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REVIEW EMERGENCY MEDICINE

Usability assessments in clinical decision support systems

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ABSTRACT

Clinical decision support (CDS) tools play a crucial role in assisting healthcare professionals in making informed decisions. However, the full potential of CDS systems has not been realized due to various usability issues. This paper provides an overview of usability issues identified in CDS tools, including graphical user interface issues, user experience problems, terminology clarity, and user control problems. Several usability assessment methods, such as heuristic evaluation, think-aloud testing, cognitive walk-through, and surveys, are employed to evaluate CDS tool usability. These methods reveal strengths and weaknesses in CDS tool design, guiding improvements to enhance usability. The findings of this review emphasize the importance of incorporating user feedback, employing iterative processes, and addressing interface design challenges to optimize the usability and acceptance of CDS tools in healthcare settings. By addressing these usability issues, healthcare professionals can leverage CDS tools effectively to improve patient outcomes.

Keywords: Decision support systems; diagnosis; heuristics; user-centered design.

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In today's healthcare landscape, clinical decision support (CDS) tools have emerged as valuable resources to aid healthcare professionals in making informed and evidence-based decisions. CDS systems have become increasingly integral in enhancing healthcare delivery, offering a wide range of benefits across various clinical domains. These systems aid in accurate diagnosis, as evidenced by their effectiveness in identifying complex conditions like coronavirus disease 19 [1], and play a crucial role in alerting healthcare professionals to adverse events and drug interactions [2]. CDS systems also contribute significantly to treatment planning, particularly in patient-specific approaches in fields such as radiotherapy [3], and are instrumental in evaluating and refining treatment protocols, especially in pediatric care [4]. Additionally, they enhance patient safety by alerting to incorrect medication dosages [5] and offer broader benefits including improved documentation and cost reduction [6]. Furthermore, CDS systems have proven to be valuable in assisting with test result interpretation, mitigating interpretative subjectivity, and reducing inconsistency [7]. Traditional CDS tools have primarily relied on rule-based systems. However, with the emergence of artificial intelligence (AI), there is growing recognition of its potential to enhance CDS systems. AI-based approaches, such as machine learning, offer the prospect of improving the accuracy and effectiveness of CDS tools. Studies have shown promising results in utilizing AI for decision support, indicating its potential to enhance clinical decision-making processes and improve patient outcomes [8].

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Despite the significant potential for implementation, CDS systems have not been fully realized in clinical settings. Numerous challenges have been identified as obstacles to the widespread adoption and effectiveness of CDS systems. These challenges include leadership deficiencies, a lack of recognition regarding the purpose and value of CDS systems, limited understanding of the complex interactions between humans and computers, and problems about workflow integrations [9].

CDS tools provide useful information, alerts, and recommendations, contributing to improved patient care and safety. However, the successful adoption and utilization of CDS tools heavily rely on their usability, which encompasses factors such as ease of use, efficiency, learnability, and user satisfaction. Understanding the usability strengths and weaknesses of CDS tools is paramount to optimizing their design, enhancing user acceptance, and ultimately improving patient outcomes. By identifying usability issues, addressing interface design challenges, and integrating CDS tools seamlessly into clinical workflows, healthcare professionals can leverage these tools effectively and efficiently. This review aimed to provide valuable insights for enhancing the usability of CDS tools, contributing to the development of user-friendly and impactful decision support systems in healthcare.

Highlight key points

- The success of CDS tools relies heavily on usability factors such as interface design, navigation, and user satisfaction, emphasizing the need to address usability issues for effective implementation in healthcare settings.
- Identified usability issues include graphical interface challenges, terminology clarity problems, transparency issues, and difficulties in navigation, indicating the necessity for comprehensive improvements to enhance overall usability.
- Various methods like heuristic evaluation, think-aloud protocols, scenario-based testing, and surveys have been employed to assess CDS usability, highlighting the multifaceted approach necessary to understand strengths, weaknesses, and areas for improvement.

USABILITY ISSUES DETECTED IN CLINICAL DECISION SUPPORT SYSTEMS

Usability issues detected during the assessments of the clinical decision support systems (CDS) mentioned in the literature are as follows:

- Graphical user interface (UI) issues, including navigation and interaction challenges [10].
- UI and user experience (UX) problems, difficulties in navigating the system and interacting with the interface [11].
- Cumbersome interaction with the graph of CDS [12].
- Challenges related to terminology clarity and interface navigation [13].
- Usability issues related to user control problems [14].
- Challenges with navigation and user interface [15].
- Usability issues related to transparency, functionality, workflow integration, automation, flexibility, and layout [16].
- Problems with clicking, hyperlinks, and unnoticed alerts [17].
- Issues with information presentation, clarity of recommendations, and navigation [18].

These usability issues were identified through various usability assessment methods such as heuristic evaluation, cognitive walk-through, think-aloud protocols, and scenario-based usability testing. Addressing these issues is crucial for enhancing the overall usability and acceptance of CDS tools in healthcare settings.

USABILITY METHODS

Assessing the usability of CDS tools is crucial to ensure their effectiveness and acceptance among healthcare professionals. Various studies have employed different methods to evaluate the usability of CDS tools across diverse medical domains (Appendix 1). These methods include cognitive walk-through, think-aloud protocols, scenario-based usability testing, heuristic evaluation, and mixed-methods approaches. Each method offers unique insights into the strengths and weaknesses of CDS tools, enabling researchers to identify areas for improvement and guide the design and development process.

Heuristic Evaluation

Heuristic evaluation involves the assessment of software, documentation, or hardware products for usability. In this method, a group of reviewers, ideally experts, examine the product and compare it to a set of design principles, commonly known as heuristics. Their goal is to identify any areas where the product deviates from these principles [19]. There are several studies in the literature that assessed the usability of CDS tools via heuristic evaluation.

Marcilly et al. [10] conducted a heuristic evaluation and obtained expert feedback on a CDS tool for medication review [10]. They identified graphical user interface issues and developed guidelines for enhancing CDS systems design through expert input. This study emphasizes the importance of expert feedback in improving usability [10]. Sanderson et al. [11] employed a heuristic evaluation approach to assess a CDS tool for massive transfusion [11]. They identified UI- and UX-related issues and utilized a user-centered design process to develop a highly usable prototype with a clear interface and intuitive blood product tracking. The study highlights the effectiveness of heuristic evaluation in identifying usability issues and guiding design improvements. Jones et al. [16] employed simulation-based usability testing and heuristic evaluation to assess a CDS tool for trauma [16]. While the tool received a high systems usability scale (SUS) score that rated usability of CDS tool, issues related to transparency, functionality, workflow integration, automation, flexibility, and layout were identified. This study emphasizes the value of combining different evaluation methods to comprehensively assess usability.

Think-Aloud Testing

The Think Aloud Test is a user testing technique that focuses on direct observation. It involves instructing users to verbalize their thoughts while carrying out a task, expressing what they see, think, do, and feel throughout the process. This approach is highly effective for managing user expectations and pinpointing any elements of a system that may cause confusion [19].

Cho et al. [14] conducted a think-aloud protocol and heuristic evaluation using severity scales to assess a CDS tool for nursing diagnosis, outcomes, and interventions [14]. The study revealed positive feedback on flexibility, efficiency of use, and user control while identifying issues related to severity scores for heuristic violations. This study emphasizes the value of a systematic and simple approach, such as heuristic evaluation, in assessing system usability before widespread implementation [14]. Greenberg et al. [13] conducted a study on a CDS tool for children with mild traumatic brain injury using a think-aloud protocol and user surveys [13]. The tool demonstrated positive usability aspects, such as ease of use and aiding in patient care determination. However, challenges related to terminology clarity and interface navigation were also encountered. The study emphasizes the importance of user feedback in improving usability [13]. Sunjaya et al. [15] evaluated a CDS tool for breathlessness using a think-aloud protocol and real-world scenarios [15]. While the tool was praised for its ease of use and clear presentation of quantitative information, challenges were faced with navigation and user interface. This study highlights the value of incorporating real-world scenarios and user feedback in usability assessment [15]. Schaaf et al. [20] conducted a Thinking Aloud Test and utilized the SUS in evaluating a CDS tool for rare diseases [20]. The study revealed positive functionality in accessing patient overviews and medical history but identified a lack of transparency in patient similarity analysis. This study emphasizes the need for revisions and improvements to enhance transparency and usability in the analysis of patient similarity [20]. Williams et al. [21] employed a think-aloud approach and formal usability assessment to evaluate a CDS tool for pediatric cardiovascular risk reduction [21]. Overall, the reactions toward the tool were positive, but suggestions for improvement were made to enhance user-friendliness and refine recommendations for better patient tailoring. This study underscores the importance of incorporating tester feedback to meet the specific needs of clinicians in the practice setting [21].

Walkthrough Methods

Cognitive walk-through is a method used to evaluate usability, where one or more evaluators assume the user's perspective and engage in a series of tasks and questioning [19]. Sanderson et al. [11] employed cognitive walkthrough using a simulated bleeding scenario, qualitative assessment, and the SUS to assess the tool's usability [11]. The findings revealed an average SUS score of 69.3, indicating a favorable level of usability. The evaluation also identified several UI and UX issues that were promptly addressed. The researchers adopted a user-centered design (UCD) process to develop a highly usable massive transfusion prototype CDS, resulting in a clear interface and an intuitive blood product tracking system. This study highlights the importance of incorporating user feedback and employing UCD methodologies to ensure the development of effective and user-friendly clinical decision support tools for critical scenarios such as massive transfusion [11].

Heuristic walkthrough is a comprehensive review approach that integrates elements from heuristic evaluation, cognitive walkthrough, and pluralistic usability walkthrough. During the application of this method,

participants go through two rounds of evaluation for the product. In the first pass, "thought-provoking" questions are utilized, and evaluators are tasked with working through a prioritized set of tasks. In the second pass, evaluators employ a set of heuristics to uncover any additional issues or problems [19]. In their study on CDS for antibiotic stewardship, Patterson et al. [22] employed a heuristic review to identify ways to enhance the usability of a prototype CDS [22]. Two independent raters conducted a comprehensive review of the entire interface using the heuristic review methodology proposed by Wiklund et al. [23]. Through a series of 90-minute meetings, the raters shared their independently generated findings, discussed similarities and differences, and reached a consensus on prioritized recommendations to improve the interface's usability. The review yielded 32 recommendations aimed at enhancing the software's usability and usefulness [22]. The researchers addressed the identified usability issues by implementing changes to the interface. Notably, negative feedback was received regarding interface display suggestions, feature suggestions, and user tailoring. In order to further refine the prototype, the revised version was subjected to three walkthrough demonstration interviews with physician and pharmacist subject matter experts, which led to additional recommendations to improve the interface, functionality, and tailoring for specific user groups. The findings highlight the importance of iterative feedback and user involvement in optimizing the design and functionality of CDS systems for antibiotic stewardship.

Survey Methods and Rating Scales

SUS is widely recognized as a popular and standardized rating scale for assessing usability. It offers a streamlined approach with a concise set of 10 questions, allowing users to provide subjective feedback. Given its widespread usage, there exists a substantial body of literature consisting of reviews and evaluations that examine the effectiveness, strengths, and limitations of the SUS, which conventionally ranges from 0 to 100 [19]. Multiple studies evaluated the usability of various CDS tools using the SUS. Sanderson et al. [11] obtained an average SUS score of 69.3 for a CDS tool for massive transfusion, highlighting UI- and UX-related issues [11]. Chen et al. [12] reported a SUS score of 66.1 for a deep learning-based CDS tool for glaucomatous visual field progression [12]. Butler et al. [24] found an average SUS score of 75 for a trauma-related CDS tool [24]. Sunjaya et al. [15] identified challenges in navigation and user interface for a breathlessness-related CDS tool, with a SUS score of 59 [15]. Jones et al. [16] reported a high SUS score of 90 for a trauma-related CDS tool but encountered issues with transparency and functionality [16]. Nanji et al. [17] achieved a SUS score of 78.1 for a perioperative medication-related CDS tool, outperforming standard workflow [17]. Schaaf et al. [20] obtained a good SUS score of 73.21 for a CDS tool for rare diseases [20], while Hoelscher and McBride [25] demonstrated high satisfaction scores for an infectious disease-related CDS tool [25].

There is also one study that used Likert scale for usability evaluation. Chen et al. [12] evaluated a deep learning-based CDS tool for predicting glaucomatous visual field progression. They assessed usability through Likert scale (ranging from 1 (strongly disagree) to 5 (strongly agree))-based recommendations and found moderate trust and utility in the predicted metric. The study highlights the importance of usability assessment in determining the effectiveness of AI-based CDS tools [12].

Mixed Methods Approach

In the realm of evaluating the usability of CDS tools, several studies have employed different methodologies to gather comprehensive feedback. Norvell et al. [26] used a mixed methods approach, including think-aloud, interviews, and the post-study system usability questionnaire, to assess a CDS tool for post-operative risk assessment [26]. The tool received favorable usability ratings, albeit with minor concerns regarding intuitiveness [26]. Salwei et al. [18] conducted scenario-based usability testing and surveys for a CDS tool targeting pulmonary embolism, reporting high usability in both experimental and real clinical settings [18]. However, the limitation of insufficient workflow integration was identified, underscoring the need for improved integration to maximize usability and effectiveness. Another study by Hoelscher and McBride [25] evaluated a CDS tool for infectious disease using the Task, User, Representation, and Function framework and the SUS, and reported high satisfaction scores among nurses and providers, highlighting the positive impact of an infectious disease alert module on usability and user satisfaction [25]. Collectively, these studies emphasize the significance of assessing CDS tool usability through a range of methods, such as heuristic evaluation, expert feedback, simulation-based testing, think-aloud protocols, and user surveys. The findings stress the importance of clear interfaces, efficient work-

flows, transparency, and integration to enhance the usability and effectiveness of CDS tools in clinical settings. It is essential to incorporate user feedback and engage in iterative refinement processes to optimize the usability and acceptance of CDS tools in practical applications.

Scenario-Based Usability Testing and Surveys

Scenario-based usability tests have been employed in multiple studies to assess the effectiveness and usability of CDS tools. Sanderson et al. [11] conducted a cognitive walk-through using a simulated bleeding scenario and the SUS to evaluate a CDS tool for massive transfusion, identifying UI and UX issues [11]. Sunjaya et al. [15] utilized a think-aloud protocol with real-world scenarios to assess a CDS tool for breathlessness, noting challenges with navigation and user interface [15]. Nanji et al. [17] employed expert-created scenarios and think-aloud verbalization to evaluate a perioperative medication-related CDS tool, observing improved efficiency but identifying usability issues [17]. Salwei et al. [18] conducted scenario-based usability testing for a CDS tool for pulmonary embolism, reporting high usability but highlighting the need for better integration into clinical workflows [18]. These studies demonstrate the value of scenario-based usability testing in identifying strengths, weaknesses, and areas for improvement in CDS tool design and implementation.

Content Analysis of Interviews and Usability Criteria

Salwei et al. [27] performed a content analysis of interviews with emergency medicine physicians to assess a CDS tool for pulmonary embolism [27]. Positive aspects, such as automatic population of vital signs, were identified, while workflow integration and support for resident-attending physician teamwork were highlighted as challenges [27]. This study underscores the importance of applying human factors engineering principles to enhance the usability of CDS systems.

Conclusion

In summary, these studies collectively demonstrate the importance of evaluating the usability of CDS tools using a variety of methods. By employing approaches such as cognitive walk-through [11], think-aloud protocols [14, 28], scenario-based testing [15, 17, 18], heuristic evaluation [10, 11], and mixed methods [18, 26], researchers were able to assess the usability strengths and weaknesses of CDS tools across different medical domains (Appendix 1).

The studies using heuristic evaluation and expert feedback highlighted the value of expert input in identifying usability issues and guiding design improvements [11]. Incorporating expert feedback can lead to the development of guidelines and enhancements that address graphical user interface issues and improve the overall usability of CDS tools [10].

In conclusion, the synthesis of these studies underscores the importance of evaluating the usability of CDS tools in the healthcare domain. The use of diverse evaluation methods allows for a comprehensive understanding of usability strengths, weaknesses, and areas for improvement. Incorporating expert feedback [10], user-centered design processes [11], real-world scenarios [15], and user feedback [26] are critical in optimizing the usability and effectiveness of CDS tools. By addressing usability issues, improving interface design, and integrating CDS tools into clinical workflows, healthcare professionals can benefit from highly usable and effective decision support systems.

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APPENDIX 1. Usability evaluations of clinical decision support systems

Study	CDS	Methods	Results	Outcome
Marcilly et al. (2023) [10]	CDS tool for medication review	Heuristic evaluation using Usefulness, Satisfaction and Ease of Use questionnaire, semi-structured interviews based on the unified theory of acceptance and use of technology.	Out of the total 47 problems including graphical user interface issues, 26 were mild, 17 were moderate, and 4 were severe	Guidelines for enhancing CDS systems design were developed through expert feedback.
Sanderson et al. (2023) [11]	CDS tool for massive transfusion	Cognitive walk-through using a simulated bleeding scenario, qualitative assessment and the System Usability Scale (SUS).	Average SUS of 69.3, UI and UX related issues were identified	User-centered design process was used to develop a highly usable MT prototype CDS with clear interface and intuitive blood product tracking.
Chen et al. (2023) [12]	Deep Learning-Based CDS tool for Predicting Glaucomatous Visual Field Progression	Clinicians evaluated the tool and provided one of four recommendations for each case: continuing present management with routine follow-up, longer follow-up, shorter follow-up, or escalating therapy and ranked statements using a Likert scale. Usability was assessed using SUS.	The mean Likert scores indicated moderate trust in and utility of the predicted metric, with lower willingness to decrease testing frequency. The overall system usability score was 66.1. Interaction with the graph was deemed cumbersome while the tool was perceived helpful in general.	The Deep Learning-Based CDS Tool had modest usability.
Butler et al. (2022) [24]	CDS tool for trauma	10-question scale System Usability Score	Average SUS was 75. There was no indication of improved usability over time or with increased familiarity.	The use of a digital real-time recording tool like the TraumaApp is comparable to using traditional paper forms for documenting clinical events.
Greenberg et al. (2022) [13]	CDS tool for children with mild traumatic brain injury	Think-aloud protocol, acceptability and usability surveys including SUS, and a semi-structured interview.	The tool demonstrated positive usability aspects, such as ease of use and aiding in patient care determination, while encountering challenges related to terminology clarity and interface navigation.	The CDS tool was deemed highly usable and useful in managing children with mild traumatic brain injury.
Cho et al. (2022) [14]	CDS tool for nursing diagnosis, outcomes and interventions	heuristic evaluation using severity scale	Severity scores for heuristic violations ranged from 0.66 to 2.00, with flexibility and efficiency of use receiving positive feedback and user control problems as negative feedback	The heuristic evaluation process is a simple and systematic approach reducing time and costs associated with establishing system usability prior to widespread implementation.

APPENDIX 1 (cont). Usability evaluations of clinical decision support systems

Study	CDS	Methods	Results	Outcome
Sunjaya et al. (2022) [15]	CDS tool for breathlessness	Think-aloud protocol using real-world scenarios	Average SUS score was 59. The system was praised for its ease of use and clear presentation of quantitative information, but faced challenges with navigation and user interface.	Employing a design thinking and practice-oriented approach with rapid usability testing provided valuable and cost-effective insights.
Jones et al. (2022) [16]	CDS tool for trauma	Simulation-based usability testing and Heuristic evaluation using common usability heuristics	The CDS tool scored 90 on the SUS, but it faced issues with transparency, functionality, workflow integration, automation, flexibility, and layout.	The dual-method usability evaluation improves sensitivity compared to relying solely on end-user or expert-driven methods.
Nanji et al. (2022) [17]	CDS tool for perioperative medication	A team of experts created scenarios and tasks to ensure appropriate complexity and clinical relevance. Think-aloud verbalization and the System Usability Scale (SUS) were used.	Average SUS was 78.1. Improved efficiency and decreased task time were observed, however usability issues were identified, including problems with clicking, hyperlinks, and unnoticed alerts.	The perioperative medication-related CDS prototype outperformed standard EHR workflow in terms of efficiency, task time, and quality of care in a simulation setting.
Salwei et al. (2022) [18]	CDS tool for pulmonary embolism	Scenario-based usability testing using survey included questions on acceptance, use, barriers, and areas for improvement to measure satisfaction with three sub-scales: system usefulness, information quality, and interface quality.	High usability was reported in both experimental and real clinical settings. However, lack of workflow integration was identified as a limitation.	CDS for pulmonary embolism demonstrated high usability, but there is a need for better integration into clinical workflows.
Salwei et al. (2021) [27]	CDS tool for pulmonary embolism	Content analysis of interviews with 32 emergency medicine physicians using Scapin and Bastien's usability criteria framework.	Positive aspects included automatic population of vital signs, while negative aspects included workflow integration issues and lack of support for resident-attending physician teamwork	Systematic application of human factors engineering principles enhances the usability of CDS systems.
Norvell et al. (2021) [26]	CDS tool for Post-Operative Risk Assessment	Mixed methods approach involving think aloud, semi-structured interviews, and the Post-Study System Usability Questionnaire (PSSUQ) completed by 10 clinicians.	The PSSUQ scores indicated favorable usability, with a mean overall total score of 1.57 and positive ratings for usability characteristics and clinical relevance. Minor concerns were raised regarding intuitiveness.	Feedback from the clinicians led improvements to the home, input, and output pages of the CDS tool.
Schaaf et al. (2021) [20]	CDS tool for rare diseases	Thinking Aloud Test with experts from Rare Diseases Centers (RDCs), followed by a questionnaire including the System Usability Scale (SUS).	Usability assessment revealed positive functionality for accessing patient overviews and medical history, but a lack of transparency in patient similarity analysis	The CDSS achieved a good usability score of 73.21 but requires revisions and improvements to enhance transparency in patient similarity analysis.

APPENDIX 1 (cont). Usability evaluations of clinical decision support systems

Study	CDS	Methods	Results	Outcome
Patterson et al. (2020) [22]	CDS tool for antibiotic stewardship	Heuristic review and walkthrough interviews	A total of 32 recommendations were gathered to enhance the usability and usefulness of the CDS software, resulting in changes to the interface to address the identified usability issues.	Walkthrough interviews with experts generated recommendations for improving the prototype's interface, functionality, and user tailoring.
Hoelscher and McBride (2020) [25]	CDS tool for infectious disease	Usability evaluation was conducted using the Task, User, Representation, and Function framework, and satisfaction was measured using the SUS.	Nurses scored a mean satisfaction of 91.25, providers scored 80.83, and the overall satisfaction score was 86.04.	The implementation of the infectious disease alert module received high satisfaction from providers and nurses, contributing to the evaluation of CDS usability and user satisfaction.
Williams et al. (2016) [21]	CDS tool for pediatric cardiovascular risk reduction	Think aloud approach with 5 clinicians and formal usability assessment using with 14 pediatricians	Overall, the reactions toward the CDS tool were positive. However, improvements were suggested to enhance user-friendliness and refine recommendations for better patient tailoring.	Tester feedback was incorporated into the design, emphasizing the importance of adapting decision support tools to meet the needs of clinicians in the practice setting.
Press et al. (2015) [28]	CDS for pulmonary embolism	Think aloud method and near-live clinical simulation with standardized patients and seven residents	CDS received positive feedback regarding its organization and ease of use, while concerns were raised about the lack of a dedicated space for comments and the potential for user fatigue due to excessive clicks.	The assessment of the CDS tool led to refinements in usability and workflow, resulting in increased usability through the implementation of suggestions

CDS: Clinical decision support; SUS: System Usability Scale; UI: User interface; UX: User experience; EHR: Electronic health record.