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Development and field testing of Teen Pocket PATH®, a mobile health application to improve medication adherence in adolescent solid organ recipients

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Abstract

Applying principles of user-centered design, we iteratively developed and tested the prototype of TPP, an mHealth application to promote medication adherence and enhance communication about medication management between adolescents and primary caregivers. A purposive sample of seven adolescent solid organ transplant recipients who were one yr post-transplant and their primary caregivers participated. Participants completed up to three face-to-face laboratory usability sessions, a 6-week field test, and a debriefing session. Primary caregivers participated in an additional usability telephone session. Participants completed usability and satisfaction measures. Sample included liver (n = 4), heart (n = 2), and lung (n = 1) recipients aged 11–18 yr (57% were female, 86% were Caucasian), and nine primary caregivers aged 42–61 yr (88.9% were parents, 88% were female, 88% were Caucasian). Ninety percent of the adolescents endorsed the graphs or logs of missed/late medication dosing as useful and 100% endorsed the remaining features (e.g., medication list, dose time reminders/warnings) as useful. All adolescents expressed interest in using TPP for monitoring medications and satisfaction with the automatic messaging between adolescent and caregiver versions of the application. Adolescents unanimously found TPP easy to use. TPP shows promise as an mHealth adherence tool.

Keywords

mobile health; adherence; medication management; pediatric transplantation; heart transplantation; liver transplantation; lung transplantation

Background and significance

Nearly 45% of all pediatric transplant candidates and recipients are adolescents (OPTN data as of August 8, 2014). Pediatric patient and graft survival decreases with time and long-term survival rates vary dramatically by type of transplant and age group (OPTN data as of August 8, 2014). For example, patient survival at five yr for 11- to 17-yr-olds ranges from 39% (lung) to 96% (kidney), and graft survival ranges from 35% (lung) to 68% (kidney, heart, liver) for the same age group. Significant differences in both graft and patient survival at five yr are evident between pediatric transplant age groups, with 11- to 17-yr-olds consistently faring worse than younger patients (i.e., 6–10 yr olds) (OPTN data as of August 8, 2014). Although biological bases for the decline in patient and graft survival play strong roles in these outcomes, other factors such as adherence to medical care and the medication regimen in particular have been linked to poorer outcomes in adolescent recipients (1–9). Medication non-adherence in particular has been cited as a major cause of rejection episodes and graft loss (10, 11). Non-adherence in adolescent transplant recipients has been identified as a widespread concern that negatively affects graft function and patient morbidity and mortality (12–20).

Solid organ transplant patients require lifelong medical management and regularly engage in multiple self-care behaviors including medication management, symptom monitoring, laboratory blood work, and attendance at medical appointments (21, 22). Managing any complex regimen is taxing and difficult, but families of children with chronic illnesses are often at odds trying to designate care roles and find a balance between what the adolescent “should be responsible for” in his/her own medical care vs. parental responsibilities (1, 23, 24). Various factors including self-management competence, self-care autonomy, and adolescent maturity level have been described in the pediatric chronic illness literature as affecting adolescents' overall ability to adhere to the medical regimen (12, 13, 23, 24). Other factors such as family interaction and difficulties in communication regarding medical care needs have been described as obstacles to successfully negotiating medical care in pediatric populations (12, 24). In the adult literature, successful completion of self-monitoring and self-care tasks (i.e., adherence to the medical regimen and management) has also been found to require self-care agency, which encompasses the individual's abilities and capabilities (e.g., being attentive and knowledgeable of care needs) of engaging in needed medical care tasks (13).

One of the emerging areas of investigation for researchers interested in supporting patients' engagement in self-care behaviors is mobile health technology or mHealth (14–17). mHealth defined as “a medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, PDAs, and other wireless devices”(18) has shown promise in assisting adolescents and their parents in managing chronic medical conditions such as asthma and diabetes (14, 19, 20). The utilization of mHealth to promote performance of self-care behaviors among adolescent transplant recipients offers a novel approach to a difficult problem. mHealth technologies can provide adolescent patients and their parents with readily accessible support for tracking and monitoring healthcare behaviors while enhancing active communication regarding completion of these tasks. The

high level of mobile technology use, acceptance, and easy access to cell phones among the population and adolescents in particular sets the stage for the suitability and utilization of mHealth (25). With the growing number of affordable cell phone plans including pay as you go plans, free WiFi available in the community (e.g., at libraries and businesses), and affordable cell phone models, mHealth has the potential to be a far-reaching medium for intervention that is extremely affordable and easily adaptable.

Even though mHealth technologies show promise, engagement of the “end user” in the development of technologies is necessary for them to be useful. Previous research in human computer interaction has shown that end user involvement leads to higher levels of user acceptance and satisfaction (16, 25, 26). User satisfaction is of particular importance when utilizing mHealth technologies as tools for behavior change or promotion since satisfaction decreases barriers to successful implementation. In this article, we will describe the iterative process of developing and testing the TPP prototype, the test-users' ratings of its acceptability, usability and satisfaction, and the features of the final TPP application.

Methods

Sample

The sample comprised seven adolescents transplanted at the Hillman Center for Pediatric Transplantation at the CHP of UPMC who participated in the study between April 2009 and October 2011. To be eligible for the study, adolescents had to reside with their primary caregivers in the immediate metropolitan area during the length of the study, and the family had to speak English. Participants were recruited during scheduled clinic visits to our transplant center. We used a purposive sampling method to recruit adolescents who represented the target age span of 11–18 yr, from both genders, with a variety of transplant types, a variety of medical illness presentations leading to transplantation (i.e., acute illness presentation leading to immediate transplant vs. chronic illness eventually leading to transplantation), varying lengths of time since transplantation, and varying levels of experience engaging in medical care. The study was approved by the University of Pittsburgh Internal Review Board, and written informed consent and assent were obtained from primary caregivers and adolescents under 18, respectively.

Five adolescents and five primary caregivers participated in *each* of the development and testing laboratory sessions. We recruited additional adolescents and caregivers as needed to fulfill the requirements of a minimum sample size of five adolescents and five caregivers per each development and testing laboratory session. The *minimum “per development/testing session”* sample size (i.e., $n = 5$) was based on established guidelines within the literature detailing best approaches to mHealth and intervention development work (27–29), suggesting that studying a small sample of end users is sufficient to expose major problems with the structure, format and content of mHealth applications and interventions (27, 30). Three of the overall sample of adolescents ($N = 7$) and three of the overall sample of caregivers ($N = 9$) participated in *all* laboratory sessions as well as field testing of the TPP application.

Design

Adolescents and primary caregivers participated in up to three face-to-face usability sessions in the controlled laboratory setting, a 6-week field-test of the TPP prototype in their home setting, and a debriefing session at the end of field testing. Primary caregivers participated in an additional phone session between the first and the second laboratory session in order to clarify their willingness to utilize a mobile device to access adherence information as the device would need to be carried in addition to the primary caregiver's existing cell phone. Design sessions with adolescents and their primary caregivers were conducted separately. Each session was audio recorded and field notes were taken. Audio recordings were later transcribed and used to guide the development of subsequent interviews.

Measures

Demographic questionnaires assessed adolescent characteristics (gender, ethnicity, type of transplant, age at transplant, time since transplant) and those of their primary caregivers (gender, ethnicity, educational status, and annual family income). Data were also collected to assess level of electronic device/media use (e.g., frequency of computer/cell phone/tablet use). Clinical information such as underlying medical condition, type of transplant, and date of transplantation were extracted from the medical record.

The PSSUQ (31, 32), a validated measure used in the development of technological applications, was administered to participants at the end of the field portion of the study in order to assess the usability of the TPP prototype and to ask specific questions regarding the experience of using TPP as part of each family's medication management routine.

Development of Teen Pocket PATH prototype

In keeping with the principles of user-centered design which highlight the importance of incorporating the feedback and needs of the end user into every step of the development process, we sought feedback from adolescents and their primary caregivers (see Table 1 for demographics of the sample) through all design phases. Our intent was to build the mHealth application in a manner that reflected the preferences of the end users while focusing on developing features to promote consistent adherence to and self-management of the medication regimen in the adolescent transplant population.

Usability testing in the controlled laboratory setting

Usability session #1—The content of Session 1 was designed to elicit recipients' and primary caregivers' current approaches to medication management and their opinions regarding utilizing mobile technology to assist them in this process. During Session 1, we collected data about the methods by which adolescents and their primary caregivers communicated about medical management, the barriers to effective medication management, the steps taken to help with medication management, the responsibility of the adolescent vs. the caregiver, and their opinions regarding the potential of using mHealth technology to assist with this process. When inquiring about adolescents' and caregivers' opinions of using mHealth technology, we inquired about potential concerns of using technology including privacy and access to data as well as availability of data to medical providers. We asked

specific questions within each of three categories including: 1. General medical management questions, 2. Medication tracking, and 3. Help features and appearance (see Appendix I for sample questions from each section). We utilized these data to limit the number of potential application “feature” possibilities and develop questions for the next usability session.

Between Session 1 and Session 2, we conducted a usability phone interview with care-givers only to explore their views and preferences regarding the application. For example, we asked primary caregivers “Would you prefer to know immediately if the adolescent took his/her dose of medication?” (e.g., receive a text message acknowledging that the adolescent took the medication) or “Would you prefer to log into a website to review the adolescent's medication taking behavior?” We also needed to know whether primary caregivers would be willing to carry a “study device” if provided.

Usability session #2—Based on the feedback provided by adolescents and primary caregivers during Usability Session #1, the Caregiver Usability Phone Interview, and in conjunction with meetings with our programmer, we made initial decisions regarding potential features for the mHealth application and began to develop low-fidelity paper prototypes of the TPP screens. The primary features identified for inclusion were the presentation and usability of a medication list accessible directly through the application, and aspects of medication management including reminders of upcoming dosing times, warnings of potentially missed medications, and tracking of medication taking. In addition, and of primary importance for the intervention, communication between the adolescent version of the application and the caregiver version of the application were specifically addressed through questions about automatic updating and texting as part of the application features. We focused primarily on the usability of each feature and the preferences of both adolescents and caregivers by presenting participants with a preliminary version of the application prototype and walking participants through each screen so that they could view the process and function of the application (see Appendix II).

Usability session #3 and field testing deployment—By the third usability session, we had a functional prototype of the mHealth application ready to test in the field. In preparation for the field study, during the third usability session we had participants enter their medication lists into the application, set up reminders, and program the caregiver device which would receive text messages alerting caregivers regarding medication taking and any potentially missed doses. Participants were given the smartphones loaded with TPP programs to use during the 6-week field study. Participants were given an instruction manual of the TPP mHealth application and asked to review the manual during their 6-week field test. Participants were also asked to assess each feature of TPP and provide feedback regarding the features after the field study during the debriefing interview.

Usability testing in the field setting

Participants utilized the application for 6 weeks in their home setting and then participated in a debriefing session in order to provide feedback about their experiences. The debriefing session focused on the factors of most importance to the feasibility and usability of the application including ease of use, simplicity of reminder and warning messages, satisfaction

with the application and its use, and perceptions regarding appeal of using the application over the long term. We also administered the PSSUQ and the open-ended questions about users' experience.

Results

Laboratory usability sessions

We compiled responses from the usability sessions to determine whether any obstacles existed in regard to utilizing mHealth technology for the intended purpose and whether any concerns existed regarding potential aspects of mHealth such as privacy and data accessibility, and to identify the specific features that adolescents and primary caregivers felt would provide the most comprehensive support and assistance to the adolescent in remaining adherent to the medication regimen post-transplantation. Table 2 depicts some of the features requested by participants from usability session 1 and expanded upon in usability sessions 2 and 3. We focused on features which would help adolescents and caregivers easily keep track of the adolescents' medication adherence, help them access transplant-specific information, and provide easy access to the adolescent's nurse coordinator. Based on the feedback obtained, a number of features were identified as preferred by either the adolescent, the caregiver, or in most instances both participants. A summary of the preferred features is provided in Table 3. Features marked with asterisks were altered or adapted to better meet the “spirit” of the application (e.g., active provision of support in remembering to take medications) or reconcile differing opinions between adolescent and caregiver. In some instances, we opted to not include a requested feature; for example, we did not include pictures of the medications since the appearance of the same medication can vary widely depending on a variety of factors including dosage strength and type of medication (brand vs. generic) being dispensed. We also opted to not allow warning messages to be easily dismissed in an effort to further promote action and encourage active adolescent participation.

Based on findings from the usability interviews, we created a preliminary version of the application on an Android platform designed to promote adherence to medications by establishing scaffolding for the adolescent that supports independence yet provides guidance when needed (Fig. 1). The application has multiple components that support engagement in post-transplant care, provide access to post-transplant discharge information, and are intended to support medication adherence.

One of the strengths of TPP is the level of support and detail that participants obtain in regard to medication taking (Fig. 2). TPP specifically prompts adolescents to take their medications at prescribed times and to confirm that they have done so. The prompts incorporate the names of the medications due, the dosage, and the time the dose is scheduled. We incorporated automatic messaging to the caregiver application/device to support medication taking and provide ongoing supervision to the adolescent. We also incorporated a two-tier “warning system” such that if the adolescent did not take action, or did not confirm taking medications as prescribed, the caregiver received a warning message. The intent of these many levels of support is to facilitate communication between the adolescent and the caregiver in a manner that still provides autonomy yet allows ongoing

parental supervision in as close to “real time” as possible (e.g., caregiver will be aware of a potential miss of a medication dose before arriving home in the evening).

Field testing findings

Findings of the field study indicated that users found TPP generally easy to use and effective in prompting adolescents to adhere to their medications. Adolescents and caregivers reported no problems with set-up of the application and all adolescent users figured out how to enter medications, medication dosages, and dosing times with limited use of the user manual instead entering data in an intuitive and spontaneous fashion. Set-up of the medication list took only a few minutes (i.e., typically 5–10 min) and required minimal investigator support. Adolescents and caregivers reported being happy with the application and finding it useful. One family found unexpected benefits to participating in the field study as the adolescent participant was scheduled to be away from home over a weekend during the field trial and the parent was able to monitor reported adherence remotely. In addition, anecdotal evidence suggests that primary caregivers felt less need to continuously ask whether medications had been taken since they were notified via the TPP application when the adolescent acknowledged taking medications without needing to inquire. It should be noted that for this developmental phase we had encouraged parents to remain highly vigilant of medication taking by their adolescent in order to assess whether adolescents would simply dismiss reminders or would engage with the TPP application as intended. Results of the PSSUQ are depicted in Table 4. Overall, participants reported being satisfied with the application.

Based on the feedback obtained during the post-field testing debriefing sessions, the TPP prototype was refined further and important features were added. For example, adolescents and caregivers requested access to the medication list on both the adolescent and caregiver devices to facilitate updating a “master list” of medications, alerts for any changes made to the medication list (e.g., adding/removing medications), and access to adolescent adherence history on both the adolescent and caregiver device. In addition, the medication list was refined in a manner that responsibility for managing the list can be transferred between the adolescent and the caregiver as appropriate. For example, a 13-yr-old would likely defer primary responsibility for the management of the medication list to his/her primary caregiver, but over time the adolescent may take on that responsibility himself/herself. With this expectation in mind, when the adolescent becomes the primary person responsible for making changes to the “master medication list,” the role can be easily transferred while still providing the caregiver with viewing access of the medication list offering the primary caregiver the opportunity to be aware of medication changes and to double-check that changes were made accurately.

Discussion

Teen Pocket PATH is an mHealth technology designed to promote adolescent independence in medication self-management. Teen Pocket PATH was developed using principles of user-centered design which emphasize the importance of involving the end user at every step of the development process. The development and usability testing of TPP provided an

opportunity to create an application that directly incorporated the preferences and needs of solid organ adolescent transplant patients and their primary caregivers.

Medication management following solid organ transplantation can be complex and burdensome. Patients often have multiple dosing times throughout the day and restrictions in regard to what medications can be taken together. Timing of dosing is often dependent on outside needs (e.g., school start times, family meal times) and can easily conflict with activities. Managing a medication schedule when attempting to lead an otherwise “active and normal schedule” can be challenging for adolescents (33). In addition, parental oversight can prove problematic, as adolescents typically have more independence and spend a larger proportion of their time outside the home.

Previous research has shown promise in improving adherence through the use of technology (12, 34). However, few studies have focused solely on adolescents and none have previously incorporated parents as an active component of mHealth treatment. In addition, no previously published research has specifically focused on how mHealth may be utilized to activate the inherent support system of the pediatric patient to promote adherence such as parental support for medication management. The TPP application was specifically designed to provide scaffolding for adolescents' medication management while involving their primary caregivers when appropriate and necessary. Our goals were to support the adolescent's need for independence, to promote communication about medication management between the adolescent and his/her primary caregiver, and to activate the caregiver into action early on so as to avoid missed and late dosing as much as possible. This usability and development study shows promise, suggesting that the TPP application we developed is not only well accepted and used by adolescents, but also by their primary caregivers.

Limitations of the study include the lack of ethnic diversity in our participant sample and the fact that TPP was tested in a single center both of which may limit generalizability. Although we attempted to recruit a racially and ethnically diverse sample of patients, the constraints of our other sampling criteria limited the pool of racially and ethnically diverse patients available. In addition, field testing of TPP was relatively short and its long-term impact is not yet clear. For example, there is the potential that after a short period of use participants could grow bored with TPP and stop engaging with the application. Previous mHealth research has shown an attenuated response with some participants engaging less with the intervention as the duration of the intervention increased (29, 35). However, this finding has also been widely reported in more typical behavioral interventions (36) and reflects the effort required for ongoing engagement in interventions requiring behavioral change rather than the medium used to deliver the intervention. An additional limitation is that we did not track immunosuppressant levels during the course of the field portion of the study and gather objective adherence data to compare to the participants' reports that TPP had a positive effect on their adherence to medications. Therefore, we cannot confirm through an objective measure that the TPP had an impact on medication adherence. Lastly, it is also possible that adolescents engaged in instances of intentional non-adherence during the course of field testing by replying that they had taken their medications when prompted to take medications, but not actually taking medications. Intentional non-adherence can

occur even when parents are “observing” their adolescents' medication taking with adolescents pocketing medications, discarding medication, and/or even regurgitating medications to avoid taking medication. Of note, however, we did not receive reports from caregivers that TPP responses to prompts differed from actual behavior. In addition, volitional or intentional non-adherence (i.e., purposefully skipping medications or throwing away medications) is less common than unintentional non-adherence (37) and this is not the type of behavior we aimed to change with the use of the TPP intervention. Medication adherence is a problematic area for pediatric solid organ transplant patients, caregivers, and providers. Adolescents in particular have been found to be at higher risk of non-adherence, and the appropriate developmental need for greater independence makes monitoring by caregivers arduous. Given the resources expended in solid organ transplantation and the limited number of interventions which specifically target adherence in this age group, the TPP application has significant potential as an adherence intervention. The TPP application was developed to be easily distributed (i.e., download of an app) and applied within solid organ adolescent transplant populations. The TPP application has the potential to keep patients and caregivers engaged in medication management on a daily basis, provide scaffolding supporting adolescents and caregivers, and potentially limit the instances of unintentional non-adherence. Based on the usability of TPP and the feasibility and user satisfaction of the prototype in the field, a randomized controlled pilot study is underway to examine the efficacy of TPP in promoting adherence post-transplantation. Our intent is to investigate the effect of TPP on objective measures of medication adherence post-transplantation and explore the impact of this intervention. Given the significant potential of mHealth and the strengths of an intervention developed utilizing user-centered designed principles, the TPP application has the potential to become an easily accepted and widely used method of supporting active medication adherence.

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Appendix I: Sample Questions from Laboratory Usability Session 1

Adolescents

General Medical Management Questions

1. How do you and your parent/caregiver keep in touch with each other when not together? How do you communicate, e.g., texting, emailing, speaking on the telephone/cell?
2. What do you do currently to keep track of your medical requirements like medications, clinic visits, other?
3. How do you and your parents/caregivers communicate about what has to be done or let each other know that things were done?

Medication Tracking

1. How do you track your medications now?
2. Do you write down when you have taken medications?
3. How does your parent/caregiver know when you have taken your medications?

Help Features and Appearance

1. Would a graph showing you how often you took your meds on time vs. delayed be helpful
2. Would you want to receive positive messages/reinforcement regarding your performance in entering information into the device?
3. Would you like a “help” feature that can assist you if you forget how to enter information?

Caregivers

General Medical Management Questions

1. How do you typically keep in touch with your child when you are not together? How do you communicate, e.g., texting, emailing, speaking on the telephone/cell?
2. Do you currently to keep track of the medical requirements for your child like medications, clinic visits, other? Does someone else do this? Does your child do this independently?
3. How do you and your child communicate about what has to be done or let each other know that things were done?

Medication Tracking

1. How would you feel about your child tracking medications on a portable device or would you be the one to track the medications?
2. What would be most helpful to you in regards to tracking your child's medications on a portable device:
 - a. Would you prefer if medications are tracked as a group?
i e.g., “Took all morning meds” or
 - b. Would you prefer if each individual medication is tracked? If so:
i Would a picture of the medication on the screen be useful?

Help Features and Appearance

- 1 Would you like to have easily accessible information regarding the organ that your child received as a transplant, e.g., information on what to expect and/or what you and/or your child should do if s/he starts to experience a symptom?

Appendix II: Sample Questions from Laboratory Usability Session 2

General Questions

- 1 This is the opening screen:
 - a. Do the pictures make sense with the labels?
 - b. Do the labels make sense?
 - c. Do you understand “where” the picture and label will send you?
 - d. What questions/comments do you have about this screen or how it works?

Medication Related Screens

1. This is the medication set-up screen:
 - a. There is a scrolling tab with an alphabetical listing of the most common post-transplant medications and a free text area.
 - b. What do you think about screen?
 - c. Can you easily read selections?
 - d. Are you comfortable with free text to enter your medications?
 - e. How do you think you would go about entering a medication?
 - f. Could you try entering a medication?
 - g. Could you try selecting a dose for the medication?
 - h. Could you try setting a time for your medication?
 - i. What questions/comments do you have about this screen or how it works?
2. This screen reminds you to take your medications:
 - a. How much time would you want as a reminder before med time?
 - b. You can set reminders between 30 min and 10 min before med time. Do you want a different range of time?
 - c. What do you think of the screen?
 - d. There are multiple options regarding what “action” you took in regards to your medication, e.g., took meds, skipped meds etc.

Appendix III: Sample Questions from Debriefing Interviews Conducted after the Field Study

Adolescents

1. Did you use the application?

2. Did you experience any technical difficulties with the application?
3. Did you experience any technical difficulties with the phone?
4. Did you change any medications during the field test?
5. Did you change dose or dosing time during the field test?
6. How was it using the application?
7. Did you look at the “Today’s Meds” screen?
8. Did you look/use the “History” tab to see how you were doing in taking your medications?
9. Did you have any trouble responding to application prompts?
10. Did you find the application helpful?

Caregivers

1. Did you experience any technical difficulties with the application?
2. Did you experience any technical difficulties with the phone?
3. Did you or your child change any medications in the application during the field test?
4. Did you or your child change dose or dosing time during the field test?
5. Were there any problems receiving texts?
6. Did you find the texts helpful?
7. Did you find the texts annoying or intrusive?
8. Did you read through any parts of the application—information/organ information?
9. Did you find those parts of the application helpful?
10. Did you call or email your child's nurse coordinator using the links in the application?

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Abbreviations

CHP	children's hospital of Pittsburgh
mHealth	mobile Health
OPTN	Organ Procurement and Transplantation Network
PDAs	personal digital assistants
PSSUQ	Post Study System Usability Questionnaire
TPP	Teen Pocket PATH®
UPMC	University of Pittsburgh Medical Center

Fig. 1.
Main screen of Teen Pocket PATH.

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Fig. 2. Icon legend and medication reminder, warning, and history screens of Teen Pocket PATH.

Table 1
Characteristics of adolescents and caregivers

	Adolescents (N = 7)	Caregivers (N = 9)
Age in years (median and range)	15 (11–18)	49 (42–61)
Type of transplant	Liver = 4 Heart = 2 Lung = 1	–
Age at transplant in years (median and range)	9 (0–17)	–
Time since transplant in years (median and range)	5 (1–17)	–
Gender (#Female)	4	7
Ethnicity (#White non-Latino)	6	8
Education	Middle school = 5 High school = 2	High school graduate = 1 Vocational/Tech graduate = 3 College graduate = 4 Graduate degree = 1
Type of caregiver relationship: (#parent of adolescent)		Parent = 8 Grandparent = 1
Caregiver employment		Employed full-time = 6 Stay at home Caregiver = 2 Other = 1

Table 2
Responses to medication tracking questions usability session 1

Question	Responses*	
	Adolescents	Caregivers
Would you like to track your medications individually, as a group or both ways?	Individually (4)	Individually (1)
	Group (2)	Group (4)
	Both ways (1)	Both ways (1)
Would you like the pictures of the medications to appear in the application?	Yes (4)	Yes (4)
	No (0)	No (2)
	No preference (1)	No preference (0)
Who would you like to make the decision about how the medications are tracked: adolescent or caregiver?	Adolescent (3)	Adolescent (2)
	Caregiver (4)	Caregiver (1)
		Both adolescent & caregiver (2)

* Responses are not mutually exclusive as participants and caregivers were able to pick more than one option.

Table 3
Desired Teen Pocket PATH features by respondent group

Features	Respondents	
	Adolescents (N = 5)	Caregivers (N = 5)
Medication tracking		
Reminders	Yes	Yes (Both applications/devices)
Every dose	Yes	Yes
Time of reminders	10 min before dose	10–15 min before dose
Warnings	Yes	Yes
As needed	Yes	Yes
Time of warning	10–60 min after dose time	15–60 min after dose time
*Warning dismiss option	Yes	Yes
Automatic messages to caregiver		
For taken and missed medications (e.g., “Sam took medication on time”) Graphs	Yes	Yes
[†] Graphs depicting how well medications have been taken grouped by dose time as opposed to per medication	No	Yes and include differentiation of: -How often medications were missed/late -Time of day of the late dose
Organ-specific information		
Medical care needs by organ type	Yes	Yes
Teaching/discharge information per organ	Yes	Yes
Help features		
Space for medical team phone numbers/emails	Yes	Yes
Trusted web-links with helpful information	Yes	Yes

* We opted to not allow easy dismissal of “Warning Messages” as requested by participants in order to more strongly prompt adolescents to take action and take their medication.

[†] Given that adolescents did not want graphs, but parents wanted a pictorial representation of how well adolescents were doing in taking medications, we opted to incorporate symbols (in this case happy, neutral, or sad faces of distinct colors) to quickly identify how well the adolescent was doing in taking medication. The history portion of the application displays this information.

Table 4
Post Study System Usability Questionnaire at the completion of field testing results (N = 5)

PSSUQ questions	Adolescent participant mean/median * range/s.d
I am satisfied with how easy it was to use the application	Median = 1.0 Range = 1–2
It was easy to learn to use the application	Median = 1.0 Range = 1–2
It was simple to add/change medications on the application	Median = 1.0 Range = 1–2
I was able to effectively respond to prompts	Median = 1.0 Range = 1–2
I felt comfortable using the application	Median = 1.0 Range = 1–2
I could clearly tell when I had missed my medication	Median = 1.0 Range = 1–3
I think it was helpful to track my medications	Median = 2.0 Range = 1–5
I liked tracking my medications	Median = 3.0 † Range = 2–7

* Scores range from 1 to 7; 1 = Strongly Agree, 7 = Strongly Disagree.

† Only one adolescent “Strongly Disagreed” with the statement “I liked tracking my medications.”