The Power of Play Based Apps in Patient Self Management of Diabetes

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ABSTRACT
Interactive animated 3D computer graphics provide a rich and engaging mechanism with which it is possible to enhance interactions with complex information. This research focused on the use of “flow”, in the form of 3D animated movement of items through depth over time, to display changes in diabetes management and blood sugar levels. It also utilizes “play”, in the form of interactive 3D game play, to demonstrate 3D systems to present complex health information for Type 1 diabetes in a more engaging form. The flow based “Diabetes Visualizer” interface described here uses circulating 3D graphical structures that flow around the users point of view to present information relating to diabetes management tasks. The Diabetes Visualizer utilizes complex diabetic blood sugar, activity level and insulin delivery information, and presents it in an interactive 3D time based animated game form. Utilizing the mechanism of the 3D flow interfaces, this 3D interactive form is quite different to other diabetes management tools (primarily 2D chart based and static) and shows potential in providing an improved interface to this complex condition and its management. Results from early experimental studies of the visualizer tool show potential in providing a more engaging form of presenting this type of information through the use of interactive 3D “flow” based systems. Being presented on a globe of the world as a significant feature but also highlighted the fact that the use of depth in the 3D tool allowed them to more easily see locations where there were significant spikes in impact and this advantage appeared to play a key role in the 3D tools preference over its flat 2D counterparts. These results indicate that the use of 3D web based applications for the visualization of world health data, in differing fields through the reusable nature of the tool, offer the potential to enhance the users interaction with the data.

Categories and Subject Descriptors
• Human-centered computing~Visualization techniques • Human-centered computing~Visualization systems and tools • Applied computing~Health informatics

Keywords
3D Data Visualization; 3D User Interface; Human Computer Interaction; Computer Game.

1. INTRODUCTION
The concept of using objects in motion, through depth and passing by the viewer, in common selection tasks, as outlined by Patterson (2007), has been demonstrated as effective for some types of information presentation [9-18]. This project extended that concept and looked at applying the flow principles in more advanced applications including more complex health information visualization and interaction. In particular this work looked at new ways to present information for type 1 (Insulin dependent) diabetic patients who manage their own blood sugars on a day to day basis. The tools primary focus is to more effectively convey information about the complex relationship between food, activity, sugars and insulin interactions. These new, flow based 3D animated forms of presenting this complex diabetes information, were designed with the purpose of providing both a tool to help with diabetes management and also a tool to assist in learning and understanding the complex task of managing blood sugars effectively.

Existing 3D flow based systems largely deal with generic search or library information, assisting in tasks such as locating items in a large search list or searching through a large structured store/library scenario. These interactions largely involve using time and movement to provide options flowing past the viewer until they actively make a choice or alter the flows features. For the case of the 3D Diabetes Visualizer the information also uses the flow but in a different way. In this case the flow is used to represent a transition in time (representing the changing state of the blood sugar/insulin levels over time and the effect that food, activity and insulin choices make).

The Diabetes Visualizer is a 3D visualization/game designed for use by the patient in self managing their Insulin Dependent Diabetes Melitis (IDDM), often more widely known as Type 1 or Juvenile Diabetes. In this condition, patients generally manage their own blood sugar levels by carefully keeping track of food intake and matching carbohydrate intake levels with calculated and injected insulin doses. This balance of food to insulin takes considerable care and the relationship between the two can be difficult to manage and understand. It is this complex relationship that the 3D Diabetes Visualizer aims to present in a simpler to understand form and thus assist patients with management and understanding of their condition.

Improving the management of the condition is important, particularly for the patient, as poor management leads to serious health complications and costs for both the individual and society at large. Diabetes represents one of the worlds biggest health concerns.

‘Immediate action is needed to stem the tide of diabetes and to introduce cost effective strategies o reverse this trend’

[World Health Organization 2012 [25]]
With this in mind the 3D Diabetes Visualizer aims to take the complex set of information that is involved in managing diabetes and present it in a simpler interactive 3D visual form. By doing so it represents a comparatively low cost tool that can assist in improving outcomes.

2. Diabetes Management & Visualization

For the patient managing their diabetes is a very involved process. Most patients independently manage their condition, monitoring their successes as they go. This management involves calculating the required amounts of insulin to inject to match food/carbohydrate intake whilst also accounting for other factors such as activity levels and stress. These calculations are quite complex and difficult, particularly for an inexperienced patient, to understand. Most patients use regular blood sugar testing to gain an insight into how their calculations have functioned. For example a patient may wake in the morning, test their blood sugar level, then using that existing level, in combination with their intended food intake and activity plan for the morning, they will make a calculated judgment on how much insulin needs to be injected.

To make these calculations the patient must be aware of the amount of insulin needed to cover the food, the rate at which the insulin will be absorbed and become available, as well as the rate at which the food will be digested and become available in the form of blood sugars. Hence a diabetic must have a thorough knowledge of the carbohydrate content of foods as well as absorption rates and the matching amounts of insulin required. For most diabetics these are skills that take many years to develop.

2.1 2D Diabetes Management & Charts

Diabetes software already exists in a range of forms. Most are simple 2D charting tools, offering a selection of different chart types, to display blood sugar data in the form of simple static bar, line and other charts (see example in Figure 1). There is some evidence that use of these simple software tools assists in improving blood sugar level and diabetic control. As shown in Blazik and Pankowska (2012), this software is safe and reduces blood glucose levels and glucose variability. There are several tools that work in this way, ranging from simple web based charts (Holl et al 2011, Hughes 2012) through to simple interactive 2D games (Bresinka 2011) [1,6,7].

Most diabetics use these charting tools in longer-term management, where they collect a series of blood sugar tests, over a period of weeks or months, and then analyze these long term averages to identify issues. For example in Figure 1 the patient might identify that there are more high values in the morning (the left of chart) and therefore there is a need to increase insulin levels overnight to address this. This type of post analysis is useful but doesn’t assist the patient in learning how to judge and match food to insulin levels, nor does it provide any advice on how to “predict” the effect of choices.

One of the key limitations of these 2D charting tools is that they are very mathematical in nature and often intimidating to the patient. The study by Tse et al. (2008) demonstrated the fact that many diabetics had limited skills with statistics and charting and found they needed specialized induction into the use of tools of this type [24]. Fortunately patients learnt quickly, but had difficulty engaging initially and staying enthusiastic about the tool use. This demonstrated a need for a more engaging way of presenting this complex diabetes management information.

2.1 The Animated 3D Diabetes Visualizer

The Diabetes Visualizer uses a simple, yet graphically rich interactive system to present the same information (see Figures 2 & 3). The key differences are in the use of interaction, 3D graphics and animation. The animation allows the viewer to see the changing status of “blood sugar” over time as an animated visualization in contrast to the more static point on a chart as shown in Figure 1.

In addition the Diabetes Visualizer was developed for use on mobile devices (thus enabling the tool to be readily available to the patient when and where they need it).

![Figure 1: Diabetes software example](image1)

![Figure 2: The 3D Diabetes Visualizer.](image2)
visualize the effect of food/insulin over several hours in a very quick accelerated cycle of less than 30 seconds.

The visualization involves the tool calculating the blood sugar level (either by using blood sugar data from patients blood tests or using a predictive model based on insulin injections and food to be eaten), these calculations are then used to display the correct amount of “sugar cubes” to match the food eaten and the correct amount of insulin “balls” to represent the insulin injected. Using calculations based on the absorption rates of the food and insulin the visualization then shows the patient the effect of the food/insulin over a period of time. The objective here is for the patient to see the impact of food and insulin decisions (the main aim being to have a match in insulin to food). When there is correct match of food and insulin there will be no sugar cubes left in the blood vessel.

The patient needs to “play” with the values to attempt to get this outcome. Although this sounds simple, the delayed impact of foods and insulin and the differing amounts in food types and absorption rates can be very confusing, and this is the difficult challenge that patients have in managing blood sugars in their normal daily lives. In this game play process, the patient comes to understand how to match food eaten to insulin injected, understanding the delays and impacts of decisions in a visual interactive way. Thus improving their skills in managing food and insulin and in the longer term their overall long term blood sugar control.

There is evidence from the long term control and complications trials that demonstrates that lower blood sugar/glucose levels are related to reduced complications thus it is worth helping patients learn how to better manage their blood sugar levels to avoid these serious complications (including diabetic retinopathy, neuropathy and blindness) [National Diabetes Information Clearing House 2008] [8].

As shown in Figure 2 & 3 the games display includes the red vessel, sugar cubes (representing blood sugars) and blue balls (representing insulin). When a blue ball and sugar cube are both in the vessel the ball moves to the cube and drags it away (as can be seen in Figure 2 where the ball is linked to cube just prior to removal), out through the blood vessel wall (this is the tools way of showing the sugar being used by the body when the insulin is present to allow absorption). Thus the insulin and sugar are taken out of the system and the user moves towards a balanced (i.e. no extra cubes) and desired level.

On the left of the game screen are the absorption rings, these show the amount of sugar and insulin currently being brought into the body (through eating for food or injection for insulin) and give the user an indication of what is coming in the near future. For example the blue ball in the ring in Figure 3 is almost full size indicating it is almost fully absorbed and will soon be able to move into blood vessel and remove one of those extra sugar cubes thus lowering the blood sugar level). As there is a delay between when food is eaten and when it appears as sugar in the blood, these absorption rings allow the user to see the level of incoming food or insulin (and as such they can visualize the rate of availability and also the times when there is insufficient supply of either sugar (hypoglycaemia) or insulin (hyperglycaemia).

The calculations of how insulin and food is absorbed are based either on a simple rule system (the default involving known absorption rates for insulin types and foods) or calculated from the users blood sugar and food data as provided by the patient. If the system is provided with information on food and insulin intake by the user and also blood sugar impact by the user and also blood sugar impact, the tool then calculates the rates of the absorption and bases its timing on those. Note that this is not a definitive system, clearly to be highly accurate in calculating blood sugars there is a need for any tool to include far more factors (eg. exercise, activity, stress). As such the tool is a simple predictive model that provides an indication of impact rather than a highly accurate blood sugar predictive tool. As its primary role is in engaging the user and helping in learning, this is not critical at this point but it does offer potential for future research to refine the predictive elements.

This visualization/game attempts to make the understanding of blood sugars easier by using a combination of rich 3D graphics in conjunction with animated 3D flow and interaction. This is much more active and graphically rich than the commonly used 2D charts and it is this rich gameplay and interaction which is the core innovation of this tool. In playing this game, and attempting to balance the insulin and sugar intakes, the player learns important skills in judging food content and matching that, both in amounts and timings, to the insulin needed to maintain good blood sugar levels.

The predictive model, although simplistic in its calculations, allows the player to propose scenarios, involving differing food intakes and then attempt to match those. This allows the patient to think through possible options and ways of handling common real-world situations and virtually play out a “prediction” of that scenario.

The “play” oriented nature of the tool allows patients to experiment with different food and insulin levels and visualize the outcomes without needing to experiment with “real” food and insulin. The game challenge of eliminating the extra cubes gives players a sense of satisfaction and in the process helps to teach the player how insulin and food interact and how to manage them more effectively.

In reality this tool is definitely slower to display the data than the equivalent 2D chart (as it will take time to “flow” through the time and changes), but it offers new levels of engagement and a much richer visual experience for the patient.

In many ways this form of data visualization is taking a leaf from the interactive entertainment fields to add “showbiz”, as Hans Rosling calls it, to the presentation of statistical data. This simple addition of bright, colourful animation has a very significant effect on how engaging the information is to the viewer. Early examples of these animated charts have drawn millions of viewers to watch presentations on statistics topics such as world population, poverty and HIV amongst others [26,27,28].

Figure 3: The Mobile Diabetes Visualizer.
Considering the positive effect that the addition of animation has caused, in relation to the impact of the data presentation to the viewer, raises the question of whether the addition/integration of other forms of interactive entertainment can also enhance viewer engagement with sources of statistical information.

3. EXPERIMENTAL RESULTS
The 3D Diabetes Visualizer was trialed in a case study scenario, with a small number of participants (six participants including both diabetic patients (2) and non-diabetic patients (4) ranging from 18 years of age up to 84 years of age) using it for a short period on a mobile device for both post analysis and predictive tasks. Given the long term nature of diabetic complications it was not possible to review the effect that the tool had on patients diabetic complications, instead the tool was measured using a qualitative survey of the participants understanding of diabetes management and how insulin and food issues are managed.

3.1 Results for the Predictive Tool
The predictive tool is the simple mathematical model used to estimate blood sugar outcomes based on input information about food, the time eaten and type of insulin injected and the time of injection. This model is relatively simple mathematically and uses simple functions to calculate absorption rates. The effectiveness of the “predictor” was measured by comparing the tools predictions to actual blood sugar outcomes with diabetic participants. In general the outcomes were closely aligned to the real values, with the tool predicting every drop and rise correctly, the key issue was the amount of the changes, with the tool overestimating the effect of insulin in some cases, this appeared to be significantly effected by activity levels and needs further research in future versions. Although slightly inaccurate the tool provided good accuracy in detecting/predicting directional changes in blood sugar levels. An example is one case where the patient started with a blood sugar level of 16.1mmol/L and then injected 16 units of short acting insulin (which would normally take 1 hour to peak and last four hours) whilst also eating 2 slices of bread (equivalent to 2 sugar cubes of carbohydrates). This scenario is quite common, where the patient started high and wanted to lower their blood sugar (from 16.1 into the ideal range of 5-8) by using more insulin than would normally be needed to match the food, while still eating normally. In this case the patient used the tool to trial different options of insulin, observing the predicted effect in the visualizer, then basing their decision on this. The patient indicated that this feature was very valuable “trailing them is excellent, I can see where it’s too much and make a choice on how aggressive to go” (Patient 3 verbal feedback).

The risk here is that if too much insulin had been injected the patient could become hypoglycaemic, but if too little the patient would remain with high blood sugar levels. Based on the feedback given the tool assisted the patient in making this choice more effectively and working it out in an engaging manner.

3.2 Results for the 3D Visualizer
Participants in the study used both 2D charting tools and also the 3D Visualizer to interact with individual diabetic cases and indicated that the visualizer provided an engaging form of understanding what was happening in the blood. When questioned specifically about how enjoyable the tool was to interact with they clearly indicated that the interactive 3D Visualizer was significantly more enjoyable than the 2D chart based system with an average response of 17.3 out of a possible 20 compared to 5.8 for the 2D chart based systems (see Figure 4).

Overall the results showed that the 3D Diabetes Visualizer was effective in engaging participants interest in diabetes management, much more so than the 2D chart based equivalents. It also received positive feedback from diabetic patients in regard to being useful for actively managing the condition and assisting in understanding and making judgments.

4. CONCLUSIONS
The Diabetes Visualizer, is actually a relatively simple interactive 3D animated display of information, yet the results indicate that this simple form of information representation (with change over time) is more effective than the complexity of the widely used charting information tools. This shows that the participants perhaps are not gaining the most that they could from the chart tools, and there is a need to simplify how that 2D chart based information is presented in order for it to reach its potential. The visual richness and game like interaction of the 3D tool evidently attracted the participants, and this alone makes the technique worthwhile. The fact that it was also useful in helping them to learn about insulin, food and blood sugar management was the major positive outcome from this research.

There is clearly a need for further study into the effectiveness of the 3D tool in terms of its long term use. In particular the need to use the Diabetes Visualizer, not simply as an interaction trial, but as a tool in affecting long term blood sugar control. Using the Diabetes Visualizer on diabetic patients in a long term trial is needed to identify if the tool is merely a good interface design or whether it can play a role in improving blood sugar control and assisting diabetic health outcomes.

Overall the use of interactive 3D animated presentation of diabetes data was effective in engaging participants. The specific use of “flow” and “play” principles seemed to enhance their interest and desire to “get it right”. The “flow” and “play” systems described here could be applied in other health management topics and clearly has benefit in presenting diabetes related information to a broad audience.

5. REFERENCES


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