for personalizing and tailoring the protocol, (d) increases opportunities for corrective feedback based on user data amenable to creating personalized reports of youth weekly practice and response, and (e) yields high user ratings along core validated usability dimensions relevant to technology innovation efforts. Herein, the REACH protocol, the app design process, and the app implementation are described. Results from an empirical study in a usability context are presented. To set domain context, the face-to-face protocol is described followed by a discussion on design, implementation, and usability.

2. THE REACH PROTOCOL

REACH for Personal and Academic Success is an indicated prevention and early intervention program targeting anxiety disorders and related problems in youth. The protocol is administered in a group format (five to seven children per group). Each session (S) in the manual is organized in terms of Overview, Content (didactic, games), Review/Closing, and After the Session (homework). Self-evaluation of emotion expressiveness is embedded in every session. The protocol focuses on broad-based exposure and problem solving skills, which have a wide reach for the range of anxiety disorders targeted. Unique session content is as follows. S1: Introduction (group name, rules, and confidentiality), Learn about emotions, and Relaxation. S2-3: Define worries, Learn cognitive self-control, and Practice cognitive self-control (Worryheads game). S4: Define social skills and Learn about conversation skills (starting and managing conversations). Practice conversations (make-believe game). S5: Learn about assertiveness and Practice assertiveness (stand-up! game). S6: Learn to face situations and Engage in behavioral exposures to mild-moderate anxiety-provoking situations. Core skill acquisition and practice tools include the use of Daily Diaries, Guided Relaxation, STOP acronym, and STIC acronym. Relevant to the REACH app, Daily Diaries are used to facilitate self-evaluation of emotion expressiveness. Youth self-monitor and describe in writing the anxiety or fear provoking situations that occurred during the week. Youth also rate using a 0-8 feelings thermometer the severity of anxiety/fear associated with the situation. Lastly, youth describe in writing thoughts that occurred before/during/after the situation (e.g., worries) and actions that resulted (e.g., avoidance behaviors). In terms of Guided Relaxation, youth are provided with pre-recorded standardized step-by-step procedures designed to improve self-regulation of anxiety related physiological hyperarousal via breathing exercises, muscle tension/release exercises, and imagery. When it comes to cognitive self-control, a four-step coping plan is introduced via the "STOP" acronym where S = Scared? T = Thoughts, O= Other [*thoughts*], P = Praise. STOP is first practiced via the Worryheads game by using pre-written emotionally ambiguous and anxiety provoking scenarios along with an accompanying "worry thought". Youth are then asked to change the "worry thought" for a more realistic and alternative solution to the scenario provided. In the game, successful resolution of the worry thought results in advances toward a common goal for each player (reaching the end to win the game). Subsequently, with basic knowledge of STOP, youth engage in prospectively applying the technique to situations that emerge as anxiety or fear provoking for them during the course of each week. Lastly, behavioral exposures are introduced via STIC jobs (STIC = Show That I Can. STICs are provided in the form of a pre-written or prepopulated Fear Hierarchies based on modules from the Anxiety Disorders Interview Schedule for Children where each avoidance behavior has been pre-populated for the child as individual exposures.

The REACH protocol has been implemented using a paper-and-pencil approach. The protocol, while effective, encountered some common limitations in practice, notably protocol compliance. Specifically, subjects did not practice skills between sessions or were not diligent in recording practice activity and outcomes. Further, as noted in section 1, lower dosage in the related Coping Cat tool resulted in lower response rates. Data capture with paper-and-pencil methods is also time consuming and subject to human coding errors or oversights. The psychology researchers believed mobile and gaming technologies could effectively address the limitations, improve compliance and data capture, thereby reducing dosage while increasing effectiveness. They teamed with software engineering researchers to conduct a multidisciplinary design and development process to construct the app.

3. DESIGN PROCESS

The multidisciplinary team embarked on a highly iterative design process focused on the capabilities and context of end users. The researchers aspired to use a *user-centered design* (UCD) approach, but in practice the designers did not have direct access to end users during the design process and as such relied on subject matter experts (SMEs) as proxies. The SMEs were the psychologists who developed the REACH protocol and had deployed it 56 times to youth over 6 months. Section 5 describes external validation via design review by a school advisory board and a usability study with independent youth end users (*n*=22).

3.1 Gap Analysis

REACH is a pre-existing protocol, so the first design activity was to review program materials and workflow, seeking opportunities to effectively translate existing steps, and later innovating on smartphone-specific solutions to achieve the domain objectives for increased dosage, engagement, and feedback (see Section 1). To better understand the domain of the app, the SMEs shared the provider manual of the REACH protocol to the designers and the materials for delivering the protocol (board games, handouts, MP3s). The manual describes how the sessions, each conducted consecutively over the course of six weeks, employ specific practice worksheets, information gathering forms, and interactive exercises designed to train youth in the preventive and coping skills. The main activities defined in the manual were Daily Diary, Relaxation, S.T.O.P, Worryheads board game, and STICs. Table 1 summarizes the protocol component steps and highlights challenges in porting these steps to the mobile environment.

Table 1: REACH protocol components and gap analysis

REACH	*Component Description / Design Challenges*
Daily Diary	Self-monitoring
	engagement; daily compliance; rich data entry
Relaxation	Pre-recorded audio exercises
	media porting and translation
S.T.I.C.	Behavioral exposures with adult feedback
	preserving steps; rewards; feedback
S.T.O.P.	Self-application of cognitive self-control plan
	encouraging tool engagement through positive UX
Worryheads	Learn and practice cognitive self-control plan with provided scenarios
	detailed alternatives; increasing dosage; feedback

A round of stakeholder interviews involving the SMEs followed the domain research of the REACH protocol. These included working sessions between the design team leads and the SMEs, visits by the SMEs to the design team's lab, and synchronous question-answer sessions over email and videoconferencing. This step of the process addressed difficulties relating to understanding the protocol and assumptions on both sides regarding implementation objectives. This step took longer than expected, with a result of inconsistent understanding of implementation outcomes. The design team conducted an internal review to identify root causes and come up with design process alternatives. The causes identified included:

1. New terminology.
2. Gaps in understanding by the design team with respect to the protocol.
3. Assumptions of the designers based on past implementations of mHealth apps in non-preventative domains.
4. Ad hoc communications patterns between SMEs and the design team, and within the design team itself.
5. A lack of understanding of the end user context.

Together, these issues are not uncommon in design processes, and some were addressed (1, 3, 4) through simple awareness of the issue in the team review. For example, improving ad hoc communication patterns was improved through more frequent design team meetings, clarifying the lines of communication with SMEs, and reiterating design team understanding of requirements back to the SMEs for validation.

Issues #2 and #5 were more significant. Issue #2 represents a "blind spot" in design, due to factors such as missing information implicitly understood by the SMEs but not apparent to the design team. Issue #5 was a recognition that the design team did not understand who would be using the app and in what context. At this point the design team realized a more patient-centric approach was required to overcome these design obstacles.

3.2 A Patient-centric Design Process

The design process described in the previous section focused on translating a field manual; it is not surprising that the translation had gaps derived from implicit knowledge assumed by the manual authors and not understood by the designers. The software engineering researchers suggested a more *user-centric* approach, where the needs of the end user, in this case the patients, is the focus of the design process. The gold standard for such a design process is User-Centered Design (UCD), originally credited to Norman and Draper [7]. UCD assumes a participatory design process with end users, but for this research we prefer the more inclusive definition of UCD as "the active involvement of users for a clear understanding of user and task requirements, iterative design and evaluation, and a multi-disciplinary approach." [14]. ISO 9241-210 [4] identifies 6 principles to UCD (quote):

1. The design is based upon an explicit understanding of users, tasks and environments.
2. Users are involved throughout design and development.
3. The design is driven and refined by user-centered evaluation.
4. The process is iterative.
5. The design addresses the whole user experience.
6. The design team includes multidisciplinary skills and perspectives.

These principles were especially attractive to the design team due to the uniqueness of the domain and protocol, and identified issues understanding the end user context. The team realized the app would not be a direct translation of the paper-based REACH protocol, and needed to focus on context and end user experience.

There is a wide range of practices supporting UCD; the design team utilized *personas*, *prototyping with iterative feedback, participatory design*, and *end user validation*. The SMEs served as participatory designers, eliminating the back-and-forth ad hoc aspects of the initial process. They also served as proxies for the end users during design as gaining access to youth (4^{th}-5^{th} grade users for an extended time for intense design activities was not possible). Access to end users would have certainly been preferable during the design process but was not possible at the time. However end user validation was emphasized before approving the app for protocol trial; these results are reported in section 5. Fortunately, prior domain research and SME interviews from the gap analysis proved useful in the context of the UCD.

3.2.1 Personas

The design team started the UCD process by developing personas, or proxies for categories of end users, and inviting the SMEs to review them. The SMEs were not familiar with personas, and after overcoming initial confusion about the technique, gained enthusiasm and effectively provided useful feedback. The personas shared with the SMEs are presented in Table 2.

Iterating over these personas led to several design insights that were previously not understood by the design team. For example, the design team came to understand subjects in this domain have a higher need for re-assurance; respond well to attention and approval, and are highly compliant (persona 2). Discussion of the personas with the SMEs further revealed that in community samples girls are more likely identified as "anxious" than boys, and anxious youth fear the evaluative nature of social situations (personas 3 and 4). After capturing a clearer idea about end user context through discussing the personas created with the SME, the design team started a phase of rapid prototyping to ensure the SMEs provided frequent feedback on each design decision.

Table 2: REACH protocol components and gap analysis

Persona 1	Jacob is 10 years old, and is currently being raised by his single mother. He was held back for behavior problems as he tends to lash out when stressed. When confronted with even minor change he shuts down, and becomes irritable. His goal is to do as little as possible, or just enough so he doesn't get in trouble.
Persona 2	Jessie is 9 years old and very shy. In larger groups of 10 or more people she panics, and is dangerously on edge. She has a strong recognition of her symptoms, and works very hard at overcoming them. Her goal is to be free from required effort as soon as possible.
Persona 3	Mike is 12 years old. He finds it difficult interact in groups. He thinks that everyone has prying eyes on him and judging his every move. He loves to read books and is distracted by day dreaming. He gets very anxious and nervous in social situations.
Persona 4	Elizabeth is 10 years old. She is relatively overweight and is embarrassed in evaluative situations. When her classmates tease her, she cries and withdraws from interacting with peers. This typically happens during physical education and school games.

3.2.2 Rapid Prototyping
Rapid prototyping is an iterative design technique refining the details of interaction models and overall user experience. Early prototypes, or *storyboards*, focus on task sequences, or the mapping of task workflows to interface screens. This leads to user interaction modeling; the identification of user input actions effecting transitions between screens or for the capture of critical information. Later iterations refine these models and also layer in thematic elements, until a final design is converged upon. Iterations are meant to be short, frequent, and focused on answering specific questions regarding the user experience.

3.2.2.1 Storyboarding and Clickthrough Prototypes
The design team used the freely available Pencil prototyping tool to construct screen and *clickthrough* mockups. Clickthroughs take simple screen mockups and overlay "hot regions" that advance the mock to a new screen, simulating a user interaction. One drawback is the tool runs its simulations in a web browser so tap and swipe gestures are not supported; however, the tool does support mobile UI "skins" to promote a look-and-feel consistent with the mobile user experience. Figure 2 shows an example of an early mockup created for S.T.O.P. activity.

The team created mockups of different scenarios in the app. Each mockup was peer-reviewed within the design team, validated against the documented protocol, and then presented to the SMEs for feedback. The design was iteratively refined until the scenario interactions were adequately captured, and the design team felt comfortable moving to implementation on the Android platform.

Figure 1: S.T.O.P. Mockup in Pencil

3.2.2.2 Translating Protocol Components
As identified in the gap analysis (section 3.1), some protocol components are a fairly straightforward translation, or port, to the mobile app, while others are not. For example, the Relaxation audio components were a straightforward port of the media to the device wrapped with a simple consistent interaction metaphor. Of course this component also requires the least user interaction of any of the components. On the contrary, the Worryheads game is a multiplayer board game involving cards. The app required limiting the game experience to a single user compared to the multiplayer board game. The design team replaced the physical cards in the board game with preset "Situations" and "Thoughts" screens. The user was then presented with a choice of four of "Other Thoughts" options to choose from. Once the user selects a choice from possible options a praise message was showed on the screen to appreciate the correct answer. Screens depicting Worryheads are shown in section 4.

A design concern in translating the protocol was the significant amount of text a child is asked to input during activities such as the Daily Diary and S.T.O.P. The mobile device is not suited for textual input that goes beyond instant messaging or social media apps, and further the end users are at an age where they are often mobile-aware, but not proficient mobile typists. The fear was that textual input would be skipped or significantly limited, or in the worst-case cause frustration of the app to the extent children would abandon it. The design team identified speech capture input as a means to facilitate better information capture.

3.2.3 Injecting Innovations in the Mobile Experience
A challenge in applying mHealth concepts to existing clinical protocols is the desire to innovate versus leveraging validated protocol steps. For this project, the mobile platform provided the means for increasing dosage by virtue of the device being ever-present. However, ubiquity is not enough, end users must be motivated to practice the protocol. Engagement was addressed through innovative features introduced in the mobile platform including thematic and age-appropriate media, game strategies (e.g. progressive reward incentives), and mobile notifications.

3.2.3.1 Designing an Appropriate Theme
A user interface *theme* refers to the consistent application of stylistic elements such as images, fonts, audio or video media, and user interface widgets (buttons, menus, taps, etc.). To gain acceptance of the app amongst users familiar with the paper protocol, the design team used the same theme used in the paper protocol. The team ensured that color codes and the fonts used in paper based protocol and the fonts used in the app are same. To

design the features of the app, the team studied the paper-based versions of the activities to be performed by youth to get a better idea of how to replicate the activities in the application. The team followed the same nomenclature of the existing activities in the screen designs reduce confusion and gain rapid acceptance.

The user experience required a gender-neutral, age-appropriate proxy for the human guide who assists in the existing REACH protocol. This proxy personifies the guide, providing instruction and feedback to the end user through the mobile interface. Initial ideas focused on themes such as “feed your pet” or “grow your plant” but were rejected as being either too “babyish” for the target age range or gender-biased.

The design team came up with the idea of an animated motivational character in the form of a *blob*. The design team referred to the character as “Bob the Blob” (Figure 3), but the male name is never used in the app itself. Based on game design concepts, “Bob” presents an age-appropriate, gender-neutral proxy for protocol guidance and feedback [6][8].

3.2.3.2 Progressive Reward Incentives

While one of the goals of the REACH protocol is to empower youth to be intrinsically motivated to enact the protocol, at the training stage it is imperative to repeat the dosage faithfully in order to attain this intrinsic motivation. A common gamification technique is to employ leveled rewards as an extrinsic motivator for performing a targeted behavior. Therefore a simple progressive (leveled) set of rewards for extrinsic motivation included in the app design. When an end user completes a task from the REACH protocol they get a reward in the form of Bob’s abilities/tricks. This way the user is motivated to follow the protocol and completing the tasks (dosage) so s/he can unlock more complicated tricks for Bob.

One concern SMEs raised during the design process was the potential to inadvertently punish the child for not performing a task. Given the domain, a design invariant was specified to keep all interactions with the child positive; therefore, all language and emotive expressions of Bob throughout the app were scrubbed to ensure there were no negative connotations. For progressive rewards, a setting in the app was designed to unlock new tricks twice every week. The presence of these tricks also served as extrinsic motivation for engagement.

3.2.3.3 Smartphone Notifications

Mobile platforms offer an “always on” communications channel between service providers and end users. Most categories of mHealth apps emphasize the communications channel between clinicians and patients, or between patients and automated big data platforms on the cloud. This project is unique in that it does *not* leverage the mobile device as a communications channel. In this generation of the app, the focus is on leveraging the device as an information collector and dosage vehicle for the protocol. In this sense the device serves more as a Personal Digital Assistant (PDA) than as a connected mobile phone.

In this modality it is still important to present to the end user a feeling of connectedness. The personification of Bob the Blob as a proxy guide is one way the design provides this connectedness. As a second design concept, the design team wanted to make use of mobile notifications, but without relying on cloud-based push notifications as these would require a persistent network connection. Therefore the design supports local notifications presented to the end user in both fixed and adaptive schedules. Fixed schedules are daily time-based notifications, such as for the Daily Diary, to complete a regular interval task. Adaptive notifications require tracking end user interactions with the app and dynamically determining whether to issue a notification to engage with Bob the Blob again. The designers are concerned with the notion of *alarm fatigue* through over-notification, though currently the mobile device is given to the end users as a locked down tool for practicing the protocol, and not as a general-purpose smartphone for personal use.

3.2.3.4 Security and Privacy

Any mHealth app needs to be concerned with how user data is stored, transmitted, and identified. These concerns can become overbearing nonfunctional requirements on the app and down to the underlying mobile operating system providing the communication and storage services. At this stage of the app’s development, it made more sense to de-identify data and work in a locked-down, disconnected mode. There were several simplifying assumptions the design team was able to make:

1. The emphasis on increased dosage over remote monitoring of compliance or personal health measurements puts this project in a different class of mHealth apps. Such apps push data to remote providers (often via a cloud-based service) and support human or automated communication reminders.
2. The relatively small number of participants in planned early studies meant the devices, with a specific chosen version of the mobile operating system, could be purchased and distributed to end users. The design team selected a Motorola phone running Android API version 19 (KitKat).
3. The relatively small number of participants makes it easier to de-identify the data and manage it external to the app. A secret user interaction combined with a password protects access to functionality that supports exporting user interaction and task completion data (see above).

Of course these assumptions will have to change in future generations of the platform to facilitate broader adoption. But as a dosage augmentation platform, the design team leveraged the weekly visits with the psychologists combined with the computational sophistication of modern smartphone platforms to provide a self-contained solution.

4. APP IMPLEMENTATION

The Android platform was selected to support the app. The openness of the Android platform, the availability of low-cost devices, the ease of the Google Speech API, and the ability to deploy the app without the involvement of an app store were the deciding factors for the first generation of the app. This section briefly describes the implementation on the Android platform.

The final user interaction model combined with scheduled interactions per protocol rules is shown in Figure 2.

This timeline in Figure 2 is based on weeks one to six of the REACH training program. Daily Diary, as the name suggests needs to be made available daily for all the six weeks whereas the Worryheads needs to be made available only in third, fourth and fifth week of the training program.

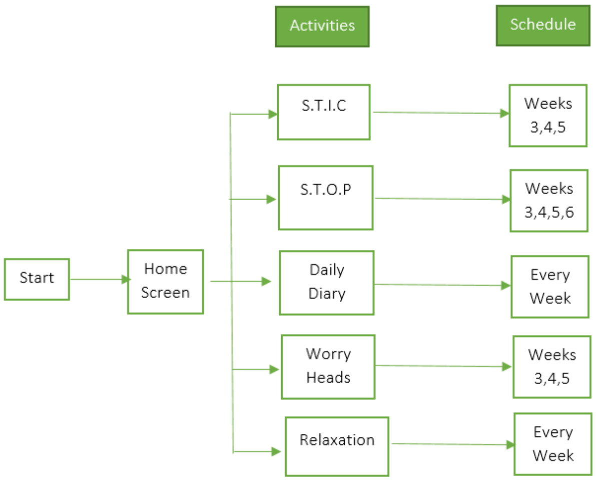

Figure 2: REACH App intervention Timeline

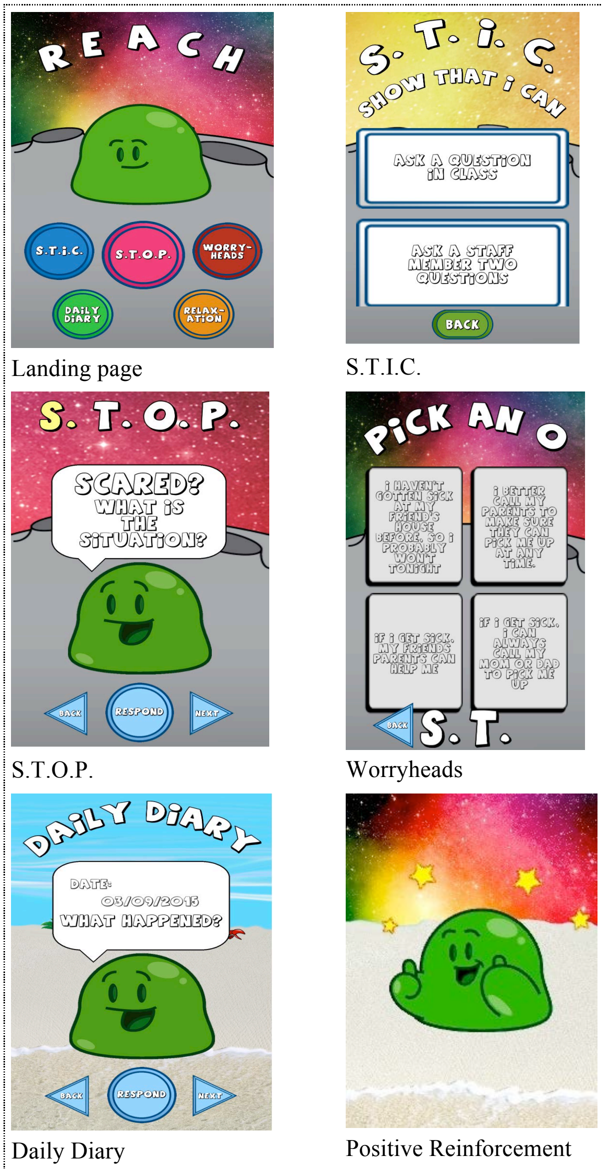

Figure 3: REACH App Interaction Screens

When the user selects the app from the Android home screen, a landing page is shown allowing the user to select from 5 available activities (see Figure 3, upper left). At any time only activities that are available can be selected from the landing page. Further, activities that are overdue are highlighted by a soft gold pulsing glow around the button (not shown) to provide a further visual cue to the end user to perform an activity.

The S.T.I.C activity is shown in the upper right in Figure 3. In this activity end users are encouraged to do a task they would normally avoid due to their anxiety. In the paper protocol, once a child completes the activity s/he receives a physical stamp from an adult (usually a teacher or parent). In the app this was implemented as a secret code entered by the adult, who could then provide an electronic stamp of approval.

The S.T.O.P. activity (Figure 3, mid-left) asks the child to provide responses to a set of questions (see section 2). Each response is stored in a SQLite database on the device. Figure 3, mid-right shows the "O" (Other Thoughts) step of the Worryheads game. This is basically a variant of the S.T.O.P. activity with pre-selected "S" and "T"s. The child has to consider the given "S" and "T" and select an appropriate "O" and "P" to complete the simulation. At the conclusion of these activities Bob the Blob praises the child (Figure 3, bottom right).

The Daily Diary (Figure 3, bottom left) is a scheduled activity available to the child each day. The activity is available during school hours but notifications are only given after school hours. As described in section 2, the Daily Diary asks the child to reflect on potentially anxiety-provoking events from her/his day, and inquires about thoughts that came to mind in that situation. Youth also rate how s/he handled and felt about the situation. This embedded diary is part of the organizational framework of REACH emphasizing the need to identify and confront anxiety-provoking situations that are threatening but manageable.

In addition to the 5 protocol activities available from the landing page, the end user also can tap directly on Bob the Blob and be taken to a table-oriented layout of "tricks" Bob can perform. The tricks (animations) available at any time are based on the protocol schedule as described in section 3.2.3.2.

Additional features were provided by the app to support research outcomes (section 2). An on-device database stores all end user responses, and tracks each user action. The latter will be used after trials to answer research questions such as whether alarm fatigue occurred, or end users were not sufficiently motivated to engage with the app. A data export feature provided only to interventionists allows data to be offloaded as csv files.

Finally, in the face-to-face protocol trial, interventionists can personalize dosage schedules or tailor training activities during weekly visits. To support this in the app, a hidden feature was embedded only for the interventionist role. A specific multi-tap sequence combined with a secret PIN unlocks this feature so interventionists can decide if a protocol component should be enabled/disabled or otherwise modify the planned dosage for that week. Additional settings include selecting the start date of the protocol, notification time windows and frequency, the schedule trick release, changing the teacher PIN, and exporting data.

5. VALIDATION

The highly iterative participatory design process described in section 3 enabled continuous feedback during app evolution. After completing the initial candidate release version, the design team and psychologists conducted two types of external validation. The first was two feedback sessions with external SMEs from a school advisory board (SAB). The second was a usability study conducted with actual youth end users in the schools.

5.1 Advisory Board Feedback

The SAB consisted of two school psychologists with experience delivering REACH, and two school district administrators who oversee student services and prevention efforts for 47 K-8 schools. Based on their experience with youth, the SAB considered the developmental appropriateness of the design and program tools included (e.g., during the face to face sessions, youth wanted to utilize Relaxation and play Worryheads on-demand, so those activities were selected for inclusion in the app).

From the SAB feedback, three issues emerged:

1. Safety and security - would youth have access to texting and Internet on the devices?
2. Cost: would parents be responsible for the devices, if lost?
3. Flexibility - would versions of the app be available for the iPhone, smartboards, and tablets?

The first issue was addressed by adding security software SureLock to every device. The second was addressed by applying procedures used by the school relevant to laptop computers where parents are financially responsible. For flexibility, it was determined that preliminary data is necessary prior to investing in additional versions of the technology for different devices.

5.2 Usability Study

5.2.1 Participants

With parental consent (and assent from child), 22 youth (Mean age = 9.67 years, 12 girls, 12 Hispanic/Latino, 5 White, 1 Black, 1 Asian, 3 "other") from public schools participated in the 'system usefulness, satisfaction, and ease' aspect of this research. The median household income was about $39,000 and most youth were recruited from the same zip code and class grades. In addition, 77% reported knowing how to use an Android smartphone and 54.5% reported playing games using a smartphone "all the time".

5.2.2 Measures

System usefulness, satisfaction, and ease were assessed via 22-items from the Usefulness, Satisfaction, and Ease of Use Questionnaire [4] modified for children and adolescents. Youth responded to each item using a 10-point rating scale (1= "not at all" to 10 = "very much"). System ease of use (SYSUSE) was measured via 11 items (e.g., it is easy to use; it is simple to use), quality of support information (INFOQUAL) was measured via 3 items (e.g., instructions and messages are easy to understand; messages to fix problems are clear), system ease of learning (SYSEASE) was measured via 4 items (e.g., I easily remember how to use it; I quickly became good at it), and system satisfaction (SYSSATIS) was measured via 4 items (e.g., I am happy with this app; I would tell a friend about this app). Consistent with the original measure, alpha reliabilities were excellent: system ease of use (α = 0.92), quality of support information (α = 0.83), system ease of learning (α = 0.92), system satisfaction (α = 0.88), and stigma (α = 0.81) scale scores, and overall usability score (α = 0.95).

5.2.3 Procedures

Parents (primary caregivers, legal guardians) received a letter from the research team describing the nature of the study and the timeframe for participation (within the next 7 to 10 days). From those contacted, 26% provided child consent and every child provided assent (n=22). Youth with consent/assent provided data at a university laboratory or at their school. At the beginning of the study, each youth was provided with an envelope that contained a device and a questionnaire. After receiving the study materials, three phases (1-Listen to the Relaxation; play Worryheads game; 2-Write a daily-dairy or S.T.O.P. entry; 3-Play with the Blob) were implemented by trained research assistants. For a phase, each prescribed interactions with the app was 2-minutes and responding to the survey lasted about 5 minutes. At the end, youth were thanked for their participation in the study, which lasted a total of 20 to 30 minutes. Parents of participant youth were provided with $15.00 at the end of the study.

5.2.4 Results

Descriptive statistics and correlations for the focal variables are given in Table 3. There were no missing data and some variables exceeded conventional cutoffs of |2| for skewness and |7| for kurtosis [16]: System Ease of Use (-3.04 skewness, 10.39 kurtosis), System Ease of Learning (-2.15 skewness; 3.9 kurtosis), and System Satisfaction (-2.23 skewness; 4.53 kurtosis). Moreover, statistically significant Shapiro-Wilks test values were found for these indicators and thus subsequent tests were conducted via non-parametric approaches. Specifically, Wilcoxon-Mann-Whitney tests were conducted to estimate any sex (boys vs. girls) or ethnicity/race (Hispanic/Latino vs. Non-Hispanic/Latino) variations in terms of: system ease of use, quality of support information, system ease of learning, and system satisfaction. No statistically significant mean differences were found suggesting robustness across sex and ethnicity/race.

Table 3. Usability Study Results

	Mean	*sd*	*Median*	1	2	3	4
Overall Usability	35.69	19.84	38.23				
1. SYSUSE	8.94	1.48	9.24	--	.61**	.92**	.47*
2. INFOQUAL	9.13	1.28	9.67		--	.80**	.53*
3. SYSEASE	8.72	2.03	9.41			--	.48*
4. SYSSATIS	8.90	1.70	9.75				--

Note: Ranges from 0 to 40 for Overall Usability, 0 to 10 for other variables; SYSUSE = system ease of use; INFOQUAL = quality of support information; SYSEASE = system ease of learning; SYSSATIS = system satisfaction; *p< .05; **p< .01

Given these findings, mean estimates for the total sample were calculated and results showed that the REACH app system was highly and positively rated, for the most part, along the four dimensions of interest: system ease of use, quality of support information, system ease of learning, and system satisfaction with means ranging from 8.72 to 9.13. Also, as shown in Table 3, statistically significant correlations were found among the four dimensions with correlation coefficients ranging from .47 to .80 ($p < .05$). Lastly, transforming SUSE-Y overall total scores into a traditional "grade" scale, analyses showed that the REACH app system earned an "A" grade from 55% of youth, "A-" from 14%, "B+" from 9%, "B" from 9%, and failing grades of "C-" or less from 13% (or 3 youth). Focusing those youth who rated the system with a "C-" grade or less, data showed that all three youth reported no knowledge of Android operating system. One of the three youth did not know how to connect the earbuds to the phone, had trouble placing earbuds in his ears, asked what he is supposed to press during the Worryheads, asked what the word "respond" means, and did not know what to press during the STOP task. Another seemed "lost" during Worryheads and the third youth was distracted by SureLock pop-ups during testing.

6. DISCUSSION

Our multidisciplinary, collaborative efforts resulted in a smartphone app to potentiate the prevention and early intervention of childhood anxiety disorders and related problems. To our knowledge this is the first research-based child anxiety prevention and early intervention app with known usability ratings. The FRIENDS for Life Program released an app for Android, but there is no research relevant to the technology developed. In child anxiety treatment, SmartCAT is a promising mhealth platform for ecological momentary intervention, used as an adjunct to the Coping Cat treatment program [11]. The REACH prevention app appears to be more similar than different to SmartCAT whereas the FRIENDS app is mostly psychoeducational. Focusing on prevention, for example, REACH and FRIENDS provide on-demand opportunities for skill practice but REACH explicitly focuses on reducing problematic anxiety at the indicated and early intervention level as it includes focused and direct features relevant to engaging youths in self-monitoring, in-vivo exposures, and cognitive self-control. In addition, REACH is capable of deploying notifications relevant to skill practice, offers tools for personalizing and tailoring the protocol (e.g., increase notifications, activate new tools based on performance, activate tools parallel to the weekly focal module), and allows for opportunities for corrective feedback based on user data amenable to creating personalized reports of youth weekly practice and response. When it comes to contrasting the SmartCAT treatment app with the REACH prevention app, both yielded high "ease of use" ratings. Moreover, as found in this research, the REACH prevention app yielded overall high ratings along additional dimensions not examined for FRIENDS or SmartCAT. That is, REACH showed high ratings for quality of support information, system ease of learning, and system satisfaction. Also, this research found no significant differences between boys and girls or between Hispanic/Latino and non-Hispanic/Latino youth on any of the usability dimensions examined.

The REACH app appears promising and has the potential to study questions not only relevant to potentiating program response and refining aspects of the technology, but about large scale diffusion, personalized care, and bridging the gap in health disparities when it comes to affective problems and its related disease outcomes. The version of the app described in this paper was designed and created through a multidisciplinary process that is user-centered in the broad interpretation of the process. Our subsequent plans for the REACH app include incorporating patients, caregivers, and interventionists directly into the design process, and broadening its applicability to minority populations, populations with sleep disorders, and studying the potential for positive remedies for negative outcomes of anxiety, notably drug abuse.

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