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Usability Analysis of a Medication Visualization Tool for Decision Support

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Abstract. *Background:* In Germany, patients are entitled to a medication plan. While the overview is useful, it does not contain explicit information on various potential adverse drug events (ADEs). Therefore, physicians must continue to seek information from various sources to ensure medication safety. *Objective:* In this project a first functional prototype of a medication therapy tool was developed that focuses on visualizing and highlighting potential ADEs. A usability analysis about the tool's functionality, design and usability was conducted. *Methods:* A web application tool was developed using the MMI Pharmindex as database. ADEs are color coded and can be displayed in three different ways – as a list, a table, or a graph. To test the tool, an online survey was conducted amongst healthcare professionals (n = 9). The test included two real medication plans to check ADEs through the tool. *Results:* The survey results indicated that the web tool was clear and self-explanatory. It scored overall "good" (score: 76.5) on the System Usability Scale questionnaire. Due to the free-text information of the database used, there were some inconsistencies in the visualized ADEs. *Conclusion:* There is a demand for a visualization tool for medications. The high quality of the database is crucial in order to correctly visualize all necessary information, such as drug-drug interactions and inclusion of patient data. This is essential to provide a trustworthy tool for medical professionals.

Keywords. Medication Information, Adverse Drug Event, Drug-drug Interaction, Usability Analysis, Data Visualization

1. Introduction

In Germany, patients have the ability to request a paper-based medication plan from their physician, which includes a list of their current medications along with information about dosage and time of intake. This information is helpful for patients to keep track of their medication regimen and ensure they are taking their medications correctly. For physicians, the plan offers a broad overview of the patient's medications. However, the plan does not include any further information, such as explicit information about adverse drug events (ADEs) or drug-drug interactions (DDIs). For physicians it can be time-consuming and error prone to manually look up information on drugs for their potential

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ADEs. Various studies in the past have found upwards of half of all ADEs are attributable to medication errors and are therefore preventable [1]–[3].

To help address this issue, a visualization tool for a medication plan was designed and developed. This tool highlights and visualizes potential ADEs and aims to help medical personnel quickly make informed decisions about a patient's treatment plan. This could potentially reduce the risk of medication errors and improve patient outcomes. A survey among clinical clinicians, pharmacists and general practitioners was conducted to determine the usability.

2. Methods

The web application developed in this project was built using the Node.js runtime and the Solid.js frontend framework. In the backend, the database from the *MMI Pharmindex* was used. It contains all drugs available in German pharmacy with their preparation and package information as well as manufacturer information. This includes active ingredient information, ATC/DDD and related ICD-10 codes. Different text-based information (dosage, composition, interactions, contraindications, side effects, etc.) is also available for around 30,000 products. This text data was used to detect ADE warnings. The focus of this project was primarily on DDIs, contraindications, and side effects.

Users can search for all products via an auto completing text input field (see Figure 1). Once a drug is added to the medication plan all the available drug information is loaded and displayed. ADEs are identified by searching through this text data. If another selected product can be found in the text of a product, the software generates an ADE warning between these two drugs. The type of drug information text in which the match was found determines the warning type.

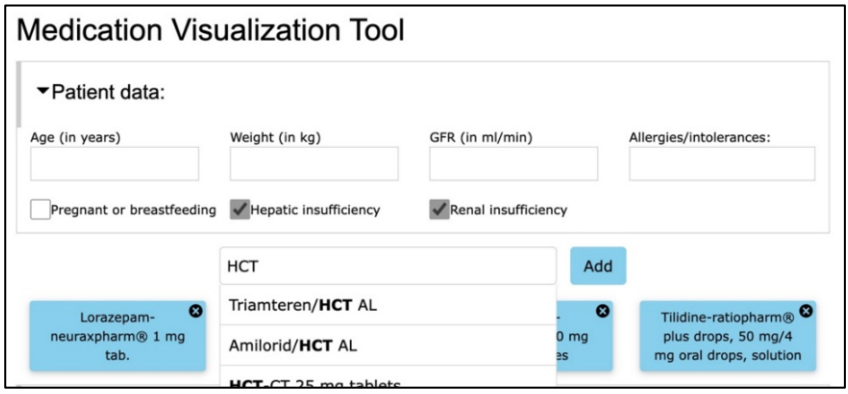
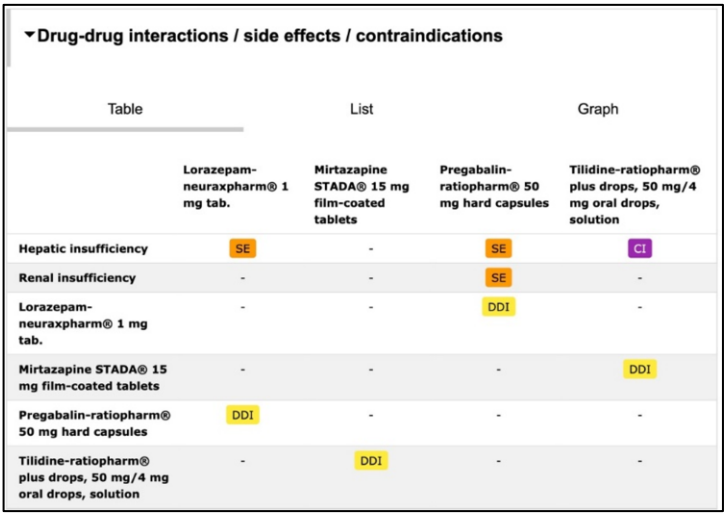


Figure 1. Screenshot of the search box and patient input data field (translated into English).

In addition to medications, patient data (e.g. age, weight, allergies) can be entered. Within the current implementation the displayed information will only be impacted by the checkboxes. If an insufficiency has been selected, the texts are also parsed for the strings "liver" or "kidney" in addition to the shortened names of all other drugs in the medication plan. If a pregnancy is selected in the patient data, then an additional tab is added to each medication with relevant information.

Warnings can be displayed in three different ways. By default, the table view is shown and is comprised of one row and column respectively for each drug (and organ insufficiencies). Any ADE is marked in the corresponding cells of the table (see Figure 2). In the list view, one warning is displayed per line, creating a vertical list. Lastly, the graph view displays products as nodes and potential ADEs between them as edges. In every representation, the types of ADEs are color coded – yellow representing DDIs, orange for side effects (SEs), and purple for contraindications (CIs).



	Lorazepam-neuraxpharm® 1 mg tab.	Mirtazapine STADA® 15 mg film-coated tablets	Pregabalin-ratiopharm® 50 mg hard capsules	Tilidine-ratiopharm® plus drops, 50 mg/4 mg oral drops, solution
Hepatic insufficiency	SE	-	SE	CI
Renal insufficiency	-	-	SE	-
Lorazepam-neuraxpharm® 1 mg tab.	-	-	DDI	-
Mirtazapine STADA® 15 mg film-coated tablets	-	-	-	DDI
Pregabalin-ratiopharm® 50 mg hard capsules	DDI	-	-	-
Tilidine-ratiopharm® plus drops, 50 mg/4 mg oral drops, solution	-	DDI	-	-

Figure 2. Screenshot of the table representation of ADE warnings (translated into English).

For the survey real medication plans were provided by a physician. They included a wide range of drugs, and thus would offer a higher potential of ADEs. Table 1 shows the complete medication plans. After the participants completed the tasks of entering the medications from the plans and checking for ADEs, they were asked if they were satisfied with the time required for the task.

The survey also evaluated the design and usability through 1 to 5 Likert scale questions. The participants were asked if they saw a potential use for the tool. The numerically high response options always correspond to positive, i.e. desired, feedback. Open-ended questions were asked to capture thoughts that were not yet prompted. The survey included the 10 standardized questions from the System Usability Scale (SUS) for a globally comparable result on the usability [4], [5]. The development of the remaining questionnaire was based on previous work [6].

To recruit participants, group private practices, hospitals and physicians in private practice in the Middle Franconian region were contacted by mail. Potential participants for the survey were anyone who prescribes medications in their daily work. The enquiry text briefly described the functionality of the online platform and explained who could take part in the survey. The respondents (n = 9) partook in the survey anonymously. Of the nine participants in the survey, four were physicians in private practice, two clinicians, and three from other professional groups. They had an average work experience of 21.9 years. Most participants had already used systems for ADE warnings; six using paper-based tools and seven using digital systems. During the evaluation period

(January 2023), participants had full access to the website and could test it for their real-life scenarios.

Table 1. The two medication plans participants were tasked with in the survey.

Task 1	Task 2
Digitoxin-Philo	Lorazepam-neuraxpharm®
Dekristol®	Mirtazapin STADA®
Bisoprolol STADA®	Pregabalin-ratiopharm®
Candecor®-Amlo	L-Thyroxin Henning
Torasemid AbZ	Candesartan HEXAL®
Simvastatin Heumann	Folsäure Injektopas®
Xarelto®	HCT HEXAL®
OMEP®	Lactulose STADA®
Novaminsulfon-ratiopharm®	Metoprolol STADA®
Tramadol STADA®	Moclobemid STADA®
Ramipril/Amlodipin-ratiopharm®	Spiriva® Respimat®
	Tamsulosin - 1 A Pharma®
	Tilidin-ratiopharm®
	Xarelto®

3. Results

The platform gave one ADE warning for the first example, and two warnings for the second task. The questions A3/A6 (see Table 2) prompted participants to list warnings which they would have missed without the tool. Table 2 shows that only one participant mentioned the ADEs warning for task one and three people mentioned one of the two warnings for task two. The table shows for task 1 that two participants mentioned that they would have missed the ADEs without the tool. For task 2 three participants found 1 ADEs. The second ADEs was totally unfound.

Table 2. Results of A3/A6 ("Have you found complications that you would have missed without the online platform?") regarding the sample medication plans.

	drug-drug interactions	found by tool?	# of mentions
A3 – task 1 (n = 9)	Simvastatin + Candecor®-Amlo	Yes	2
	Ramipril + Candecor®-Amlo	No	1
	OMEP® + Xarelto®	No	1
A6 – task 2 (n = 8)	Mirtazapin + Tilidin	Yes	3
	Lorazepam + Pregabalin	Yes	0
	Lorazepam + Mirtazapin	No	1
	Lorazepam + Metoprolol	No	1
	Lactulose + Digitoxin *(Digitoxin only in task 1)*	-	1

Some participants however listed ADEs that were not found by the software. In total five extra interactions were found, of which one was erroneous because drugs from the

different tasks were mixed. Participants who are already using tools for medication therapy were more likely to mention additional interactions.

Participants fully agreed, that a software like this would have long term success and could reduce the number of ADEs, specifically by avoiding complications between multiple indications.

The three different methods for visualizing complications were evaluated separately. List visualization was the preferred choice with a mean of 4.3 and a median of 5. This was the most visually simplistic display method compared to the other two and thus appeared to be the most user-friendly. Representation as a table had a mean of 3.7 and a median of 4. And the graph was rated with a mean of 3.1 and a median of 3. The average score for the SUS questionnaire was 76.5, indicating "good" usability; minimum score 52.5 and maximum score 100.

For the strengths of the platform, the participants mentioned the clarity and intuitiveness most frequently (n = 6), followed by the speed and ease of use of the search functionality and the visual representation of DDIs (both n = 4). The additional warnings for hepatic or renal insufficiency were positively noted (n = 2). Lack of further information on ADE warnings was the most common negative aspect (n = 5). It was also mentioned that some DDIs were not found by the software (n = 2) and requested that patient data should be taken into consideration (n = 2).

4. Discussion

In addition to the drug information presented, participants wished for further information. They requested to see more warnings, such as an indicator of severity or a classification as to what mechanism causes the ADE. Clicking on a specific ADE in any of the visual views could automatically jump to the location in the drug free-text information where that warning was generated and highlight the relevant text in color. This would make it easier and faster for healthcare professionals to extract more detailed information about an interaction.

During testing of the online tool, it was found that the software could not find all ADEs from the text-based data source. Participants identified four more potential ADEs that were missed by the software. The text-based approach has inherent limitations. The information in natural language form contains many edge cases where different search heuristics are needed to extract the correct information. As an example, two participants found an interaction between “Xarelto®” and “OMEP®”. The tool did not find this because the base text of “Xarelto®” mentions the active ingredient “omeprazole”. With a text-based approach, the tool always searches for a specific text module (possibly taking typing errors/Levensthein distance into account). In this case, the short name is “OMEP®”. Due to the ®, “omeprazole” could not be found. For a reliable text based approach, all conceivable scenarios would need to be covered by appropriate heuristics.

The database used and the data quality are crucial in development and implementation of a tool for visualization of ADEs. Pauly et al. [7] examined eight databases (ABDA-database (ABDA), MediQ, Pharmavista, MMI Pharmindex, AiD Klinik (AIK), Lexi-Interact (LI), Eporates, and drugs.com) for accuracy, comprehensiveness and user-friendliness. These are databases that contain knowledge about drug interactions. Lexi-Interact was found to be the best one because it was the most comprehensive. Unfortunately, access to such high-quality databases is associated

with high licensing costs, which makes the university-based, free development of a medication support system much more difficult.

In addition, the search function can be further improved. Users requested a batch-input, matrix 2D barcode scanner for paper-based medication plans and the ability to find the desired results even if they mistyped by one letter. An implementation of the Levenshtein distance algorithm could achieve this [8].

One participant made an error in task two, they named a drug in response to A6 that was only in the first medication plan. This could indicate a potential misuse of the platform, that not all drugs were removed after the first task. Normally this is achieved either by clicking the remove buttons manually for all drugs, or by simply reloading the page. A "clear all" button could easily solve this problem.

Currently only the selection of a pregnancy or organ failure (hepatic or renal insufficiency) in the patient data affects the displayed information and warnings. End users indicated that other patient data such as allergies, GFR, or age should also be included in the identification of ADEs. Ideally, other connected software systems would automatically load the patient's data and their current medication. As there is still a heterogeneous IT landscape in the German health care system, the connection to existing IT systems could require many individual solution approaches, depending on the state and the respective health care institution (hospital, private practice, pharmacy, etc.). However, this would significantly increase the acceptance and frequency of use of the systems; as the participants of this study confirmed.

In this study, the visualization of ADEs by graph performed worst, but the graphical representation has not been fully explored in this work. Two publications from France [9], [10] describe a similar tool that graphically visualize drug interactions. Their representation is easy to understand and read. The specific strengths and weaknesses of their approach could be examined in a follow-up study to determine its acceptance.

The number of respondents is rather small and cannot be generalized, however it is large enough to identify the majority of severe usability problems as shown in prior studies [5], [11].

5. Conclusion

Survey participants consider an online medication visualization tool to be useful. It should provide physicians a user-friendly and quick way to discover warnings in order to reduce the number of medication errors. The list view of ADEs, the speed of the search function, the simplistic layout and the intuitiveness were rated positively. Overall, the usability in the SUS questionnaire achieved a rating of "good" with 76.5.

The database used is of crucial importance in the implementation of a medication visualization tool. With a comprehensive database, additional information such as liver insufficiency, pregnancy status or drug-food interactions could be incorporated into the determination of warnings.

Including additional patient data in the analysis of ADEs was an often-requested feature. To further increase acceptance, integration into existing IT systems would be a potential approach.

Declarations

Ethical vote: There is no legal obligation to consult.

Conflict of Interest: The authors declare that there is no conflict of interest.

Contributions of the authors: LS: programming, conduction of survey; LS, WR: conception of the work, data analytics and interpretation, writing the manuscript; LS, JC: patient recruitment; MW: generation of medication plan; All authors approved the manuscript in the submitted version and take responsibility for the scientific integrity of the work.

References

[1] D. W. Bates *et al.*, "Incidence of adverse drug events and potential adverse drug events. Implications for prevention. ADE Prevention Study Group," *JAMA*, vol. 274, no. 1, pp. 29–34, Jul. 1995.
[2] O. Laatikainen, J. Miettunen, S. Sneck, H. Lehtiniemi, O. Tenhunen, and M. Turpeinen, "The prevalence of medication-related adverse events in inpatients-a systematic review and meta-analysis," *Eur J Clin Pharmacol*, vol. 73, no. 12, pp. 1539–1549, Dec. 2017, doi: 10.1007/s00228-017-2330-3.
[3] A. Krähenbühl-Melcher, R. Schlienger, M. Lampert, M. Haschke, J. Drewe, and S. Krähenbühl, "Drug-related problems in hospitals: a review of the recent literature," *Drug Saf*, vol. 30, no. 5, pp. 379–407, 2007, doi: 10.2165/00002018-200730050-00003.
[4] Brooke, John, "SUS: a quick and dirty usability," . *Usability evaluation in industry*, p. 189, 1996.
[5] Brooke, John, "SUS: a retrospective," *Journal of usability studies*, vol. 8, no. 2, pp. 29–40, 2013.
[6] W. Rödle *et al.*, "User-Centered Development of an Online Platform for Drug Dosing Recommendations in Pediatrics," *Appl Clin Inform*, vol. 10, no. 4, pp. 570–579, Aug. 2019, doi: 10.1055/s-0039-1693714.
[7] A. Pauly *et al.*, "Evaluation of eight drug interaction databases commonly used in the German healthcare system," *Eur J Hosp Pharm*, vol. 22, no. 3, pp. 165–170, May 2015, doi: 10.1136/ejhpharm-2014-000561.
[8] E. S. Ristad and P. N. Yianilos, "Learning String-Edit Distance," *IEEE Trans. Pattern Anal. Mach. Intell.*, vol. 20, no. 5, pp. 522–532, May 1998, doi: 10.1109/34.682181.
[9] J.-B. Lamy, "Visualization of Potential Drug Synergies," *Stud Health Technol Inform*, vol. 272, pp. 91–94, Jun. 2020, doi: 10.3233/SHTI200501.
[10] A. Mouazer, K. Sedki, R. Tsopra, and J.-B. Lamy, "Visualization of Drug Interactions for Supporting Medication Review," *Stud Health Technol Inform*, vol. 272, pp. 107–110, Jun. 2020, doi: 10.3233/SHTI200505.
[11] T. Tullis and J. Stetson, "A Comparison of Questionnaires for Assessing Website Usability," Jun. 2006.