Health Informatics Meets eHealth
G. Schreier et al. (Eds.)

doi:10.3233/978-1-61499-645-3-191

Animated Scatterplot – Analysis of Time-Oriented Data of Diabetes Patients

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Abstract. Animated scatterplot visualizations promise to be useful tools for analyzing trends in time-oriented data. We evaluated such a visualization for the analysis of time-oriented medical data. We found 10 medical professionals to test the software which visualizes clinical diabetes patient cohorts. To analyze the usability of the software, the methods "Thinking Aloud" and structured interviews were used. Results show that animated scatterplots do support medical professionals in their daily work, in contrast to more negative results of scientific research in the past.

Keywords: medical data, animation, time, information visualization, time-oriented data, evaluation

1. Introduction

One of the major problems for physicians treating patients with chronic diseases is that in such cases a large amount of data accumulates over the years (e.g. blood tests, blood pressure etc.). Especially older patients may also have multiple diseases at the same time. This places a large burden on the physicians who have to study all these tests and reports. Information visualization is a possibility to ease this burden and to provide medical doctors with an overview of these data at a glance. It is especially suitable to represent heterogeneous data from various sources which come in different formats, e.g. data from blood tests, medication and body mass index.

A program using animated scatterplots is a possibility to represent such data. The main goal of animations is to show time-oriented data in a "natural form" – time is supposed to represent time. In contrast to timeline representations, the x-axis of the visualization can be used to show a second variable. This enables the user to see the temporal development of the relationship between two variables (e.g. body mass index and blood sugar). The temporal development is shown as the movement of the dots (which represent the patients) on the screen. In the literature, there is a controversial discussion about animation. Some authors argue that animation can be very confusing, and that small multiples is the better method to support exploration [8]. Tversky et al [9] are also sceptical about the usage of animation, although she argues that interaction can help to alleviate the problems with animations. Recent research indicates that some forms of interaction can help to get insights with animations. Kriglstein et al [5] conducted a literature review and argue that the reviewed studies indicate that VCR-like control elements (see Figure 2) can help users to get insights more easily. It is especially valuable if the users are able to control the speed of the animation.

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The goal of the study was to test the usability and utility of the Animated Scatterplot software for the presentation of time-oriented medical data. The results indicate that the program had some usability problems which were solved in a later version. Nevertheless, the users were able to use the program fairly well after a trial time. We also investigated more general issues, especially the question whether animation can be beneficial for the work of physicians and whether such a program can be learned easily.

1.1. Related Work

There is a controversial discussion in scientific literature concerning animation. Bartram [1] discusses potential advantages of the use of animation. She describes animation as an additional and useful display dimension to represent large amounts of multivariate dynamic data. Griffin et al. [4] describe the additional advantage of using animation in recognizing trends regarding timing (i.e., frame rate).

Nowell et al. [6] see a potential disadvantage in the perceptual effect of change blindness, where significant changes are not recognized. In Tversky et al. [9] static and animated representations were compared. They state that static and animated cases were not comparable (e.g., representations differ or include less or more information). They expressed three main concerns on animation: (i) developments may be hard to detect, (ii) developments may be perceived as a sequence of frames, and (iii) there is no or less interactivity. They recommend that users should be able to change orientation of parts or the whole animation and are able to control the speed, view, review, start, stop, zoom in and out.

In the literature there is no clear view on animation in visualization. Therefore further research is necessary to explore animation in visualization.

1.2. Description of the Animated Scatterplot Program

The basic feature of the Animated Scatterplot program (see Figure 1) is a scatterplot for two variables. Users can select variables from two combo boxes next to the respective axes (e.g. blood sugar level versus body mass index). Development over time is represented by the movements of the dots of this scatterplot diagram. One dot represents one patient. Additional variables (e.g. sex of the patients) can be represented by the form or the color of the dots. A VCR-like panel allows the users to control the animation, but it is also possible to use a timeslider and choose the speed of the presentation manually. The program offers several different possibilities of interaction. It is, for example, possible to zoom into the data within the scatterplot diagram. It is also possible to filter the data (e.g. to show only patients with values above a certain threshold). Users can also get detailed information of individual patients (by hovering over the dot of this specific patient). There are two possibilities to show the "age" of data, that is the temporal distance from the last measurement of variables: transparency and traces. In transparency mode, marks fade out more and more. This makes patients with current data clearly stand out. In trace mode, all traces of the movement of dots stay visible. Thus, at the end of the animation, complete patient histories can be seen (see Figure 3). Rind, et al [7] provide a more extensive description of the software.

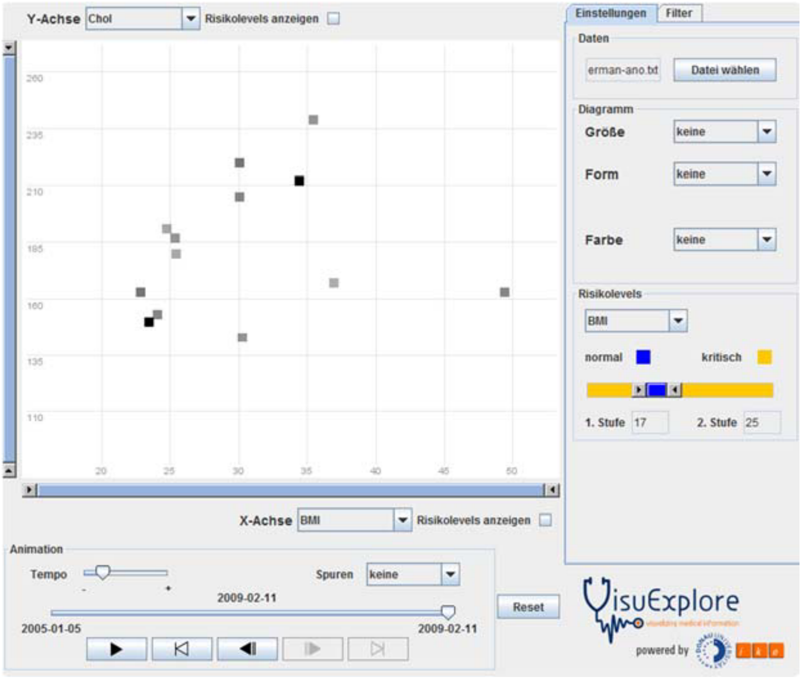

Figure 1. Animated Scatterplot (main screen)

2. Methods

The goal of the study was to test the usability of the Animated Scatterplot program for the presentation of time-oriented medical data (specifically diabetes data). The participants of the study were 10 medical doctors. This makes the study especially valuable. It is well known that it is difficult to get real experts, especially physicians, for evaluation studies in information visualization. Therefore, visualizations are often tested with students which makes the results in many cases less valid.

The methods which were used were content analysis based on screen capture of the interactions of the users and interviews which were conducted after the experiment. For the content analysis, two different taxonomies were used for categorization purposes, the taxonomy developed by Yi, et al [10] and the categorization scheme developed by Forsell and Johansson [3]. The categorization scheme developed by Forsell and Johansson is especially relevant for this paper. Their categorization scheme is based on other well-known heuristics. They derived empirically the most important usability heuristics for information visualization: information coding (mapping), minimal actions, flexibility (number of possible ways to achieve a goal), orientation and help, spatial organization (e.g. distribution of elements on the screen), consistency, recognition rather than recall, prompting (all means to support the users to find alternative ways of doing things), remove the extraneous (distraction through unnecessary information), data set reduction. Even if these categories are mainly meant for heuristic evaluation, we think that they can also form a valuable framework for the interpretation of user actions working with information visualizations.

The participants of the study first got a brief introduction into the system. Then they had to solve 4 tasks which were developed together with medical experts and which reflected realistic activities in medical diagnosis. Task 1 was designed to let the participants familiarize themselves with the software, tasks 2 and 3 had concrete questions to answer, and task 4 allowed the participants to freely explore and interact with the software.

Below, we want to show task 3 as an example for the tasks used in this investigation:

Parameters: x-axis: NBZ (fasting glucose level)
y-axis: RR diast (mmHG) (diastolic blood pressure)

Task description: Limit the data set to NBZ < 100; RR diast < 80. Choose a setting that gives a good overview of the trends of the patients. Which patients shows a favorable trend? What is the general trend of the group? Explore at will. Describe your findings.

The interactions of the participants were logged with a screen capture program. The participants were asked to think aloud while they solved the tasks. This was also recorded with the screen capture program. After the participants had solved the 4 tasks, an interview was conducted to identify the subjective attitude of the participants concerning the program. The duration of the whole experiment was approximately 60 to 90 minutes.

According to Boren and Ramey [2] the method of “Thinking Aloud” can provide immediate insights into the reasoning processes accompanying the solution of cognitive tasks. While study methods that are applied after the interaction with the system can also yield interesting results, there is a tendency of the users to re-interpret their activities retrospectively. In thinking aloud it is possible to avoid this source of misinterpretation. Therefore, this method is often used by usability researchers to get a more detailed view of the users’ interaction processes with the system under investigation.

3. Results

3.1. Screen Capture and Thinking Aloud

The screen capture showed that all the participants could solve all the tasks with the animated scatterplot program. The solution process for task 4 showed that the participants also tried out new parameters and new features on their own in task 4 which asked them to freely explore the data. 8 of the 10 participants used new parameters in this task, only 2 used parameters from previous tasks to study them in more detail.

The largest amount of usability errors according to the classification of Forsell and Johannsson (2010) was in the areas of spatial organization and consistency. It is clear that the spatial organization of the system was novel for the participants and therefore, they had difficulties with the visualization. Physicians, in general, tend to use visualization like line charts and bar charts and avoid more novel forms of representation. Therefore, at first they tended to interpret the x-axis as the time axis because they were used to this from static line graphs. At the beginning, they also had problems to understand the dynamic nature of the animation. For some patients no data existed for the first time periods. Participants were confused that dots appeared for these patients all of a sudden while they worked with the visualization. It must be mentioned, however,

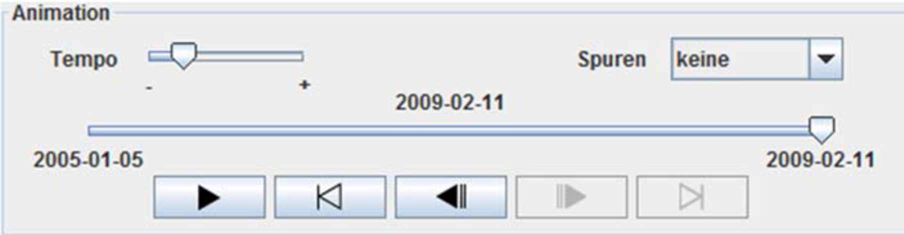

Figure 2. VCR-type of control and time slider

that the participants got used to these novel features fairly quickly and understood them at the end of the testing period.

Consistency was a problem for the users because the animated scatter plot program does not resemble standard Microsoft application programs. The other categories identified by Forsell and Johansson [3] only played a minor role as sources of usability errors.

The participants appreciated the possibility of the program to show groups of patients and several points in time in the same visualization. The animation was new and interesting, but it took some time to adapt to it. None of the participants used the VCR-type of control of the animation, but only the time slider (see Figure 2). They commented that the speed of the animation was too slow. They dragged the time slider manually again and again (all in all the participants used the time slider approximately 600 times). They argued that this helped them to understand the temporal development better. This conforms to the assumption of Tversky et al [9] who posits that animation can be beneficial if interaction possibilities are provided.

3.2. Interviews

The main questions which were asked in the interviews addressed general problems of the program, advantages of the program, possible application areas of the program, interaction possibilities, and visualization and animation.

Advantages of the program: Participants mentioned that the main advantage of the program was the possibility to see the data of all patients at the same time and to get an overview of the data.

Possible Application areas: Participants said that a possible application area could be for monitoring the effects of new medications. Another possible application was the education of healthcare professionals.

Interaction possibilities: Participants mentioned that they would appreciate the possibility to highlight single or a small group of patients which was not possible in their version of the program. They also enjoyed the extensive possibilities to filter data. This was seen as very beneficial. Even the combination of several criteria for filtering was intuitive and easy to understand. Zooming into the data was only appreciated by 3 out of 10 participants. This might be due to the design of this functionality.

Visualization and animation: Participants mentioned that at first they interpreted the x-axis as time, but they quickly got used to that. Participants had different opinions concerning the number of patients (=dots) they wanted to see on the screen. Some preferred more patients to be able to see trends more clearly, and others found the large number of dots too confusing. Participants preferred to manually operate the time slider instead of the VCR-type of control. The development of the patients (that is, the

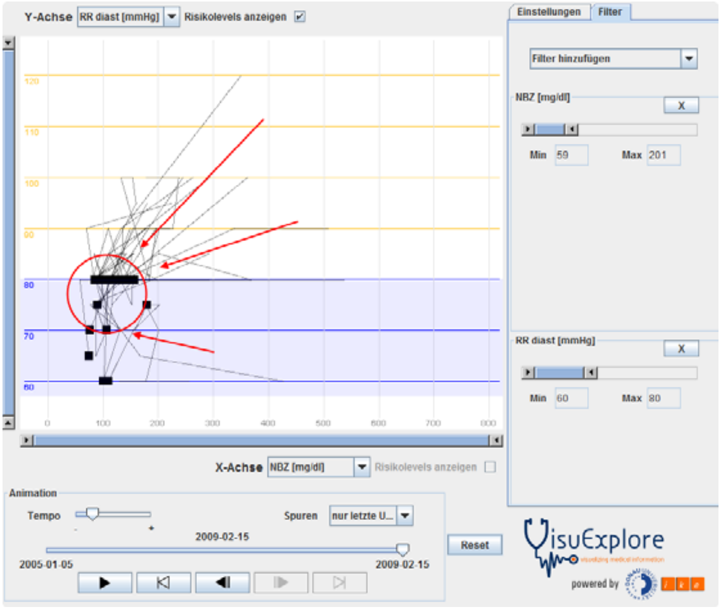

Figure 3. Trend recognition (traces)

movement of the dots) during the animation can be shown as a static picture using traces. These traces show the movement of the dots on the screen as static lines. Traces can be used during the animation to support the recognition of a group trend (see Figure 3). Participants appreciated this possibility to show trends, although some mentioned that traces get cluttered when too many patients and time steps were being shown.

One of the most serious usability problems was the design of the risk levels. The "normal range" was highlighted, not the "at risk" range, and although the physicians know what the normal range of the different medical parameters is, they focused on the highlighted area and interpreted it as risk level (see Figure 2). Apparently, the affordance of the highlighted area implies that it shows the risk level, not the normal range.

Strategy: All participants mentioned that they first studied the whole group of patients and then significant single patients – either outliers or patients who are typical for a certain group. They start with the whole group and then reduce the number of patients they want to investigate.

4. Discussion

In this paper we describe a usability and utility evaluation of an animated scatterplot software for medical data. Although the evaluation addressed one specific system, some general conclusions can still be drawn. On the one hand, this study is a contribution to the discussion concerning the value of animations in information visualization. On the other hand, our results can also contribute to the discussion about how to deploy novel systems.

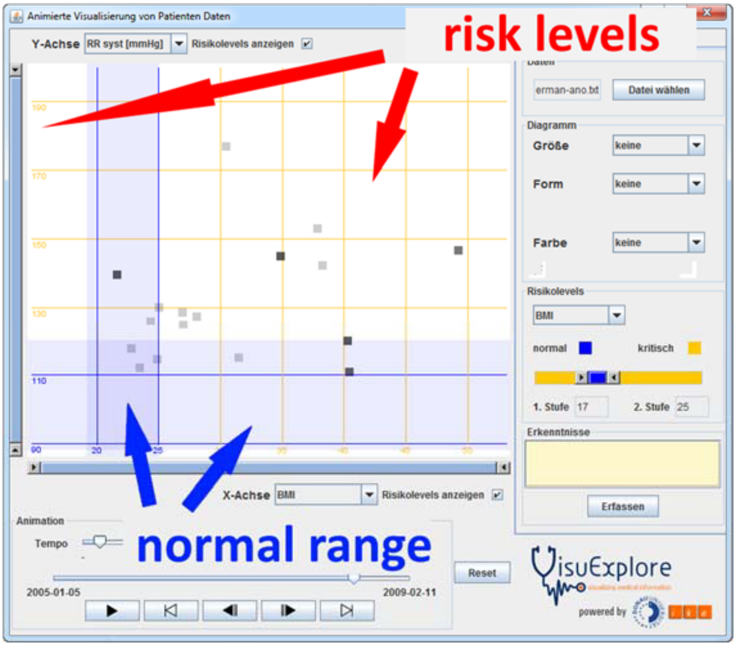

Figure 4. Risk levels

The animated scatterplot system was at first confusing for the physicians who participated in the study. We could observe, however, that they quickly learned how to use the system. They could solve all the tasks presented to them fairly easily. We also found that interaction plays an important role in this context. The participants did not use the VCR-like control but the time-slider which allowed them much more control over the speed of the animation and provided the possibility to stop the animation anytime they wanted to. These results indicate that animations can be used to help experts to explore data and get insights, contrary to Robertson's et al [8] sceptical attitude. We would like to point out that it is important to design the visualization appropriately, so that it is intuitive to use. The study also indicates that systems that are easy to learn can help in the implementation process. In general, physicians are sceptical about novel visualization because their time constraints are very severe. Our study shows that this can be overcome by a system that is easy to learn.

We also identified some usability problems as, e.g., the design of the risk level. Based on this study the system was redesigned to enable physicians to work with it more easily.

There are also some limitations concerning this study. It can be argued that the situation in which the Animated Scatterplot system was tested was not realistic. In addition, it seems plausible to assume that users will behave differently if they have used a system for a longer period of time and are more acquainted with it. Possible future work would be to test the system over a longer period of time, so that the participants of the study get a more realistic picture of the system. In such a situation, users are better able to assess the advantages and disadvantages of the system and how it can be used most efficiently to support the work of physicians.

Acknowledgements

This work is conducted in the context of the CVAST (Centre for Visual Analytics Science and Technology) project. It is funded by the Austrian Federal Ministry of Science, Research, and Economy in the exceptional Laura Bassi Centres of Excellence initiative, project number 822746. We want to thank B. Neubauer for the development of the Animated Scatterplot System.

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