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0 Preface

About the DaCHI technical report series

The present report series, published by the Danish Centre for Health Informatics (DaCHI), disseminates results of and experiences from research and development projects in health informatics. The reports are intended to present the materials as early as possible in the research and development process, thus making feedback to the authors possible. Therefore, each report is an essential element from the research and development idea to the final article's publication in an international, peer-reviewed journal. Consequently, the editorial committee also accepts manuscripts that do not present finished works. The suitability of the manuscripts as contributions to discussions is decisive, and the readers are invited to comment on and criticise the reports, either directly to the authors or through the editorial committee. If the committee finds the reports relevant, the DaCHI can publish supplements for and revised versions of already published reports. The state of a specific report and its following threads are accessible on the website www.dachi.dk. Through open and constructive criticisms from colleagues, it is possible to achieve the necessary quality of our work.

The present report

This technical report is part of a PhD project that investigated, explored and conceptualised the design of mobile learning technology for children and teenagers with type-1 diabetes by applying participatory design. Central to this project was a German diabetes summer camp as the site for the design, exploration and testing of the design concepts. The PhD project was framed within the maXi project, a Danish research project that experimented with a user-driven design of ICT supporting everyday living with the chronic illness diabetes. Creating participatory methods for patient participation and design concepts for digital diabetes practice were main results of the maXi project. Granted funds by the Danish Business Authority, the maXi project was a co-operative undertaking of Aalborg University, the Foundation Skagen-Helse and the Danish Technological Institute.

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1 Introduction

Carbohydrate counting is a daily and essential task for people with type-1 diabetes since it is the basis for calculating the required insulin doses. Carbohydrate counting means calculating the number of carbohydrates and consequently, the carbohydrate units (BE, KE, KHE[1]) in foods. Thus, different methods and tools can be used (Glasemann et al. 2010b). Adolescents with diabetes gradually have to learn these skills and tasks to become independent and responsible for self-managing their disease (Schilling et al. 2006).

A mobile game prototype ('the food quiz') addressing and providing a motivation for learning about carbohydrate counting (that is, estimation and calculation) was designed in a participatory design process involving youth with type-1 diabetes (Glasemann et al. 2010b; Glasemann et al. 2010a; Glasemann & Kanstrup 2010; Glasemann & Kanstrup 2011). During this process, a first, low-fidelity version of the prototype was explored with a small focus group in a German diabetes summer camp. Based on those results, the prototype was enhanced and redesigned to evaluate its usage and effect in a second iteration on the same campsite in the following summer of 2010.

This paper reports on the youth's experiences with and perceptions of the mobile learning game prototype, as well as their practices, skills and attitudes about carbohydrate counting during the summer camp in 2010. The study was based on quantitative and qualitative data collection. It intended to gain a comprehensive perspective on the carbohydrate-counting problem (in particular) and on the design of mobile learning games for youth with diabetes (in general).

1.1 Setting

The 'Food Quiz' prototype was designed for children and teenagers aged 10 years and older. The prototype test was evaluated in two setups. The first setup involved children aged 11.2 to 14.9 years as the primary user group (Group A). Those children were chosen from the two oldest summer camp groups[2]. The participants were allowed to use the prototype for four days in a row during their camp stay. Each participant had access to the game on a mobile phone for approximately two hours a day, such as during the afternoon nap time and other slots with free time. The children could decide on their own about the intensity of their use, as well as in which social context they wanted to use the game (co-operation or competition with campmates, contacting the nutrition specialist for help, and playing outdoors or indoors). In line with the camp philosophy of motivating camp participants and honouring their "good" behaviour, the camp organisation preferred us to use an official ranking system. Therefore, the game scores were summarised at the end of the day for each

[1] German standards for carbohydrate units: BE: Broteinheit (most commonly used) and KE/KHE: Kohlenhydrateinheit (less common)

[2] In the summer camp the children were assigned to one of six groups dependent on age and gender.

member and each team. The participants competed in teams of four[3] to have a final individual winner and a final team winner. Due to equipment limitations, the test was first performed with all boys for four days, followed by all girls.

An additional secondary reduced setup was designed for another user group (Group B), whose members ranged from 9.7[4] to 12.4 years old. This group had access to the prototype for two sessions, each lasting for about 40 minutes. The participants played the game in pairs, with the intention of helping each other. A dietician was present to give active support upon request.

2 Methods

For this study, quantitative and qualitative data collection (i.e., questionnaires, assessment tests, probes, as well as observations and informal conversation techniques) was combined to evaluate the youth's perceptions and experiences in testing the mobile learning game. Data was also collected to evaluate their practices and skills in carbohydrate counting.

2.1 Questionnaires

Four types of questionnaires were used to address different perspectives, that is, those of the youth and their parents, as well as the measurements before and after using the prototype. Table 2.1-1 presents the types of questionnaires and the received number of responses.

Table 2.1-1: Questionnaire types and participants

Type – Abbreviation	***Number of Considered Responses***
Parent – PQ	51[5] parents of children in Groups A and B
Initial – DIQ	28[6] children, male: 12, female: 16; 9.7 to 14.9 years old, Group A
Concluding – DCQa	27[7] children, male: 11, female: 16; 11.2 to 14.9 years old, Group A
Concluding – DCQb	12[8] children, all female; 9.7 to 12.4 years old, Group B

The questionnaire items were assigned to a Likert scale (1: I don't agree at all to 5: I totally agree; occurrences ranged from 1: never to 5: always). Additionally, yes/no items, multiple-choice questions and open-ended items were used for different purposes. The questionnaires were coded with unique identifiers to guarantee

[3] Teams were formed based on sleeping room assignments during the camp.
[4] It was only possible to involve whole camp groups for testing the prototype in the camp due to organisational reasons. Therefore, one girl under 10 (i.e., 9.7 years old) was involved.
[5] Out of 53, two parents were not present during the questionnaire evaluation.
[6] Out of 29, one child was unable to complete the questionnaire due to cognitive disabilities.
[7] Out of 29, one child was unable to complete the questionnaire, and another refused to fill out the questionnaire.
[8] Out of 24, the originally considered boys' group did not test the prototype due to disciplinary problems; consequently, the questionnaire was unnecessary.

anonymous data analysis and to allow comparison between the questionnaires and triangulation with other data sources.[9] For better readability, statistical numbers were rounded to the first digit after the decimal point for both the mean and the standard deviation. Percentages were rounded to integers.

2.1.1 Parent questionnaire (PQ)

Parents have the main responsibility for supporting their children in managing the disease in daily life. Therefore, the parents' views should complement the youth's views. The parent questionnaire (PQ) addressed practices, materials, the child's performance and the responsibility regarding carbohydrate counting. Furthermore, attitudes towards the prototype and learning games for diabetes in general were assessed. The PQ was handed out and collected during the check-in day, when the parents registered and brought their children to the camp.

2.1.2 Initial questionnaire (DIQ)

Insights about the everyday living of youth with diabetes in relation to carbohydrate counting are useful for understanding the participants' attitudes towards and reactions to the prototype. The initial questionnaire (DIQ) targeted the children who tested the prototype for a four-day period (Group A). It evaluated practices and materials and assessed the participants' self-evaluation in carbohydrate counting, with a focus on the calculation of nutrition panels. Additionally, it aimed to form a baseline of children's expectations about the prototype for practising and of their motivation in improving their skills. The children filled out the DIQ in a classroom session after listening to a short introduction about the prototype and its evaluation.

2.1.3 Concluding questionnaires (DCQa and DCQb)

The concluding questionnaire intended to evaluate the prototype use. Since the participants had used the prototype in two scenarios (Group A for four days and Group B for two sessions), the questionnaire was designed in two versions (DCQa for Group A and DCQb for Group B), acknowledging the intensity of usage and the reasonability for assessing learning effects. The questionnaire addressed self-evaluation and confidence in relation to motivation and learning, as well as perceptions about the prototype in relation to previous expectations and future usage. The children filled out the questionnaire in a classroom session.

2.2 Assessing carbohydrate-counting skills

Conducting the test about carbohydrate counting aimed to assess the participants' skills, in addition to the questionnaire items that focused on perceived confidence. According to Lave (1988), the assessment of numeracy in a math test is vague in relation to the actual practice and performance in real life. A comparative study shows that failure in a math test does not indicate lack of success in solving math problems

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[9] The parents agreed to give me access to specific demographic and personal data from the summer camp children's database (e.g., age and gender) to avoid the input of extra data.

in real-life situations (Lave 1988). According to Lave (1988), a test in a real-life situation would reflect the best insights into a person's practice in calculation and the tools that he or she uses. A staged situation could also be reasonable for assessing these skills. Acknowledging Lave's arguments, in combination with finding a feasible method for the camp, I chose a paper-based test that assessed the calculation of carbohydrate counting. I decided not to assess the basic math skills needed for nutrition tables, such as addition, multiplication, division and the rule of three. Instead, the test assessed the ability of applying these skills to real-life examples by visualising nutrition panels, which was thus context related in contrast to traditional math calculation tests. While the written calculation test is easy to conduct and time saving, its result can have some biases, including guessing, cheating, errors made in haste, and the test situation.

With a dietician's help, two tests and the setup were developed for the participants. The goal was to assess different aspects (i.e., rounding off, fractions and rule of proportion) of calculating carbohydrate units of food panels. In the beginning of the camp, a pilot test with six, 10-year-old boys (not part of test Group A or B) led to revisions in relation to the difficulty level (making questions easier) and the setup (skipping the use of the calculator). Table 2.2-2 presents the two types of tests, as well as the numbers and age ranges of the participants.

Table 2.2-2: Types of carbohydrate-counting assessments and participants

Type – Abbreviation	*Considered responses (of assumed responses)*
Initial – DIA	53 children, 9.7–14.9 years old, Groups A and B
Concluding – DCA	24[10] (of 29) children, 11.2–14.9 years old, Group A

2.2.1 Initial assessment (DIA)

Based on the pilot test, it was decided that only the two camp groups with the oldest participants (forming test Group A) would be assessed since most of the younger participants between 10 and 12 years old did not seem to handle carbohydrate counting on their own yet. The paper-based initial assessment (DIA) was handed out to the participants in a group session. It contained two introductory questions, as well as eight questions about calculating the carbohydrate contents of food panels. The test was assessed, and individual interviews were conducted with those participants whose performance revealed a lack of clarity according to skills (missing the written approach). The results were rated based on a predefined scheme of points; a level was defined by using a range between level 0 (no knowledge at all) and level 3 (can do all calculations).

[10] Out of 29, one male refused to take part, another male was excluded because of very low cognitive abilities, one female had a very high blood glucose level during the test, and one female and one male were absent during the assessment.

2.2.2 Concluding assessment (DCA)

The concluding assessment (DCA) was conducted individually with the participants to assess their understanding of the calculation approach. A paper-based sheet containing two carbohydrate calculation tasks (similar to DIA) was used. The children were asked to explain their calculations. The results were rated by assigning a level similar to DIA. Measuring the prototype's effect on improving skills was done with reservation since the tests (DIA and DCA) were not similar. Furthermore, learning about carbohydrate counting also happened during the camp, independent of the prototype use. The concluding test was only conducted with Group A since Group B used the prototype only for two sessions, with limited learning content based on their individual maturity in calculation.

2.3 Probes (DPro)

The probe technique (Gaver et al. 2004; Tsvyatkova & Storni 2014) was chosen to obtain the daily feedback at the end of day 1, day 2 and day 3 during the four-day prototype test. It should complement DIQ and DCQ, which where used before and after the intervention. In this regard, an open casual format encouraged the participants to articulate their perceptions by composing messages with the prompt statement: "Describe your experiences today with the game! Dear …,". The participants should imagine writing to special addressees, for example, day 1: to their parents or best friend, day 2: to a friend or a person with diabetes and day 3: to the dietician or the doctor. Probes (DPro) were offered in a postcard format with the task and addressees. They should put their postcards back into the post box dummy. Alternatively, the participants were allowed to use a mobile phone to record an audio or a video message instead of writing postcards. For the data analysis, the answers to the probes were coded, focusing on the aspects and levels of motivation and learning. Additionally, redesign implications were extracted.

Table 2.3-3: Overview of feedback with probes, types, gender, time and content

***Total* (m/f)**	***Day 1* (m/f)**	***Day 2* (m/f)**	***Day 3* (m/f)**	***Types of probes (m/f)***	***Aspects mentioned in probes***
46 (18/28)	29 (13/16)	12 (2/10)	5 (3/2)	29 (18/11) postcards 17 (0/17) digital messages	42 motivation 22 learning

Table 2.3-3 presents the number of received messages. In total, the participants created 29 postcards and 17 audio or video messages, with their feedback on the prototype. Female participants favoured digital messages while males preferred postcards; the males were also less inclined to give feedback in comparison to females. Furthermore, the number of feedback on the probes decreased day-to-day.

2.4 Observations and informal conversations (DObsCon)

Besides scheduled and controlled activities, the camp setting supported the observation of the participants' reactions when using the prototype. Additionally, the participants discussed and articulated themes about carbohydrate counting during informal and spontaneous conversations. Important aspects of the observations and conversations (DObsCon) were logged and coded for analysis to complement the quantitative data.

3 Results

The results of the evaluation aim to contribute to the understanding of the youth with diabetes, including their practices, attitudes and perceptions, as well as to provide some implications for the design and redesign of learning games that address carbohydrate counting. The analysis primarily focuses on the questionnaires and carbohydrate-counting assessments but is complemented by the results from the qualitative data where appropriate.

3.1 Current practices, sources and tools

This section gives an overview about the practices, sources and tools used in relation to carbohydrate counting. The information highlights previous design decisions, helps identify the distinct characteristics of the user group and re-examines learning content for potential enhancements of the prototype.

3.1.1 Terms and ranges

The findings during the previous prototype exploration in 2009 pointed towards a diversity of practices and standards in carbohydrate counting while the concrete derivation and affordances remained vague due to the focus on qualitative data collection (Glasemann et al. 2010b),. Therefore, the items of the questionnaires (PQ, DIQ) investigated the usage of terms and ranges.

Three competitive diabetes standards that combine terms and ranges are commonly used in Germany (i.e., BE = 12 g, BE = 10–12 g and KE/KHE = 10 g). The term 'BE', also used in the prototype, is most often used (PQ, 92%) in practice. In relation to range, some children explicitly pointed (DObsCon, DPro) to the need for calculating with specific values when giving feedback on the prototype use, instead of the given range of 10–12 g. Some families even used term–range combinations that differed from the three standards, highlighting the adoption of their own practices. Comparing the specifications of the parents and their children (PQ, DIQ) showed that 39% of the children (mostly below 12 years old) differed from their parents.[11] The reason might be these young children's minimal awareness of calculation practices.

The findings support the choice to set up the default term and range (BE: 10–12 g) for the prototype since these fit the usage of the majority of families. Furthermore, the

[11] The children specified opposite ranges, did not state any range or gave invalid answers. A bias was caused by different item styles; the parents (PQ) could select among different options, while the youth (DIQ) had to fill out a text field.

results emphasise the importance of a flexible setup that differs from the standard to facilitate inclusiveness and learning that are adapted to individual needs. At the same time, this issue points out the limits in finding common right and wrong approaches and the comparability of the results among the learners in the camp context.

3.1.2 Tools and resources

The participants were using different tools and applying different practices for counting carbohydrates in their daily lives. A BE scale is a tool that calculates carbohydrate units based on food weight and food classification. The parents stated that this tool was not commonly used in families (PQ, 77%: never). The calculator, another device to ease calculation, was fairly used (23%: often or always). As a potential source of carbohydrate information on food products, the Internet was rarely used (64%: never, 6%: often or always).[12] In contrast, 60% of the respondents answered that mental abilities (i.e., remembering, estimating and calculating carbohydrate units) were often or always used. A reason might be that acquired skills are in practice faster to use after having gained certain capabilities and experiences than using supportive tools (i.e., a BE scale, a calculator, the Internet).

In the DIQ, the use of practices and tools in relation to calculating carbohydrate units was assessed for two scenarios – at home and on the move. The items "only estimate",[13] "eating something different" or "call parents" point to alternative solutions yet indicate that calculation can be a challenge for some youth. For example, 22% of the participants stated that they often or always "only estimate[d]" when eating packaged food with food panels outside their homes. The participants stated that mental arithmetic was used most frequently (mean at home/on the move: 3.7/3.5, std[14]: 0.9) as opposed to the use of tools such as a calculator, a BE table[15] or paper. Relating the usage of tools to the assessment results (DIA, cf. 3.2.3) showed that mental arithmetic was used less often by the youth who lacked calculation skills (mean at home/on the move[16]: 3.2/3.1, std: 0.9) in comparison to those with high scores in the DIA (mean: 4.1/3.8, std: 0.7/0.8). In contrast, choosing another solution, that is, "eating something different" was used more frequently by the youth who lacked calculation skills (mean: 2.2/2.3, std: 1.3 vs. mean: 1.8/1.2, std. 1.1) though on average, the frequency was low in both groups.[17]

Choosing alternative solutions when lacking skills is positive since it shows the

[12] The data referred to 2010. Usage has now potentially increased due to better Internet accessibility, particularly on mobile phones.

[13] Carbohydrate units can be determined exactly by calculating based on food panel information. Estimation of food (e.g., without using the information on panels) avoids calculation though correct estimation depends on the person's experiences, skills and competencies.

[14] Std: standard deviation

[15] Look-up tables for carbohydrate units do support estimation and calculation of carbohydrate units in foods without nutrition panels.

[16] The skills in carbohydrate counting based on food panels were classified into levels, from Level 3 = can do all calculations correctly to Level 0 = no skills shown at all. Here, the youth were divided into two groups: Level 3 vs. lower than Level 3.

[17] 1 = never, 2 = sometimes

youth's awareness of the situation. However, it could also limit the youth's freedom of activity, such as being forced to eat something different or replacing calculation by estimating the food's carbohydrate content. This finding supports the chosen approach of promoting the acquisition of carbohydrate-counting skills. The design of tools for substituting estimation or calculation would be an alternative path that was not the focus of my study.

3.1.3 Education

According to their parents (PQ), 26% of the children participated in the lessons about carbohydrates during a previous summer camp, while many were taught during a hospital stay or a rehabilitation treatment (42%). Around 17% reported that diabetes or nutrition specialists taught their children, while 13% stated none, and 2% indicated other sources of education.

Carbohydrate education mainly concerned general topics about food, such as the food pyramid and nutrition (DIQ, 79%). Lessons about estimation were more often taught (89%) than calculation (64%) or looking up the amount of carbohydrates (25%). None of the participants was ever taught about how to use the Internet for carbohydrate counting. About one-third of the respondents knew non-digital games about diabetes, but none of them knew digital games.

The findings support the qualitative findings in previous camps that calculation in carbohydrate counting gains little attention in comparison to teaching about estimation. The prototype seems to be a valuable add-on to focus on calculation. It seems reasonable to study settings and usage scenarios other than camps since teaching about carbohydrate counting takes place not only in camps. It is also essential to consider that formal teaching is not the only resource to learn about carbohydrate counting since parents also play a role in training their children to acquire skills and to gradually take over the tasks. Nonetheless, in the PQ's open-text items, the parents stated the value of tools that allowed their kids to learn and practise independently from them.

3.2 Responsibility, confidence and skills in carbohydrate counting

Different questionnaire items (DIQ) assessed the children's responsibility for and confidence in carbohydrate counting. Additionally, their skills were evaluated in relation to calculating carbohydrate units on food panels (DIA).

3.2.1 Responsibility

The relation between age/maturity and responsibility for different diabetes tasks is stated in the literature (Schilling et al. 2006), which is supported by this study's findings. The parents reported that their children were more likely to become responsible for carbohydrate counting on their own as they grow older (PQ, 27%: aged 10, 25%: aged 11, 71%: aged 12).

These numbers indicate that carbohydrate-counting skills are transferred early from parents to children. Introducing the prototype to children at the age of 10 or 11 (when appropriate math skills are acquired in school) seems reasonable (also compared to the parents' opinions expressed in the PQ). However, it should be handled carefully, depending on individual maturity and interest, to avoid overburdening the children.

3.2.2 Confidence

The parents rated their children's confidence in carbohydrate counting (PQ), while the children rated their own confidence (DIQ). Both children and parents ranked the confidence in estimation lower than in calculation on average (mean estimation/calculation of children in Group A: 3.7/3.9, mean of parents of children in Group A: 3.4/4.0, mean of parents of children in Groups A and B: 3.3/3.7, std: 0.9 to 1.2).

An item evaluated the youth's perception of difficulties in estimation and in calculation. On average, the difficulty level[18] was ranked higher for estimation than for calculation (mean estimation/calculation: 2.3/1.8, std: 1.1/1.1). Even higher levels of difficulty were reported by the youth lacking carbohydrate-counting calculation skills[19] (mean estimation/calculation: 2.8/2.6, std: 1.1/1.3) in comparison to youth showing very good skills (mean estimation/calculation: 1.9/1.2, std: 0.9/0.4).

The process of estimation seems to be a difficult activity, even for those living with diabetes for years. In comparison, it can be assumed that once the calculation approach is understood, the youth's ability and confidence is increased.

3.2.3 Skills

The ability to calculate carbohydrates was related to the children's age; the older they were, the better their skills were in calculation, as assessed in the DIA.[20] Within Group A, 59% of the youth already had very good carbohydrate-counting skills, according to the assessment test. However, 21% of the teenagers (13 years and older) seemed to have difficulties in calculating (50% of this group seemed to lack even basic skills). Around 71% of the 12-year-old children showed difficulties in counting from nutrition panels in the test.[21] Approximately 10% of the 10- and 11-year-old children showed very good calculation skills, and another 10% showed good calculation skills, according to the DIA.

Assuming the validity of the assessment data, these findings support the fact that children are able to take over the responsibility of counting carbohydrates, depending on their age (Schilling et al. 2006). A minority of the younger kids showed maturity in calculation, whereas a minority of the older children lacked (partly even basic) skills.

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[18] "I find it difficult to estimate food."/"I find it difficult the calulate the BE of food with nutrition panels difficult.", 5 = I total agree, 1 = I do not agree at all

[19] Levels 3 (skilled in carbohydrate counting) vs. levels lower than 3, i.e. Level 0 to 2 (lacking skills) according to DIA

[20] Pearson correlation: 0.600 (age in relation to received points in the assessment). Correlation is significant at the 0.01 level (2-tailed).

[21] Levels lower than 3 (i.e. Level 0 to 2)

The results showed that the participants who used the prototype for four days were already very skilled, which affected the results differently than selecting participants by their skills. When intending to improve skills in calculating carbohydrates with the help of the learning game, the data indicate that the focus should be on 12-year-old children and younger. Nevertheless, the game emphasises not only obtaining correct calculation results but also teaching easier ways of calculation and estimation practices, both not assessed in the DIA.

3.3 Expectations and motives for digital diabetes learning games

The expectations for the food quiz were evaluated from both the parents' and the youth's perspectives (PQ, DIA). In this regard, the questionnaires contained scales of usefulness and interest, as well as open-text items related to motives.

3.3.1 Usefulness of and interest in the game

Most parents considered the prototype useful for their children (PQ, 71% estimation, 73% calculation: agree or totally agree). Approximately 77% of the parents who disagreed or were undecided had children with very good calculation skills (DIA). In the PQ, the item aimed to find out the parents' views about the usefulness [22] of their children playing the game. Asking about usefulness did not seem to be age-appropriate for the children. Therefore, in the DIQ, the children were asked to rate their interest[23] in playing a game about carbohydrate counting.

Around 50% of the children in Group A, who lacked calculation skills, were interested in practising calculation with the game, while 17% were undecided, and 33% disagreed or were not interested at all. The perceived usefulness of or interest in estimation was ranked higher in comparison to calculation (mean of all parents on usefulness estimation/calculation: 4.0/3.9, mean of parents of children in Group A on usefulness estimation/calculation: 3.6/3.5, mean of children in Group A on interest in estimation/calculation: 3.3/3.1, std: 0.9 to 1.1).

The qualitative arguments highlighted why parents considered the prototype either useful or not useful for their children (cf. Table 7-4). Nineteen positive responses could be classified in relation to improvement of skills, repetition/assessment, confidence/responsibility and motivation. Training in and practising carbohydrate counting with the game were viewed as possibilities for increasing responsibility, confidence and independence ("to be more independent and more responsible" and "confidence in use → better blood glucose values"). Motivation was regarded as an argument for learning with an educational game ("He likes to learn through play."). Even when the children already possessed the skills, the usefulness of practising was still emphasised ("to be more sensitive about how many BE units are in fast food, which one (supposedly) knows").

[22] "I think it would be useful for my daughter to play a game about BE estimation."/ "I think it would be useful for my daughter to play a game about BE calculation."

[23] "I'd like to play a game about BE estimation/ "I'd like to play a game about BE calculation."

Five responses that expressed reservations about the usefulness of the prototype were given by the parents of the children who already possessed skills and by the parents who questioned the added value of the game. Two of those parents missed the additional fun elements ("She would consider the game maybe too boring. Maybe the content should be more wrapped into a game scenery [to be] more attractive for [a] teenager."). Besides, the mobile phone as an inadequate medium and reservations about the content were stated as "cons" once.

Similar to their parents, the youth gave 11 positive comments on their interest in playing, related to increasing their skills and confidence through practice, as well as to motivated learning (e.g., "maybe an easier approach to calculation", and "because you can learn better while gaming"). Seven arguments were given regarding their lack of interest due to existing skills (e.g., "NP[24]: I have other things to do!"). However, some children who lacked skills[25] also expressed no interest in the game (e.g., "I do not need this."). Another statement referred to the difficulties in predicting the interest beforehand but showed an open attitude towards testing (cf. Table 7-4).

3.3.2 Motives for usage

The motives for playing the game were evaluated (DIQ). The youth expressed the highest motivation for improving their skills[26] (mean: 3.6; std: 1.1), followed by the items about practising[27] (mean: 3.3, std: 1.2), playing on a mobile phone[28] (mean: 3.1, std: 1.1), and using the mobile phone[29] (mean: 3.0, std: 1.6). Open-text comments (cf. Table 7-4) in relation to other motives were positive (e.g., "Learning in a game is fun", "I like to be knowledgeable on diabetes issues" and "because I am often wrong [in carbohydrate counting]").

These responses showed commitment to self-management norms (improving and practising) to a certain extent although a diversity of opinions existed, most likely caused by different attitudes and skills.

3.3.3 Attitudes toward learning games about diabetes in general

An additional item in the PQ addressed the general opinion on learning games about diabetes[30]; 12% of the given answers noted the parents' difficulty in giving their opinions on this issue. A reason might be that the parents did not feel capable about judging how interested or not interested their children would be to play the game. Another reason could also be their inability to imagine practically how such a game would look like. Approximately 6% of the answers expressed reservations about the concept, such as by calling this way of learning "tomfoolery". Another parent had

[24] NP: acronym for "no plan"
[25] According to DIA, level 0 to 2
[26] "I like to be better in carbohydrate counting", on a scale from 1.0 = don't agree at all to 5 = I totally agree)
[27] "I like to practise."
[28] "I like to play [the game] on a mobile phone."
[29] "I like to use the mobile."; the use of mobiles (e.g. to call parents) was only allowed during specific hours during the day
[30] "How do you evaluate the use of digital learning games in diabetes education in general?"

higher expectations for the playability of learning games than she could observe in the suggested prototype ("The raw learning content has to be delivered [in an] interesting [manner]; otherwise, one will not be motivated to engage."). A third parent stated that it was "very much dependent on the person".

Nonetheless, 74% of all answers were positive. Besides short answers, including "positive", "useful" and "important", a range of specific reasons was given, in which the parents underlined the importance of supporting beginners. The need for continuous learning was also emphasised for the specific topic of carbohydrate counting by pointing out the importance of overcoming carbohydrate "blindness".[31] Other parents emphasised the contemporary and motivating aspect of learning technology for diabetes education as particularly relevant for the adolescent age group, thus referring to the youth's identity and modern way of learning. "I like the idea because it fits the spirit of the times and this generation" (cf. Table 7-4). In summary, most of the parents were positive about learning games about diabetes for various reasons.

3.4 Impact of the game

The effects of using the prototype were evaluated in different items of the DCQ. These included items related to fun in general, the interest in estimation and in calculation, experienced improvements, as well as the prototype's prospective use. Additionally, the results of the DCA, the DPro and the DObsCon complement the questionnaire results for an overall understanding on the youth's perceptions and experiences with the prototype.

3.4.1 Fun and amusement

Both the general fun[32] and amusement[33] in relation to the two game sections (that is, estimation and calculation) were evaluated in the DCQ (Groups A and B, mean fun/estimation/calculation: 4.1/4.1/3.9, std: 0.9 to 1.0). Having used the prototype for only two sessions, Group B was more positive about the prototype (mean fun/estimation/calculation: 5.0/5.0/4.6, std: 0.0/0.0/0.5). In contrast, having used the prototype for four days, the older participants (Group A) showed high deviations (mean fun/estimation/calculation: 3.8/3.7/3.6, std: 0.9/0.8/1.0). Both groups rated the calculation part a little less amusing in contrast to estimation, which might be due to the more demanding calculation tasks. This made it more difficult to succeed in this part of the game in comparison to estimating and remembering carbohydrate units from pictures.

The qualitative data from the DPro and the DObsCon revealed the course of perceptions during the four days of usage. The participants with more than one-time feedback on probes foremost articulated a stable and high level of motivation when

[31] Due to wrong practices occurring over time
[32] "I think the game was fun overall."
[33] "I found the estimation/calculation quiz games amusing."

compared across the days. The initial high level of motivation experienced on day 1 decreased with the repletion of using the prototype. The attributes expressed in DPro changed from "funny" and "unique" to "boring when played every day". A certain disillusionment with the game to remain entertaining was observed. Particularly, with the children who had extensively used the prototype and already reached all game levels. While some of those children continued repeating levels to compete against others in beating their high scores, others decreased their intensity of use (DObsCon).

3.4.2 Practices

The kids' motivation to practise carbohydrate counting was assessed.[34] Their attitudes were primarily positive towards practising estimation/calculation (mean: 4.3/3.9, std: 0.8/1.2). Again, calculation was rated lower on average with a high deviation, pointing out the challenges with this topic.

3.4.3 Improvements and confidence

The children were asked to indicate whether they thought they did learn something by having played the game.[35] About three-quarters of the children (71%[36] in Group A, 80% of the children in both groups) noticed a learning gain in estimation (agreed or totally agreed); two-thirds noticed a learning gain in calculation (61% in Group A, 65% in both groups). Some children (of Group A) did not think that they learned more (three participants partly disagreed on estimation, while seven participants partly disagreed or did not agree at all on calculation). Six of the seven children already possessed very good skills in the initial assessment (DIA). The children[37] cited different issues about what they learned in the free text. The 16 given answers could be categorised as follows: a) general improvements in carbohydrate counting (being better in estimation and/or calculation), b) specific improvements in relation to unknown or specific foods, c) awareness of existing assumptions/practices (e.g., food has more BE content than assumed) and d) (new) approaches to calculation (cf. Table 7-4). The categories a) and c) were also found in the feedback of the DPro.

Around 50% of the participants in Group A expressed constant confidence before and after the prototype use, 35% felt more confident, and 14% admitted reduced confidence in calculation. Figure 7-1 presents a graphical overview of the level of confidence experienced before and after intervention, and the increase in forming a positive attitude.

In summary, a majority of the participants believed that they had learned something new and that they were better in estimation/calculation. Some children did not feel that they had learned something new, which was caused by either their initial good skills or the barriers to learning by using the game (both motivational and learning

[34] "I liked to practise estimation/calculation with the help of the game."
[35] "I have learned something about the estimation of carbohydrate units"/"… calculation of carbohydrate units."
[36] Since the frequency of using the game was very different in Groups A and B, the results were considered for Group A and in total for Groups A and B.
[37] This item was not chosen for Group B since the participants used the game only for two sessions.

challenges). These effects were supported by the results of the assessment test (cf. next section).

3.4.4 Assessing improvements in skills

To find indications about improvements of skills, the initial and concluding assessments for Group A were compared (DIA, DCA). Five participants (four of them with levels 0 to 2) could not participate in the concluding assessment. All participants maintained or increased their skill levels; 52% already had very good skills in the initial assessment. Other participants (28%) showed an increase in the level of their skills in calculating carbohydrates. Compared to the items of experienced learning and improvements, the assessment test was in this sense limited since it did not investigate easier or faster ways of calculation, which could lead to the feeling of improvement.
Estimation skills were not assessed during my study since the camp teachers were assessing the participants' estimation skills during each camp. The teacher responsible for the test noticed subjectively higher sensibilities and skills related to estimation. In her view, using the game caused these results.

3.4.5 Prospective use of the game

Different items in the DCQ addressed the children's view of the game in relation to its prospective use, that is, considering it as valuable for themselves or for others.

The children highly agreed about recommending the game to other children with diabetes who were not that knowledgeable in carbohydrate counting (mean: 4.5, std: 0.8) or to a friend with diabetes (mean: 3.8, std: 1.3). They agreed that the game should be used in diabetes teaching sessions (mean: 4.1, 1.1) and that they wish more diabetes games (mean: 4.3, std: 1.1). There was a difference between the groups A and B whether the participants liked to have the game on their mobile phones (mean all groups: 3.7, std: 1.4, mean Group A: 3.2, std: 1.3, mean Group B: 5.0, std: 0.0) and about their wish to play the game in the camp again (mean all groups: 3.6, std: 1.3, mean Group A: 3.1, std: 1.2, mean Group B: 4.8, std: 0.9).

In summary, all items within this category indicated a rather high diversity of opinions among the participants. The majority of the kids had positive perceptions of the game. Even when some youth might have experienced the game as not useful for themselves or considered it enough to have tried it, they were often positive about it.

The results of a free-text item (of the DCQ) indicated what participants liked about the game in particular. Their answers could be categorised as follows: a) general positive feedback, b) mobile game as a motivator to learn, c) appreciating the opportunity for practising, as well as for acquiring skills and confidence and d) highlighting specific features of the game (cf. Table 7-4). The same categories a) to d) were also found in the feedback of the DPro.

3.4.6 Constructive learning by creating own content or playing together

During the camp, the participants of Group A could choose the opportunity to take part in a session about designing a game level for the prototype. The idea of involving children in the creation of the learning material fits the concept of active learning through participation based on their own experiences (Piaget 1953; Papert 1991).

An item in DCQa assessed the children's interest in creating their own levels. The activity comprised 1) researching for and creating content, 2) preparing the content on the computer and transferring it to the mobile phone and 3) testing the game level. While not all children participated in the activity, most liked the idea of creating content for others. The reasons for their interest were as follows: a) helping and challenging others to learn, b) the fact of creating their own content and c) thinking that creating new levels would challenge them as well. Six of the children did not like the idea of creating their own levels (two of them participated in the session) because they considered it boring or too time consuming. The concept seemed to have the potential to engage and challenge some, but not all, children.

Group B played the game in pairs. Although the healthcare consultants had selected compatible pairs, playing in pairs could not lead to positive experiences in all cases. Half of the children had neutral or negative comments ("dump"). The other half of the participants liked to play together and even realised the benefit of learning together ("We could help each other."). The qualitative data showed that the participants in Group A explicitly welcomed the possibility of collaboration although this was given only as an optional setup.

Learning individually or in groups, as well as the experience of learning together with others, seemed to be matters of individual preference. Similar results were observed in camp 2 in the dragon quest game (Glasemann et al. 2010a).

3.5 Implications from the user perspective

A free-text item about what the children did not like about the game and an item about any comments or ideas they had in general could be used to investigate the constraints of the prototype, as well as to find implications for improving the prototype to have a more mature game design. Once more, the diversity of the user group became obvious, represented by varying perceptions in relation to learning and motivation, for example, ranging from the children who were too challenged to those who were not challenged at all with the game ("There, you have to calculate so much" vs. "[…] it is very easy"). The prototype in camp 3 was elaborated on and particularly enhanced with more levels in comparison to that in camp 2. Nevertheless, some of the children were able to attain the highest level of the prototype (200 different tasks and 12 levels) and consequently, after they played it several times, experienced it as being too short and with time boring (e.g., "The game is slowly getting boring. Nevertheless, I have won 15,000 points! I have learned a lot already."). Suggestions for improvements were made in relation to more content and levels, as well as more features focusing on motivation, such as in terms of competition, fun elements and characters similar to the suggestions evaluated in camp 2.

Reusing the game as a tool was perceived as useful (DCQ, "[…] one could create a table where you can see and learn how much BE is in the food; when there is no time for playing, then you can just look it up.") in supporting everyday life on the move. Enthusiasm about the game in relation to presentation skills and pride was recognisable in the quote of a ten-year-old child, who claimed that she would use it also in the future outside the camp ("I would like to have it on my mobile, and I would recommend it because the game is really super. You can learn something new, and you can show it to a friend, how good you are […]."[38]).

4 Discussion and Reflection

The evaluation intended to give a broad overview of the youth's practices, skills and attitudes towards carbohydrate counting, as well as their perceptions of a mobile learning game. In the following sections, I discuss the results to summarise and reflect on the themes relating to the prototype game and to the youth, as well as to draw conclusions about the design and redesign implications. Finally, I reflect on the used methods, particularly on using quantitative data.

4.1 Trigger of prototype design

The chosen design (both the software and the setup) triggered diverse and partly critical reactions concerning the prototype's fidelity, the youth's expectations for games and the involvement of a broad user group (in terms of age range, skills and attitudes). Themes emerged, reflecting on how the design provoked perceptions. I consider these findings important in the iterative design process, allowing a deeper understanding of the youth and enriching future designs towards more concrete and mature specifications.

4.1.1 Low fidelity

Some diabetes research projects have taken the challenge to acknowledge the increasing demands of the sophisticated audience by investing several years and involving an interdisciplinary design team for high-fidelity games (Baranowski et al. 2008; Lieberman 2012). They are endeavouring to create video games focusing on learning and seriousness that have an entertainment value and are not boring. However, creating a game with a high entertainment value does not guarantee that players will not alienate themselves from the game (Buday et al. 2012).

The designed prototype for my study was mature enough to be used in a real learning scenario although its fidelity and design were simplistic and far different from commercial mobile or computer video games. Consequently, in prototype iteration 1 (in camp iteration 2, in 2009), the participants articulated high expectations for gaming (Glasemann et al. 2010b). Those were only considered to a certain extent for the prototype test in 2010. This was due to the focus on learning in the research project and being aware that my design could not compete with games on the market.

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[38] Group B, DIA level 0

The participants’ experiences in other games and the low-fidelity prototype might, to a certain degree, have influenced their ratings and motivations about the prototype and attitudes for prospective use. Nonetheless, a range of positive feedback on the prototype indicates that high fidelity or high playability is not always presumed as long as the game has a specific value for the individual.

4.1.2 Extensive use

With its concept of a mini game, the prototype was designed for brief, casual use. The test setting (group dynamics, access to the mobile for hours) provoked extensive use of the prototype. An initial very high motivation of using the game turned into trying to reach the limits and partly to overuse. This led to the users expectations for more complexity, higher levels and variety, which the prototype could not offer. In turn this constrained motivation. This finding becomes obvious when comparing the results of Groups A and B, which used the prototype with different intensity levels (for four days vs. for two sessions), as shown in section 3. The critical claims can be regarded as adding value to the design process since they reflect motivation and engagement, having tested the limits of the prototype and articulating the demand for extending it towards a mature software solution. In this respect, all kinds of feedback are valuable.

4.1.3 Neglecting or respecting motivation and maturity

Buday et al. (2012) claim that research-driven games are particularly at risk of being designed for the wrong participants and causing alienation of players. The prototype results support this statement since a number of participants considered nonsensical the need for learning about carbohydrates by using the game (cf. section 3.4). This effect was provoked through the research design process. I involved a diverse and broad group of youth living with diabetes, independent of their initial motivations and skills in carbohydrate counting, to investigate the “fits-all” perspective and to gain future insights into narrowing the user group. In this respect, different and also critical attitudes and perceptions about using a mobile game for learning about carbohydrate counting were articulated.

The evaluation revealed that the participants who initially had critical views valued the game and/or showed improvements in the post-measurements. In contrast, some initially engaged users’ expectations for the game could not be fulfilled. Nonetheless, the context of using the game – that is, group dynamics and group persuasion, the camp setting, interventions and the players’ medical status – could influence their attitudes before, during and after playing the game.

In this regard, defining the right users/participants of a game that is provided as an intervention reveals constraints and challenges. One important aspect is eliminating the risk of harm. While the prototype in itself allows it to be adapted to individual needs, it primarily focuses on numbers and carbohydrate-counting skills. Particularly, it should be considered to what extent the youth with dyscalculia, ADHD,[39] mental disabilities or huge motivational challenges could benefit from being included and participating in such an intervention and not feeling overly confident about these skills. Introducing the game in the educational context requires the healthcare educators to be sensitive about the kids' attitudes and skills and the learning setting to find the best learning scenario for a group and for each individual.

4.2 Adding value

Within the diversity of perceptions about the prototype, a range of opportunities and added values became apparent.

4.2.1 Different values for individual needs

The participants individually consider and value the prototype, depending on their different backgrounds (i.e., motivations, age and skills) and needs. Therefore, the prototype (and the learning setting) was claimed to be a valuable tool in various ways, as follows:

- to support initial learning,
- to allow upgrading of existing skills (e.g., the method of calculation),
- to support repetition and practice to overcome wrong routines (e.g., countering carbohydrate-counting blindness),
- to support individual learning paths and pace,
- to assess and validate current skills,
- to support informal learning and to integrate it into daily life,
- to motivate the user and overcome learning barriers (due to facilitated social interaction and the digital game features),
- to positively influence identity building (such as having enthusiasm and pride about the game and presentation skills) and
- to acknowledge individuality and to facilitate inclusiveness (e.g., respecting different levels of skills and competencies).

Considering these benefits, the evaluation showed the prototype as valuable for much more than supporting learning.

4.2.2 Broadening the solution space

The practices of families with youth with diabetes showed that mental math was used more frequently and seemed more feasible than supportive tools (e.g., calculator and look-up tables). One design direction could have been to design more adequate supportive tools on which people can rely, thus reducing their burden. However, the evaluation showed that addressing the learning and skill perspectives would be an opportunity to broaden the solution space. The prototype has shown its potential to support the youth on the path of becoming gradually more independent. Thus, it expands the possibilities of solutions to choose from.

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[39] ADHD: attention deficit hyperactivity disorder

4.2.3 Short time span within a lifelong process

Children with type-1 diabetes manage their disease, supported by their families and healthcare specialists. With increasing maturity, they adopt practices and exercise the responsibility for self-management (Schilling, Grey, & Knafl 2002). Learning mainly occurs in an informal and situated context, while formal teaching (such as camp interventions or diabetes lessons) also plays an important role. Even in adulthood, the lifelong learning and coping process continuously adopts a management regime towards the medical ideals (Garner & Thompson 1978; Saucier & Clark 1993).

Even the carbohydrate-counting topic, as one of the fundamental tasks in diabetes management, has shown to be continuously relevant and not only for newly diagnosed people. However, an essential reflection is that in contrast to other crucial tools needed on a daily basis (such as the insulin pump and the blood glucose meter), learning about carbohydrate counting and its supporting tool is relevant only from time to time and just for short periods during a person's life with diabetes.

With its mini games, the "Food Quiz" promotes casual usage and micro learning spaces. Participants and parents consider the prototype an adequate tool at different and short time spans within a lifelong coping and learning process with diabetes, once carbohydrate counting is in focus (i.e., initial learning and repetition).

The evaluation has shown that the prototype can bridge the gap between informal and formal learning and addresses not only aspects of learning, but also motivation, inclusiveness and identity building. One future design direction could focus on how such a game could be used and integrated into daily life at home.

4.3 Sharpening the learning design

The prototype evaluation revealed a range of values, as well as of limits and constraints. These should be considered for the redesign of specific aspects of the prototype and for reframing the educational setting, that is, the selection of users and usage setting.

The following implications and challenges arose when the game was used within a health intervention such as in a camp:

- Defining the game usage as an obligatory intervention, independent of motivation and skills, affects the acceptance level of using the prototype. Nonetheless, the youth's liberty and ability to decide about participation on their own should be critically investigated (obligatory intervention vs. opportunity for learning).
- Including specific participants only (e.g., based on skills, on motivation) affects group dynamics in the camp setting, as well as the individual participants' motivation (honour vs. duty to learn with mobile games, inclusiveness vs. overburden and group pressure).
- Individual practices and backgrounds require adapting learning goals and

learning content to the specific needs of the individual youth. This issue points out the limits in finding common right or wrong approaches and the comparability of the results, as well as social interactions among the learners.

- Children aged 10 to 12 years old are revealed as the most relevant user group for the designed prototype. They seem to gain the most benefits from learning with the prototype in terms of acquiring initial skills and they have a high motivation to learn. Nevertheless, their readiness and maturity in being able to cope with this issue should be considered. Since often, teenagers starting at 13 years old have already acquired good skills, the focus should be on refreshing and assessing these skills with a different learning scenario than those needing initial learning. It is not always possible to rectify already existing incorrect practises. Generally, it seems difficult to encourage a proper attitude towards learning during the teen years and this can hinder successful involvement.
- Selecting participants only by age seems inadequate. The game itself could be used for assessing existing skills to define the learning focus and scenarios about carbohydrate counting.

The prototype game has shown its strength in being an adequate tool for adapting to learners' individual needs. It has both the potential for motivating users and for creating barriers when the prototype is used in a social context with peers. Sensitivity towards this issue is needed. Other learning settings, such as using the prototype at home or in individual sessions with a healthcare educator or a dietician, might be alternative paths of investigation. In all respects, the prototype should not be regarded as an isolated tool, but the learning design should be considered in terms of facilitated assistance and discussions and how it integrates into the self-management routines and processes.

4.4 Reflections on methods

In the following sections, I reflect on the data collection setup (time, user group and types) and on the role of quantitative data in my mainly qualitative study.

4.4.1 A broad user group

The evaluation involved a broad group of participants, independent of their carbohydrate-counting skills and of their motivation in considering the game relevant for learning. This approach allowed depicting the overall perspective of the user group, with its diversity of characteristics and perceptions. The general position of the healthcare team, stating that learning about carbohydrate counting (with a game) is relevant for all, does not totally hold true from the youth's or the parents' perspective. Reasonable critical voices could be identified. By investigating different characteristics (e.g., skills, age and practices) of the user group, it was possible to recognise some patterns of perceptions of the participants. However, the initial intention to identify the characteristics of the target group with the help of quantitative data has shown to be a challenge. Defining one well-defined target group (user group) remains an illusion. Instead, the diversity of perceptions enriches the iterative design process with implications for further design decisions.

4.4.2 Assessing skills

The validity of assessing skills in calculating carbohydrates in a test can be perceived as critical since the lack or the existence of skills might not reflect the actual practice and performance in real life (Lave 1988). Due to the awareness that the chosen setup would be insufficient for a medical intervention (e.g., the prototype's effect on the health status), the main intention was to consider it a supplement to other techniques.

4.4.3 Role of quantitative data

The quantitative data analysis, which was the focus of the camp study, should function as a supplement to my primarily qualitative perspective within my research. It should have a summative character. The intention was to show the quantification of the differences that existed in the phenomena, which the qualitative data had pointed out earlier in my study.

The data from the questionnaires and assessments reflected perceptions at specific points in time before and after the intervention, but these were detached from the interviewees' individual contexts and moods. The qualitative data collection helped overcome this dilemma and enabled obtaining insights into the course of perceptions over time. Furthermore, it offered insights into the diversity of the answers within the heterogenic user group by explaining deviations from the average (e.g., in relation to attitudes, motivations and skills). Being highly involved in the camp as a researcher, a designer and a participant consequently biased the results. Thus, another aspect of using quantitative data was to allow space for a more critical and honest representation of the youth perspective.

5 Summary

In this paper, the results of evaluating carbohydrate-counting practices among the youth with type-1 diabetes and their perceptions of a mobile learning game have been presented by focusing on quantitative data analysis, supplemented by qualitative data analysis. The reported practices, skills and attitudes have turned to be manifold, as well as the perceptions. The youth's and the parents' perspectives contrast with the "relevant-for-all" medical view and have enabled presenting a holistic picture of the carbohydrate-counting topic and of the youth confronted with this challenge.

While the prototype evaluation of a mobile learning game has been demonstrated as feasible and valuable in different ways, the limits and constraints have also become obvious. Critical feedback pointed out the need to examine how the users' characteristics potentially affect users' ability to adopt the tool as a game, as well as the effects of using the game in a social context. While it is meant to be an individual learning tool, it has shown to be feasible for use in a group intervention.

The prototype game has demonstrated its potential of broadening the solution space of the youth who are challenged in carbohydrate counting. The game concept has manifested its strength of being a casual tool with opportunities for initial learning, as well as for assessing and refreshing the youth's skills. The prototype has also shown to be valuable in contributing to self-confidence, motivation, inclusiveness and identity building. Nonetheless, the design solution is not an answer to the narrowed problem of carbohydrate counting, nor does the solution fit all the youth, all the time.

The tensions and constraints of developing this topic could be presented as pointing to the challenges and opportunities for future design and design research. The diversity of the findings is considered important in the iterative design process to understand the youth living with diabetes and to enrich future designs. The prototype could be a basis for taking different directions, depending on the focus and intention, towards more concrete and mature specifications.

6 References

Baranowski, T. et al., 2008. Playing for Real. *American Journal of Preventive Medicine*, 34(1), pp.74–82.e10.

Buday, R., Baranowski, T. & Thompson, D., 2012. Fun and Games and Boredom. *Games for Health Journal*, 1(4), pp.257–261.

Gaver, W.W. et al., 2004. Cultural Probes and the Value of Uncertainty. *interactions*, 11(5), pp.53–56.

Glasemann, M. & Kanstrup, A.M., 2011. Emotions on diabetes: a design case of user mock-ups by young people living with diabetes. *CoDesign*, 7(2), pp.123–130.

Glasemann, M. & Kanstrup, A.M., 2010. IT for learning diabetes. *Studies in Health Technology and Informatics*, 157, pp.154–159.

Glasemann, M., Kanstrup, A.M. & Ryberg, T., 2010a. Design and exploration of a mobile game scenario in a diabetic youth camp. In *IADIS International Conference Mobile Learning 2010*. Porto, Portugal, pp. 132–140.

Glasemann, M., Kanstrup, A.M. & Ryberg, T., 2010b. Making Chocolate-covered Broccoli: Designing a Mobile Learning Game about Food for Young People with Diabetes. In *Proceedings of the 8th conference on Designing interactive systems*.

Lave, J., 1988. *Cognition in Practice: Mind, Mathematics and Culture in Everyday Life*, Cambridge University Press.

Lieberman, D.A., 2012. Video games for diabetes self-management: examples and design strategies. *J Diabetes Sci Technol.*

Papert, S., 1991. *Constructionism*, Ablex Pub, US.

Piaget, J., 1953. *Origin of Intelligence in the Child*, Routledge & Kegan Paul PLC.

Schilling, L.S., Knafl, K.A. & Grey, M., 2006. Changing Patterns of Self-Management in Youth with Type I Diabetes. *Journal of Pediatric Nursing*, 21(6), pp.412–424.

Tsvyatkova, D. & Storni, C., 2014. Adapting Design Probes to Explore Health Management Practices in Pediatric Type 1 Diabetes. In *Proceedings of the*

2014 Conference on Interaction Design and Children. IDC '14. New York, NY, USA: ACM, pp. 277–280. Available at: http://doi.acm.org/10.1145/2593968.2610471 [Accessed September 16, 2014].

7 Appendix

Table 7-4: Qualitative arguments (pros/cons) for the 'Food Quiz'

Theme	***Parents' quotes (PQ)*** ***- Usefulness of the game***	***Children's quotes (DIQ)*** ***- Interest in playing***	***Children's quotes (DCQa and DCQb)*** ***What they liked or disliked about the game***	***| Learning aspects***
Pros: Motivation, specific and general features of the game	"edutainment, a gasser" "He likes to learn through play."	"because you can learn better while gaming" "edutainment" "That is finally something new."	"everything" (three times), "everything" (two times), "very good" "the idea" "that you can exercise with a mobile [phone]" "that levels got more and more complicated and that you really had to think about it" "the monsters and that you learn how you can calculate this" "that there were also tips" "that there was a detailed explanation of how BE was determined concretely on the feedback panel" "explanations and help" "that it is a mobile game, and thus, you can learn better because it is fun" "that it is on a mobile!" "that we could use the mobiles during the day" "that there were points, and the levels [offered] a certain motivation" "many different levels, that you could receive points" "that levels got more and more complicated and that you really had to think about it" "that one could play at different levels" "levels" "that there were different levels" "that you could [get] free after a certain number – one, two new levels"	
Pros: Skills, awareness and general arguments	"Calculation is difficult for her; she does not like to use her head." "because there are knowledge gaps [in estimation and calculation]" "because she is sometimes wrong in estimating" "It does no harm." "to be more sensitive about how many bread units are in fast food, which one (supposedly) knows" "Sometimes he is in a hurry and forgets important things (e.g., dessert)." "for practice [calculation], but she is skilled already"	"because I can maybe learn something new" "Then, you learn faster."	"estimation of BE" "that you can estimate better now" "that I learned so much" "that you can learn a lot about the estimation of food" "that you can learn more about food and its BE" "that you could learn how you could estimate and calculate BE" "that you could progress in the game and consequently, you learned more and more new stuff" "that you learn the BE of different foods" "that you can learn" "that one could exercise in estimation and in calculation of nutrition panels" "that you could practise and that you learned something new"	"I can estimate better." "I can estimate better now." "estimate BE" "calculate BE" "calculation" "a lot" "the BE of other [unknown] foods" "the examples of McDonald's" "different BE from meals" "that mayonnaise has no BE" "that you have to look first" "that the food has more BE [than] assumed" "the exact calculation of BE" "the correct calculation with nutrition panels" "how I have to calculate" "easier approach to calculation"
Pros: Respon-sibility/ Confidence/ Repetition/ Test	"Then, she can determine her correct insulin dose alone on the move." "to be more independent and more responsible" "assurance for the parents, independence" "confidence in use → better blood glucose values"	"maybe an easier approach to calculation" "because it is a useful exercise and in 'case of an emergency', it might help" "related to everyday [life]"	"that you learn more about it and that you feel secure when you can do it correctly" "that you can calculate correctly now what you calculated wrongly before" "that you can exercise without risk" "that one could exercise so well" "that we were allowed to exercise"	

	"assessing the existing knowledge" "for practising, but she is skilled in it already" "It cannot harm." "be more sensitive about how many BE units are in fast food, which one (supposedly) knows" "assessing the existing knowledge"	"because you need it [calculation and estimation] in everyday life" "that one can see, if one is able to calculate" "One can test one's own skills [calculation and estimation]."	
Cons: Motivation, specific and general features	"She would consider the game maybe too boring. Maybe the content should be more wrapped into a game scenery [to be] more attractive for [a] teenager."	Participants skilled in calculating carbohydrates[40]: "NP[41]:I have other things to do! – sleep, play, eat." "NP: I prefer music and [browsing] on the Internet." Participants with lacking skills: "I am not interested in it [estimation]." "I prefer to do something different [than calculation]." "I do not need this [calculation and estimation]."	"In principle, good, but after a while, it was getting boring." "that there was no game over" "that there were still too little tasks and not more levels" "that one got to know all the levels down pat" "that you could memorise all levels very quickly" "that it is very short only (and also very easy)" "that [it] was very often the same" "that you can complete the whole [game] very fast" "If you have finished all levels, you could only play the same again." "that [it] was nearly always the same" "After a while, you stopped estimating because you memorised all pictures." "If you calculate with the calculator, it does not accept the exact value." "some mistakes" "the design" "It was boring after a while." "In principle, good, but after a while, it was getting boring." "that you have to do everything exactly" "that we had to practise in pairs" negation in open-text item for cons: "I liked everything." "None" or "I liked everything" (six times)
Cons: Skills	"She can calculate BE based on the [food package] information." "[she is] confident."	"I am good in calculation and estimation." "Estimation is sufficient [in everyday life]."	"that one did not know everything in the calculation game" "the tables where you have to calculate the BE" "package game" "the subsets [a game level] before I got them explained" "package game, there, you have to calculate so much" "calculation of food" "that it is (very short only and) also very easy" "that it is totally easy and boring after having played all of it"
Cons: Learning content and presentation (or undecided)	"Estimation would be relevant for certain foods (rice, noodles), for others, not (yoghurt, fruits)." "On pictures, it is difficult to estimate."	"Let's try and see."	"that one could not see everything exactly" "that you could not recognise some panels in the package game"
.Implications: General comments	"a great idea in the present days of games" "I like the idea because it fits the spirit of the times and this generation."	"It is a good idea." "Maybe one can integrate mini games."	"for example, that one could have more levels" "more food and package labels, more difficult levels" "One should create more games for it […]."

[40] skilled: Level 3, lacking skills: Level 1 to 2 according tot he results in DIA
[41] NP: acronym for "no plan"

(e.g., on the learning game concept, suggestions for improvements	"That is the way it is meant to be in the present digital world, easy not only for diabetics." "PC, mobile games and so forth are the likely used toys. Children would rather accept them." "Edutainment is always good." "Good, unfortunately, there are few games, and those are all for smaller children" (parent of a 12-year-old boy).	"I am not that good in calculating BE." "The game should be compatible with all kinds of mobile phones." "Sorta, then it would be a game [for the youth aged] 18 and upwards."	"I would like to have it on my mobile, and I would recommend it because the game is really super. You can learn something new, and you can show it to a friend, how good you are […]." "I would like it [to] be also available on other mobiles or as a computer game." "It should exist as a test and a full version if you sell the game […]." "more tasks, to combine the tasks" "more levels" "levels for beginner, advanced and professional, e.g., levels for 'sweets' or 'on the move'" "Maybe one should create some other tasks besides estimation and calculation of BE." "One could have a character that you use to solve tasks … like in SIMS, only for diabetes." "Yes, design it [in a] more funny [way]. Definitely, replace people by toast animals [monsters]. Toast animals FTW[42]" "mini games to estimate" "You could connect via Bluetooth and play with each other [to find out] who is better in estimation." "I would suggest integrating more characters and levels into the game. It would be cool if you could in the beginning create your own character and you could create your own level to try it out. Also, it would be very cool to get bonus levels in case you have played very well, e.g., one could shoot other monsters (on top, there is a question and on the monster, there is the BE or the amount in grams)." "I have an idea. One could create a table where you can see and learn how much BE is in the food, and when there is no time for playing, then you can just look it up."

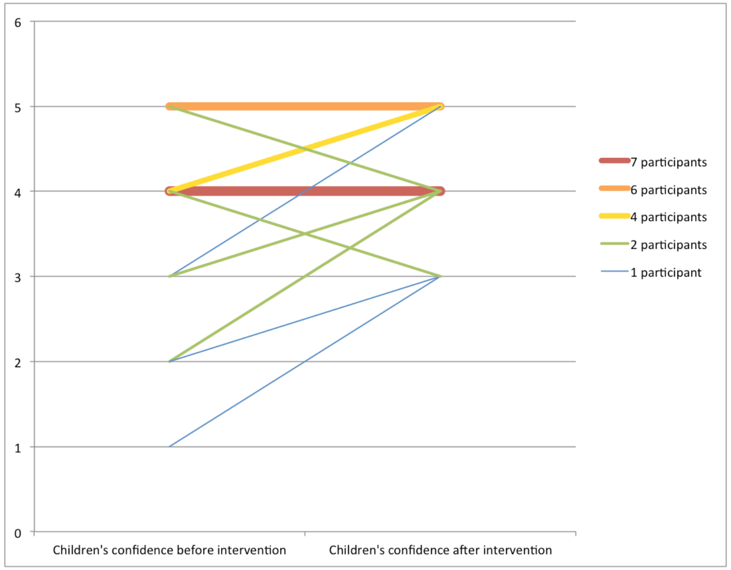

Figure 7–1: Children's confidence in calculating carbohydrate units (DIQ and DCQ)[43]

[42] FTW: acronym for 'for the win'
[43] "I feel confident in determining BE based on food panels" (1 = I don't agree at all to 5 = I totally agree).