ABSTRACT
In this study we interviewed several adolescents with type 1 diabetes to gain insight in the needs of this specific group regarding mobile self-management applications. The interviews involved questions about the usage of mHealth applications that could support them in their diabetes self-management, and involved questions about possible features of a new type 1 diabetes self-management mHealth application that is planned to be be developed in co-operation with the Gelderse Vallei Hospital. The goal is to develop a virtual coach that supports self-management in the patient and improves the relation between the patient and healthcare professional.

The problem we are investigating is how to stimulate adolescents with type 1 diabetes in their blood-glucose measurement frequency and how to support them in the self-management of their condition.

We found that mHealth usage was very low, but the ideas behind mHealth were very well received by patients and parents. We found several possible indications of how the information exchange between the patient and healthcare professional should take place. Besides we found indications on how the patient should be reminded by an application and by the healthcare provider. We also found which self-management functionality was most appreciated and what kind of stimulation in the form of rewards could be introduced in a type 1 diabetes mHealth application.

The findings gave some new insights, but mainly confirmed the chosen strategy and direction.

General Terms
Diabetes management, type 1 diabetes, glucose levels, coach, adolescents, youth, iOS, Android, blood sugar, gamification, measurements, mHealth, eHealth

1. INTRODUCTION
The rate of adolescents with type 1 diabetes in Europe is increasing and if the trend continues, new cases of diabetes type 1 in adolescents younger than 15 years old, will rise by 70% between 2005 and 2020 [35].

Type 1 diabetes is a chronic condition. The disease emerges in childhood and requires self-management for the rest of a patient’s life.

Blood glucose levels have to be frequently measured and the functioning of a person with type 1 diabetes his or her metabolism is reliant on the delivery of insulin. When the correct amount of insulin is administered (based on the self-monitored glucose levels) a person with diabetes 1 is able to replicate the metabolism of a non-diabetic.

Intensive self-management where the patient checks his or her blood glucose levels at least 3 times per day has shown to reduce mortality and complications like cardiovascular and renal disease [2].

In spite of the ability to control blood glucose levels, studies have shown that adolescents around the world do not meet their self-management targets [21]. During the transition to adolescence, the declining treatment adherence of glycemic control of young adolescents with diabetes type 1 may be greater than declines among older adolescents [41]. Training of skills and better metabolic control by self-management has shown to reduce the incidence and progression of microvascular disease and neuropathic complications [14].

As of 2013 there are 381.8 million people that have diabetes worldwide, with 24.4 million people in the U.S. and 56.3 million people in Europe. The costs of diabetes in 2013 in the US are around 236 billion US$ and 147 billion US$ (110 billion EUR) in Europe (including the Russian Federation). 80% of people with diabetes live in low- and middle-income countries [11].

In the past years mHealth, or mobile health applications, are becoming increasingly popular. It is reported that there are currently approximately 97,000 mobile health applications available in the major application stores (Google Play and Apple application Store). This market has a growing rate of nearly 40 percent per year [4].

One of the biggest and fastest growing mHealth market segments is the mobile diabetes application segment. According to a "Research2guidance" report, there are currently 1,100 iOS and Android specific diabetes applications who target diabetes patients or healthcare professionals. The usage of
diabetes applications by diabetics who own a smartphone will grow to 7.8% in 2018, where only 1.2% are using a mobile diabetes application as of march 2014 [23]. Most of the diabetes mHealth applications are diabetes coaches. These digital diabetes coaches help patients in self-management. They do this by logging and transmitting blood-glucose values to the healthcare professionals, they can also motivate, warn and remind patients, which eventually could result in more pro-active self-management [4].

A report by PWC [37] states that mHealth applications will have an enormous socio-economic impact in the EU. They state that 472,000 doctor days can be saved by using mHealth where patients could avoid complications and seek medical attention earlier by monitoring their condition. 466,000 of these doctor days are accounted for type 2 diabetics.

As smartphone ownership is expected to grow from 1,76 billion people in 2014 to 2,73 billion people in 2017, especially in the low- and middle-income countries [10], and Western European countries rank in the top 10 of worldwide smartphone penetration [42], mobile diabetes applications may hold the key for better schooling and more accessible care regarding diabetics worldwide.

This study is related to the BLink project, a closed-loop diabetes decision support system using smartphones by the Gelderse Vallei Hospital [45]. In this study the needs of adolescent diabetes patients for a new mobile diabetes self-management coach were investigated. Questions that we ask ourselves in this study are: What is the current practice in the field of guidance of adolescent diabetes patients?, Where is the guidance aimed at?, What does an adolescent type 1 diabetes patient need to know about his or her condition?, and What does the patient need to do to help him or herself in self-management? Furthermore we want to investigate how we can stimulate and motivate the users to meet their self-management targets (frequency of their glucose measurements) and what functionality requirements and improvements the user may want to see compared with the current range of diabetes self-management applications that are available in the major "app" stores.

2. RELATED WORK

2.1 Metabolic control and adolescents

Poor metabolic control can have a big impact on the lives of adolescents and young adults. Vice versa, the mood and way of life of a patient can have a big impact on metabolic control and diabetes self-management.

The most import reason of intensive blood glucose control is that it reduces the risk of eye disease by 76%, kidney disease by 50% and nerve disease by 60% as was found by the DCCT study [15]. In the EDIC study [43] it was found that intensive blood glucose control reduces the risk of any cardiovascular disease event by 42% and the risk of nonfatal heart attack, stroke, or death from cardiovascular causes by 57%.

It is clearly demonstrated that intensive diabetes therapy delays the onset and slows the progression of the above diseases in adolescent type 1 diabetes patients [40].

Besides physical health effects, poor metabolic control can also have impact on psychological aspects. Depression in children and adolescents with type 1 diabetes have been associated with negative diabetes-related health outcomes such as poorer glycemic control and more diabetic ketoacidosis admissions [22].

In a study by Graue et al. [33] 116 adolescents with type 1 diabetes participated in an experiment where they had to complete a questionnaire with questions regarding coping styles (conscious effort to solve personal and interpersonal problems) and quality of life. Increase of HbA1c values (average glucose concentration over extended period of time) was correlated with aggressive coping and behavioral disengagement. Poor control over their diabetes and lower degree of diabetes-related quality of life were associated with greater use of emotion-focused coping in adolescents with type 1 diabetes.

Another study by Helgeson et al. [20] showed that metabolic control declines with age. Also eating disturbances, poor self-care, depression, and peer relations were related to poor metabolic control, good family relations were related to better metabolic control for females. In the study 70 girls and 62 boys were interviewed annually for four years.

A newer study from Helgeson et al. [19], where 132 adolescents with type 1 diabetes and their parents were interviewed annually for 5 years, showed that more frequent blood glucose monitoring was related to better glycemic control. Adolescents who monitored more frequently were younger, were from higher social status families, used insulin pumps, and had higher self-efficacy. A decline in blood glucose monitoring occurred among adolescents with low self-esteem, high stressful life events, and lower parental support.

In a 2014 study by Berndt et al. [38] it was shown that their "Mobil Diab" application had a big impact on the overall mean HbA1c value of the participants. There were also indications of a positive impact on the improvement of psychological parameters and the system appeared to be an efficient and time saving tool in diabetes management.

2.2 Diabetes self-management and mobile devices

Different studies [5, 39, 43] have shown that diabetes self-management through mobile devices lead to improved results and that they are well received by the users in terms of usability and user-experience.

In the previous study, the BLink project by the Gelderse Vallei Hospital, 29 adolescent type 1 diabetes patients were included [45]. Blood glucose measurements were synchronized by the patients with a web-based personal health record, linked to an electronic medical record system. Although there was no significant increase in frequency of blood glucose measurements, a positive correlation was found between the mean frequency of blood measurements and HbA1c values. Also the usability of the system in patients and diabetes nurses was positively evaluated [10].

In a 2006 study from Rami et al. [39] it is shown that the HbA1c values of diabetes type 1 adolescent patients im-
proved over a 3 month period when self-management was im-
plemented where the patients send glucose, carbohydrate in-
take and insulin dosage (divided into short- and long-acting insulin) by SMS to the healthcare provider. The healthcare provider used regular mobile phones to send feedback to the participants. In contrast, the glycemic control of the group who used a regular paper diabetes diary would deteriorate over time.

Kollman et al. [28] investigated a mobile phone-based data service for type 1 diabetes over a period of 3 months. They created a Java-based application back in 2007 (pre iOS and Android) where the users could enter their measurements and received feedback from the healthcare professional by SMS. The visualization of the data like graphs and tables could be seen on a website. The metabolic control of the participants increased and the application was well received.

The Diabeo application [23] emerged from a study by Char-
pentier et al. [23] where 180 poorly controlled adult type 1 diabetes patients separated in 3 groups, were followed for 6 months. The Diabeo application consisted of a self-adjusting insulin calculator and digital diary for long and short-acting insulin doses, that is tailored to nutritional intake and physical activity. The data could be shared with diabetes health-
care professionals. The patients who used the application had a substantial improvement of their metabolic control, and spent less time on hospital visits.

Not every study resulted into improved glycemic control. In a 2005 study by Farmer et. al. [44] a 9-month experi-
ment with adolescent diabetes type 1 patients was conducted with a graphical telemedicine system where the participant could enter their glucose levels. The patients received nurse-initiated support through a web-based interface. There were no significant differences with the control group, the authors mention that access to real-time decision support for medica-
tion dosing and changes in diet and exercise may be required to improve glycemic control.

In a study by Hanauer et al. [15], forty adolescents and young adults with diabetes received reminders to check their blood glucose levels by SMS and e-mail reminders for 3 months. The reminders were automatically generated and the participants had to reply with a blood glucose result. The participants could set their schedule for reminders on a secured website. The 22 participants in the SMS group received more reminders and responded with more blood glucose results than the e-mail group. In the first month the SMS group submitted twice as many results as the e-mail group, but after 3 months the usage declined to the same amount of blood glucose values as the e-mail group. The re-
searchers suggest that although the system focuses on spon-
taneity and encouragement, this could be due to that the system becomes repetitive and exhausting with time.

A study by Klaassen et al. [24] showed that diabetics pre-
ferred to receive messages while they were relaxing in front of the television and while having a (lunch)break. They did not want to receive any message while at home in a hurry. Half of the respondents would not mind getting a congratulatory message about achievements while having dinner and less than half of the respondents indicated to welcome messages with their weekly medicine intake or re-
quests for a new glucose measurement. They also found that messages for blood glucose measurements were preferred to be received on televisions, computers and smartphones.

Klasnja et al. [25] mention that mHealth applications use four main strategies to encourage healthy behaviors. Tracking and feedback (e.g. measurements), goal setting (e.g. future goals), social influence (e.g. social media) and gamifica-
tion (e.g. serious gaming). Besides these wellness strategies they defined patient-care strategies that included symptom monitoring, self-management coaching, and automated decision support. Furthermore they state that mHealth appli-
cations have a vast potential to support patient care outside the hospital. This is important since patients manage their health outside the clinic and this is also where most health problems occur.

For the future they envision two classes of mHealth appli-
cations: adaptive systems that take the changing circum-
stances of patients into account and which provides finely tuned support to the patient’s current needs. The second class of applications would be life-companion applications that are used over many years and devices, helping patients to reach the goals they care most about.

Overall research has found that use of mHealth technology with diabetes patients is acceptable and user-friendly. The greatest barriers for these technologies are patients not hav-
ing access to smartphones and internet, and patients having to get used to using an application on a daily bases [31].

2.3 Diabetes self-management and games

Games (or gamification) can be of great use to motivate, encourage and educate adolescents with type 1 diabetes. In a study by Kumar et al. [29] a motivational game was developed in which adolescents could guess their 4th blood glucose value of the day based on the three earlier checks. The previous results were shown on a PDA along with car-bohydrate intake and administered insulin doses. All blood glucose results were transmitted to a server. In the four week study, the game group increased their blood glucose measurements, reduced hyperglycemia, and improved dia-
abetes knowledge.

A popular example of a "mainstream" game is the Didget game, which resulted in the Didget Meter by Bayer [3]. The Didget meter connects with a Nintendo DS handheld game console and awards points based on timing, frequency and results of blood glucose measurements. With these points, the player can unlock levels. The game also uses positive rewards to encourage healthy behavior. The study showed that the game and meter were precise and clinically accurate in the hands of patients and healthcare professionals, and may help children and adolescents manage their diabetes more effectively [20].

A different type of game is GRIP [10]. a Dutch-language diabetes self-management game that is connected with the patient’s electronic health record. In this game players learn to make decisions and develop skills based on their current personal health information. The game enables parents and clinicians to monitor the patient’s condition over time. Players observe how daily activities and food choices influence their blood glucose levels [30].
3. DATA COLLECTION METHOD
For this study we joined healthcare professionals at multiple consultation hours with adolescent type 1 diabetes patients at the Gelderse Vallei Hospital and were able to ask questions. Besides the consultation hours we conducted interviews with adolescent type 1 diabetes patients at their homes.

3.1 Consultation hour
All patients were questioned by the researchers (the author of this paper and Xiaohao Ye) on two different occasions (June 2, 2014 and June 5, 2014) at the Gelderse Vallei Hospital, Ede, the Netherlands. There were 7 participants in total, of whom 4 used a pump and 3 used an insulin pen. Five of the participants were male, two were female. The interviews were not structured since they were held during the regular consultation hours between the patients and their physician.

Patients told about events and experiences concerning their type 1 diabetes and the investigators would elaborate with questions on their dialogue. The information was directly written down. The researchers reassured the respondents that they would not be identifiable in any subsequent report.

3.2 Interviews
All participants were interviewed by the researcher at their homes on two separate days, July 16, 2014 and July 17, 2014. The interviews took place in and around Ede, the Netherlands. Since this study was aimed at adolescents with type 1 diabetes who use insulin pens, all six participants used an insulin pen.

All interviews were recorded, with the permission of the participants being interviewed. When the participant was underage they were recorded with the permissions of their parent(s). During the interview forms with Likert-scales had to be filled in. After the interviews, the recordings and data were annotated in tables.

The researcher reassured the respondents that their identity of their address would not be identifiable in any subsequent report. The computer files were confidently stored. After this study the recordings will be erased.

4. DATA ANALYSIS METHODS
All of the interview recordings were listened to by the researcher and annotated and encoded into tables. Eight category headings were generated from the data and under these all of the data were accounted for. This included demographic data like age, gender, duration of type 1 diabetes and education.

5. FINDINGS

5.1 Consultation hour
During the consultation hours we found that 3 patients used mobile applications with their type 1 diabetes, one used his meter in combination with his PC to send the glucose values to the healthcare professional. Others used a paper glucose diary or used their blood glucose meter as a diary.

The blood glucose measurement frequency of the patients who used an insulin-pen averaged 4 times a day.

Table 1: Consultation hours participants

<table>
<thead>
<tr>
<th>Part.</th>
<th>Gender</th>
<th>Age</th>
<th>Device</th>
<th>Diabetes since</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Male</td>
<td>17</td>
<td>Insulin pen</td>
<td>1 month</td>
</tr>
<tr>
<td>2</td>
<td>Female</td>
<td>15</td>
<td>Insulin pump</td>
<td>6 years</td>
</tr>
<tr>
<td>3</td>
<td>Male</td>
<td>15</td>
<td>Insulin pump</td>
<td>5 years</td>
</tr>
<tr>
<td>4</td>
<td>Male</td>
<td>7</td>
<td>Insulin pen</td>
<td>8 months</td>
</tr>
<tr>
<td>5</td>
<td>Male</td>
<td>12</td>
<td>Insulin pen</td>
<td>4 months</td>
</tr>
<tr>
<td>6</td>
<td>Female</td>
<td>5</td>
<td>Insulin pump</td>
<td>2 years</td>
</tr>
<tr>
<td>7</td>
<td>Male</td>
<td>17</td>
<td>Insulin pump</td>
<td>12 years</td>
</tr>
</tbody>
</table>

5.2 Interviews

5.2.1 Demographics
The demographic data can be seen in table 2. The participants ranged from the age of 12 up to 17 years old. There were 3 males and 3 females. The majority were high school students and the duration of diabetes ranged from 5 months up to 5.5 years.

Table 2: Interview participants

<table>
<thead>
<tr>
<th>Part.</th>
<th>Age</th>
<th>Gender</th>
<th>Diabetes since</th>
<th>Education</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16</td>
<td>Female</td>
<td>5 months</td>
<td>HAVO 4</td>
</tr>
<tr>
<td>2</td>
<td>13</td>
<td>Female</td>
<td>3.5 years</td>
<td>VMBO 1</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>Female</td>
<td>5 months</td>
<td>HAVO 1</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>Male</td>
<td>5.5 years</td>
<td>HAVO 5</td>
</tr>
<tr>
<td>5</td>
<td>17</td>
<td>Male</td>
<td>1 year</td>
<td>HAVO 5</td>
</tr>
<tr>
<td>6</td>
<td>12</td>
<td>Male</td>
<td>6 months</td>
<td>HAVO 1</td>
</tr>
</tbody>
</table>

5.2.2 Type 1 diabetes self-management
Most participants responded that they measured their blood glucose values 4 times a day: before breakfast, lunch, dinner and before going to sleep. Sometimes they would measure extra in case of sports or extra meals. Participant 5 only measured when he was not feeling "good" (being too high or too low). Some did not measure on fixed times, but helped remind themselves to measure intuitively or "automatically". Others were reminded by their parents or were alerted by the fact that e.g. dinner is ready. The most frequently forgotten measurement was the measurement before going to sleep. One participant would forget it when she did not measure before dinner. Another participant would forget it because of conviviality.

Participant 5 did not think that it was important to measure: "If I'm feeling good, I'm not going to measure". When asked for an explanation, he mentioned that he is a lot of time too "high" or too "low". He said that he is fairly sloppy with his diabetes self-management. This might be an indication of the peaks and drops of his glucose.

The healthcare professional at the Gelderse Vallei Hospital stressed that he had to measure at least 2 times a day and should measure once a week 4 to 5 times on a fixed day, in this case on Tuesdays. However, this patient failed to achieve this, especially because of the holidays and his accompanying lack of rhythm. "It should go better when school starts".

All participants except one did not care where they measured their blood glucose levels. This could be e.g. in public or in class. One participant had a special room at school where she could measure her blood glucose.
Some of the participants would write down their values directly after measuring, others would just save them in their meters.

### 5.2.3 Experience with diabetes mHealth technology

When asked if they had ever used an application for saving their blood glucose measurements, two participants responded affirmatively. One participant mentioned that he would connect his meter with his computer, but the software would freeze very often. They were well satisfied with the graphs and averages the software can show.

The other participants had never used an application for tracking their blood glucose values, although they could see benefits in using such an application;

Participant 3: “It seems useful when I do not have my meter with me. I guess I’d still prefer to use my meter to keep track of the values”.

Participant 5: “It would be easier because I would always have my phone with me to see my recent values. I forget my meter sometimes”.

Participant 6: “I can see some benefits in having the values directly on my phone”.

**BLink.** The two participants who said that they used an application, still used the application from the previous project of the Gelderse Vallei Hospital, called BLink [15]. They connect their blood glucose meter with their smartphone over bluetooth. One of the participants, participant 2, thinks that the BLink project is very nice, because she could send her data with the GlucoLog Mobile application [33] and the nurse would advise her based on her values. She did not send it every day, but every week or two weeks. She is very positive about the fact that she no longer has to write down the values in a diary. Less nice is that she can not enter her administered amounts of insulin and sometimes the bluetooth dongle will go on in her backpack so the battery is empty when she wants to use it. Besides that the dongle works fine. Also the connection between the application and the server can be slow and drops once in a while.

Participant 4 finds the system convenient. Previously he wrote the glucose values down in a diary, and now it’s very easy to send it to his mobile phone. He also likes receiving a 3 month average of his values. Sometimes the dongle connection fails. He thinks that the bluetooth part should be directly integrated in the blood glucose meter. There are occasionally some errors in the connection between his phone and "Patient1", the service that manages the data online.

Besides participants who used the BLink project application and participants who do not use any application for logging their blood glucose values, they were asked whether they used other applications that helped them with their condition. Almost all participants responded that they used or had used a carbohydrates calculator application called HelpDiabetes [12]. One participant mentioned about the HelpDiabetes application that: "You can put in what you want to eat, the app counts the carbs and then it will calculate how much insulin you need to inject. The carb and insulin values are right.". Another participant mentioned that the carbohydrate counts from the HelpDiabetes application were not always right and that a lot of meals and products are not available in the application’s database. The main advantage of the application was that it is available in Dutch.

### 5.2.4 User requirements

To see which features are most beneficial in everyday use, we developed a list with features that the participant had to rate by a 7-point Likert-scale. The list was based on counts of features that emerged in different studies [27, 6]. The 7-point Likert scale was categorized from 1 "Totally disagree" to 7 "Totally agree". We asked if the function should be part of a self-management type 1 diabetes application.

The results can be seen in table 3. *BGM = blood glucose measurements*

<table>
<thead>
<tr>
<th>Table 3: Features Likert-scale</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Participant nr.</strong></td>
</tr>
<tr>
<td>1. Receive values from meter</td>
</tr>
<tr>
<td>2. Watch (previous) results</td>
</tr>
<tr>
<td>3. Watch extensive results</td>
</tr>
<tr>
<td>4. Watch graphs</td>
</tr>
<tr>
<td>5. Statistics</td>
</tr>
<tr>
<td>6. Customization</td>
</tr>
<tr>
<td>7. Receiving rewards</td>
</tr>
<tr>
<td>8. Unlock games with BGM*</td>
</tr>
<tr>
<td>9. Export and send values</td>
</tr>
<tr>
<td>10. Add photo with BGM*</td>
</tr>
<tr>
<td>11. Add photo of meal</td>
</tr>
<tr>
<td>12. Save weight data</td>
</tr>
<tr>
<td>13. Save blood pressure data</td>
</tr>
<tr>
<td>14. Set reminders</td>
</tr>
<tr>
<td>15. Carbohydrate calculator</td>
</tr>
<tr>
<td>16. Save carbohydrate values</td>
</tr>
<tr>
<td>17. Diabetes information</td>
</tr>
</tbody>
</table>

Table 3 shows that the items "Diabetes information", "Set reminders", "Customization", "Save carbohydrate values" and "Watch graphs" scored slightly positive. The items "Receive values from meter", "Watch (previous) results", "Watch extensive results", "Export and send values" and "Carbohydrate calculator" scored very positive.

When asked if the participant would add more functions a participant mentioned; "A insulin calculator that should be based on what is eaten, so that you fill in how many carbs you eat and it shows how much insulin you have to inject". Some features where further explained. A participant responded that it can be handy to enter activity information such as biking. She also said that the weather can be of influence on her glucose levels, "So maybe something can be done with that". Another participant liked graphs so she could anticipate on peaks and she can detect trends such as recurrent glucose peaks on sundays. She liked the idea that she could directly show and send her latest measurements to her mother in the morning instead of first having to find her
minder types with a 7-point Likert-scale categorized from 1 
reminding/alerting. The participants had to judge these re-
tient should receive, we created a list with different ways of 
To find out what kind of reminders a type 1 diabetes pa-
meter in the bottom of her backpack. She also would like to 
customize user-interface elements like backgrounds etc. 
Another participant would also like to see graphs on his 
mobile phone instead of on a computer screen. Diabetes in-
formation about what to do in certain situations would be 
handy. The last participant thinks that the application should not be 
crammed with functions, speed and responsiveness are more 
important for daily use.

5.2.5 Type 1 diabetes self-management reminders
To find out what kind of reminders a type 1 diabetes pa-
tient should receive, we created a list with different ways of 
reminding/alerting. The participants had to judge these re-
minder types with a 7-point Likert-scale categorized from 1 
"Totally disagree" to 7 "Totally agree". We asked if the type of 
reminder was suitable. The results can be seen in table 4.

Table 4: Personal reminder types Likert-scale

<table>
<thead>
<tr>
<th>Participant nr.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. SMS</td>
<td>6</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>2</td>
<td>3</td>
<td>3,8</td>
</tr>
<tr>
<td>2. E-mail</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>2,3</td>
</tr>
<tr>
<td>3. Message in app</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>4</td>
<td>7</td>
<td>6</td>
<td>5,2</td>
</tr>
<tr>
<td>4. Message in notifi.-centre</td>
<td>3</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>7</td>
<td>6</td>
<td>5,7</td>
</tr>
<tr>
<td>5. Specific sound</td>
<td>4</td>
<td>6</td>
<td>4</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>6. Vibrating alert</td>
<td>5</td>
<td>7</td>
<td>4</td>
<td>6</td>
<td>7</td>
<td>2</td>
<td>5,2</td>
</tr>
<tr>
<td>7. LED notifi. with color</td>
<td>4</td>
<td>6</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>3,8</td>
</tr>
</tbody>
</table>

Table 4 shows that the items "Message in app", "Message in notification-center", "Specific sound" and "Vibrating alert" scored best.

We asked if the participants had an opinion about receiving reminders. A participant mentioned that she would like to use reminders and that she should be alerted 30 minutes or a hour before her normal measuring time. The application should be smart enough to detect this.

Another participant tells that reminders would help him a lot in remembering to measure. When asked if they would like to customize reminders, participants reported that they wanted to be able to customize the reminder in something very specific. When it is on screen it should be a very short message with an icon in the notification-center that says "puncture". The tone of the messages may be neutral and sometimes motivating. One participant thinks the messages should be funny once in a while.

Participants report that they only want their phones to give a vibrating alert as a reminder. They would rather not be disturbed when they are in class, in the middle of the night or in church.

Some studies investigated the personal privacy aspects of mHealth applications [36]. We asked if the participants would mind if others would see their reminder or other information. One participant replied positively: "A little bit yes, a little bit no. They may see if I have to take a blood sample, but as long as they do not see my blood sugar levels".

5.2.6 Communication with healthcare professionals
Messages on the phone can also be useful for information and reminders from healthcare professionals. Again we asked which type of message/reminder would be most suitable when the participant would receive such a message/reminder from the healthcare professional. The participants had to judge these message/reminder types with a 7-point Likert-scale categorized from 1 "Totally disagree" to 7 "Totally agree". The results can be seen in table 5.

Table 5: Healthcare professional reminder types Likert-scale

<table>
<thead>
<tr>
<th>Participant nr.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. SMS</td>
<td>6</td>
<td>6</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>4,3</td>
</tr>
<tr>
<td>2. E-mail</td>
<td>1</td>
<td>6</td>
<td>1</td>
<td>4</td>
<td>6</td>
<td>2</td>
<td>3,3</td>
</tr>
<tr>
<td>3. Message in app</td>
<td>4</td>
<td>7</td>
<td>6</td>
<td>3</td>
<td>6</td>
<td>6</td>
<td>5,3</td>
</tr>
<tr>
<td>4. Message in notifi.-centre</td>
<td>3</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>6</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>5. Specific sound</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4,2</td>
</tr>
<tr>
<td>6. Vibrating alert</td>
<td>5</td>
<td>7</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>3</td>
<td>5,2</td>
</tr>
<tr>
<td>7. LED notifi. with color</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>3,7</td>
</tr>
</tbody>
</table>

Table 5 shows that the items "Message in app", "Message in notification-center" and "Vibrating alert" scored best. The item "Specific sound" scored slightly positive on the scale.

A participant mentioned that she wanted to be able to turn off messages from the hospital.

When asked how far in advance a reminder from the health-care professional should be sent, the majority answered a week, others would say a day in advance. Most participants did not forgot appointments or had problems with complying with agreements.

All participants, except one, were enthusiastic about the idea that they could send their blood glucose values to the hospital and in turn would receive feedback from the health-care professional. A participant responded that she wanted to see her diabetes record in the application.

The participant that did not like this idea said that he would forget to send his data even when he would receive a reminder. He simply did not want to send his blood glucose values and did not like the idea of being monitored; "For example, if I go out and get high blood glucose levels, I would not like to get a rap over the knuckles because of that".

We asked how many times they would like to receive information and feedback. Most participants responded that they preferred to take the initiative to send their values themselves. Others prefer once a week on a fixed day, or when the blood sugar values are not at the right level.

5.2.7 Rewards
Studies have shown that serious-games or adding game elements to specific mHealth applications (gamification) can have benefits for the patients by controlling their condition 
and for the user’s age.

Most mHealth applications that use game-elements do this in the form of rewards [30].

When asked what participants think of using rewards most participants responded positively. A participant said she liked the idea, but not as a main part of an application, but more as an extra. Others liked the idea of reaching goals. Another participant thinks that blood glucose measurements would be more fun when game elements are introduced. The game-elements and rewards should be optional and suitable for the user’s age.

Two participants did not like game-elements in a diabetes
In table 4 and 5 we can see the results of what type of re-
mindation strategy is applicable on items 7 and 8. These items
are not directly aimed at blood glucose monitoring. Item 7,
which falls in the goal setting strategy, was less well received
and involved a statement about receiving awards when a
patient would achieve a certain goal. When asked later on
most participants reacted positive, but would see it as some-
thing for other age groups like children. Items 10 and 11 fall
into the social influence strategy. Participants were asked
whether they would like to take photos that are sharable,
these were not well received by the participants. The gami-
fication strategy is applicable on items 7 and 8. These items
involve the application of game-elements and were received
negatively.

It becomes clear that the participants were most positive
about the tracking and feedback strategy. This can be seen
in relation with the interviews, where participants mentioned
that they liked the idea of a digital diabetes coach where
they would receive personal feedback based on their mea-
measurements. The items that were not in the tracking and
feedback strategy did not score well, this can be explained
by the interview results where most participants stated that
the application should be as basic and functional as possi-
ble, and should only focus on measurements and personal
feedback.

In table 4 and 5 we can see the results of what type of re-
minder the participant would want to receive from the appli-
cation itself and the healthcare professional. As a personal
reminder, the visual reminders, a message in the applica-
tion and in the notification-center scored highest, as well as
the auditory reminder in the form of a specific sound and
the tactile reminder in the form of vibration. When looking
at receiving reminders from the healthcare professional, the
message in the app and notification-center, as well as the
vibration scored highest. SMS and a specific sound were re-
ceived slightly positive. The reason for this could be that
patients don’t want to be bothered too much and when they
are they want to have control over the reminder, as was also
seen in Klaassen et al. [24].

Furthermore it was surprising to see that only a few par-
ticipates used mobile applications in supporting their dia-
betes self-management, as the smartphone penetration of
the Netherlands is one of the highest in the world [42]. Al-
though this low usage could be due to the availability and
quality of Android diabetes self-management apps. The
prevalent app that participants had tried in the past and
some were still using was the HelpDiabetes application [12],
which is a carb counter application with a food database.
But nonetheless when asked all participants were enthusias-
tic about the possibilities of a new diabetes application. If
they had used or were currently using applications related
to diabetes, they used a carbohydrate calculator application,
subsequently the HelpDiabetes application [12], out it, most participants were positive afterward.

5.2.8 Comments
At the end of the interview we asked if the participant had
questions or comments. One participant wanted to mention
that being able to view statistics and graphs based on
his blood glucose levels would be most important. Another partic-

Klasnja et al. [25] described the four main strategies for
mHealth applications. We can see that the results of items
1-5, 9, 15 and 16 of table 3 fall into the tracking and feedback
strategy and scored well. From the interviews it became clear
that the participants liked the idea to manage their
measurements and to receive feedback from the healthcare
provider. Items 12 and 13 also have to do with tracking but
are not directly aimed at blood glucose monitoring. Item 7,
which falls in the goal setting strategy, was less well received
and involved a statement about receiving awards when a
patient would achieve a certain goal. When asked later on
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In table 4 and 5 we can see the results of what type of re-
In future research a bigger population should be interviewed to make sure that a high level of relevance is achieved. Besides qualitative research, quantitative research should be done where participants are subjected to prototypes that can be improved upon every iteration.

As already mentioned by a participant, the age aspect should be taken very seriously, since big differences in needs may exist between age groups. Also gender should be taken into account, which was not done in this study.

Besides the strategies and the research population, future research should also focus on (self-learning) automated decision support on smartphones that are becoming more powerful in combination with smartwatches that are packed with all types of sensors. These devices are becoming more common and will result in situational- and context-aware solutions. These devices are particularly interesting for diabetics since it could e.g. detect what the exact relations are between food-intake, location, stress and cardio. Such a system could deliver exact feedback and could give more precise decision support and would be of great value for the healthcare professional.

The motivational aspect should also be investigated more profoundly. In the current study we asked what tone of voice the application and reminders should have, but to have a real added value it is necessary to motivate the patients over a longer period of time to control and maintain their HbA1c value, which eventually reduces complications in the future. Realizing that present glycemic control has consequences for their health in the future can be difficult for adolescents.

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Also we would like to thank the participants and their parents for their hospitality and the personnel of the Gelderse Vallei Hospital for their assistance.

9. ATTACHMENTS
See table I in the attached page.

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