Relational and Metaphorical Approaches to Information Visualization: Effects of Age and Graphical Facility

Mark D. Lee, Lena Mamykina and Chandra Harrison

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Relational and Metaphorical Approaches to Information Visualization: Effects of Age and Graphical Facility

Mark D. Lee, Lena Mamykina, Siemens Corporate Research, Princeton NJ and Chandra Harrison, City University, London, UK

Diabetes requires continual monitoring of diet, glucose level, and other personal data so that a balance may be achieved between a desired lifestyle and one that is healthy and sustainable. While ubiquitous computing technologies can capture data necessary to make judgments, individuals need to be able to easily comprehend the data to draw conclusions. To help individuals with diabetis with this task, we designed two types of visualizations, a relational visualization using traditional graph-based techniques for presenting data, and a metaphorical visualization that conveys data using familiar, domain-specific imagery in an aesthetically pleasing composition. This paper presents a comparative analysis of these visualizations which indicated that older individuals with lower general graph-interpretation skills perform superior data analysis when using a visualization based on a familiar metaphor. These findings suggest that metaphorical visualizations constitute a viable alternative when designing informational displays for the elderly.

Introduction

Diabetes is one of the most common chronic illnesses among the elderly, affecting an estimated 20% of men and women 65 or older in the United States (National Diabetes Association Facts and Figures Sheet, 2005). One consequence of this disease is the need to strictly regulate one's diet, exercise, and medication schedule. However, due to high individual differences in diabetic cases, developing a regimen well suited to each individual is a lengthy and complex trial-and-error process. Individuals must carefully observe their experiences with different food types, or levels of exercise, to make adjustments to their behaviors.

While there exist techniques for manual (diary) or automated (utilizing sensors) monitoring of activities and blood sugar levels, there is a lack of visualizations tailored to aging adults that could help them review their past experiences and draw necessary conclusions. Not all people have the same facility in interpreting graphs, and there are potential cohort and educational differences in people's ability to interpret the data collected. In this paper we discuss two alternative strategies for visualizing information, and assess their effectiveness in context of diabetes management for aging adults.

The first visualization technique, *relational visualization*, employs people's ability to learn relationships between abstract visual properties of objects (e.g., size, color, and spatial position, etc.) to encode information. Relational visualizations are ubiquitous in our everyday lives in the form of simple graphs or charts, and are also common in scientific visualization work (Tian, Clement, Ellis, Steele, and North, 2001). This technique is especially common for depicting historical records (Viegas, Wattenberg, and Dave, 2004). Despite its popularity, this technique could be ill-suited for aging people (Kaufmann, 2002). The alternative technique, *metaphorical visualization,* is relatively common in interface design practices, but less frequently employed in information visualizations (Stasko, Miller, Plaue, Pouseman, and Ullah, 2004). This method utilizes analogies with real world phenomena to encode and communicate information.

This paper presents initial steps in investigating these issues by comparing the efficacy of one instance of each type of visualization. The results indicate that older people with lower graphical facility (GF, defined as a general ability to interpret graphs) have superior performance with the metaphoric visualizations, whereas younger people with higher GF have superior performance and general preference towards relational interfaces. Additionally, there was a significant effect of sex on performance, with females performing better with metaphorical visualizations than with relational ones. While we appreciate the limitations of comparing only one example of each visualization type, we believe these initial results have heuristic value for the design of information displays for the elderly and for home-based technologies.

Visualization Design

To compare differences between relational and metaphorical visualizations, we developed two visualizations for the same data set. The data consisted of high-level groupings of information essential to managing diabetes: vital signs, medication intake, activities, and emotional state. Specific measures included blood glucose level (captured every 10 minutes), blood pressure and heart rate (captured every hour); meals, exercise, social activities, recreation and sleep; measures of pleasure, dominance and anxiety (Bradley and Lang, 1994). To enhance the generalizability of the findings, each visualization was designed with a careful consideration of general usability principles, such as text readability, font size, etc.

Relational Visualization

The relational visualization (Figure 1) utilizes the concept of stacked timelines, a technique commonly used in clinical visualizations (Plaisant, Milash, Rose, Widoff, and Schneiderman, 1996). Each data type is represented on a separate timeline, with green background shading used to indicate "normal" ranges for each measure. Red ink and textual annotations draw attention to vital sign values above or below the normal range. Light red, vertical stripes in the background highlight time intervals with abnormal blood glucose levels.

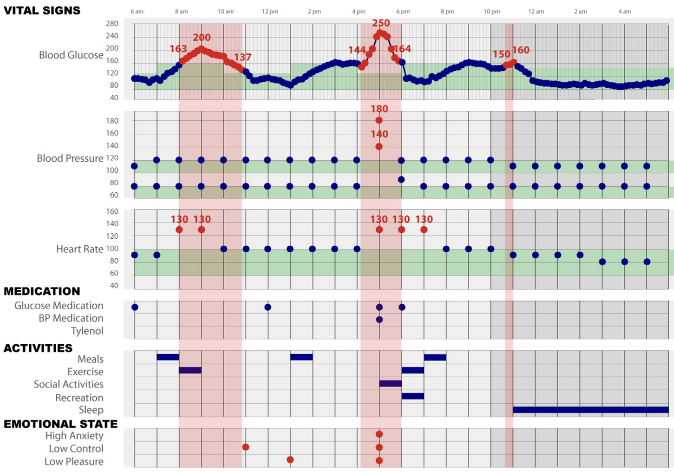

Figure 1: Relational Visualization - Monday

Metaphorical Visualization

In the metaphorical visualization, we use a clock as a metaphor for visualizing the captured data. All the records are placed "around the clock" at the appropriate times. To depict a full 24 hours, we present two clock views, one showing readings from 6am to 6pm (daylight to darkness), and another from 6pm to 6am (darkness to daylight). Additional hints about daylight hours are provided through background gradients (Figure 2).

As in the relational interface, we highlight time intervals of abnormal blood glucose values with a light red background shading and iconic annotations. Activities and emotional state are also represented using symbolic icons. For example, a knife and fork represent meals, while caricatures of human faces convey emotional state. Curved line segments indicate the duration of the activities.

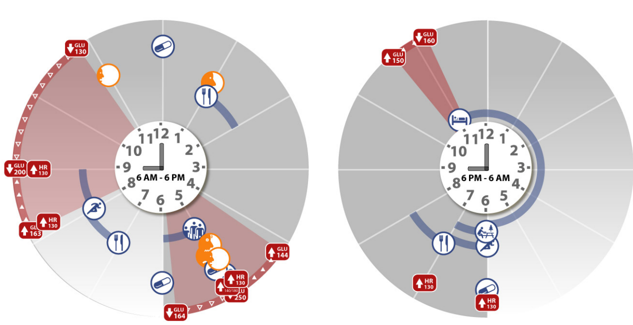

Figure 2: Metaphorical Visualization – Monday

Trend Analysis

In both cases, day-to-day activities are summarized by overlaying recent records on top of one another. To help distinguish the most recent data readings from others, previous days' readings are slightly enlarged and blurred (Figure 3).

Evaluation

Our study examined these two visualizations by considering the following hypotheses:

- Older people with low GF (graphical facility) will prefer metaphorical visualizations and demonstrate superior performance (in terms of accuracy and efficiency of data analysis) using these visualizations.
- Younger people with high GF will demonstrate superior performance and overall preference towards relational visualizations.

Method

Thirty-five participants were paid $125 to participate in a two hour experimental session. Participants with diabetes were recruited from two age groups, younger adults and older adults. Seventeen younger (mean age 36.24 years, range 25-40) and eighteen older adults (mean age 69.18 years, range 60-75) participated. Each participant had been living with diabetes for at least 2 years.

Within age groups, our goal was to have individuals who differed in their ability to interpret graphs and data trends. Accordingly, one group consisted of high school graduates with little formal statistical knowledge, and no specialized experience in interpreting data trends or graphs. Another group consisted of individuals with a Bachelors or Masters Degree, and some formal statistical training, with the expectation that they would be more capable of using graphs and extracting data from them. Each participant was given a test taken from the graph understating portion of the Graduate Record Examination (GRE) (ETS, 2004) to help validate our sampling methods. Participants were split into high and low GF based on their score. Participants with zero or one correct answer were placed in the low GF group. Participants with 2-4 answers correct were placed in the high GF group. This produced an approximate median split, with 16 low and 19 high GF participants. Sex was not a variable of interest, but each group was approximately gender-balanced.

To assess participants' ability to interpret visualizations, we designed experimental software that utilized the following procedure: After a short training session, participants were presented with static pictures of the visualization, based on scenarios developed with the help of clinicians. Each case contained a story of a person and the records captured for her during one week. The participants were free to look at each day separately, or to view the consolidated (overlaid) visualization.

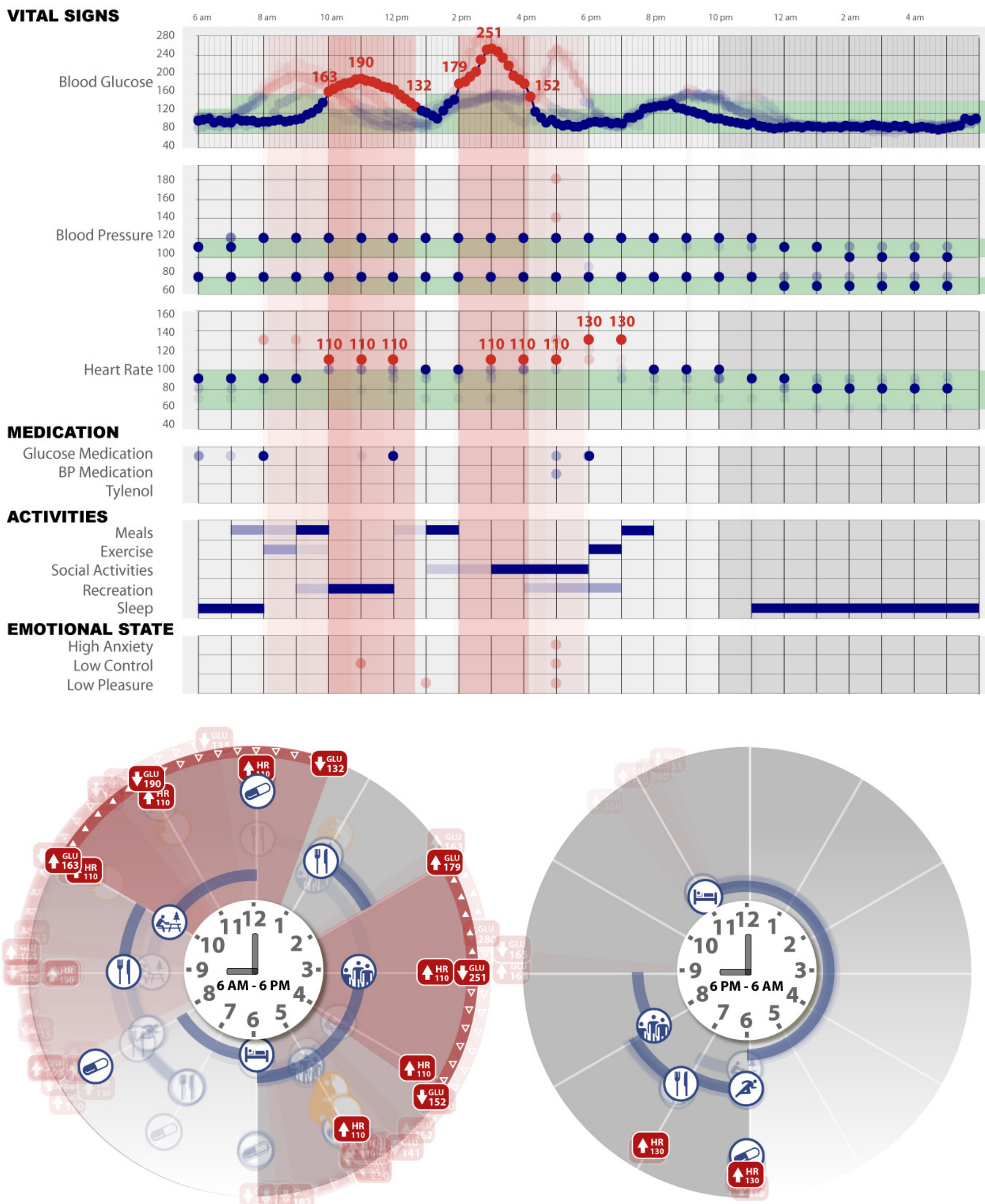

Figure 3: Trend Visualization – consolidated across a week

During the testing session, participants answered 20 questions about the records. Questions required participants to either locate a reading on a screen ("What was the recorded value of Blood Glucose at 9:00 am on Monday?"); form a hypothesis regarding relationships between activities and vital sign readings ("from the records on the screen, what could be a possible reason for: High Blood Glucose at 9 am on Wednesday?"); or identify overall trends in data ("Blood Glucose is usually too high after breakfast"). Because all the participants were diabetic for at least 2 years, they were expected to be familiar with the general terminology used in the questions. Participants' subjective rating for ease of use, accuracy, and time per question were recorded.
The study used a within-subjects design; visualizations and case orders were counterbalanced to counter potential learning effects.

Results

Mean time to answer questions (Time), the proportion of correct answers (Accuracy), and the subjective ratings of how easy each type of display was to understand (Subjective Preference) were calculated for each participant. These data were each analyzed using a Sex (Male, Female) X Graphical Facility (High, Low) X Age (Young, Old) X Display Type (Relational, Metaphorical) Analysis of Variance (ANOVA) where Display Type was a within-subjects factor. All analyses were weighted due to unequal cell sizes, and only significant effects are provided to save space. Effects for each dependent measure are described below.

Time. For Time, the results showed a significant interaction between Display Type and Graphical Facility $F(1,27) = 4.37$, $p < 0.05$. The means that make up this interaction are presented in Fig. 4. Participants with high graphical facility were faster on the Relational displays than on Metaphorical displays $F(1, 15) = 5.242$, $p < 0.05$. For people with low graphical facility, the opposite was true; however the difference failed to reach significance. The main effect of Age was also significant, $F(1, 27) = 4.91$, $p < 0.05$. Specifically, the older participants were slower on average to answer questions than their younger counterparts. The mean time to answer questions was 38.0 seconds on average for the older group, and 26.9 seconds on average for the younger participants. There were no other significant Time effects.

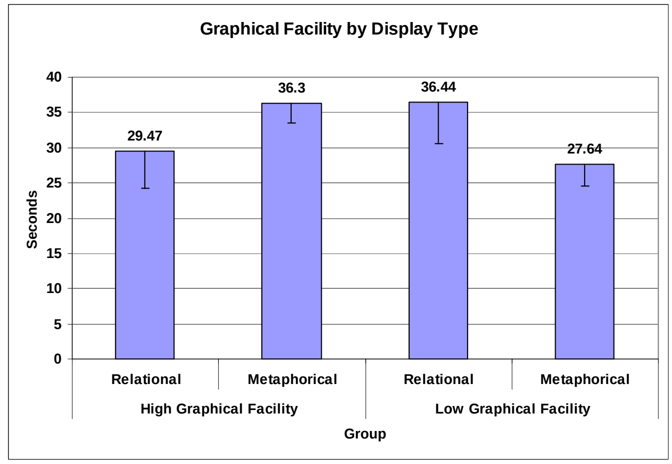

Figure 4: Graphical Facility by Display Type

Accuracy. For Accuracy, the results showed a significant interaction between Sex and Display Type $F(1,27) = 7.94$, $p < 0.05$. The means that make up this interaction are presented in Fig 5. Female participants were more accurate with Metaphorical displays than with Relational displays $F(1,10) = 12.49$, $p < 0.05$, whereas the male participants were about as accurate (no significant difference) with the Relational displays as they were with the Metaphorical displays. Significant main effects were found for Graphical Facility, and for Age. People with high Graphical Facility got 73% of the questions correct while those with lower Graphical Facility were correct only 64% of the time. This difference was significant $F(1,27) = 6.08$, $p < 0.05$. Further, as with the Time data, older adults were less accurate overall (mean percent correct of 64% for the older adults compared with 72% for the younger adults $F(1,27) = 5.56$, $p < 0.05$. No other Accuracy effects reached significance.

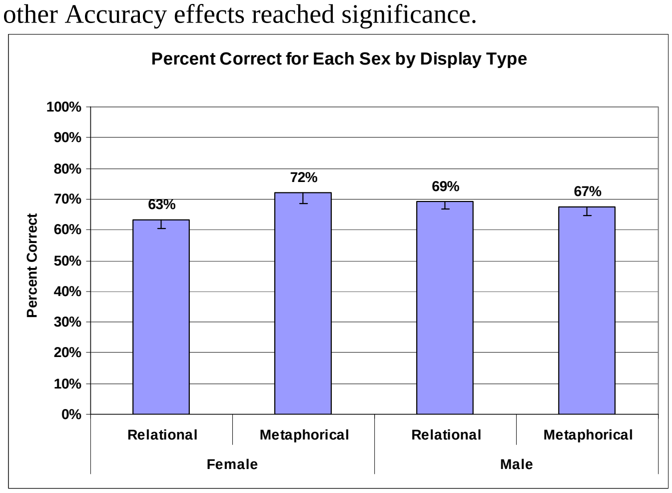

Figure 5: Accuracy for Sex by Display Type

Subjective Ratings. Participants were also asked to rate each display type for ease of understanding. Those data were compared to generate a Subjective Preference between the two displays. The result for Subjective Preference showed that participants preferred the Relational displays overall $F(1,27) =$

6.53, $p < 0.05$. The mean rating on a 5-point scale for Relational displays was 3.56 compared to 2.75 for the Metaphorical. There was also a significant interaction of Display Type and Age $F(1,27) = 7.47$, $p < 0.05$. The interaction is presented in Fig. 6. As shown in the figure, older adults did not significantly prefer either display type while younger adults strongly preferred Relational displays to Metaphorical displays $F(1,13) = 8.43$, $p < 0.05$. No other significant effects were observed in the preference data.

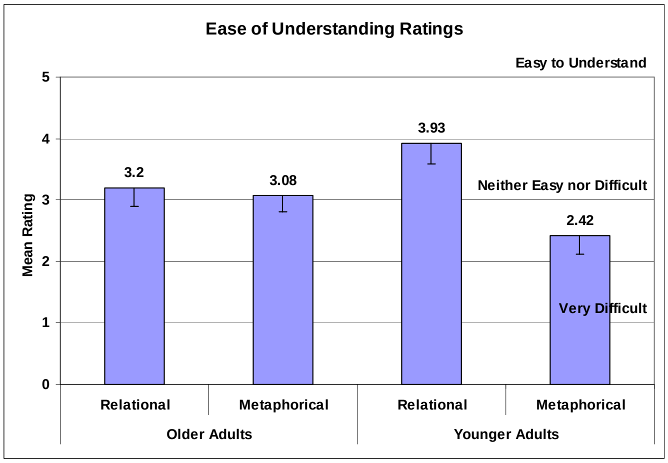

Figure 6: Ease of Understanding Ratings

Discussion

The findings supported our hypotheses, although to a smaller degree than anticipated. As expected, younger adults with higher GF required less time to interpret relational visualizations, whereas older adults with lower GF required less time to interpret metaphorical visualizations, without significant reductions in accuracy. In addition, younger adults with high GF showed strong preference towards the relational interface, though this was a general preference among all participants. The only group that showed slight preference towards metaphorical visualization was older adults with lower GF, although that trend was not significant (specific data not shown).

In addition to age and GF, sex appeared to be an important factor in accuracy of the interpretations; the accuracy of the female participants was significantly higher on the metaphorical visualization.

Implications

As stated earlier, the present study has limitations, and there is a risk from overgeneralizing from the present results. As computer interfaces take root in the home, it is essential to understand how traditional interaction methods, output conventions, and aesthetics must be combined, particularly for use with special populations such as older diabetic adults. Metaphorical visualizations provide the capability to display information in aesthetically pleasing ways, which may make them more suitable for use in the home space. Additionally, our findings indicate that they can be effectively used, and are of tend to be of more value for aging adults with low graph interpretation abilities. Clearly more research is needed in this area, and we plan to follow-up in this area.

In the future, we plan on expanding our study to include additional examples of both types of visualization techniques. In addition, we are deploying for field trials a metaphoric interface driven by sensor- and self-report data to enable situated, real-world assessment of its impact on diabetes management.

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