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The design and development of MyT1DHero: A mobile app for adolescents with type 1 diabetes and their parents

Bree E Holtz[1], Katharine M Murray[1], Denise D Hershey[2], Joshua Richman[3], Julie K Dunneback[4], Arpita Vyas[5] and Michael A Wood[6]

Abstract

Introduction: Type 1 diabetes impacts approximately 1.25 m Americans, many of them young children. As a child grows, there is a transition towards independence and they must learn to manage their diabetes independently. The objective of this study was to design, develop and conduct a prototype test to assess the satisfaction and feasibility of a mobile app for adolescents with type 1 diabetes and their parents to aid in this transition.

Methods: Ten parent/adolescent groups used MyT1DHero for four weeks. They were given a pre-test/post-test survey regarding family conflict with three tasks of diabetes management and the general tone of family communication. At post-test they were asked questions regarding their satisfaction and perception of ease of use of the app. They also participated in short interviews regarding the app. Additionally, we used server data to examine actual app usage.

Results: The parents' perceptions of conflict around the results of the blood sugar tests increased ($t(9) = 2.71$, $p = .02$) as did perceptions of conflict around logging the blood sugar results ($t(9) = 3.67$, $p = .005$). The adolescents perceived increased conflict surrounding the results around logging the blood sugars results ($t(9) = 3.09$, $p = .01$).There was no change in the tone of general family communication. During the prototype testing, we discovered that the app crashed repeatedly and several of the functions were not working properly. In the interview data, three main themes emerged, app-crashing issues, problems with notifications and positive feedback.

Discussion: Through this process, all of the reported issues were corrected and new features were planned for subsequent versions. A smartphone application has the potential to be a novel intervention for engaging adolescents and their parents in positive communication to support type 1 diabetes management.

Keywords

Type 1 diabetes, mhealth, telemedicine

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Introduction

Type 1 diabetes (T1D) is a serious and chronic health condition that impacts approximately 1.25 m Americans and it is estimated that 40,000 new cases are diagnosed each year.[1] Currently, there is no cure for T1D. In many cases, the diagnosis of T1D is made in young children and parents are responsible for managing the illness.[2] Management of T1D is complex and includes monitoring multiple daily blood glucose measurements, carbohydrate intake, physical activity and adjusting insulin doses for injections or, if the child has a pump, for basal and bolus insulin delivery. However, as a child grows, there is a gradual transition towards independence and the child is given more responsibility for the management of the diabetes. This transition often starts at the time of early adolescence.[3] Due to the complexity of proper T1D management, during the adolescent transition, approximately 75% of teens do not achieve adequate control of their blood sugars, as measured by the American Diabetes Association (ADA) haemoglobin A1c (HbA1c) targets.[4]

[1]Department of Advertising & Public Relations, Michigan State University, MI, USA
[2]College of Nursing, Michigan State University, MI, USA
[3]Department of Surgery, University of Alabama-Birmingham, AL, USA
[4]Department of Paediatric Endocrinology, Sparrow Health System, MI, USA
[5]Department of Paediatrics, Texas Tech University, TX, USA
[6]Department of Paediatrics, University of Michigan, MI, USA

Corresponding author:
Bree E Holtz, Department of Advertising & Public Relations, Michigan State University, 404 Wilson Road, Rm 309, East Lansing, MI 48824-1212, USA.
Email: bholtz@msu.edu

Past research has demonstrated that improved and continuous family involvement has myriad positive benefits as the adolescent becomes self-managed.[5–8]

mHealth is the use of mobile technology to impact health outcomes. It has been shown to improve results in a plethora of health issues, including diabetes.[9,10] mHealth offers a way to help improve the management of the disease for this age group as digital technologies are so frequently part of the daily routine.[11] Almost three-quarters of teens have access to a smartphone and 94% report going online daily.[12] Additionally, 76% of parents report having a smartphone.[11] mHealth may offer a possible method of educating and encouraging communication about diabetes tasks to ease the transition to full adolescent self-management. Therefore, we developed an app to help in the transition of management. The objective of this app is to improve positive communication, self-efficacy, trust and autonomy to aid in the adolescents' transition to T1D self-management.

Theoretical underpinnings

The development of this app has been guided by theoretical components of social cognitive theory (SCT) and self-determination theory (SDT). The use of SCT to guide interventions has demonstrated success in changing behaviours around disease management.[5,13–15] SCT posits a reciprocal relationship between an individual's environment, personal factors and behaviours.[16–18] The overall goals of this app and the app intervention were designed using SCT. For example, we hope to change the individual's personal factors by providing social support through the parent/child messaging feature,[19–22] including prompts to set small and achievable daily goals, reminders and educational tips about living with T1D to improve the adolescents' self-efficacy.[23–28] SDT is a theory of motivation that has been used in health domains in the past. To encourage the use and engagement of the app,[29] we used SDT to develop many of the gamification features (i.e. points for usage).[30]

Study objectives

The aim of the present study was to discuss the design and development of a mobile phone app for adolescents with T1D, and to conduct prototype testing of the app. We followed a user-centred design approach in which we actively engaged all key stakeholders throughout the process. The main objectives of the prototype testing was to assess the feasibility, satisfaction and ease of use of the app. Additionally, we were interested in issues around communication of managing the adolescents' diabetes to prepare for our future intervention study.

App development

The development process consisted of four key stages: 1. inductive focus groups and interviews with adolescents and teens with T1D, parents of children with T1D and certified diabetes educators; 2. development of an application wireframe; 3. app development; and 4. app prototype testing. Stages 1 and 2 have been discussed elsewhere;[31,32] therefore a brief summary of the findings is presented here. Stage 3 includes information regarding the app development process and Stage 4 describes the prototype testing study.

Stage 1: Inductive focus groups and interviews

The first stage of this process included conducting focus groups and interviews with key stakeholders. This was done in order to gain a broader context of T1D management as an adolescent and parent. Through this process, we learned that communication between the adolescent and parent was important in the management of the disease. However, this communication was perceived by the adolescents as frequently negative.[31] Therefore, we decided to focus on promoting positive family communication as a way to improve adherence to management.

Stage 2: Wireframe development

In this stage, a multi-disciplinary team of paediatric endocrinologists, nurse practitioners who specialise in diabetes, health communication experts and technology developers used the information from Stage 1, along with a review of current literature to develop a wireframe of the app. This included use cases for the flow of the messaging, logging blood sugars and development of pre-programmed messaging for the parents and the adolescents.

In order to understand the perspective of the parents and the adolescents, focus groups were conducted to demonstrate our vision of the app. We received feedback that aided in finalising our design.[32] Through this exercise, it was decided to include gamification (i.e. the application of game-design elements in other environments) aspects in our app for the adolescent interface.

Stage 3: App development

Once feedback from all of the user groups was compiled, the app development group began developing the app. This process included finalising the back-end server process for registration (i.e. linking the parent app to the child's app), completing design components, and adding game features and educational components. Full design and development of the app took 10 months.

App description. MyT1DHero is an app that links parents and their children by creating two separate app interfaces, one for the parent and one for the child, that work together to help them communicate about diabetes management. The app has customisable blood glucose reminders and ranges, videos of support from other adolescents with T1D, snack lists, and other educational information on T1D.

On the parent app interface, parents have the ability to send and receive messages from their child and view their

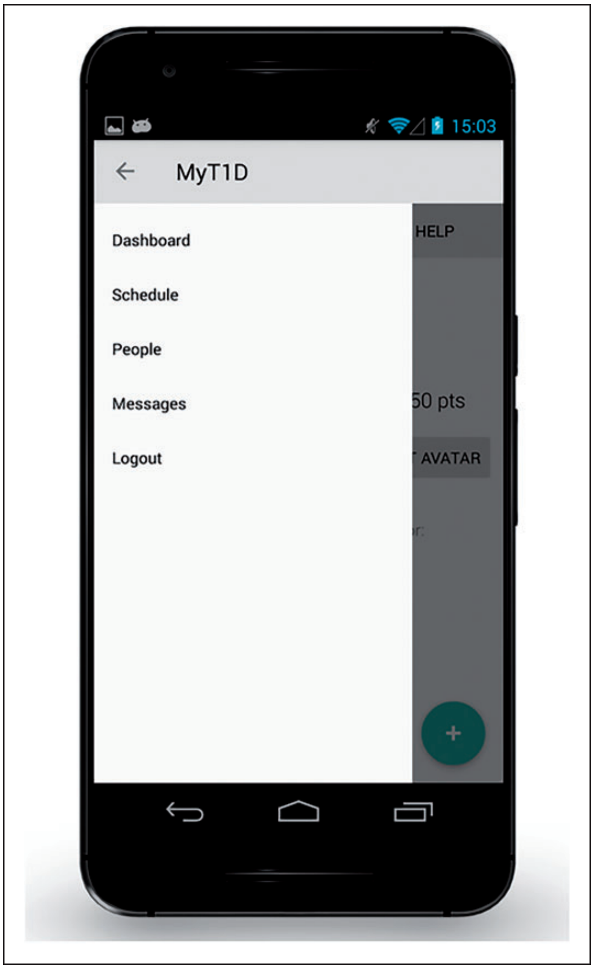

Figure 1. Parent screenshot.

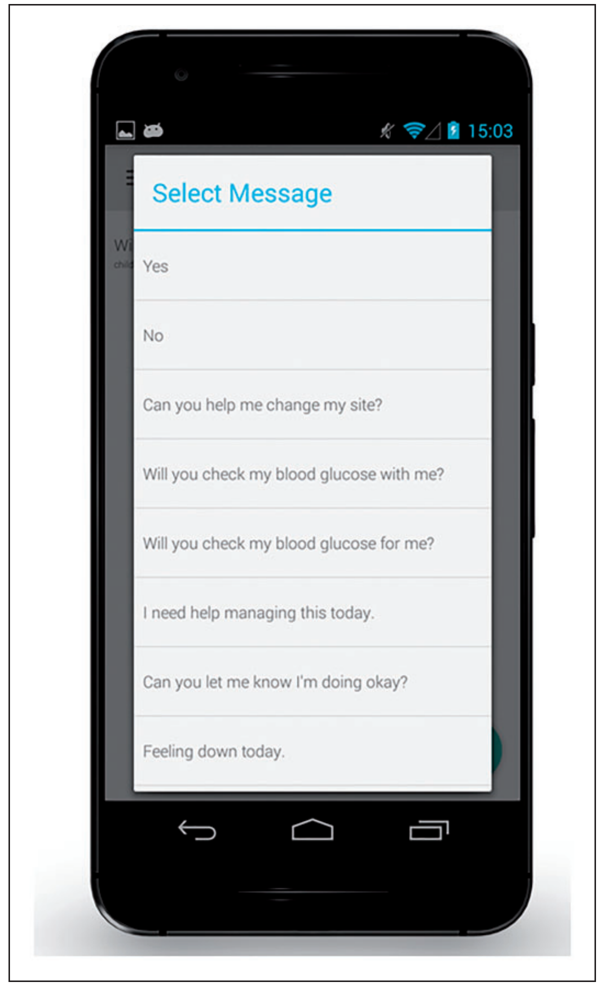

Figure 2. Parent screenshot.

child's blood glucose trends. Parents receive notification of a blood glucose test that has been entered into the app and are able to communicate with their child about their plan for care via the app. Parents also receive social support through positive messages sent through the app. Additionally, there are pre-populated supportive parent messages that can be sent to their child. See Figures 1 and 2 for parent screenshot examples.

On the child app, the adolescents have a place to log their blood glucose, and send and view their blood glucose trends. The app also uses a super-hero avatar that can be customised. By using the app, the adolescents can earn points, which can be used to purchase 'accessories'. Furthermore, the app has pre-programmed messages that the child can send to the parent asking for specific help in managing their diabetes. See Figure 3 for an example of an adolescent screenshot.

Methods

Stage 4: Prototype testing

Participants and recruitment. The prototype testing literature states that five users would be sufficient to test the app.[33] In order to get a wider variety of opinion and feedback we hoped to enrol 10 family pairs.

To be eligible for the study, the adolescents had to be 10–15 years old, have had a T1D diagnosis for at least six months, be fluent in English, have a parent/guardian willing to participate and be allowed to use a mobile phone for the study. The parent had to have a child with T1D, be fluent in English and have daily access to the Internet. Participants were recruited through the Southeast Michigan JDRF (formerly Juvenile Diabetes Research Foundation) social media groups, word-of-mouth and snowball sampling. Ethics approval to conduct the study was obtained from the Michigan State University Human Research Protection Programme.

Procedures. Once the participants were screened, enrolment and training sessions were held at local coffee shops to enrol the families and demonstrate the app. If participants did not have an Android phone, they were provided with a phone and a service plan for the duration of the study.

Study variables. Short pre-test/post-test surveys were administered using three items from the Diabetes Family Conflict Scale (DFCS), a validated scale to measure perceived frequency of family conflict[34] surrounding remembering to test blood sugars, results of the blood sugar tests and the logging of the results. Four items assessed the tone of general family communication; for this scale we used adjectives that were used in our focus groups and the open-ended survey responses. These items were measured on a five-point Likert scale (1 = always to 5 = never). The main objective of this study was to investigate the perceptions of usability and satisfaction with the app. Therefore, we did not use the full versions of the DFCS, but wanted to understand if there was any change in a few of these key measures. For the post-test, validated scales were used to measure the usability and satisfaction of the app,[35] along with a short interview regarding feedback about using the app. The interviews ranged from 12–30 min long, were audio-recorded and transcribed verbatim. Finally, server data was extracted to understand actual use of the app.

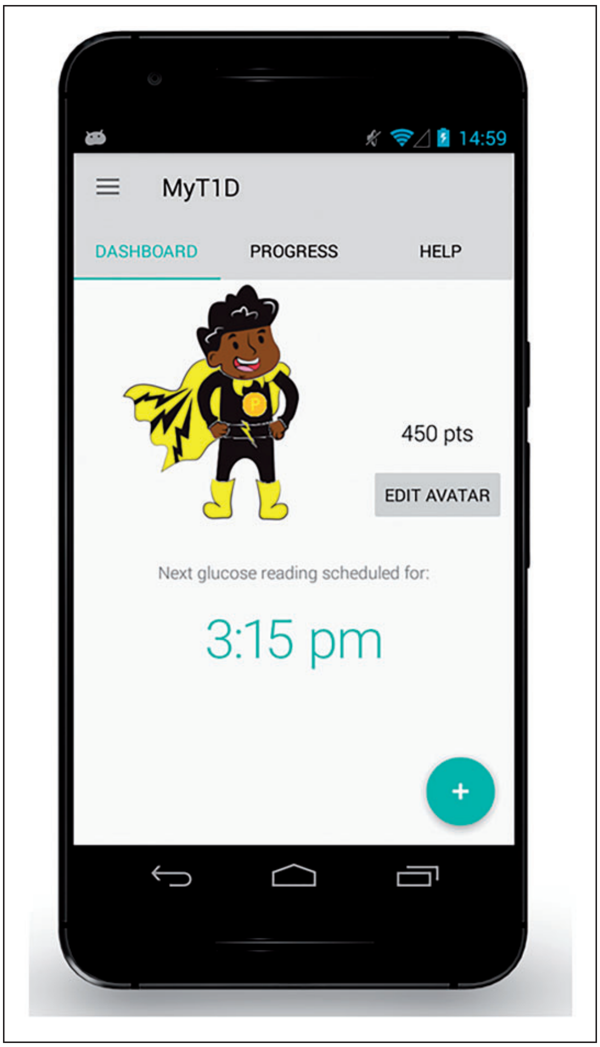

Figure 3. Adolescent screenshot.

Data analysis. The survey data was analysed using SPSS version.[36] Descriptive statistics were used to analyse the demographic questions as well as the ease of use and satisfaction questions. For the satisfaction questions, there were no significant differences between the parent and adolescent responses so they were analysed together. For the pre-test/post-test questions, we conducted a paired independent sample *t*-test for the parent results and the adolescent results. The interview data was analysed by hand, using thematic analysis.[37] Two members of the research team independently read through the transcripts and developed key themes, which were then compared, and codes assigned. Disagreements were resolved through discussion.

Results

These results focus solely on the prototype testing (Stage 4).

Participants

Thirteen families came to the enrolment sessions, but three families dropped out of the study before completion. One family was unable to get phone service on the provided phones in their home. Two families never completed the post-test survey and did not respond to follow-up, see Figure 4.

All of the parent participants were female ($n = 10$), the biological mother of the adolescent and white. Most were between the ages of 45 and 54 ($n = 7$) and were married ($n = 6$). Four of the parents had some level of college, but no degree. The average income of the families by county was $72,209 (range: $61,097–$84,783). The adolescent participants ranged in age from 11–15 years, half were 12 years old ($n = 5$) and six were male. Eight of the

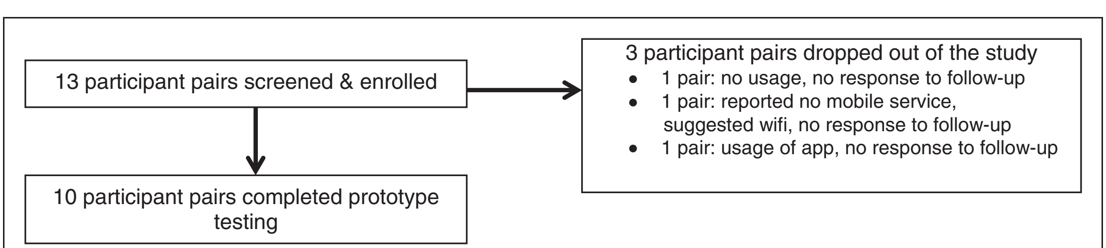

Figure 4. MyT1DHero prototype testing participant diagram.

Table 1. Participant demographics.

Age of Adolescent Participants		Age of Parent Participants	
Age (years)	Count	Age range (years)	Count
11	1	25–34	1
12	5	35–44	2
13	2	45–54	7
14	1		
15	1	Education	Count
		Some college, no degree	4
Length of Diagnosis	Count	Associate's degree	1
6 mths–12 mths	2	Bachelor's degree	1
13 mths–5 yrs	5	Master's degree	1
6 yrs–10 yrs	3	Professional degree (Ex. JD, MD)	1
		Did not answer	2
Management of Diagnosis	Count		
Pump & CGM	3	Marital Status	Count
Injections & CGM	1	Single, never married	1
Pump	5	Married or domestic partnership	6
Injections	1	Divorced	1
		Did not answer	2

Table 2. Conflict around diabetes management.

	Parent			Adolescent		
During the past month, I have argued with my parent/my child about	Pre-test Mean SD	Post-test Mean SD	Cohen's *d*	Pre-test Mean SD	Post-test Mean SD	Cohen's *d*
Remembering to check blood sugars	3.50 (.97)	3.40 (.70)	0.12	3.70 (1.16)	3.30 (1.34)	0.31
Results of blood sugar monitoring	4.30 (.68)	3.70 (.82)	0.79	4.10 (.99)	4.30 (.95)	0.21
Logging blood sugar results	4.60 (.84)	3.40 (.84)	1.42	4.70 (.68)	3.50 (1.08)	1.33

1 = always, 2 = very often, 3 = sometimes, 4 = rarely, 5 = never

adolescents managed their diabetes by using an insulin pump. Four of the 10 used a continuous glucose monitor (CGM). Half of our adolescents had been diagnosed for between 13 months and five years ($n = 5$); two had been diagnosed for a year or less, and three greater than five years. See Table 1 for more detailed information.

Quantitative results

The pre-test/post-survey asked both the parents and the adolescents to report on conflict around diabetes management tasks during the past month. The parents reported no change around perceived conflict surrounding remembering to check blood sugars ($t(9) = .36$, $p = .72$). However, subjects reported arguing more with their child about the results of the blood sugar tests ($t(9) = 2.71$, $p = .02$) and logging the blood sugar results ($t(9) = 3.67$, $p = .005$). The adolescents reported no change around perceived conflict surrounding remembering to check blood sugars ($t(9) = .61$. $p = .56$) or the results of the blood sugar tests ($t(9) = -.39$, $p = .7$). They did perceive an increase in conflict around the logging of the blood sugar results ($t(9) = 3.09$, $p = .01$). See Table 2 for more information.

When examining general perceptions of communication, there were no significant differences pre- and post-test. We asked about positive communication (parent results, $t(9) = -.56$, $p = .59$; adolescent results, $t(9) = .68$, $p = .21$), strained communication (parent results, $t(9) = -.61$, $p = .55$; adolescent results, $t(9) = 1.5$, $p = .33$), stressful communication(parent results, $t(9) = -1.46$, $p = .18$; adolescent results, $t(9) = 1.37$, $p = .43$) and calm communication (parent results, $t(9) = -1$, $p = .35$; adolescent results, $t(9) = .71$, $p = .25$). See Table 3.

Table 3. General communication characteristics.

During the past month, my communication with my parent/my child has been...	Parent			Adolescent		
	Pre-test Mean (Std. Dev.)	Post-test Mean (Std. Dev.)	Cohen's *d*	Pre-test Mean (Std. Dev.)	Post-test Mean (Std. Dev.)	Cohen's *d*
Positive	1.80 (.42)	1.90 (.57)	0.2	1.70 (.68)	1.60 (.70)	0.14
Strained	3.80 (.63)	4 (.67)	0.3	4 (1.5)	4.4 (.84)	0.33
Stressful	3.60 (.70)	4.10 (.57)	0.78	3.90 (1.37)	4.40 (.70)	0.46
Calm	2 (.54)	2.13 (.35)	0.29	2.13 (.64)	1.75 (.71)	0.52

1 = always, 2 = very often, 3 = sometimes, 4 = rarely, 5 = never

Table 4. Ease of use and satisfaction.

	Mean (Std. Dev.)	Range
The MyT1DHero app was understandable	4.10 (.97)	1–5
It was easy to become skilled at using the app	4.00 (1.08)	1–5
I found the MyT1DHero app easy to use	4.16 (.69)	3–5
The MyT1DHero was confusing	2.15 (.67)	1–4
Learning to operate the MyT1DHero app was easy to use	4.40 (.59)	3–5
I liked using the MyT1DHero app	3.63 (1.07)	1–5
I thought using the MyT1DHero app was fun	3.40 (.68)	3–5

1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree

Regarding the user's ease of use and satisfaction of the app, the participants found it understandable, easy to use and were satisfied with the app. Additionally, they disagreed with the statement that they thought that the app was confusing. Participants were neutral about whether they liked using the app and that the app was fun to use. See Table 4.

App server data revealed that the app was used every day for the full month. We defined this as the number of times that each individual logged into the app. The daily mean ranged from 2–86 times daily. There was an early peak of app use at the start of the prototype testing and then a drop-off around day 21. See Figure 5. Additionally, the users explored many features each time they logged in. The dashboard was the most used feature, followed by the blood glucose logging, and the avatar character section (child participants only).

Qualitative results

There were three main themes that emerged from the data: app-crashing issues, problems with notifications and positive feedback.

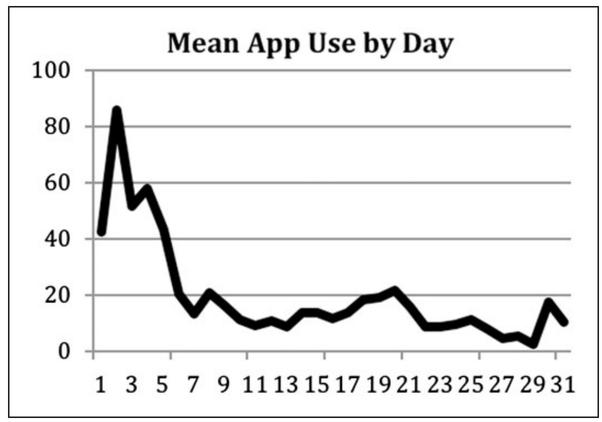

Figure 5. Mean app usage by day.

App-crashing issues. The most frequently reported issue during prototype testing was that the app often crashed. At the beginning of the study, the user registration process was not clear to the participants and the app often crashed during this time. The registration process included having the parent set up the child's information, including blood sugar ranges and blood sugar testing times. Developers began working to fix the app-crashing issues immediately after being notified, and although most of the crashing issues were fixed before the end of the study, participants reported some crashing for the entire study duration. One parent said,

> Mornings are the worst for the app to work. I've tried logging out but then the login button will not respond. Sometimes if I reboot the phone the login will either automatically log him back in but usually it will ask to login again and the button will not respond, then minutes or hours later he will be logged in again.

One participant noted, 'I would go to something else and when I would go back to the app itself it would always crash with an error message so I would have to open it back up again.' Toggling between two different apps caused the app to crash, even after the major crashing issues had been fixed.

Problems with notifications. Notifications sent by the system included reminders to the child that they needed to test, notification to the parents that their child had tested, and communication between the parent and the child. Because of problems with this feature of the app, the users were not receiving clear notifications to go into the app. In fact, the prototype version of the app did not have reliable notifications for any of the tasks. According to many of the parents, this resulted in very low adherence in terms of the child entering their blood glucose values. As for feedback from the participants, the majority of individuals, both parent and child, stated that notifications would be helpful for them in remembering to check and enter blood glucose values, in seeing their child's blood glucose values and in exchanging messages within the app.

Positive feedback. Despite the many changes needed to fine-tune the app based on participant feedback, their overall view of the app was very positive. One parent said,

> I know things have to be tweaked, they always do in the beginning. We love to be able to help get this to be an awesome app. We both love the idea of the app and when it works it's a great tool and a way the child can become independent with a little supervision.

Many of the kids also really enjoyed the app, 'It was very fun and I couldn't stop using it and I kept wanting to check my sugar to put it in and get new stuff to upgrade the person [hero].'

Discussion

This paper describes the design, development and prototype testing of the MyT1DHero mobile phone app. This app seeks to improve the communication around diabetes management between an adolescent and parent. While both participant user types generally liked the app, technical issues were found and impacted many of the overall results of prototype testing.

Our prototype testing included 10 family dyads ($n = 20$), which is adequate for prototype testing,[33] over a four-week period. In regards to the family conflict results, we believe that we may have triggered a Hawthorne effect,[38] which was exacerbated by the lack of functioning reminders to log glucose values throughout this test period. The app was intended to help the adolescents remember to test the blood glucose and to log those results, which would then be sent to the parent to view. However, with this function not working properly, it is possible that the app caused more conflict. Alternately, as the participants were aware conflict was being examined as part of the study, they may have thought about and identified this behaviour in a more salient manner.[39] Past literature has suggested that family conflict is normative, especially between parents and adolescents[40] and conflict provides an opportunity for a more open conversation.[41] However, it has been demonstrated that conflict specifically surrounding diabetes can lead to poorer adherence and blood glucose control[42] and thus should be monitored. Again, we suspect that this was likely to have been around the parents asking if their child had entered their blood sugar number because the app was not sending notifications, as well as conflict around the app crashing, both of which have been fixed.

While there was no significant effect on general communication, those results trended in a positive direction. We hypothesise that with a properly working app used over a longer period of time, family communication would improve in the future. Additionally, while our effect sizes are somewhat larger than expected, they should be taken with extreme caution, as we believe that they are due to the small sample size and the homogeneity of the sample.[43]

Due to technical difficulties, the app user data may have underestimated potential future benefit. All of the technical issues reported by the participants have been resolved, and user experience is likely to improve. Additionally, a spike in use was noted at the beginning of the trial, which is expected in the use of new apps. There was a slight drop in use at day 21; this also seems to be common.[44] Therefore, the frequent addition of new content or updates to the app may be necessary to keep people engaged in using it.[45] Furthermore, as this was a test to see what the users would do with the app, we did not require as specific a 'dose' of the app during the prototype testing. However, we did suggest at least four times a day as the minimum recommended blood glucose testing frequency. Based on user feedback, planned app enhancements include a free-text option for messages, additional badges for uses, daily schedule changes and other usability fixes (e.g. making the ranges easier to program) will be included in the next iteration of the app. Overall, the participants generally thought that the app design was easy to use, learn and understand.

Limitations to this study include a small and homogeneous sample size, which limits generalisation of results. Additionally, the app was only used by mothers; father participants may have provided a different perspective.

Although the number of apps targeting diabetes and specifically T1D is increasing, there is no other current app (of which the authors are aware) that specifically focuses on adolescent–parent communication. Overall, the feedback was positive, despite the technical issues. The qualitative results provided a number of suggestions to improve the app. Through this testing and feedback process, issues were corrected and new features are planned for subsequent versions. A larger intervention is currently being conducted to test the efficacy of the revised version of the app and will include assessment of blood glucose control by measuring the child's HbA1c. Smartphone applications have the potential to be a novel intervention for engaging adolescents and their parents in positive communication to support T1D management.

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