

CareView: Analyzing Nursing Narratives for Temporal Trends

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ABSTRACT

In a study of home-healthcare practitioners, we found that temporal trends contained in patients' clinical records form one of the most critical pieces of information when selecting and administering appropriate treatment. However, these records are comprised of quantitative and qualitative data, and recorded as a *narrative*. This format makes the extraction of historical trends difficult and time-consuming. To address this limitation, we introduce *CareView*, a system that utilizes a set of visualization techniques to increase the visibility of temporal trends in clinical narratives. Specifically, our system focuses on integrated temporal visualizations of numeric and qualitative records; a visualization to facilitate rapid comparison of a patient's condition against previously established care goals; and the ability to immediately visualize data as it is entered. Two experiments comparing the market-leading tabular interface with *CareView* revealed a significant reduction in the time required to identify trends in patients' conditions. However, interviews with nurses highlighted the importance of preserving the integrity of the holistic narrative and suggested extending the design space.

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Author Keywords

Temporal visualization, timelines, medical records, interaction design, screen design, ethnographic observations

INTRODUCTION

Home healthcare nursing is an increasingly widespread type of healthcare that typically involves a nurse driving to a patient's place of residence to provide the necessary monitoring and treatment. There are a wide variety of cases in which home healthcare is recommended by physicians, and recent years have seen a steady increase in the need for this type of care [2].

The effectiveness of home healthcare practitioners often

depends on their ability to synthesize knowledge about a patient's condition from the patient's medical record. The traditional way of presenting clinical data in medical records is through a clinical narrative—a story captured on a sheet of paper describing a patient's conditions as observed by a clinician and reported by the patient. The most popular way of presenting clinical narrative in a computerized patient record is in a series of structured tables. However, a large number of clinicians in home healthcare continue to rely on paper-based records.

A study we conducted with home healthcare nurses revealed that the accurate assessment of a patient's conditions often depends on a nurse's ability to perceive changes in conditions over time. The essence of a nurse's task is to establish a pathway for a patient's recovery towards the desired goal, and to track the progress of the recovery along that pathway. In this context, the two main forms of medical records – a free-form paper based nursing narrative and a tabular computerized patient record – lack necessary historical context while overlooking care goals as reference points.

Inspired by the findings of our study, we set our goal to investigate user interface designs that focus on recreating the temporal trajectory of the patient's health by decomposing clinical narratives into a series of records that can be visualized as a history. A large number of challenging design objectives suggested rapid prototyping as the most appropriate methodology for developing an efficient interface design. In the first phase of our research we developed *CareView*, a system that utilizes a number of simple visualization techniques for recreating historic trajectories from clinical narratives. In particular, *CareView* focused on the following features:

- Integrated visualization approach for presenting numeric and qualitative data entries along the timeline
- A visualization technique that plots multiple measurements against the corresponding target care goals to facilitate appreciation of the patient's recovery trend
- An instantiation of overview-and-detail concept for rapid assessment of the overall trend and viewing detailed records in the temporal context

Evaluation of CareView with home healthcare nurses allowed us to gain a better understanding of the design objectives and to significantly revise a number of our initial assumptions. One of the major findings revealed the significant importance of preserving the integrity of the narrative itself. While CareView considerably enhanced nurses' ability to monitor changes in the conditions overtime, it made it difficult to reconstruct the comprehensive picture of a patient's condition captured at a particular date.

STUDY OF HOME CARE NURSES

In this section we briefly discuss findings of the exploratory study with home healthcare nurses that led to our initial design. Two home healthcare agencies participated in the study that consisted of over 15 office interviews with administrative staff and management, and on-site observations of 8 nurses at patients homes, during a total of 10 patient visits.

Need for temporal assessment

During each visit a nurse captures a number of clinical readings, such as vital signs, subjective observations of a patient's status, and any complaints from the patient. In many cases, knowledge of only the current clinical reading is not enough for the nurses to classify the findings and make a decision about the appropriate action. For example, a particular blood pressure value could be considered elevated for some patients, normal for others, and lower than normal for others. The way for a nurse to reach a conclusion as to the significance of a particular reading is to analyze it in the context of the patient's clinical history, comparing it with the previous readings. This temporal comparison could indicate, for example, that although the patient's blood pressure value is elevated, it has improved significantly upon previous readings, and hence is a sign of recovery.

Goals of care

The main task of a nurse in a home healthcare setting is to monitor the patient's condition and the progress of recovery towards the care goals established by the patient's physician. These goals address desired changes in physical or mental conditions of the patient and, for example, can include a target blood pressure or blood sugar level, or a projected level of physical activity and independence. In cases of patients with chronic diseases, a plan often involves educating the patient and their family about the disease. During each visit, the nurse administers prescribed treatment and assesses a patient's progress towards the goals. If the progress is unsatisfactory, the nurse can recommend modifications to the treatment that will be discussed with the physician.

Non-linear data access

Most of the information capturing happens during free-flow conversations between the nurse and the patient. The flow of such conversations is difficult to predict and rigid

application structures typical for tabular applications force nurses either to use paper to write down notes from the conversation only to re-enter them later, or ignore comments that appear out of the predefined order and risk appearing inattentive. To avoid these situations, any interface should allow for non-linear data entry and for easy transfer between different areas while following a conversation with the patient.

Need for decision support integrated with data entry

Nurses' time is a very scarce and expensive resource requiring judicious management. Compensation strategies reflect this reality, requiring nurses to visit as many patients per day as possible. To be most useful, data visualization and any other decision support tools need to be available to nurses at the time of data capture. Any tool that requires nurses to increase the time spent with one patient by engaging in extensive data exploration has a high probability of being abandoned.

Hands-free input and navigation

Capturing a patient's vital signs, administering medication, wound-care and many other procedures involved in skilled nursing visits requires nurses to wear sterile gloves. Using a computer keyboard at these times is not possible. This forces nurses either to memorize the measurements for input later, or to make brief notes with a sterile pencil. Sometimes, when an important observation needs to be recorded during a particular procedure, the nurse must remove the gloves, use the keyboard to enter the observation, wash hands, don new gloves, and resume the procedure.

PROTOTYPE DESIGN

Enhanced temporal visualization

As was noted previously, our goal was to apply existing visualization techniques, enhancing them as necessary, to meet our initial design objectives, and evaluate their effectiveness and efficiency as compared to the tabular interface. We chose to use a concept similar to the one introduced by Posner and Tufte [4] and Plaisant et al [3] and present all the data plotted on a series of timelines positioned one below the other in the following fashion:

Quantitative or numeric values, such as readings of various vital signs, lab results and others are plotted in two-dimensional space along the horizontal timeline.

In our first design we chose to plot *qualitative* values in the similar fashion, decomposing them into multiple-choice entries, an approach extensively used by the nurses. We use these choices as points on the vertical axis and plot corresponding records along the timeline. In addition, CareView provides free-form text entry in a comment field. Color-coding is used with both numeric and qualitative entries to add the assessment value to the data where applicable. For example, we provide the clinicians with a customizable color-scheme to indicate ranges of expected

values; in the default scheme blue corresponds to values below normal range, white – values within the range, and red – values above it.

To present the large volume of data contained in the historic patient records we utilize the overview-and-detail approach. The detail view shows the absolute meaning of each record captured in time. The summary view condenses the presentation to one line allowing the application to present a large number of lines on one screen while preserving the semantic color-coding denoting the severity of the captured readings. To provide data analysis support at the time of data entry, the detailed view includes data entry elements. In this case, each reading is immediately plotted on the timeline highlighting its temporal context and hence, simplifying interpretation. The resulting interface design can be seen in Figure 1.

To simplify the assessment of a patient's progress towards the established goals, we developed a new visualization that focuses on the discrepancy between the current reading and the established goal. In this visualization, the multiple care goals established for the patient are re-scaled to the horizontal axis. The recovery trend against the care goals can be clearly visualized as the distance above or below the central horizontal axis. Values with a larger discrepancy are plotted further away from the centerline, and values with smaller discrepancies are plotted closer.

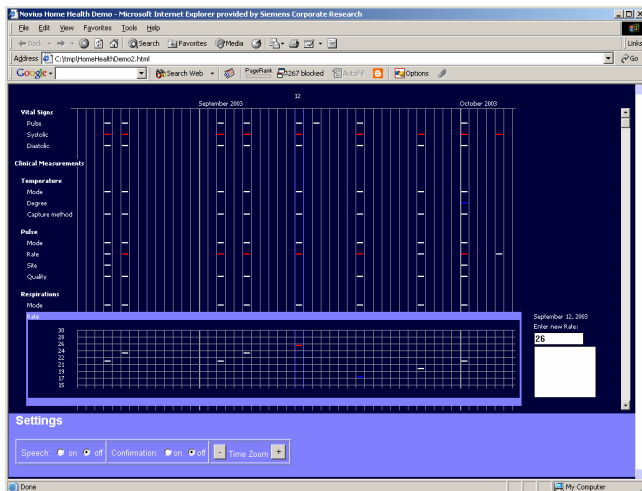


Figure 1: CareView design.

In addition to a number of visual design elements described above, we chose speech recognition for insuring nurses' ability to easily navigate between categories of data. This solution had an additional benefit of supporting hands-free input important for nurses during the physical examination when they need to ensure sterile conditions. In the interface, the nurse can navigate, or enter freely using speech, and can at any time toggle between the summary and detail views.

EVALUATION

Rapid prototyping and continuous evaluation with potential users allowed the research team to quickly confirm or

disprove our assumptions and understanding of the design space. We used several different evaluation methods. First, we performed design/prototype reviews with experienced home healthcare nurses, to assess the feasibility of the design with the domain experts. Second, we conducted two controlled subject experiments assessing the general information delivery properties of our design. The first experiment was conducted with non-clinical participants. The second was conducted with experienced home healthcare nurses. In both experiments, subjects answered questions about the data space while navigating through it. We hypothesized that efficient temporal visualization of data, as exhibited in the CareView prototype, will allow users to answer temporally-oriented questions about a patient's medical record faster (error free) than with the current commercially-available tabular system. For the first experiment with non-clinical participants, correct answers depended on the participants' ability to perceive temporal data trends but did not require clinical expertise. For the second experiment with trained nurses we categorized the questions based on their type, as well as on their level of difficulty. The categories included: exact date, presence/absence of records, interval comparison and temporal trend. The two categories corresponded to two levels of difficulty, depending on whether they required locating information in one or multiple tables within the tabular interface. We used a within-subjects repeated-measures design, and collected answers to a total of 40 questions in the first experiment and 120 questions in the second one. A more detailed description of the experimental design is available from the authors upon request.

Results

In the first experiment, the CareView prototype was faster than the current system as measured by error-free response time ($t < 0.05$) with a mean of 41 seconds per question with the CareView prototype vs. 63 seconds per question for the current system. Mean total response times including incorrectly answered questions were similar. In addition, accuracy was increased from 47% (9/19) with the current system to 89% (17/19) with the CareView prototype; a data recording error occurred with the 20th question.

The second experiment showed much higher levels of individual differences; the overall difference in error-free response time between CareView (mean=93.4) and the control application (mean=75.1) was insignificant ($t=1.658$). However, when compared separately, the error-free response time for questions that required multiple table lookup was significantly shorter ($t=0.01$) for CareView (mean=66.4) than for the control system (mean=138.4). On the other hand, the time required to answer single lookup questions was longer for CareView (mean=81.2) than for the control system (mean=62.8). This difference was not significant. The accuracy of the answers was comparable between the two applications.

In addition to measuring error-free response time, the questionnaire was used to assess participants' subjective experiences with both applications. The results of the questionnaire are presented in Figure 2.

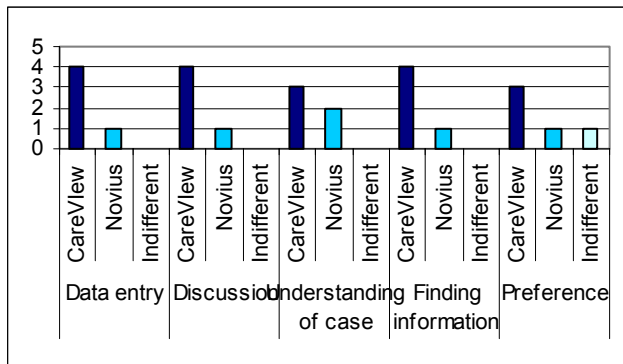


Figure 2: Results of the questionnaire

Discussion and future work

Based on the results of our experiments and informal design reviews, we can conclude that CareView accomplished our design objectives with relative success: nurses demonstrated superior performance in assessing temporal trends in the data, felt that the application would allow them to better follow conversation with patients, and to develop a better impression of the patient case.

There were, however, a number of particular limitations of visualizations utilized by CareView that were identified during the post-test interviews. Some of these limitations could be addressed by perfecting particular features of the CareView interface. For example, while color-coding was considered as one of the most useful features, devising a universal color-coding scheme proved non-trivial. The initial low-normal-high approach was considered too narrow and applicable only to a limited subset of clinical readings. Additionally, in some cases during the evaluation, nurses expressed desire to compare different values and categories side by side. Such comparison could highlight correlations between particular findings or trends and assist in assessing the case.

When designing the summary view, we decided to use presence or absence of records on the screen as a way to visually guide nurses to areas of particular interest. In reality, on the other hand, nurses viewed empty fields with suspicion and saw them as a possible sign of neglect to record data. In the desired application, areas with no complaints or problems should be explicitly noted as such, rather than implying that lack of entries means lack of progress.

There were, however, a number of limitations that suggested alternative design solutions. For example, one of the reported difficulties, and the one that perhaps explains the slight increase in error-free response time for CareView in case of single table lookup questions, is the fact that displaying multiple-choice entries along the vertical axis

visually removed them from the corresponding values on the timeline. Participants had to continuously trace the visual connection between the depictions and their actual meaning.

In addition, most of the participants expressed concern that the visual representations were limited to the predefined choices and free-form comment entries were not available for trend analysis. Free-form entries should be honored in the same way as predefined multiple choice, and they should also be available for trend analysis.

One of the most interesting findings that emerged from our conversations with nursing supervisors highlighted the importance that was placed on the daily narrative itself. CareView, while providing a more informative temporal representation, made it difficult to reconstruct the complete narrative. In addition, the nursing supervisors felt that placing the foremost importance on the temporal trends will motivate nurses to focus on “growing” the trends, instead of “painting the picture of the patient’s conditions as observed at a particular moment”.

These findings suggest that a successful visualization should preserve the integrity of the clinical narrative as captured by nurses currently in the paper-based records. In such an interface, temporal visualization of records should be supplementary to the display of the current narrative, and present historic trends in a way that would not compete with the assessment of the narrative itself. One promising approach in this direction is suggested in the Fluid Documents [1] architecture that can dynamically display supplementary comments within the primary text.

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