A novel hand-held interface supporting the self-management of type 1 diabetes

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ABSTRACT

For pressing health, economic and social reasons a hand-held interactive interface supporting the self- management of a chronic condition has much to offer.

We describe the design of an interface specifically for people with Type-1 diabetes, but it is potentially generalizable to other chronic conditions. Three sets of constraints influenced the design. One derives from clinical considerations. Another recognizes the preferences of users, expressed as inherent interests or reactions to successive interface designs. A third constraint arises from the small size of the hand-held device.

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Considerations of all three constraints, as well as accepted guidelines concerning design for human-system interaction, led to the novel interface described in this paper. The principal features include: a very 'flat' data space; the extensive use of visible context; techniques to ease menu selection by the visually impaired; an interactive diary displaying both qualitative and quantitative aspects of data; and the dynamic manual exploration of interrelationships.

KEYWORDS
Mobile devices; health; interaction design

INTRODUCTION

In light of the prevalence of chronic disease and its associated economic and social consequences, a hand-held application allowing a patient to self-manage their condition has much to offer. Suboptimal care in this population comes with a significant socioeconomic burden arising from physical and psychosocial complications. Mobile health applications are cost-effective tools that empower users to better understand and self-manage their conditions.

Type 1 diabetes (T1DM) is a chronic condition characterized by insulin insufficiency due to the autoimmune destruction of pancreatic beta cells [5]. Subcutaneously administered insulin replacement therapy is the mainstay of treatment, and can be delivered as multiple daily injections or via a continuous subcutaneous insulin infusion pump. Diabetes health applications have been shown to successfully improve treatment outcomes (e.g., blood glucose control), health behaviour (e.g., self-monitoring of blood glucose), patient self-confidence, and patient satisfaction [2]. However, a study [4] from the leading mobile engagement platform found that a quarter of users abandon apps after just one use, with poor software user experience being a major barrier in mobile health application penetration. Therefore, a primary objective when developing the health app interface described in this paper was to ensure usability across a wide demographic without compromising the following;

1. Manual data input (e.g. meal selection and exercise intensity); 2. Automated input of physiological parameters from wearable devices (e.g., blood glucose levels and heart rate); 3. Presentation, to the user, of recommended treatment (e.g., insulin dosage and risk aversion strategies); 4. Real-time visual presentation of predicted outcomes that would follow from treatment recommended by machine learning algorithms; 5. Manual dynamic exploration of interrelations between relevant parameters (e.g., carbohydrates, predicted blood glucose and insulin recommendation).

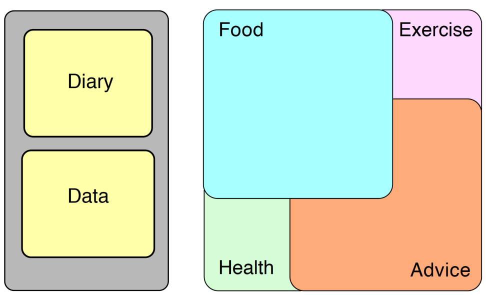

Figure 1: Left: The allocation of display area to temporal data (top) and data input and output (lower). Right: Layout of the four data regions occupying the lower part of the hand-held display.

BACKGROUND

The majority of diabetes health apps provide treatment decision support by presenting automatic and manually entered data inputs from existing diabetes technologies in a meaningful fashion [6]. Arsand et al [1] used various end-user-based assessments to evaluate the functionality of ten diabetes mobile health app features and outlined key components for future app development. Important features included; use of automatic data transfer, motivational and visual interface design, greater health benefit-to-effort ratio, dynamic usage, and applying context to app output.

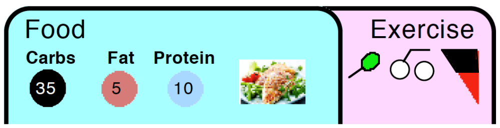

Figure 2: Examples of the data concerning Food and Exercise that the patient can enter. Note that part of the Exercise area is always visible while data concerning Food is being provided by the patient.

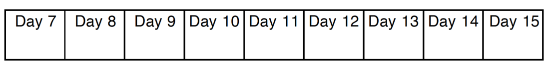

Figure 3: A linear presentation of consecutive days, having a shape unsuited to a limited display area

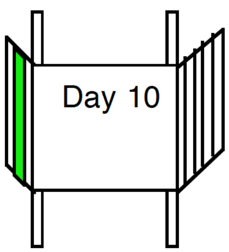

Figure 4: Diagrammatic illustration of the 'distortion' associated with the metaphor of the Bifocal Diary.

A review of commercially available diabetes health apps [7] established that having a structured display was a feature that significantly improves blood glucose control. This association is likely a result of positive health behavior changes in response to well-presented health outcomes (e.g. blood glucose data). The presentation of structured glucose prediction data generated from an AI with self-learning capabilities and the ability to take account of real-time physical activity provides an opportunity to engage the user and further improve clinical outcomes [3]. The presence of educational and lifestyle modification features are also low risk additions that increase self-awareness and improve glucose control [7]. Interface design for most diabetes decision support apps struggles to efficiently permit layered multi-source data inputs and present various outputs (e.g. blood glucose and insulin dose recommendation) without compromising ease of use, context and the number of device interactions. The app ARISES (An Adaptive, Real-time, Intelligent System to Enhance Self-care of chronic disease) described in this paper aims to overcome these hurdles by adopting evidence derived from the current literature and by including patients with varied exposure to technology within the design framework.

INTERFACE DESIGN

The design of the interface reported in this paper is influenced by many factors. Foremost are the clinically-based requirements needed to support effective interaction by a user. Of paramount importance in this connection is clear sight of current blood glucose data and any recommendations (e.g., of insulin dosage) that would directly impact upon blood glucose levels. The ability to display the glycaemic impact following similarly encountered recommendations, and vice versa, provides context and insulin confidence in decisions recommended by the system.

Following a detailed review by specialist diabetologists of current diabetes decision support systems, five groupings of data required from, and to be presented to, the user were identified. These were: (1) Blood Glucose: graphical presentation of blood glucose data over the last six hours and access to continuous historical data on a displayed diary. (2) Food: parameters such as carbohydrate ('carb') and protein values as well as alcohol intake. (3) Exercise: A categorical choice of planned exercise type and intensity.(4) Health: The ability to trigger AI adaptations during periods of stress and intercurrent illness as well as to access recorded customizable parameters significant to the management of diabetes. (5) Advice: Presentation of trends associated with negative outcomes on blood glucose levels.

User Preferences

A series of focus meetings with people with T1DM, observed by clinicians, engineers and experts in human computer interaction, supported the co-design of the app. The identification of four principal input data types (Food, Exercise, Health, Advice) was agreed within the focus meetings, with an emphasis on ensuring that important data associated with each type could remain visible as interaction proceeds. The result of interaction design is illustrated in Figures 1 to 6 and summarized below.

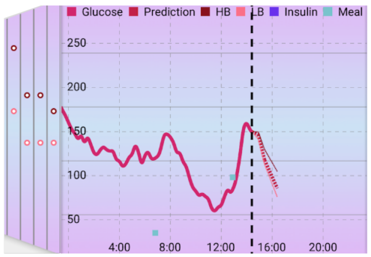

Figure 5: The actual (before the vertical black line denoting 'Now') and predicted variation of blood glucose for the current day.

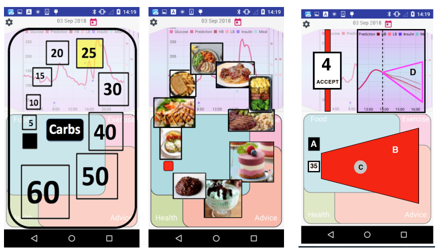

Figure 6: Left: Menu options are more easily selected if made large. Middle: A carousel presentation of past meals. Right: Interface appearance following touch on the icon A.

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Fig. 1 (left) shows the allocation of display real estate to temporal (upper) and fixed (lower) data. Fig. 1 (right) shows overlapping regions associated with important fixed variables. Touch on any region brings it to the 'top' of the stack, leaving the remainder in their previous order. A fixed sub-area of each region is always visible, providing valuable context. Fig. 2 provides an example of interactive icons allowing Food and Exercise data to be entered. Fig. 3 shows an unsuitable diary presentation.

Fig. 4 shows how distortion of the unsuitable presentation of Fig. 3 can provide a diary showing quantitative detail for a single day and summary qualitative detail for adjacent days. Fig. 5 is an example for the current day showing, in the focus region, the detected and predicted blood glucose level: dashed vertical line indicates 'now'. Fig. 6 (left) shows that when entering carbohydrate levels, a user need only pay attention to available values, so the remainder of the display is rendered inconspicuous, though present to provide context. People are creatures of habit, so the ARISES app provides, on request (Fig. 6 centre) a slowly moving carousel of past meals, allowing easy selection. The interface also allows (Fig. 6 right) a user to ask (in this example) the question "What will happen to my blood glucose level if I (a) select different carb values by a finger slide along the (red) carb range, or (b) explore different insulin doses ?" Both (a) and (b) result in the immediate display of results, calculated by a machine-learning algorithm.

CONCLUSION

A hand-held interface has been developed to support people with Type-1 diabetes in the management of their condition. It combines a number of novel approaches to deliver a usable interface which will maximise its adoption by patients, impacting on chronic disease management.

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