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Research paper

Assessing the Usability of a Prediabetes Self-Care Application: a Multi-Method Approach

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Abstract

Increasing demand for digital technology, worldwide, has unlocked new pathways for diabetes prevention. Health behavioural change theories when integrated in the design of novel health applications can foster effective self-health management and prevention. We developed *i-PreventDiabetes*, a self-care application for prediabetics, that enables lifestyle monitoring, goal setting and activity planning, which is accessible via both web and mobile. In this study, we evaluated the usability barriers and enablers, and assessed the user experience with the system by using a multi-method approach with 20 participants. This approach includes cognitive walkthrough, think-aloud method, question-asking protocol, System Usability Scale (SUS), User Experience Questionnaire (UEQ), and open-ended questions. The results indicate that the users are satisfied with the concept of preventing diabetes by using a self-care application that includes a variety of functionalities that empowers prediabetics to take charge of their own lifestyle in preventing diabetes.

Keywords: *Behavioural change theories; Diabetes prevention; Digital health technology; Prediabetes; Self-care; System usability; User experience.*

1. Introduction

High blood glucose is life-threatening and as such, it should be prevented or delayed at prediabetes stage itself. Prediabetes is a stage where the blood glucose level is not high enough to be categorised as diabetes, but it is higher than the normal level. With proper lifestyle and diet, diabetes can be prevented at this stage [1]. Digital health technology is advancing rapidly and it leads to a new direction in empowering patients to self-manage their lifestyle. There are many self-care applications to manage diabetes, but not in preventing or delaying its onset by managing lifestyle. Existing applications, mostly aimed to deliver a specific functionality (such as weight management), are not designed based on behavioural change theories, and do not incorporate perspectives of health professionals [2]. Integrating health behavioural change theories, such as Transtheoretical Model, Theory of Planned Behaviour, and Health Belief model, into health support applications can enhance the effectiveness of self-managing diseases and foster sustainable use of a solution [3]. These theories allow people to be aware of their behaviour towards their health and aid them in achieving their personal health goals.

User requirements analysis for a prediabetes self-care application [4, 5] and a framework to develop self-care application for prediabetes [6] helped us to develop a functional prototype of *i-PreventDiabetes (i-PreDi)*, a novel and ubiquitous self-care application to empower prediabetics, which integrates behavioural change theories and techniques. Figure 1 illustrates the framework for *i-PreDi*. In this paper, we present a formative evaluation of *i-PreDi*. The objectives of this study were to identify the usability barriers and enablers for *i-PreDi*, and to assess the user experience with the system. This paper is organised as follows: (1) a brief overview of *i-PreDi*, (2) methodology employed in conducting the evaluation, (3) results, (4) discussion, and (5) conclusion and future work.

2. Overview of I-PreventDiabetes

i-PreDi is a self-care application for prediabetes, which integrates health behavioural change theories and offers a variety of functionalities to enable prediabetics to control their blood glucose levels. The aim is to prevent or delay diabetes by empowering prediabetics to take charge of their own health. Table 1 shows the behavioural change techniques (BCTs) or functions which forms the *i-PreDi*. Figure 2 is the dashboard of the prototype, showing the main functions. The self-care application precedes with a survey (adopted from Transtheoretical Model/Stages of Change Model [7]) that enables one to identify the health behaviour stage. Individual stages of behaviour are clearly indicated and it changes (to other stages) based on system usage. According to Transtheoretical Model, the five stages of behaviour change are pre-contemplation, contemplation, preparation, action, and maintenance [7]. Figure 3 illustrates the current behavioural change stage of the user, as it is depicted in the application.

i-PreDi allows prediabetics to set their personal health goals (e.g. setting an achievable duration for exercise) and track their lifestyle. Figure 4 shows the screenshot of the blood glucose level chart with a personalised goal. Besides that, the system has graphical charts to illustrate the user's health progress (e.g. blood glucose level, physical activity, food, weight, and stress). Figure 5 illustrates the performance bar, indicating the progress of physical activity of the user, and figure 6 is a screenshot of recording blood glucose reading. In addition, the system displays a multi-axis graph that projects the tracked health parameters and visibly compares the trend of these values with one another. It also provides a summary of blood glucose readings in graphical format, as shown in figure 7.

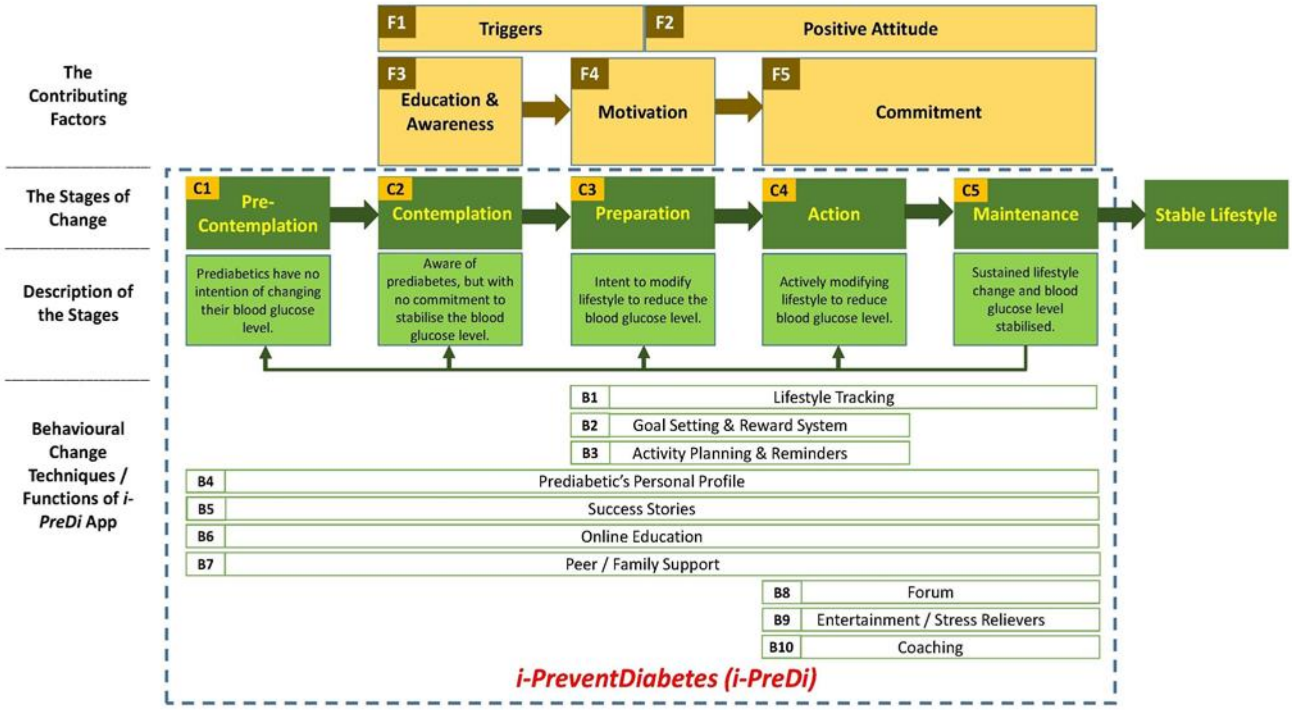

Fig. 1: Framework for *i-PreDi*

Table 1: BCTs/Functions of *i-PreDi* application

BCTs/Functions	Description
Lifestyle Tracking	To track blood glucose readings, physical activities, count calories of food consumed, amount of carbohydrates consumed, food intake, weight and stress level. Readings will be presented using visuals to show how far they are from the desired target level.
Goal Setting & Reward System	To set desired and achievable lifestyle goal(s) based on the items measured in B1 for a particular duration (e.g. 3 months, 6 months, 1 year). If succeeded, score points will be given.
Activity Planning & Reminders	Planning of activities (e.g. 20 minutes of brisk walking every day, 10,000 steps in a day, cut down carb intake) to achieve the desired goals. Reminders will be sent for each of the activities planned.
Prediabetic's Personal Profile	Prediabetic to have his/her own profile with information such as name, age, gender and etc. Current health status of the prediabetic, the stages of change and the score points will be updated here.
Success Stories	Display of success stories of other prediabetics, where they manage to stabilise their blood glucose level because of the lifestyle changes they have made.
Online Education	Education about prediabetes, lifestyle changes, calorie content in each type of food, type of physical activities to burn calories, etc.
Peer / Family Support	Support by family or friends, in the form of text messages or e-mail, as reminders and as a companion to do physical activities and managing the type of food they eat.
Forum	A platform where prediabetics can communicate with each other to share what worked, what did not work and support each other in their lifestyle changes.
Entertainment / Stress Relievers	Activities or sharing of education materials to reduce stress level (e.g. jokes, cartoons, YouTube videos, games).
Coaching	Prediabetics can communicate with their healthcare professionals to discuss about their health.

Besides that, a weekly *i-PreDi* score (i.e. an accumulated score of the system usage and health progress) is presented to motivate the users and to keep track of their progress. Figure 8 shows the weekly score. Other than that, the users are also able to connect with other *i-PreDi* users to motivate each other, engage in discussions, and share success stories.

Fig. 2: Dashboard of the *i-PreDi* prototype

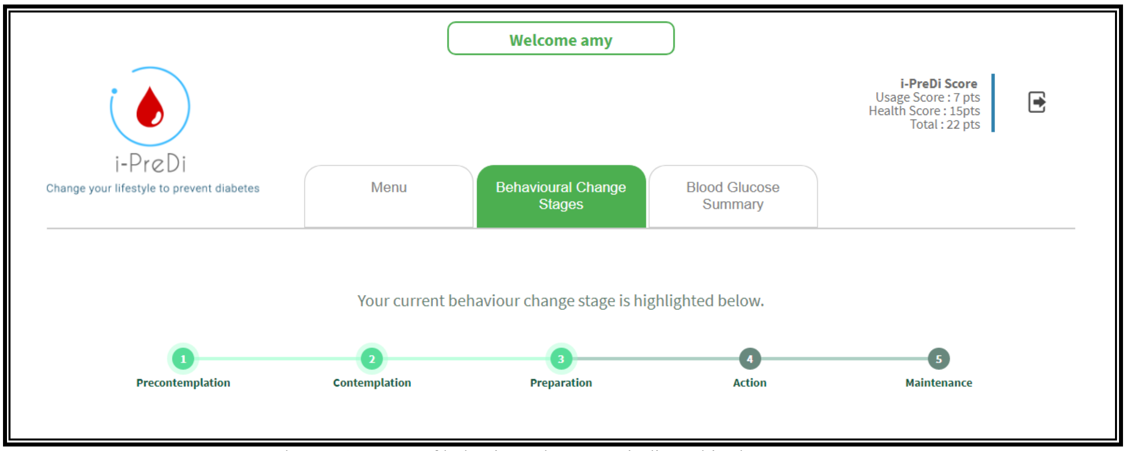

Fig. 3: The user's status of behaviour change, as indicated in the *i-PreDi* prototype

Fig.4: A line graph showing the actual blood glucose level and the desired blood glucose level

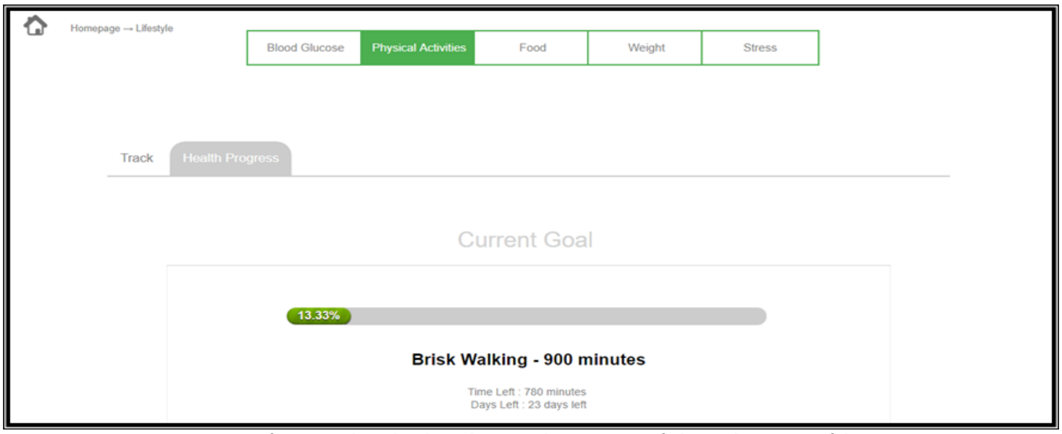

Fig. 5: A performance bar clearly indicating the progress of physical activity of the user

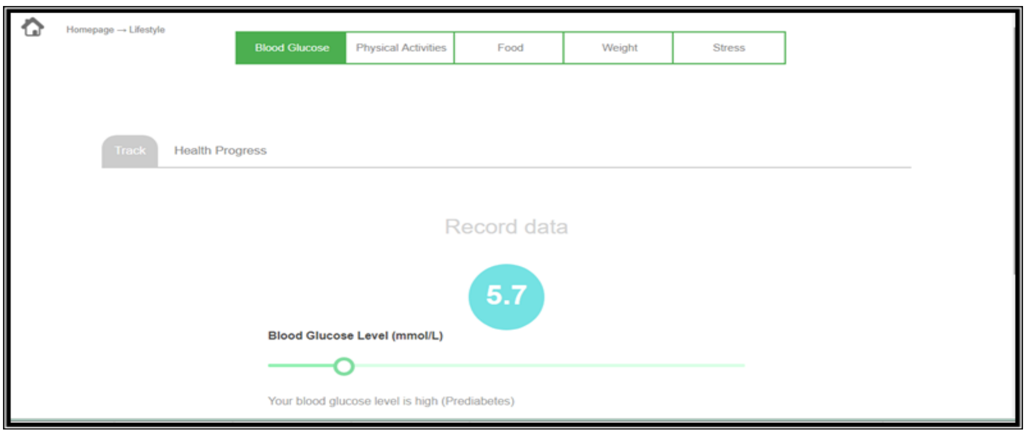

Fig. 6: A user interface, which allows users to record their blood glucose level

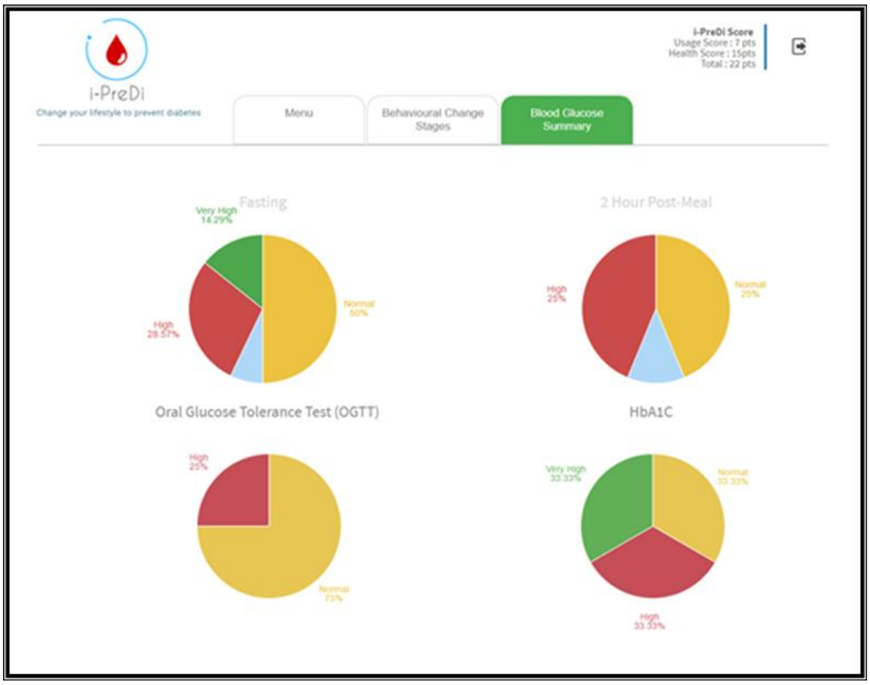

Fig. 7: A clear indication of the user's four different types of blood glucose reading

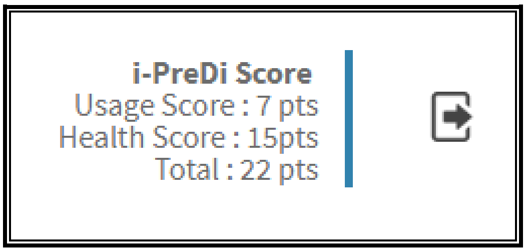

Fig. 8: A score depicting the usage and health score of the user, with the intention to motivate users to use *i-PreDi*

3. Methodology

This study followed a multi-method approach, which enables a deeper understanding of a system and it offsets the weakness of any one method with the strength of another [8, 9, 10, 11]. We have employed the following methods: cognitive walkthrough, think-aloud, question-asking protocol, questionnaires, and open-ended questions. This study was conducted between July and August 2017. It is established that 20 participants are sufficient to identify usability problems of a system [12, 13] and therefore the sample size used for this study is justified. The participants were selected randomly from the public. They were not expected to have any experience using computers or mobile apps. Individual evaluation sessions were conducted with 20 participants, which lasted approximately on average 50 minutes each session.

The evaluation began with the participants completing the demographic data form. An overview of *i-PreDi* was presented with its specific objective and the participants were allowed to explore the system on their own.

Then, the participants were expected to carry out a series of tasks with *i-PreDi* and evaluate the level of easiness of the performed tasks. This cognitive walkthrough method helps to predict how easy it will be for users to learn to do certain tasks on a computer-based system [14]. The participants were urged to think-aloud to express their feelings, thoughts and opinions during the process [8, 11]. Participants' responses to the system were recorded and their gestures were noted. After each session, the recordings were transcribed and coded for data analysis to identify the usability barriers and enablers for *i-PreDi*. The responses were analysed based on Nielsen's 10 Usability Heuristics [15].

During the think-aloud method, the question-asking protocol was executed by asking ad hoc questions about the system. This method was useful as it revealed how the participants perceived *i-PreDi* and the problems they encountered with the system.

After completing the task list, the participants were required to complete a post-test questionnaire with two sections: system usability and user experience. In the first section, the well-known System Usability Scale (SUS) questionnaire was used to assess the overall usability of the system [16]. Subsequently, another well-known and previously validated User Experience Questionnaire (UEQ) was administered [17]. UEQ allows users to immediately express feelings, impressions, and attitudes that arise when they use the system.

At the end of the study, open-ended questions were asked to participants to gain further insights into the positive and negative aspects of the system.

4. Results

4.1. Demographic Characteristics

The characteristics of the study participants are presented in Table 2. All the participants use computer 5 days a week or more and no one uses a self-care tool.

Table 2: Demographic characteristics of the participants

Characteristic	N	%	Characteristic	N	%
Age (years)			***Educational Background***		
20-24	2	10	Secondary	1	5
25-29	8	40	Degree	10	50
30-34	2	10	Masters	8	40
35-39	4	20	PhD	1	5
40 and above	4	20	***Computer Usage***		
Gender			5+ days/week	20	100
Male	6	30	***Uses a self-care tool***		
Female	14	70	No	20	100
Ethnicity					
Malay	5	25	Chinese	3	15
Indian	9	45	Others	3	15

4.2. Task List

The participants' mean ($\bar{x}$) and standard deviation (σ) values towards completing the given task list were calculated and shown in Table 3. Each task was accompanied by five-Likert scale (very difficult, difficult, medium, easy and very easy). Overall, answering the survey has the least mean, which is 3.35 (above medium) and the easiest is the login into the system with the mean value of 4.85. All the given tasks have a mean value of above 4, except for setting desired goal, tracking blood glucose level and answering survey.

Table 3: Mean and standard deviation value of easiness for completing the task list

Task List	$\bar{x}$	σ
Create User Account with *i-PreventDiabetes*.	4.55	0.686
Log in to the system.	4.85	0.366
Answer the survey.	3.35	0.933
Set your desired goal for physical activity.	3.85	0.745
Track your blood glucose level.	3.90	0.640
View your blood glucose chart.	4.20	0.696
Track your physical activity.	4.45	0.510
View your physical activity progress.	4.45	0.826
Check your score history.	4.55	0.605
Read education materials.	4.35	0.671
Update your profile.	4.70	0.470
Check your score ranking.	4.50	0.607
Check your tracking history.	4.65	0.489
Create a forum.	4.40	0.598
Read success story.	4.65	0.489
View your current behavioural change stage.	4.50	0.513
View your blood glucose summary.	4.35	0.671
Log out of the system.	4.30	0.979

Note: *Higher* $\bar{x}$ *represents the easiest and the maximum value for very easy is 5.*

4.3. Think-Aloud Method

The system's usability problems were captured and analysed according to Nielsen's 10 Usability Heuristics. Table 4 shows the classifications and the frequency of the usability issues. About 75% of the participants felt that answering the health behaviour change survey in the system was complicated and rather confusing. Eleven out of 20 participants expressed that the system lacked instructions on how to proceed in the system and in many instances, they were lost. Half of the participants could not log out from the system and shared that the background, font colours and the text were not readable at some places. The frequencies of other mentioned usability issues are 30% and lesser.

Table 4: Classifications and frequency of the usability issues

Nielsen's 10 Heuristics Violated	Problem Description	Frequency (n = 20)
Visibility of system status	No e-mail verification upon creating a new user account.	2
	No confirmation after add record or track.	2
	No notifications for success story upon publishing.	1
	No notifications when users comment in a forum thread or create a forum.	1
Match between system and the real world	Answering health behavioural change survey is complicated or confusing.	15
	Log-out button not visible.	10
	Ambiguous terminology used.	5
	Tracking hours and minutes are confusing.	1
User control and freedom	Forgot password link missing.	1
	Forum thread not clearly visible.	1
Consistency and standards	Score ranking is confusing.	4
	Height field in creating account page is confusing.	3
	The score and indication are not shown after taking stress survey.	3
Error prevention	Unexpected error (codes).	6
	Undetected error (not stable).	4
Recognition rather than recall	Fewer instructions or explanation on pages.	11
	Lack of visuals or graphics.	6
	The highlight of the current stage is not clear, when the user is at the 5th Stage.	3
Flexibility and efficiency of use	Dragging values on number bar does not give an exact value to record.	5
	Complete menu for navigation should be on each page.	3
	Desire to have search function and categories in Forum.	2
	How to earn score points link should be placed clearly on the page.	1
Aesthetic and minimalist design	Background, font colours and text are not attractive or readable.	10
Help users recognize, diagnose, and recover from errors	No confirmation upon deleting own forum.	1
Help and documentation	Not enough guidelines to use the system.	4

4.4. System Usability

SUS is a five-Likert scale (strongly disagree to strongly agree) with 10 statements. The participants' responses to these statements were calculated as a single score, ranging from zero to 100, and corresponds to seven adjective ratings (best imaginable, excellent, good, OK, poor, awful, and worst imaginable). SUS score above 70 is described as acceptable usability level [18, 19]. The participants rated the *i-PreDi* system usability, positively, with average SUS score 74.63 and adjective rating "Good". The individual SUS score of the participants is displayed in Figure 9. The scores range from 35 to 97.5, with a median of 77.5. Figure 10 shows the frequency of the SUS adjective ratings for the individual SUS scores. Eight participants rated it as "Good" and four participants rated it as "Excellent".

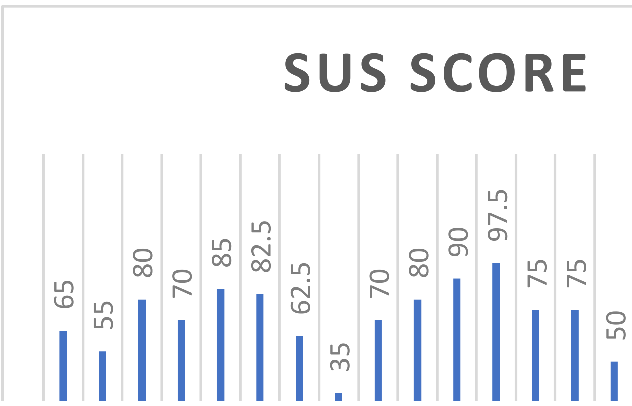

Fig. 9: SUS score of the participants

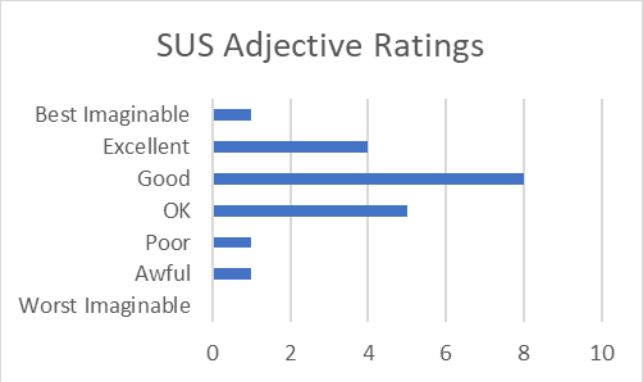

Fig. 10: Frequency of SUS adjective ratings

4.5. User Experience

There are six scales with 26 items for measurement in UEQ: attractiveness, perspicuity, efficiency, dependability, stimulation and novelty. Values above 0.8 are considered positive, -0.8 to 0.8 are neutral and below -0.8 are negative values. Figure 11 shows the UEQ scales result. Based on the graph, all the six scales are above 0.8 and have positive values [17]. The lowest value is 1.263 (novelty) and the highest value is 1.888 (stimulation). Figure 12 illustrates the UEQ benchmark, which compares our system with other 246 products [20].

Based on the benchmark, attractiveness and stimulation are rated as "Excellent" and the other four scales hold "Good" ratings.

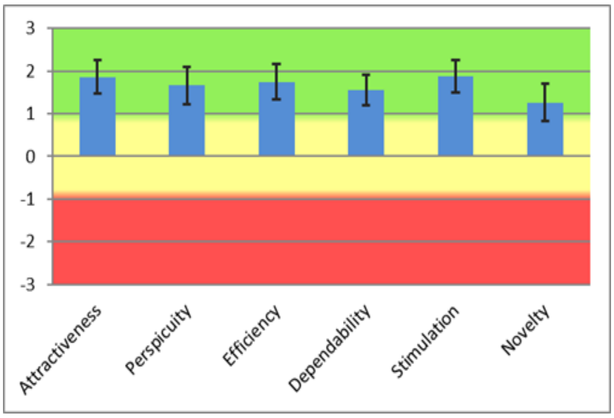

Fig. 11: UEQ scales result

4.6. Open-Ended Questions

Towards the end of the session, the participants were asked to answer three open-ended questions. Table 5 highlights the most frequent response towards the three questions.

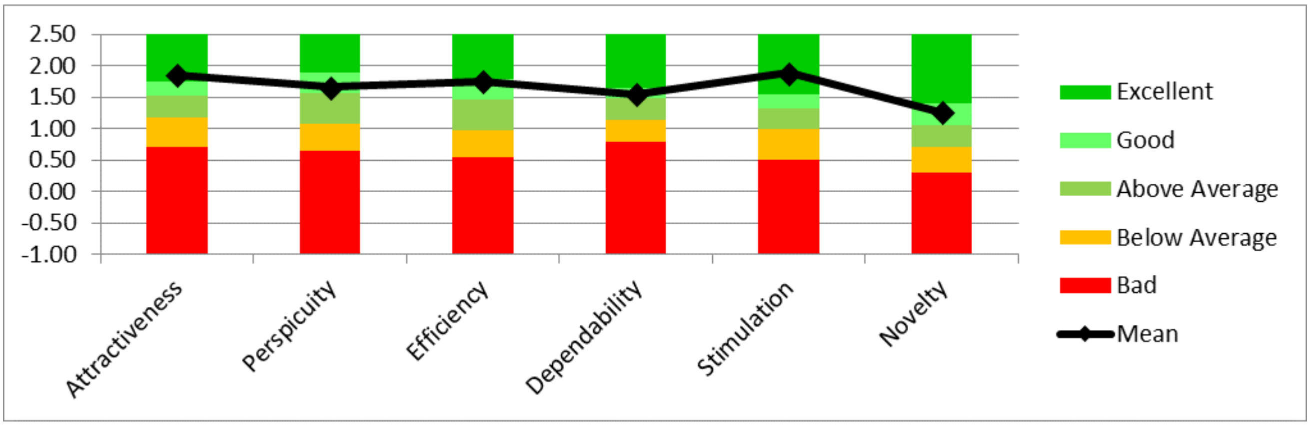

Fig. 12: UEQ benchmark

Table 5: Participants' most frequent responses towards the open-ended questions

Open-ended Questions	Participants' Responses	Frequency (N=20)
List the most negative aspect(s):	Colour is not attractive and suitable.	4
	Answering health behavioural change survey is complicated or confusing.	3
	No clear instruction to navigate the page.	2
List the most positive aspect(s):	It is a good platform to store or track your goals against your activities.	9
	Simple design.	4
	Good colour scheme and theme layout.	3
Do you have any other comments?	Need more graphics on interfaces.	3
	Alert a user when he/she receives a comment.	1
	The use of keypad for inserting numerical data.	1

5. Discussion

Based on the results, it is noted that the *i-PreDi* system is well accepted by the users. They embrace the idea of having all the necessary functions for prediabetics in one system. The feature of presenting blood glucose level summary in a pie chart to view their overall progress triggers them to change behaviour. In addition, the score system is a motivating factor for the users to continue using the system. They also prefer the easily accessible navigation or menu buttons on every page. A graphical user interface with readable colours encourages the users to use the system.
Besides that, the participants appreciate the freedom on how they want to interact with the system. They do not want to be forced to do certain things. Integrating the behavioural change theories with the system helps the users to identify their behavioural change stages explicitly. They want the stages to be highlighted to them clearly. By knowing their current stage, they feel they are in control of their actions. The evaluation supports that the system will help with lifestyle changes by encouraging the prediabetics to take greater responsibility for their health.
However, a number of constructive feedbacks on the user interfaces were shared by the participants to improve the system. They expect the system to provide visual feedback on their health progress. Users prefer to have their lifestyle monitoring records to be presented in visually (e.g. via graphs, pie charts, multi-axis graphs) to motivate them. Besides that, they prefer an interface with both text and images for better absorption. They want an automated or intelligent system that would respond to their interaction. The

participants prefer a guided flow in using the system, to avoid getting lost in the page.

On the whole, the participants gave positive responses on the user experience and system usability, and there were several suggestions to refine the system. The *i-PreDi* system, although it is not productively used in its current form, it can be an exemplar for developments to come. Results obtained from this study would be useful to application developers or healthcare solution providers to better understand the needs and expectations of prediabetes towards novel diabetes prevention applications.

6. Conclusion and Future Work

Various data collection methods derived a comprehensive set of the usability barriers and enablers for a prediabetes self-care application. The evaluation provided constructive feedback and comments to develop a self-care application for prediabetes, which integrates health behavioural change theories and offers a variety of functionalities to enable prediabetics to control their blood glucose levels.

The perception of users towards *i-PreDi* and the functionalities provided by the system were useful to validate the user requirements of the developed system. The SUS score and UEQ scales result indicated that the users were satisfied with the concept of preventing diabetes via an application that presents a variety of functionalities and encourages sustainable use.

Results obtained will be used to improve the system and subsequently, an extensive 6-weeks summative evaluation will be executed with a larger sample size of prediabetics to assess the feasibility, acceptability and effectiveness of the system.

Acknowledgement

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References

[1] Sénéchal, M., Slaght, J., Bharti, N., & Bouchard, D. R. (2014). Independent and combined effect of diet and exercise in adults with prediabetes. Diabetes, metabolic syndrome and obesity: targets and therapy, 7, 521.

[2] Gulla, J., Neri, P. M., Bates, D. W., & Samal, L. (2017). User requirements for a chronic kidney disease clinical decision support tool to promote timely referral. International journal of medical informatics, 101, 50-57.

[3] Subramaniam, S., Dhillon, J. S., Ahmad, M. S., Teoh, C., & Leong, J. W. S. (2016). Integrating health behavioural change theories in the design of prediabetes self-care applications: A systematic literature review. Journal of Theoretical and Applied Information Technology, 88(2), 189-201.

[4] Subramaniam, S., Dhillon, J. S., Ahmad, M. S., WS, L. J., Teoh, C., & Huang, C. S. (2016). Eliciting user requirements to design a prediabetes self-care application: a focus group study with prediabetics and diabetics. Indian Journal of Science and Technology, 9(S1).

[5] Subramaniam, S., Dhillon, J. S., Ahmad, M. S., Leong, J. W., & Teoh, C. (2017, April). User Requirements for Prediabetes Self-care Application: A Healthcare Professional Perspective. In International Conference of Reliable Information and Communication Technology (pp. 616-626). Springer, Cham.

[6] Subramaniam, S., Dhillon, J. S., Ahmad, M. S., Teoh, C., & Leong, J. W. (2017, July). A framework for developing prediabetes self-care application. In Research and Innovation in Information Systems (ICRIIS), 2017 International Conference on (pp. 1-7). IEEE.

[7] Prochaska, J. O., & Velicer, W. F. (1997). The transtheoretical model of health behavior change. American journal of health promotion, 12(1), 38-48.

[8] Årsand, E., & Demiris, G. (2008). User-centered methods for designing patient-centric self-help tools. Informatics for health and social care, 33(3), 158-169.

[9] Bozkurt, S., Zayim, N., Gulkesen, K. H., Samur, M. K., Karaağaoglu, N., & Saka, O. (2011). Usability of a web-based personal nutrition management tool. Informatics for Health and Social Care, 36(4), 190-205.

[10] Gibson, B. E., King, G., Kushki, A., Mistry, B., Thompson, L., Teachman, G., Batorowicz, B. & McMain-Klein, M. (2014). A multi-method approach to studying activity setting participation: integrating standardized questionnaires, qualitative methods and physiological measures. Disability and rehabilitation, 36(19), 1652-1660.

[11] Georgsson, M., & Staggers, N. (2016). An evaluation of patients' experienced usability of a diabetes mHealth system using a multi-method approach. Journal of biomedical informatics, 59, 115-129.

[12] Faulkner, L. (2003). Beyond the five-user assumption: Benefits of increased sample sizes in usability testing. Behavior Research Methods, Instruments, & Computers, 35(3), 379-383.

[13] Macefield, R. (2009). How to specify the participant group size for usability studies: a practitioner's guide. Journal of Usability Studies, 5(1), 34-45.

[14] Rieman, J., Franzke, M., & Redmiles, D. (1995, May). Usability evaluation with the cognitive walkthrough. In Conference companion on Human factors in computing systems (pp. 387-388). ACM.

[15] Nielsen, J. (1995). 10 Usability Heuristics for User Interface Design. Available from: https://www.nngroup.com/articles/ten-usability-heuristics/ (accessed 19 June 2018)

[16] Brooke, J. (1996). SUS-A quick and dirty usability scale. Usability evaluation in industry, 189(194), 4-7.

[17] Laugwitz, B., Held, T., & Schrepp, M. (2008, November). Construction and evaluation of a user experience questionnaire. In Symposium of the Austrian HCI and Usability Engineering Group (pp. 63-76). Springer, Berlin, Heidelberg.

[18] Bangor, A., Kortum, P., & Miller, J. (2009). Determining what individual SUS scores mean: Adding an adjective rating scale. Journal of usability studies, 4(3), 114-123.

[19] Brooke, J. (2013). SUS: a retrospective. Journal of usability studies, 8(2), 29-40.

[20] Schrepp, M., Hinderks, A., & Thomaschewski, J. (2017). Construction of a Benchmark for the User Experience Questionnaire (UEQ). IJIMAI, 4(4), 40-44.