# Visualizing Daily Hospital Routine

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This article was originally published in German in the publication "Entwerfen Wissen Produzieren" (November 2010. Bielefeld: transcript Verlag) of the Annual Conference of the German Society of Design Theory and Research (DGTF).

**Introduction**

Hospitals, just like other businesses with a comparatively complex organizational structure, are often confronted with analyzing and evaluating complex sets of data that are hard to monitor. Standardized forms of presentation (e.g., pie or bar charts) are frequently used for the visual analysis and presentation of data in such cases. From a visual communication perspective, the potential that visualization offers has not been exhausted. Collaboration between statisticians and designers—with the pooling of theme-specific practical and creative competences—is therefore a worthwhile objective. The research project, "Visual Atlas of the Daily Hospital Routine,"[1] joins these competences to research the options of alternative forms of visualization of complex sets of data for process optimization.

The specialist department for quality management of the Bern University Hospital Inselspital (Annekäthi Bischoff), which provided the data for this research project from four selected sub-processes, is a contact point for quality management issues for the entire hospital. During process optimization, the goal is to analyze and optimize hospital-internal procedures. For data collection, qualitative procedures are often applied, including field research, participatory observation, and interviews. For purposes of analysis and evaluation, standardized quantitative representation models (e.g., bar graphs) are almost exclusively used. The visualization of qualitative data, in contrast, is hardly considered significant.

As a sub-discipline of visual communication, "Knowledge Visualization"[2] generates context-specific visual representations of quantitative and qualitative data. The goal of the visual representation is to provide access to complex sets of data, often with great advantages over linguistic or standardized visual representation models. Edward Tufte describes this potential as follows: "Often the most effective way to describe, explore, and summarize a set of numbers—even a very large set—is to look at pictures of those numbers."[3] The viewing of such images can help to present work processes more clearly and thereby to analyze procedures and manage them more efficiently.

The goal of this research project was to develop alternative presentation forms for four organizational and communicative sub-processes in the environment of the Inselspital. As a secondary means of analysis, the images developed in the project were

1 The research project is a project initiated by the Bern University of the Arts in cooperation with the Bern University Hospital Inselspital (Annekäthi Bischoff, Specialist Department for Quality Management). Run-time: January 2008–July 2009; financing by Bern University of Applied Sciences.

2 "Knowledge Visualization" is a form of knowledge transfer that uses all types of graphic media to guarantee an effective transfer of information. Beyond the mere transfer of facts (cf. information visualization), the aim of knowledge visualization is to promote the acquisition of knowledge that supports decisions and triggers actions by actively confronting the content.

3 Edward R. Tufte, *Visual Display of Quantitative Information*. (Cheshire, Connecticut: Graphics Press, 2001), 9.

intended to enable an alternative—visual—access to and evaluation of the data. The three central research questions for the project were these: How and in which specifications can the different strategies and methods of knowledge visualization make complex procedures in the patient process (i.e., the process of caring for the patient from admission to discharge and further to post-hospitalization treatment) visible and recognizable, and therefore, help to improve the work processes at the Inselspital? Does the knowledge generated through the visual analysis provide added value in comparison to the conventional statistical methods? What new knowledge can be gained from the alternative presentation form?

**Initial Situation**

The data used for the project had been collected for internal process optimization projects at the hospital and had been evaluated and analyzed according to conventional statistical methods[4] by the corresponding clinics. In addition, the process optimization had already taken place for two projects. Thus, the visualizations developed in this research project are a visual secondary analysis of the data. The data from the four sub-processes can be categorized both temporally and thematically for different parts of the patient process.[5] Each of the project's sub-processes dealt with occurred on the organizational level of "clinic care" (the level where the medical care takes place—the other two levels of the patient process are "facility management" and "administration").

Using these four sub-processes, the project developed and tested exemplary strategies and methods to enable knowledge visualization. The following paragraphs explain the sets of data and describe the parameters of data acquisition.

1. *Waiting times*: Analysis of this process sought to determine how long patients have to wait before being able to consult a doctor and how much they are bothered by having to wait. The data were collected by means of a questionnaire and a stopwatch. In addition to the waiting time and the individual disturbance factor (self-assessment on a scale of 1 to 5), other data collected included the treatment ward, area of specialization, and the age and gender of the patients. The data were collected in 2006 for 349 patients and in 2007 for 283 patients. Between the first and second data collections, the hospital undertook process optimization changes with the objective of shortening the waiting times.[6]
2. *Decubitus risk*: A decubitus ulcer is a pressure sore (i.e., bed sore) that can occur in patients when they are bedridden for long periods of time. For early detection and prevention, the nursing staff assesses decubitus risk for each patient at regular intervals and documents the assessment in the patient file. For the data collection, 171 patient files

4 The statistical analysis was made with SPSS software.

5 Annekäthi Bischoff, *ProPat Modellprozess Patientenbetreuung* (Bern: Inselspital Bern, 2007), 6.

6 Sandra Puliafito, *Resultate Evaluation Massnahmen Poliklinik* (Bern: Inselspital Bern, 2007).

were examined to determine whether nurses had indeed conducted both an initial and second assessment and how high the risk was assessed to be—statistics based on the Braden Scale.[7] Additional data recorded were hospital ward, area of specialization, mobility, type of bedding, and gender and age of the patient.[8]

3. *Ward rounds*: Here, the object of the study was the level of cooperation between the interns and the nursing staff, as well as the transmission of information and the timing of the workflow. In 2006 and 2008 a questionnaire, completed by both interns and nursing staff, was used to evaluate 20 aspects of cooperation between the two. Each professional group answered the same questions in regard to the other group. Using the results from the first survey, the hospital undertook process optimization, and then a second data collection occurred to evaluate its effects.[9]
4. *Patient discharge*: The objective here was to discover how well patients were informed at discharge about the most important aspects relevant to their recovery. These data were collected by means of an 18-item questionnaire for a group of 89 patients.[10]

A conventional statistical evaluation and presentation of the data already existed in the form of consecutive sequences of 15 to 35 PowerPoint slides, with an equal amount of bar charts, for all four process optimizations (Figure 1).

**Methodology**

The methods applied in the research project are design-based and derived from the discipline of visual communication or communication design. As communication designers, we see great potential

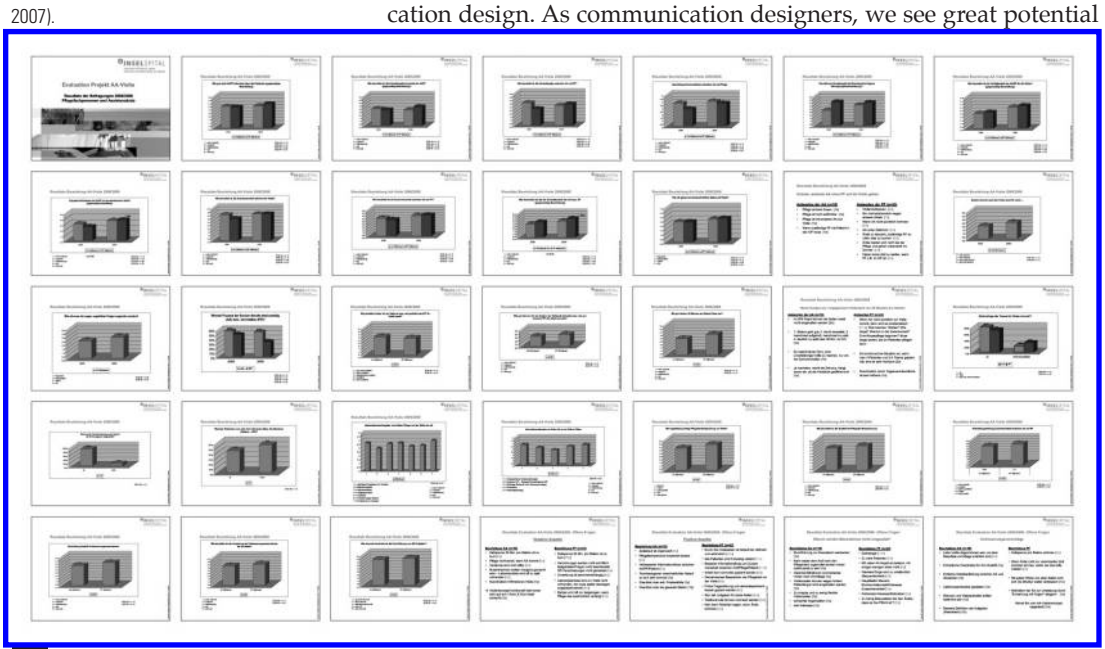


Figure 1
Statistical evaluation of the sub-process "ward rounds" in the form of 35 PowerPoint slides with bar charts.
Photo: Sandra Puliafito, Resultate Evaluation Massnahmen Visite (Bern: Inselspital Bern, 2007).

7 Direktion Pflege, medizinisch-technische und medizinisch-therapeutische Bereiche, *Pflegestandard Dekubitusprophylaxe und Dekubituspflege* (Bern: Inselspital Bern, 2006), 19; Klaus-Dieter Neander, "Aktuelle Therapieformen des Dekubitus," *Die Schwester/der Pfleger* 11/95 (1995).

8 Barbara Hürlimann and Höfagruppe DMLL, *Monitoring Konzept Erfassung und Behandlung Decubitus DMLL* (Bern: Inselspital Bern, 2008).

9 Sandra Puliafito, *Evaluation Projekt AA-Visite* (Bern: Inselspital Bern, 2008).

10 Sandra Puliafito, *Projekt PAOK Resultate Patientenbefragung, Ist-Analyse* (Bern: Inselspital Bern, 2008).

for approaching content from a context removed from design and to process and analyze it from our designerly perspective. To do so means questioning the visual representations with which the department for quality management usually works and to develop alternatives for these. Furthermore, we analyzed and explored the four sub-processes, not only on a content and text-based level, but also in terms of visual means and work methods.

Our research process can be described as the systematic testing of content-relevant parameters (e.g., waiting times, disturbance factor, gender, age, etc.) and their adequate translation into visual variables. The thus generated wide range of visual experiments and their constant evaluation characterizes such a visually conducted, reflected research. Three aspects play a significant role in this "graphic transcription."[11] First, it is a matter of the type of information carrier, including typography, photography, cartography, or graphic elements (e.g., point, line, plane, irregular form, etc.). Second, it is a matter of graphic parameters, including size, color, opacity, brightness, angle, length/width/height, and structure/surface/material. Third, it is a matter of the graphic processing or visualization of, for example, abstraction, comparison/contrast, scaling, overlapping, and marking. Structured experimentation with these three levels of visual coding of content provides numerous options for developing a wide range of alternative presentation forms.

Together with our project partner, we continuously evaluated the designs and visualization approaches created. Testing at regular intervals determined whether important questions became visible with the visualization system and which additional aspects and insights surfaced. Based on several evaluation loops, we concluded by mutually selecting one visualization system each per theme. These were then processed and fed back to the clinic managers and nursing professionals towards the end of the project, and evaluated in discussions.

**Approach**

We began by receiving an introduction to the hospital's internal sub-processes in the form of discourse with the department of quality management. The object was always to understand the content and the goal of the process analyses that had already been conducted, the data acquired in those analyses, and their evaluation. In the introductory talks, the objective was to understand the insights attained during the previous analyses and where unresolved questions still existed.

Subsequently, the idea was to study the available material in detail and to determine the structure of the information complexes: "The precise determination of the components of the information, their number, length, and their level of classification precede each graphic processing."[12] In our case, a corresponding number of

11 Jacques Bertin, *Graphische Semiologie. Diagramme, Netze, Karten* (Berlin, New York: Walter de Gruyter, 1974), 24.

12 Jacques Bertin, *Graphische Semiologie. Diagramme, Netze, Karten* (Berlin, New York: Walter de Gruyter, 1974), 40.

between 24–42 parameters for between 52–350 persons was collected or requested. We analyzed the questionnaires, data, and previous evaluations according to an intensive study and observation using categorized lists, hierarchical tree displays, and hand sketches. We followed this analysis with a broad content-relevant and visual investigation on the theme, during which our objective was to explore the visual potential of the four themes. Associative brainstorming resulted in initial ideas expressed through keywords and hand sketches. In addition, we conducted broad image research on topics, ideas, keywords, associations, and metaphors for the individual processes. Both strategies resulted in a broad and very free layout of visual and text-related elements, from which primary visualization approaches and ideas were collected and sketched by hand. Often, we used a photo from the "image research" phase and abstracted it into thematic associations with the help of a sketch and with corresponding parameters, so that these associations might result in an introductory visualization idea.

From these idea sketches, we generated initial digital conversions. However, the existing data sets were not yet implemented in this work step. These digital conversions were only roughly simulated to help determine which content-related parameters could be encoded with which formal parameters. Then, in a subsequent work phase, individual visualization approaches were selected and roughly transcribed with the data. The idea was to develop a feeling for the data, which is vital for the conception of an adequate and meaningful visualization. Comparing the individual designs helped to reveal what each visualization system could render, which aspects became correspondingly visible, and whether the visualization altered the apparent meaning of the data. Scaling, data distribution, and data variance play a significant role in the latter. Also during this work phase, we determined whether the conversion from content-relevant parameters to graphic parameters had been wisely managed, and which scaling or grid made sense for the visualization.

The search for an appropriate "graphic density"[13] is essentially a balancing act between complexity and reduction, whereby the objective is to assess and define the number of content-relevant parameters that can be displayed within one visualization. The goal is for the visualization to be sufficiently complex but at the same time for the individual aspects to still be registered and comprehended by the observer. Stephen Few describes the search and definition of content-related parameters and their reference as a core task in visualization: "Most data analysis involves searching for and making sense of relationships among values and making comparisons that involve more than just two values at a time."[14] In the end, one visualization system per theme was selected, in cooperation with the department of quality management, and was graphically elaborated. Here, we also determined which medium

13 Jacques Bertin, *Graphische Semiologie. Diagramme, Netze, Karten* (Berlin, New York: Walter de Gruyter, 1974), 183.

14 Stephen Few, *Now You See It* (Oakland, CA: Analytics Press, 2009), 30.

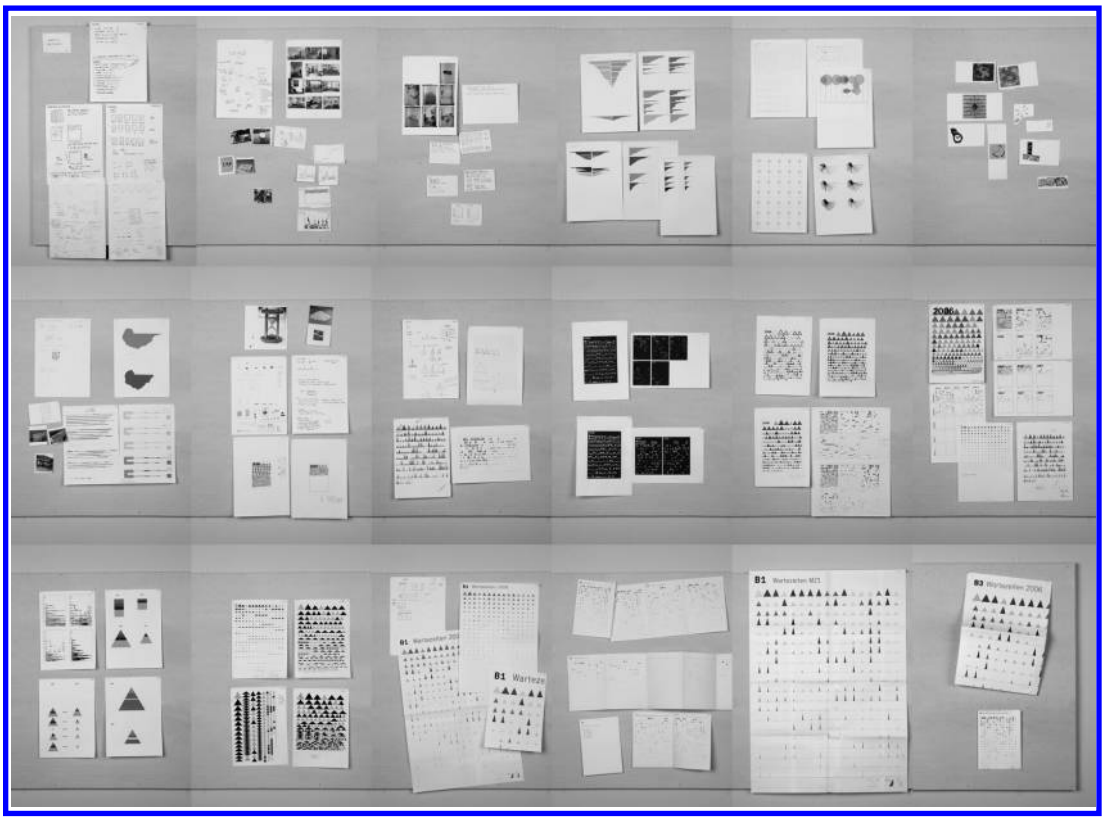


Figure 2
From the first content analysis to the finished visualization: excerpts from the work process on the "waiting times" sub-process.
Photo: Barbara Hahn, Christine Zimmermann, Visual Atlas of the Daily Hospital Routine (Bern: Bern University of the Arts, 2008–2009).

(e.g., poster, card set, fold-out booklet, etc.) was most suitable for the corresponding visualization (Figure 2).

**Findings**

The visualizations selected flowed into a wall installation, which is conceived of as a work tool for process analysis and enables a simultaneous viewing and analysis of all sub-processes. The wall installation including the visualizations of the four processes serves to illustrate, in an exemplary fashion, how visualization as a work application aids in process optimization in the hospital. In its modularity, the installation represents the model process for patient care. The visualizations that have been developed for the four themes—waiting times, decubitus risk, ward rounds, and patient discharge—can be found at the corresponding points in the process, on clipboards provided for this purpose. The clipboards which contain the visualizations make reference to the daily hospital routine as object-like quotations.

Variations in medium and format were consciously used for the different visualizations (e.g., poster, fold-out booklet, card set, drawer with cards), and we conducted experiments in regard to their suitability. The specific formats were intended to support the communication of the content beyond the form of presentation, and we selected the format on the basis of the optimal relationship between information quantity and space (i.e., "data density").[15]

15 Edward R. Tufte, *Visual Display of Quantitative Information* (Cheshire, Connecticut: Graphics Press, 2001), 162.

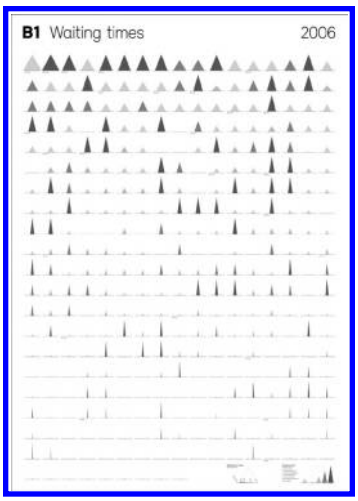



Figure 3 (left)
Visualization for waiting times, consisting of posters for 2006 and 2007 and eight fold-out booklets with various focus views. Photo: Barbara Hahn, Christine Zimmermann, Visual Atlas of the Daily Hospital Routine (Bern: Bern University of the Arts, 2008–2009).

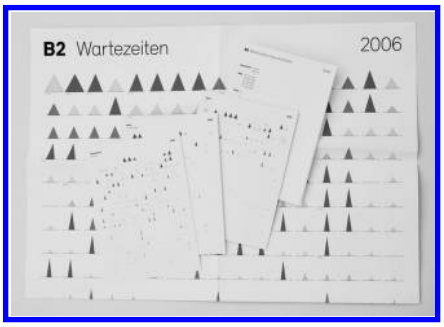


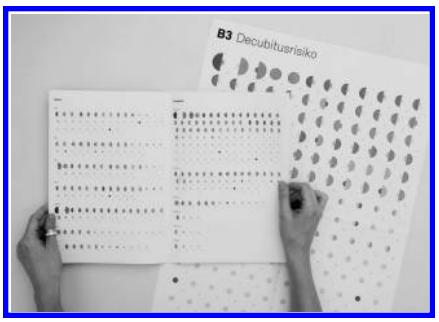

Figure 4 (right)
Visualization for waiting times, poster on the 2006 survey. Photo: Barbara Hahn, Christine Zimmermann, Visual Atlas of the Daily Hospital Routine (Bern: Bern University of the Arts, 2008–2009).

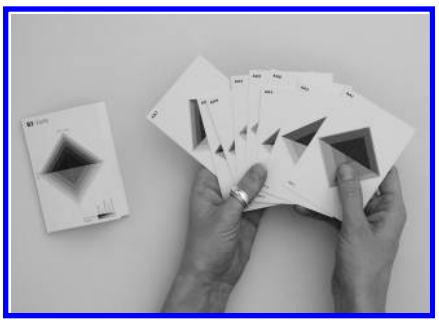
In addition, various print media were implemented to allow for different readings (e.g., the overall picture of a poster, or focused views on a fold-out booklet or a card set to support non-linear reading of the information presented). The deliberate selection of a medium can be helpful in fulfilling the visualization principle of "focus+context,"[16] meaning that readers are shown the most important data in detail, and at the same time, its relation to the overall context.

The following paragraphs briefly explain the developed visualizations:

1. *Waiting times:* In 2006 and 2007 the hospital conducted surveys on waiting times and their related disturbance factors. For each of the two surveys, a poster was developed that showed an overall view of all waiting times, and a fold-out booklet was developed that showed various focused views (e.g., wards, teams, gender, age, etc.). The waiting time of the patients (represented by the width of the triangle) is placed visually in direct connection with the assessment of how much the waiting disturbed the patients (i.e., triangle height and coloration). The more disproportional the waiting time was in relation to the disturbance factor of a patient, the more disproportionate the form of the triangle becomes (Figures 3–4).
2. *Decubitus risk:* The poster shows the consistency with which the data on decubitus risk have been acquired and how the risk of all patients has changed between the two assessments. The two risk assessments are visualized by two semicircles and presented in a side-by-side comparison. The visualization element has been derived from a picture of a fingerprint and shows the graphically abstracted form. Three circle sizes show whether there is a low, medium, or high risk; the line thickness increases with an increase in risk. Patients who have actually developed decubitus are highlighted in red. Missing data are marked in gray (see Figures 5–6).
3. *Ward rounds:* The level of collaboration between interns and nursing staff was surveyed in 2006 and 2008 by means of a questionnaire. The rhombus shape shows the assessment

16 Stephen Few, *Now You See It* (Oakland, CA: Analytics Press, 2009), 113.



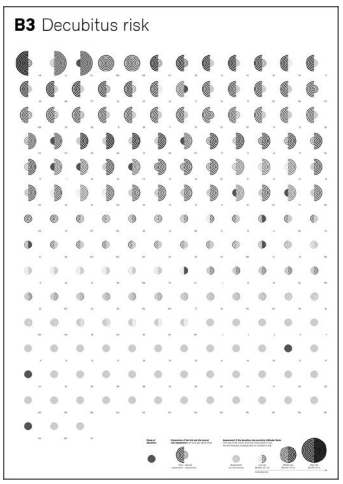



Figure 5 (left, top)
Visualization for decubitus risk, consisting of a poster and a fold-out booklet with various focus views.
Photo: Barbara Hahn, Christine Zimmermann, Visual Atlas of the Daily Hospital Routine (Bern: Bern University of the Arts, 2008–2009).

Figure 6 (right)
Visualization for decubitus risk, poster. Photo: Barbara Hahn, Christine Zimmermann, Visual Atlas of the Daily Hospital Routine (Bern: Bern University of the Arts, 2008–2009).

Figure 7 (left, bottom)
Visualization of ward rounds, card set consisting of ten cards.
Photo: Barbara Hahn, Christine Zimmermann, Visual Atlas of the Daily Hospital Routine (Bern: Bern University of the Arts, 2008–2009).

of the collaboration between the interns (blue; top) and the nursing staff (green; bottom) in the annual comparison (2006=left, 2008=right). Each rhombus shape correlates to one question. The varying assessments are shown according to the opacity of the color areas (dark=very good, light=very bad). Thus, both a comparison of the assessment of each professional group and the temporal change through optimization methods is visible in compressed form at one glance. The result is a card set, with ten questions (on the back) and their visualization (on the front), which stimulates discussion about the different assessments by the professional groups and the changes between 2006 and 2008 (Figure 7).

4. *Patient discharge:* About 90 patients were surveyed upon their discharge by means of a questionnaire to discover how well they were informed about the important issues of their recovery. In the visual matrix, all questions were shown horizontally and all patients (divided into five treatment teams) were shown vertically. If a patient is well-informed, a black square is filled in at the corresponding area of the matrix. Information gaps are marked with red points. The greater the information gap is for a patient, the larger the red point in the matrix. Thus, the issues about which the patients have received incomplete information and the issues about which information has been well communicated are easily recognizable. The matrix enables two different readings: a focus on individual patients (horizontal) and a focus on issues (vertical).

Various focus views can be viewed in isolation on individual cards, including the five levels of information (from very well informed to very poorly informed) and non-surveyed data. A paper slipcase for

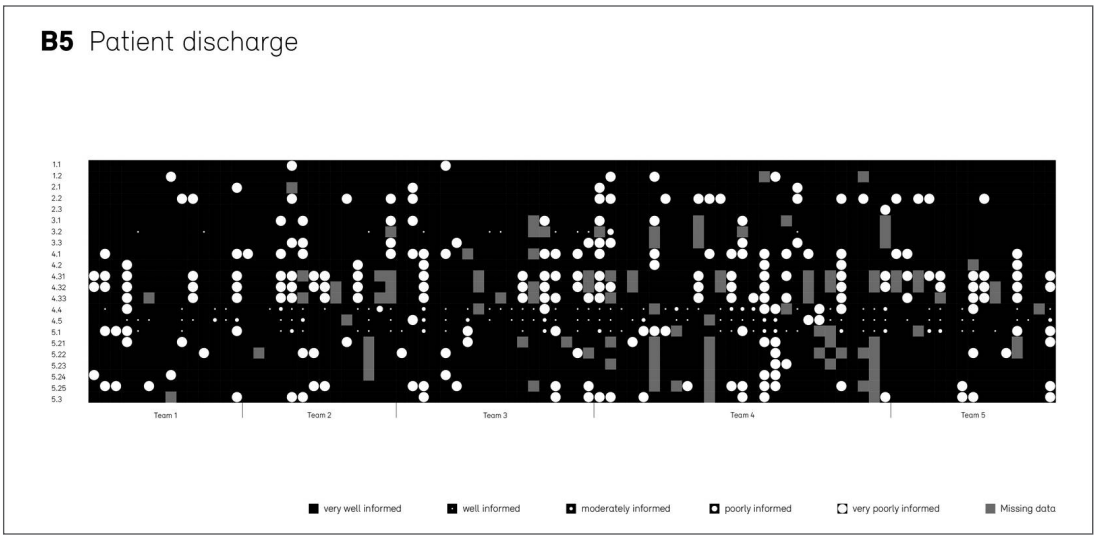



Figure 9
Visualization of patient discharge, card with overall view.

Figure 8
Visualization of patient discharge, consisting of a slipcase and eight cards.

the card set has a window on the front side that allows for an isolated view of individual questions. Gray areas show the areas for which no data were available (Figures 8–9).

**Discussion**

Because all four processes had already been evaluated according to conventional socio-scientific and statistical methods, we were able to conduct a detailed follow-up on the question of what the visualizations achieved in comparison to the previous evaluation methods at the conclusion of the research project. The assessment is based in part on a comparison of the revised visualization with the findings resulting from the conventional evaluation methods. In addition, the visualizations were returned to their place of origin—to the specialist department for quality management—and evaluated in discussions with medical professionals. The discussions proved very fruitful because the participants worked in the corresponding specialization at the hospital and were familiar with the hospital's internal studies.

The visualizations developed during the project have been presented and discussed within the scope of research and specialist symposia, both in a design and in a medical context. They have also been presented and discussed within the scope of process optimization. From these discussions, we can identify both the added value they present and the problems that have been identified.

An identifiable added value is that the effects of process optimization are clearly visible in the visualizations. The visualizations indeed make aspects visible that were lost or not visible in the statistical evaluations. Furthermore, the visualizations raise new questions that had not been raised by the original analysis. For example, in the visualization that deals with waiting times, the short waiting times were deemed unproblematic in the statistical evaluation. Under the assumption that short waiting times need

not be optimized, they were not included in the first evaluation. However, the visualization considers these data and shows that many short waiting times are accompanied by a high disturbance factor. This repeating pattern raises the question of whether the patients might have even felt disturbed by other factors (e.g., room conditions, noise, etc.) during the short waiting times. These additional factors may not be linked primarily to the waiting time but rather to the waiting situation, and might therefore also be of interest in terms of process optimization.

In addition, the visualization—in comparison with the sequential observation of statistical evaluations—achieved a condensed overview of the data from an overall perspective while allowing for visualized correlations and patterns, despite the high complexity. For example, in the concluding observation of the visualization on patient discharge (Figure 9), the specialist who had collected and analyzed the data herself was surprised at how many issues were still unresolved on the patient side. She had perceived that the same set of data was not so significant (by her own evaluation) and suggested that the visualization as overall picture provides a better overview of the data than the sequential bar charts used in her study (Figure 1).

In addition, the observer is more strongly involved in the information acquisition process and thereby is motivated to pursue his or her own questions and to help answer these with the aid of the visualization. Because the results are not presented in a linear manner according to an already restricted inquiry, the visualization admits other questions. We consider this achievement a central aspect in the creation and reception of complex visual representations. The visualizations that have the ambition of involving and fascinating an observer are described by Edward Tufte as "intriguing and curiosity-provoking, drawing the viewer into the wonder of the data, sometimes by narrative power, sometimes by immense detail, and sometimes by elegant presentation of simple but interesting data."[17]

According to the assessment by the medical staff, the visualizations also are well suited for group discussion. The visual material can serve as a basis for an exchange in which the team collectively explores and reflects upon the connected work processes by means of discussion, questions, and reviews.

A further added value is derived from the precise formal conversion of content. In the best-case scenario, the representation form is developed from the corresponding content and helps then to precisely communicate this content and to make it perceptible on an intuitive level. The visualization has also been attributed with a certain emotional value—one that is not recognizable in either a numerical table or a bar chart. It has been documented that a visualization that consciously uses formal means to communicate an issue (Figure 6) is in a position to trigger more than a standardized chart.

17 Edward R. Tufte, *Visual Display of Quantitative Information* (Cheshire, Connecticut: Graphics Press, 2001), 121.

The aesthetic dimension allows the associations of the recipient to contribute to information acquisition and processing. Therefore, the visualization can be considered a work tool—and in the specific case of the visualization on the theme, decubitus risk, as a call for action—for medical specialists.

Value added also lies in the presentation of the patient view, which in the visualizations is always identifiable and comprehensible at the level of the individual patient. This patient view gets lost in the statistical evaluations, but it is this information in particular that can lead to relevant findings. With this type of visualization, a follow-up review can be conducted for individual patients, and treatment-relevant influences can be considered as a result of the individual mapping—thereby also enabling other conclusions for the clinical practice.

Even data that have not or have only partially been collected are consequently recognizable as data gaps in the visualizations; in the statistical evaluations, these data are lost or have been neglected. The relationship between the data that have and have not been collected became apparent first through the visualizations, and its visibility raised the question regarding the quality of the data collection.

The complexity of the visualizations, which can initially have an intimidating character, proved to be problematic in the discussions. The observer must be willing to deal with the respective system of the visualization. Because the visualization—just like the content—can be highly complex, viewers might not comprehend meaning right from the start, so the data might demand a longer confrontation. The "intellectual effort"[18] that needs to be invested to read information and findings from the visualization is greater than the reading, for example, of the content for a bar chart. The observer is being asked to involve himself in unusual presentation forms and models, which in contrast to the conventional bar and pie charts are neither familiar nor common. Image reading competence, unlike text comprehension competence, is unfortunately rarely taught today, so that observers might already be overwhelmed from the very first moment by a new presentation form with which they are unfamiliar or by which they are intimidated. Viewers of images, in comparison with viewers of text, are not accustomed to reading images that are able to communicate complex information. However, the question is whether a statistical evaluation in the form of 30 bar charts on equally as many PowerPoint slides (Figure 1) justifiably presents and satisfies the demands of the complexity of the data. In his essay, "The Cognitive Style of PowerPoint," Edward Tufte analyzes the quality of PowerPoint presentations and questions their suitability for the communication of statistical analyses: "Alas, slideware often reduces the analytical quality of presentations. In particular, the popular PowerPoint templates (ready-made designs) usually weaken verbal and spatial reasoning and almost always corrupt

18 George Kingsley Zipf, *The Psycho-Biology of Language* (London: George Routledge & Sons Ltd., 1936), 147.

statistical analysis."[19] The mere illustration of data using prefabricated representation models often not only does not do justice to the complexity of the data, but also can substantially hinder a differentiated analysis of it.

A further, quite concrete point of criticism pertains to the potential numeric target of process optimizations, which might, for example, declare that "80% of the waiting times should be less than 20 minutes." This purely numerical aspect, in contrast to its representation in a statistical evaluation (bar chart), is not visible or readable at one glance for the visualization models.

Because the developed visualizations were made after the initial process optimizations, we cannot say what the outcome of the process optimization would have been if the specialists had referred to the visualization models as a work tool. A performance measurement did not take place.

The questions of how and which kind of knowledge originated in the project require a differentiation between two points or disciplines. On the one hand, the developed visualization forms have led to new insights and questions regarding the work processes surveyed and therefore contribute to the improvement of existing process optimization procedures in the model process patient care—relevant findings for the daily hospital routine.

On the other hand, knowledge about the application and further development of methods and strategies of our own discipline—methods relevant to visual communication or the field of knowledge visualization—is present in this research. As a next step, we envision more systematic method collection, designation, and evaluation to make both the knowledge gained and the means to convey it more explicit. The objective is to further develop, consolidate, and systemize and to structure the methodical findings of this project, so that ultimately they are transferable and applicable for the areas of communication design and knowledge visualization.

19 Edward R. Tufte, *The Cognitive Style of PowerPoint* (Cheshire, Connecticut: Graphics Press, 2001), 3.