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Visualization of Patient Progress Monitoring and Vital Signs Trends in Electronic Nursing Reports

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Abstract

Given the increasing number of elderly individuals and a declining number of caregivers, the importance of effective information exchange becomes crucial. This work addresses the challenges and opportunities of data exchange within nursing care and the visualization of nursing care information history. Based on preliminary studies, a concept for enhanced digital nursing care situation reports is proposed, which displays patient progress information and vital signs trends. An evaluation using expert interviews and usability tests shows the empowerment of caretakers due to monitoring critical changes of patients' progress and adjusting care plans over institutional borders.

Keywords: Interoperability, Nursing Documentation, Health Information Exchange, HL7 Clinical Document Architecture, Continuous Vital Sign Monitoring, Fast Healthcare Interoperability Resources

1. Introduction

Due to demographic trends, an increase in the number of elderly individuals is expected, leading to a rise in the need for care, especially at home. Although the demand for skilled professionals increases, a shrinking younger workforce threatens to limit the pool of eligible caregivers. Demographic trends demand high quality homecare and an increased number of caregivers worldwide (Rappold and Juraszovich 2019).

Seamless exchange of care data fosters knowledge sharing among all stakeholders, promising better care delivery. Traditional data exchange methods in day-to-day care settings can be cumbersome and are prone to gaps. Digital solutions offer the potential to bridge this gap and provide access to the most up-to-date information, thereby increasing care providers' confidence in their actions (Kubek 2020). This work investigates the information needs of healthcare professionals and informal caregivers. A fully structured extension of standardized nursing documentation is proposed, which allows the generation of vital signs trends and a patient's progress.

The focus of this work is on the enhancement of data quality, which is an important topic in the area of simulation for healthcare, such as image data for modelling ortheses (Zwettler et al. 2023), modelling epileptic seizures (Zwettler et al. 2021), or database modelling for medical data (Pointner et al. 2023). The focus on data visualization and monitoring within nursing care is relevant for interdisciplinary.

This work covers the use of anamnesis conducted by professional nurses, of nursing guidelines and pathways and of fully structured and standardized documentation, as well as on the integration of professional nurses, general practitioners, specialists, therapists, hospitals, and the documentation by healthcare providers vs. non-professional caretakers or patients themselves.

Interactive visualization of such trends within digital nursing documents is evaluated using qualitative and

quantitative usability tests. Our conducted studies show that the approach prioritizes a clear, dynamic presentation, allowing caregivers to identify critical changes in health situations, regardless of institutional borders or spoken languages. It underlines that efficient care delivery depends significantly on effective information exchange among healthcare providers.

The remainder of this publication is organized as follows. Section 2 provides an overview of the state of the art. Section 3 gives an overview of the user studies and expert interviews that were conducted, with Section 4 presenting the results of this work. In setion 5 the findings are discussed, and conclusions are drawn in section 6.

2. State of the Art

The following section delves into the background technologies and standards to enable technical and semantic interoperability in health data exchange.

2.1 Health Hub

In our test setting, the Health Hub acts as a central hub for patients and healthcare providers and uses the state-of-the-art standards HL7 Clinical Document Architecture (CDA) and the HL7 Fast Healthcare Interoperability Resources (FHIR) as two primary information exchange standards. Standardized guidelines ensure clear and consistent communication, particularly between nursing services, care facilities, medical doctors, and hospitals in the format of entire health documents or resources. Furthermore, it facilitates secure data exchange through standardized guidelines for CDA documents and FHIR resources. Technical integration of various systems is based on the Integrating the Healthcare Enterprise (IHE). The Health Hub allows for exchange of information between IHE compliant systems. Reports detailing the care situation are of paramount importance for communication between nursing services, care facilities and hospitals. These documents contain up-to-date, pertinent information on an individual's care and support needs at the time of compilation, facilitating seamless information transfer.

2.2 Clinical Document Architecture

An XML-based Clinical Document Architecture (CDA) document includes document metadata in a header and legible clinical information in a body, including text, images etc. as well as machine-readable elements for automated reprocessing (Benson 2016). Applications render readable content of a CDA in a typical web browser through XSLT. CDA documents rely on distinct style sheets, which contain rules targeting specific elements and attributes within the XML data, to determine the presentation of data. A reference style sheet specifically addresses medical documents following nationwide implementation guidelines.

2.3 Fast Healthcare Interoperability Resources

The HL7 Fast Healthcare Interoperability Resources (FHIR) is a next-generation standards framework for the exchange of electronic health records (EHR) data after HL7 V2, V3 and CDA (Bender et al., 2013; HL7, 2024). It uses a REST-based approach and describes how applications exchange individual resources, i.e., packs of information, between healthcare providers/health information systems. FHIR aims to improve data exchange between medical devices and information systems.

2.4 Evaluation of visualization approaches

Visualization approaches for CDA documents are already available. For FHIR Resources there exist several tools for browsing the resources (Hong et al. 2019), but less for interactive visualization of the contents, especially from various resource providers.

Existing studies like (Khairat et al., 2018; Monsen et al., 2023a; Monsen et al., 2023b) either focus on only one domain like intensive care units or on information generated in one setting. They do not focus on the visualization of information exchanged over institutional borders, national borders or between professionals and non-professionals speaking several different languages.

3. Materials and Methods

To identify the gap between what is available in standardized information exchange and what healthcare personnel and informal caretakers require for the home nursing care sector, we conducted user studies and expert interviews (Bogner 2009). Based on these interviews, we enriched the existing standards with additional information, which we then visualized and used to undergo usability tests.

3.1 User requirements analysis

In a preliminary study we interviewed a sample of twenty-four potential users, clustered into user groups, to investigate information needs of healthcare professionals and informal caregivers. The user groups are informal caretakers, nursing professionals, 24-hour care personnel, community nurses, therapists, and medical doctors. We analyzed the findings according to (Kuckartz and Raedecker, 2019) and results divided into 14-15 categories for each user group. We conducted a valence analysis and built group clusters to achieve objective user requirements.

3.2 Systematic expert interviews

To explore the challenges and opportunities of data exchange in the care sector, we conducted structured expert interviews as defined in (Bogner 2009). This second study addresses the user requirements and analyzes existing exchange documentation and systems

to document nursing care information in home care settings. Twelve structured systematic expert interviews with focus on technical content like used standards, coding systems and infrastructure for health (nursing) data exchange, complement this study. Systematic expert interviews facilitate the capture of valuable insights not readily available elsewhere (Bogner 2009). A pre-defined interview guide ensures consistency and focus in the discussion.

3.3 Usability Tests

According to a user-centered iterative incremental approach (Hartson and Pyla 2018), we use a combination of analytic and empiric evaluation methods to evaluate and refine the proposed solution. Three usability experts performed several analytical usability tests, using the methods heuristic evaluation and cognitive walkthrough. Furthermore, we ran twelve empirical usability tests with informal caretakers in situ at the client's homes, with (1) using provided hardware as well as a fully documented pre-defined patient and (2) using their own smartphones and notebooks and real-life data. For observation of the tests a pre-defined we used a structured test protocol. In addition, we performed eight A/B tests (split tests) in a lab situation to evaluate versions of the interactive visualization of the progress/vital signs trends. Test persons applied the method thinking aloud, additionally to traditional observation in all empirical usability tests. Informal interviews concluded each test session.

3.4 Test setting

Our test setting was implemented in a living lab in a city (population > 11000), where a network of informal caretakers, mobile care and therapists, primary and secondary health collaborate use our health hub as an e-health infrastructure to enhance data quality (see figure 1). Nursing personnel and informal caretakers either use their own documentation system, if applicable, or our mobile application, which generates HL7 CDA documents as well as FHIR resources in the current IT infrastructure. Our microservice architecture uses our own FHIR server implementation, as well as the Health Hub implementation for exchange of FHIR resources. We conducted tests using further FHIR servers during FHIR Hackathon and added simulated nursing care data for tests of our prototype.

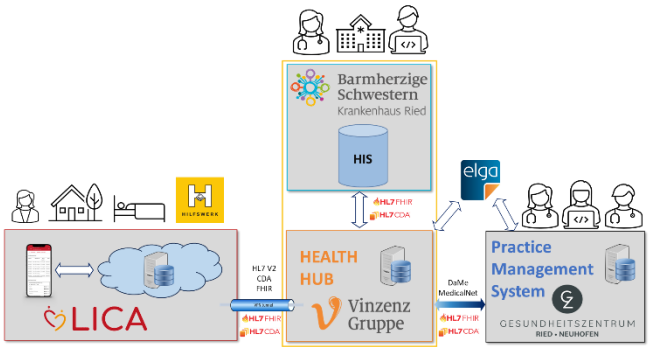

Figure 1. Health Hub test setting

4. Results

The study results define which data the user groups - informal caretakers, nursing professionals, 24-hour care personnel, community nurses, therapists, and medical doctors - deem necessary for nursing care purposes. Interesting is that the structured representation using tables is deemed necessary for an overview of the development of vital signs measurements and nursing data over time.

4.1 Identifying necessary information for historical insight

The systematic expert interviews with technical focus show that most of this data is available in existing electronic nursing documentation systems, although not always in encoded form. Additionally, not all institutions or caregivers use electronic systems already. Care situation reports defined comprise either most of the required information, but often in free text, i.e., not based on available coding systems or are lacking progress information, since only a defined situation is reported. The developed solution uses a fully structured approach – figure 2 shows an excerpt.

Our application collects relevant care data during various interactions like house calls, mobile care interventions, discharge procedures etc. Particularly trends in vital signs and progress information are deemed crucial for primary care physicians with infrequent patient contact.

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    </effectiveTime>
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Figure 2. Fully structured nursing care data

Structured data exchange in this sector is limited primarily to hospitals, leaving social service providers reliant on paper-based data obtained from relatives, which results in data destruction upon termination of the care relationship.

Consequently, the absence of a robust digital infrastructure impedes the analysis of longitudinal trends and the generation of comprehensive historical insights into patient health. While trend analyses offer valuable clinical information, it is paramount to acknowledge the data source (specialist, smart device, nonprofessional) to ensure its validity and reliability for informed decision-making.

4.2 Visualization of patients' progress and vital signs trends

Based on the insights outlined in the conducted interviews, we refined the current care situation report and fully encoded using terminology systems like ICNP and SNOMED-CT, which we analyzed, mapped, and extended using pre-defined terms and extensions based on (details see (Diesenreiter et al., 2023)). This allows the use of interactive charts to visualize the progress of nursing data and vital signs over time. We evaluated different visualization approaches. See figures 3-6 in the appendix section for visualization examples.

The usability tests confirm that care providers can now easily track changes in vital signs and nursing progress over time, facilitating a more comprehensive understanding of a patient's health status. We achieve this integration by extending the existing static stylesheet with Javascript to extract vital signs, nursing data among others from the machine-readable entry section of the CDA and from FIHR resources. The application uses this data to populate the charts. Users can interactively filter the display data area based on a selected date range. Additionally, the application populates the start and end date pickers with the earliest and latest recorded vital sign dates within the document. This ensures that the visualization provides a relevant initial view without manual intervention.

4.3 Usability Tests

The usability tests show a high deviation in time, from 40-65 minutes for the achievement of all tasks, which correlates to the user's experience in language used to document and in the use of technical systems. In the split test, all participants state the importance of tabular form for documentation of vital signs. Users see the interactive visualization as a helpful addition. Seventy-five percent of interviewed health professionals state that the source of provided information is necessary for veracity. Remarkable is that all test users state the importance of contextual information which must be provided in case of outliers.

5. Discussion

Documentation and visualization not only of the development of vital signs over time but especially of the progress of care data like orientation, due to the enhancement of nursing documentation, allow the monitoring of nursing information over time. Static data is still critical for fast analysis of information and should not be replaced fully. Enhancement with interactive charts in care situation reports unlocks a range of benefits for improved patient care, if contextual information is provided. These charts convert data points into a dynamic picture, allowing healthcare professionals to:

- **Identify outliers and trends.** Replacing static data with interactive charts empowers caregivers to effortlessly track changes in patient progress and vital signs over time. This visual representation facilitates the identification of patterns and outliers that might be missed in raw data formats.
- **Spot critical changes faster.** Fluctuations in vital signs and outliers in patient progress become more readily apparent with interactive charts enabling faster interventions when necessary.
- **Foster better communication.** The use of fully structured documents and clear and concise data visualizations within care situation reports promote better communication among all healthcare professionals involved in a patient's care. All participants gain a shared understanding of the patient's health trajectory, promoting a more collaborative approach to care.

While interactive charts offer significant advantages, the effectiveness heavily relies on the quality and consistency of the recorded data and cannot replace well-known tables. Inaccurate or incomplete data can lead to misleading visualizations and potentially flawed clinical decisions. Implementing robust data collection and validation processes is essential.

Additionally, knowing the source of the vital sign data is equally important. Data provenance, whether from a specialist, a smart device, or a caregiver, allows healthcare professionals to assess its reliability. For example, data obtained from a medical-grade device may

be more significant than information provided by a patient's relative.

Overall, fully structured documentation of nursing care information allows for automated processing of the progress of nursing information.

6. Conclusions

Due to the use of code systems like SNOMED CT and standards like HL7 CDA and FHIR, it is possible to exchange data in a semantic interoperable way independent of the used language or which country the data comes from. Especially in home healthcare it is important to provide a system that supports various languages, since informal caretakers often come from different countries and speak various languages. Thus, not only technically and semantically interoperable exchange over institutional and national borders is important, but especially over language barriers, not only concerning nations, but also in lieu of various user groups and their professions.

This work identifies and closes a gap in the information required for (informal) caregivers to efficiently treat a patient, as well as information delivered back to medical facilities and qualified nursing care practitioners. Visualization and capturing of care episodes are necessary, as well as context information and data provenance. Additional to findings stated in (Brekke et al. 2019), this work shows the importance of simple data visualization using tables as well as the necessity of contextual information and knowledge of the data source and its reliability. This work shows the applicability for various languages, due to the semantically interoperable approach using SNOMED CT.

Advantages of integrating interactive visual aids into digital care situation reports are shown, which provides an effective and informative method of examining vital sign patterns and a patient's progress. This results in improved patient care delivery, provided information about context and data provenance (data source, reliability) is available.

Future work leverages Artificial Intelligence and infers hints and contextual information using a rule-based system for structured data and small as well as large language models for unstructured data.

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Appendix A. Visualization examples

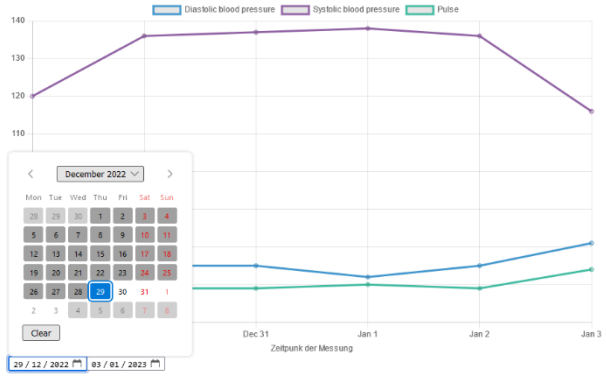

Figure 3 Visualization of blood pressure measurements in a filterable time range.

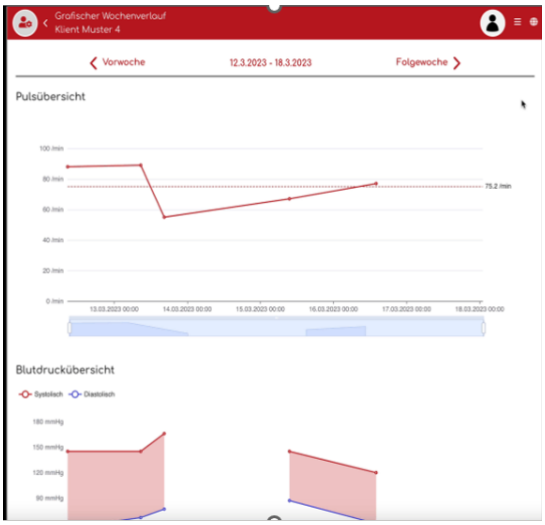

Figure 4 Visualization of pulse and blood pressure separated into two different views.

Figure 5 Visualization of a vital signs table joined with a line graph.

Figure 6 Visualization of multiple vital signs over one week, a hover box gives information about the cross section of vital signs at a specific point in time.

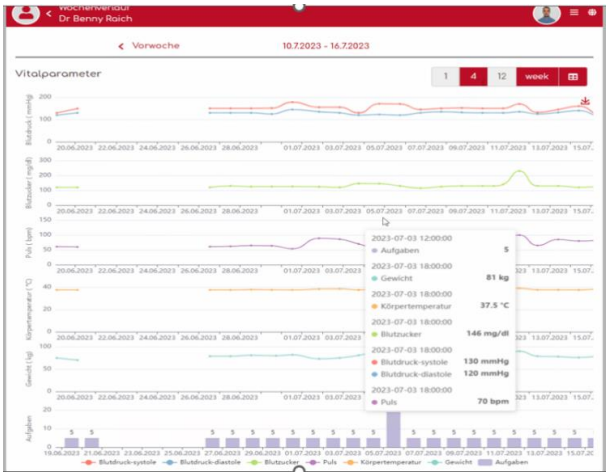

Figure 7 Visualization of multiple vital signs over four weeks, a hover box gives information about the cross section of vital signs at a specific point in time.

References

Bender D, Sartipi K, 2013. HL7 FHIR: an agile and RESTful approach to healthcare information exchange. In: Computer-Based Medical Systems (CBMS), 2013 IEEE 26th International Symposium 2013, pp. 326–331.

Benson, T. Principles of health interoperability: SNOMED, CT, HL7 and FHIR. 2nd ed. Cham, Switzerland: Springer International Publishing; 2016.

Bogner A, Littig B, Menz W. Experteninterviews : Theorien, Methoden, Anwendungsfelder. 3rd ed. Wiesbaden, Germany: VS Verlag für Sozialwissenschaften; 2009.

Brekke IJ, Puntervoll LH, Pedersen PB, Kellett J, Brabrand M. The value of vital sign trends in predicting and monitoring clinical deterioration: A systematic review. PLoS One. 2019 Jan 15;14(1). doi: 10.1371/journal.pone.0210875.

Diesenreiter C, Krauss O, Traxler B. Extending International Terminology Systems to Enhance Communication Between Nursing Services In 12th International Workshop on Innovative Simulation for Health Care, in Bruzzone, A. G., Frascio, M., Longo, F., Novak, V. (eds.). Cal-Tek srl, (Proceedings of the International Workshop on Innovative Simulation for Health Care, IWISH) 2023.

Hartson R, Pyla P: The UX Book. Agile UX design for a quality user experience, Second Edition, 2018, Morgan Kaufmann, https://doi.org/10.1016/C2013-0-19285-9.

HL7. HL7 FHIR Release 5. hl7.org/fhir, 2024. Accessed: 2024-07-15.

Hong, N., Wang, K., Wu, S. et al. An Interactive Visualization Tool for HL7 FHIR Specification Browsing and Profiling. J Healthc Inform Res 3, 329–344, 2019. https://doi.org/10.1007/s41666-018-0043-8

Khairat SS, Dukkipati A, Lauria HA, Bice T, Travers D, Carson SS, 2018. The Impact of Visualization Dashboards on Quality of Care and Clinician Satisfaction: Integrative Literature Review JMIR Hum Factors 2018;5(2):e22, https://doi.org/10.2196/humanfactors.9328.

Kubek V, Velten S, Eierdanz, F, Blaudszun-Lahm A. Digitalisierung in der Pflege: Zur Unterstützung einer besseren Arbeitsorganisation. Berlin, Germany: Springer; 2020.

Kuckartz U and Stefan Raediker S, Analysis of qualitative data using MAXQDA, 2019.

Monsen, K. A., Heermann, L., & Dunn-Lopez, K. 2023. FHIR-up! Advancing knowledge from clinical data through application of standardized nursing terminologies within HL7® FHIR®. Journal of the American Medical Informatics Association, 30(11), 1858-1864.

Monsen K. A., Heermann-Langford L., Bakken S, Dunn-Lopez K, Standardized nursing terminologies come of age: advancing quality of care, population health, and health equity across the care continuum, Journal of the American Medical Informatics Association, Volume 30, Issue 11, November 2023, Pages 1757–1759, https://doi.org/10.1093/jamia/ocad173

Pointner, A., Praschl, C., & Krauss, O. Enhancing Interoperability of HL7 Resources Using Namespaces in Graph Databases. In 12th International Workshop on Innovative Simulation for Health Care, in Bruzzone, A. G., Frascio, M.,

Longo, F., Novak, V. (eds.). Cal-Tek srl, (Proceedings of the International Workshop on Innovative Simulation for Health Care, IWISH 2023.

Rappold E., Juraszovich B. (A prognosis of the need for care personnel in Austria (in German, Pflegepersonal-Bedarfsprognose für Österreich). Vienna, Austria: Bundesministerium für Arbeit, Soziales, Gesundheit und Konsumentenschutz (BMASGK); 2019.

Zwettler, G. A., Reichhardt, A., Stradner, M., Praschl, C., & Helm, E. EpiMon: Vision-Based Early Warning System for Monitoring Uprising Epileptic Seizures During Night. In 10th International Workshop on Innovative Simulation for Health Care, (Proceedings of the International Workshop on Innovative Simulation for Health Care, IWISH) 2021.

Zwettler, G. A., Trixner, M., Schartmüller, C., Bauernfeind, S., Stockinger, T., & Praschl, C. Towards an Automated Process for Adaptive Modelling of Orthoses and Shoe Insoles in Additive Manufacturing. In 12th International Workshop on Innovative Simulation for Health Care, in Bruzzone, A. G., Frascio, M., Longo, F., Novak, V. (eds.). Cal-Tek srl, (Proceedings of the International Workshop on Innovative Simulation for Health Care), IWISH 2023.