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Review article

Barriers and facilitators influencing medication-related CDSS acceptance according to clinicians: A systematic review

Leonie Westerbeek [a,*], Kimberley J. Ploegmakers [b], Gert-Jan de Bruijn [a], Annemiek J. Linn [a], Julia C.M. van Weert [a], Joost G. Daams [c], Nathalie van der Velde [b], Henk C. van Weert [d], Ameen Abu-Hanna [e], Stephanie Medlock [e]

[a] Amsterdam School of Communication Research, University of Amsterdam, Amsterdam, the Netherlands
[b] Department of Internal Medicine, Section of Geriatric Medicine, Amsterdam Public Health Research Institute, AmsterdamUMC, University of Amsterdam, Amsterdam, the Netherlands
[c] Medical Library, Amsterdam Public Health Research Institute, Amsterdam UMC, University of Amsterdam, Amsterdam, the Netherlands
[d] Department of General Practice, Amsterdam Public Health Research Institute, Amsterdam UMC, University of Amsterdam, Amsterdam, the Netherlands
[e] Department of Medical Informatics, Amsterdam Public Health Research Institute, Amsterdam UMC, University of Amsterdam, Amsterdam, the Netherlands

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A B S T R A C T

Background: A medication-related Clinical Decision Support System (CDSS) is an application that analyzes patient data to provide assistance in medication-related care processes. Despite its potential to improve the clinical decision-making process, evidence shows that clinicians do not always use CDSSs in such a way that their potential can be fully realized. This systematic literature review provides an overview of frequently-reported barriers and facilitators for acceptance of medication-related CDSS.

Materials and methods: Search terms and MeSH headings were developed in collaboration with a librarian, and database searches were conducted in Medline, Scopus, Embase and Web of Science Conference Proceedings. After screening 5404 records and 140 full papers, 63 articles were included in this review. Quality assessment was performed for all 63 included articles. The identified barriers and facilitators are categorized within the Human, Organization, Technology fit (HOT-fit) model.

Results: A total of 327 barriers and 291 facilitators were identified. Results show that factors most often reported were related to (a lack of) *usefulness* and *relevance* of information, and *ease of use* and *efficiency* of the system.

Discussion: This review provides a valuable insight into a broad range of barriers and facilitators for using a medication-related CDSS as perceived by clinicians. The results can be used as a stepping stone in future studies developing medication-related CDSSs.

1. Introduction

Medication-related problems are responsible for approximately 3–5% of all hospital admissions and approximately 20 % of all readmissions [1,2]. Various aspects, such as relevant patient characteristics and drug-drug interactions, need to be considered by the clinician during medication-related processes (e.g. prescribing, medication review etc.) [3,4]. Errors made during these processes can cause preventable injuries, negatively affecting patient safety and leading to unnecessary health care costs [3]. Therefore, it is of great importance to diminish the number of adverse drug events.

Clinical decision support systems (CDSSs) are systems that link patient health data with health knowledge (e.g. computer-interpretable guidelines) to guide the clinical decision making process [5]. CDSSs can support many aspects of care, such as preventative care, diagnosis, or therapy, including medication [6,7]. A medication-related CDSS is a system that supports medication-related decisions and processes, such as prescribing, administration, and monitoring for effectiveness and adverse effects.

Research shows that medication-related CDSSs offering advice to clinicians can prevent medication errors and thereby improve patient safety and healthcare quality [8–10]. However, clinicians override

* Corresponding author at: Amsterdam School of Communication Research, University of Amsterdam, Nieuwe Achtergracht 166, 1018 WV Amsterdam, the Netherlands.

E-mail address: l.westerbeek@uva.nl (L. Westerbeek).

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49–96% of all drug-safety alerts [11]. This raises the question of which factors influence the acceptance of these systems. Acceptance entails not just accepting the CDSS (i.e. purchasing or using it), but also accepting its guidance and advice. Barriers are considered factors that negatively influence the acceptance of the CDSS. Facilitators, on the other hand, encourage acceptance of a CDSS. Insight into barriers and facilitators is needed to improve the acceptance of CDSSs.

In particular, it is useful to know what the clinicians themselves, as the primary users of CDSSs, see as barriers and facilitators for CDSS acceptance. Recently, Van Dort and colleagues [12] systematically reviewed 13 qualitative studies regarding barriers and facilitators for using medication-related CDSSs. They found that perceived threats to clinical autonomy, mistrust of information and irrelevant alerts were important barriers, while perceived improvements to patient safety and efficiency and ease of use were important facilitators. In our review, we aim to expand these findings by creating a broader overview of barriers and facilitators for medication-related CDSS acceptance. Qualitative studies provide an in-depth view from a small sample which is typically not representative of a larger population, while surveys provide a less detailed view, but of a larger and more representative section of the population [13]. Combining knowledge from qualitative as well as survey studies will result in an overview of the full continuum of research in the field. This systematic review thus aims to create a complete overview of barriers and facilitators of medication-related CDSS acceptance as reported by clinicians.

2. Materials and methods

2.1. Search strategy

The systematic review was pre-registered in Prospero (Ref. CRD42020171318). The literature search was performed on 14 April 2020 in four databases: Medline, Scopus, Embase and Web of Science Conference Proceedings. The search was developed with the aid of a medical librarian (JD), and customized for each of the databases (Appendix A). To verify the search strategy, we confirmed that 21 relevant articles obtained by citation analysis and similarity tracking appeared in the search results. Furthermore, the references of included papers were manually checked for possible additional relevant papers.

2.2. Study selection

We applied the following inclusion criteria: (1) The study was a qualitative or survey study investigating barriers and facilitators for CDSS acceptance. Investigating barriers and facilitators did not have to be an aim of the study. (2) The study reported the results of primary data collection (thus not a review or other secondary data). (3) The study focused on medication-related CDSSs. This entails patient-specific advice about medication-related care processes (e.g. prescriptions, drug alerts). Thus, an e-prescribing system or Computerized Provider Order Entry without drug-related alerts was not considered a CDSS. However, a study reporting on clinicians' opinions of drug-drug interaction- or allergy alerts within such as system would be eligible for inclusion. (4) Study participants were clinicians who were (potential) users of the CDSS, with barriers and facilitators gathered from these clinicians. We excluded usability studies, as these look at more system-specific usability problems rather than general barriers and facilitators, and two systematic reviews on usability aspects have been conducted recently [14,15]. While screening the titles and abstracts, articles that did not allow a clear inclusion/exclusion decision were retained for the full paper phase. Subsequently, during full text screening, all of the inclusion criteria had to be fully met.

To ensure reliability in the screening process, all records were screened in Rayyan [16] by at least two reviewers (LW, KP, KV, SG, LS). To ensure a common understanding of definitions and inclusion criteria, decisions on the first 200 titles screened by any two reviewers were compared and discussed before completing the rest of the screening. All full texts were screened by two reviewers (LW, KP, KV, SG). In both phases, any disagreement was resolved through discussion between the two reviewers, if any uncertainty remained, a third reviewer was consulted (SM).

2.3. Data extraction

Data were extracted from all studies by one author (LW) using a data extraction sheet tested independently by four authors (LW, GB, JW, SM). Title, authors, year of publication, and journal were extracted from each article. Furthermore, for each study we extracted the setting, year of data collection, type of study, type of questions asked, country, aim of the study, number, age and work experience of participants, and type of clinicians participating. Relevant information regarding the CDSS and its target users, and the barriers and facilitators for CDSS acceptance as mentioned by clinicians were extracted. We classified an item as a barrier or facilitator according to the classification used in the source study; no attempt was made to reclassify related items (e.g. "takes time" as a barrier and "saves time" as a facilitator).

2.4. Quality assessment measure

To assess the methodological quality of each of the included studies, the validated QualSyst tool [17] was used, as it allows scoring of both qualitative and quantitative studies. Quality assessment was done concurrently with data extraction by one author (LW). A summary score for each study was calculated by dividing the total score by the total possible score, resulting in a score between 0.0 and 1.0. Studies with a score of 0.5 or higher were considered of sufficient or good quality.

2.5. Data analysis

The extracted barriers and facilitators were categorized using the Human, Organization and Technology-fit (HOT-fit) model, intended for evaluation of health information systems, such as CDSSs [18] (Fig. 1). HOT-fit extends the IS success model's [19] constructs of Use, User Satisfaction, and Information, System, and Service Quality with the organizational factors and concept of "fit" from the IT-organization fit model [20]. Barriers and facilitators to acceptance among clinicians (Human), technical problems with the software (Technology) and the extent to which the system can be integrated in the organizational environment (Organization) all affect CDSS usage [10]. For each of these dimensions, Yusof and colleagues provide "evaluation measures" [18] which constitute sub-categories of the eight components (e.g. System Quality, Information Quality, Structure etc.), and were used to categorize the extracted barriers and facilitators.

Barriers and facilitators that did not fall into this classification were placed in an "other" category, and then grouped into emergent themes. There seemed to be partial overlap between the component User Satisfaction and other components (which sometimes included indirect

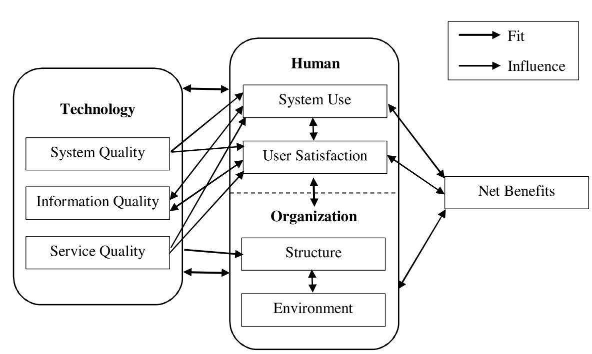

Fig. 1. The HOT-fit framework [18].

indications of satisfaction). Therefore, we defined User Satisfaction as remarks specifically about satisfaction, and not remarks from other categories that imply satisfaction. Categorization was carried out by one author (LW). Any ambiguities were thoroughly discussed by a team of four of the authors (LW, GB, JW, SM). The total number of barriers and facilitators related to each HOT-fit component and underlying evaluation measure was counted, resulting in an overview of the most-frequently-mentioned barriers and facilitators.

3. Results

3.1. Search results

Our search strategy resulted in 6816 records. After removing duplicates (n = 1412), 5404 records remained for title and abstract screening, during which, 5264 records were excluded. Subsequently, the remaining 140 full-text papers were screened. Agreement on independent full-text screening was 86 %, all disagreements were resolved after discussion. In total 63 articles were included. Fig. 2 summarizes the complete screening process in a PRISMA flow diagram.

The review includes a mixture of qualitative ($n = 42$), survey ($n = 16$) and mixed methods ($n = 5$) studies. The studies were performed at various sites, with hospitals ($n = 31$) and general practices ($n = 11$) being represented most frequently. The studies include data collected in 23 different countries, with the most common being the USA ($n = 20$) and Australia ($n = 12$). Information on each included paper can also be found in Table 1. Quality assessment of the included papers yielded an average score of 0.71 (range 0.42–0.89), with two studies having a score below 0.5. We checked to see if these two studies influenced our results. However, the themes presented in our results section below still predominated when excluding these two studies. We therefore retained them in our analysis.

3.2. Barriers and facilitators

In the 63 included studies [21–83], 327 barriers and 291 facilitators were identified. Barriers or facilitators named in more than one study were consolidated, resulting in 195 unique barriers and 174 unique facilitators. Barriers and facilitators were categorized into HOT-fit's evaluation measures, which are sub-categories of the dimensions Information Quality, Service Quality etc. An overview of the most-frequently-encountered evaluation measures with example barriers and facilitators can be found in Table 2. In this table, the total amount of barriers and facilitators is reported for each evaluation measure. In the text below, we report the unique number of barriers and facilitators for the most frequently encountered evaluation measures. The complete list of barriers and facilitators can be found in Appendix B.

3.2.1. Technology

Barriers and facilitators from all three categories in the Technology component of HOT-fit were encountered. Information Quality was represented in more barriers than facilitators (n total barriers = 97, n total facilitators = 67), while System Quality (n total barriers = 97, n total facilitators = 104) and Service Quality (n total barriers = 2, n total facilitators = 4) were recognized in more facilitators. The most-often-encountered evaluation measures related to Information Quality were *usefulness* (n unique barriers = 12, n unique facilitators = 16), *relevance* (n unique barriers = 14, n unique facilitators = 2), *format* (n unique barriers = 4, n unique facilitators = 17), *conciseness* (n unique barriers = 5, n unique facilitators = 6), *reliability* (n unique barriers = 4, n unique

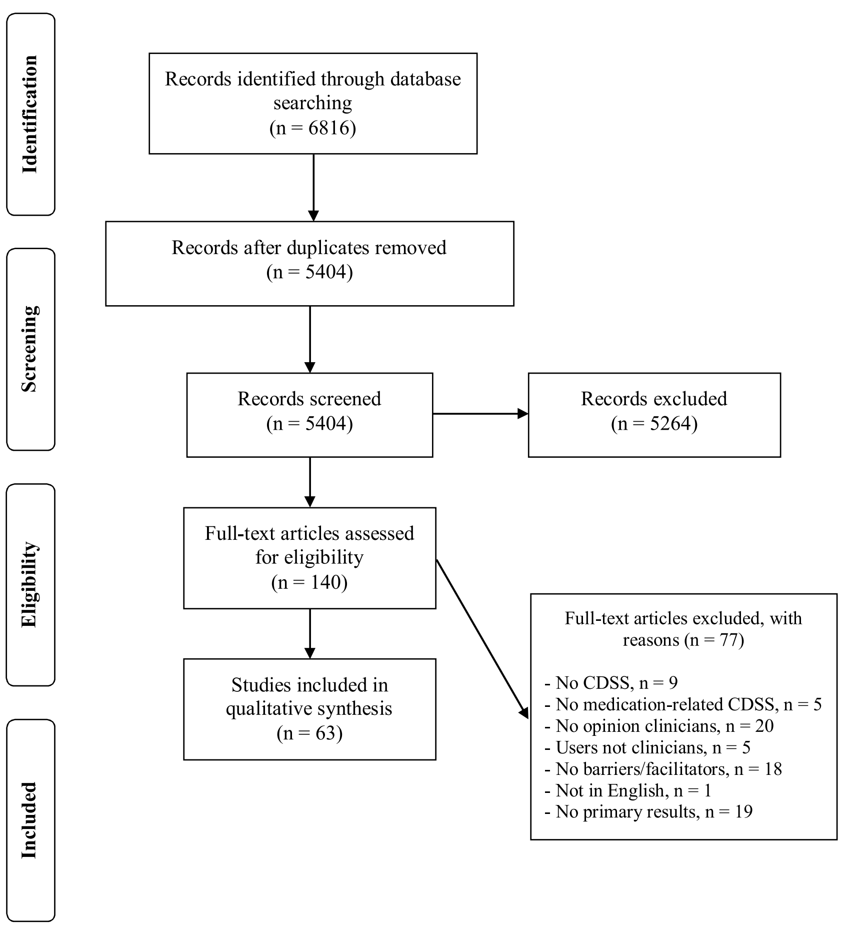

Fig. 2. Flow chart of the article selection process.

Table 1
Characteristics of included studies.

Authors, year published, country	Study type	Setting	Participant info	Clinician type	CDSS	Questions about
Abarca et al., 2006, USA [21]	Survey	Pharmacies from 18 metropolitan statistical areas	$N = 736$	Pharmacy managers ($n = 736$)	Existing system. Pharmacy computer system with built in drug-drug interaction (DDI) alerts.	Previous real life experience with system.
Agostini et al., 2008, USA [22]	Qualitative	Large academic medical center	$N = 36$	Interns first postgraduate year ($n = 29$), interns postgraduate year 2 or higher ($n = 7$)	Developed for this project, has been in place for 1 year. Point-of-care computer based reminder that provided brief educational review of potential adverse effects of medication + offered recommendations. Reminder incorporated in existing system.	Real life experience during the past year.
Ahearn et al., 2003, Australia [23]	Qualitative	GPs from 1 rural and 2 urban divisions	$N = 22$, n female $= 7$	GPs ($n = 22$)	Existing systems. Different systems used by different GPs with prompts, warnings, or links to additional information to assist in the decision-making process and streamline work practices.	Previous real life experience with their own system.
Ballard et al., 2017, USA [24]	Survey	Academic tertiary healthcare center	$N = 105$, n female $= 53$, M work experience $=$ 13.6 years	Nurse practitioner ($n = 15$), physician assistant ($n = 4$), physician ($n = 39$), physician in training ($n = 47$)	System was developed by the center. Links to the decision aids are located in the Electronic Medical Record (EMR). System helps clinicians and patients discuss pro's and con's of statin use and uses electronic issue cards to display the impact of different medications.	Previous real life experience with the system.
Bastholm Rahmer et al., 2004, Sweden [25]	Qualitative	General hospital	$N = 21$, n female $= 11$, M age $= 37$, M work experience $= 5$ years	Physicians	Existing system. Integrated with current medical record systems and gives access to decision-support functions such as recommended drugs, alerts for interactions/pregnancy/breast feeding, search tool for adverse drug effects etc.	Questions about hypothetically implementing this system.
Baysari, et al., 2013, Australia [26]	Qualitative	Teaching hospital	$N = 7$	Prescribers	System classifies antimicrobials according to a traffic light system (red/orange/green).	Real life experience with system.
Baysari, Westbrook et al., 2013, Australia [27]	Survey	Teaching hospital	$N = 21$	Registrar ($n = 10$), resident ($n = 6$), intern ($n = 5$)	Existing system. Decision support alerts regarding allergy, intolerance, pregnancy, therapeutic duplication and prescribing advice. Alerts appear immediately after selecting a drug.	Previous real life experience with system.
Baysari et al., 2014, Australia [28]	Qualitative	Teaching hospital	$N = 16$	Prescribers	Existing system. Electronic medication management system that links prescribing, pharmacy review and drug administration. Alerts delivered to prescriber right after drug selection.	Previous real life experience with system.
Baysari et al., 2017, Australia [29]	Qualitative	Teaching hospital	$N = 11$	Senior doctor ($n= 1$), junior doctors ($n = 10$)	Decision support was added to an existing CPOE system for this study. Approved indications were incorporated into pre-written orders, so prescribers didn't have to read a whole alert text but could select from a pre-approved list.	Real life situations right after they occurred.
Baysari et al., 2020, Australia [30]	Survey	Teaching hospital	$N = 96$	Clinicians ($n = 36$), nurses ($n = 60$)	Decision support added to an existing EMR. E.g. allergy and intolerance alerts, therapeutic duplication alerts, pregnancy alerts, and drug-drug interaction alerts.	Real life experience with current alerts and wishes for changes.
Böttiger et al., 2018, Sweden & Finland [31]	Survey	Two geriatric wards & three primary healthcare centers	$N = 40$	Physicians ($n = 40$)	System developed in this study. Buttons signaling in color if there is safety information to be retrieved for the individual patient, drug-drug interactions, dosing recommendations, and	Real life experience during pilot study

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Table 1 (*continued*)

Authors, year published, country	Study type	Setting	Participant info	Clinician type	CDSS	Questions about
					warnings related to unsuitable drugs for the elderly	
Bright et al., 2013, USA [32]	Qualitative	Two hospitals	*N* = 12, *n* female = 7	Resident/fellow physicians (*n* = 6), nurse practitioners (*n* = 3), clinical pharmacists (*n* = 3)	System is in development. Commercial CPOE system providing basic antibiotic decision support.	Functional requirements for the system.
Bury et al., 2004, UK [33]	Qualitative	Hospital	*N* = 36	Clinicians	Existing system. Web based service which gives protocol based advice.	Simulated cases
Chow et al., 2015, Singapore [34]	Mixed methods (focus groups + survey)	Tertiary care hospital	*N* focus group = 11, *N* survey = 265	Focus group: senior physicians (*n* = 6), junior physicians (*n* = 5). Survey: senior physicians (*n* = 115), junior physicians (*n* = 150)	Existing system. Patient-specific antibiotic recommendations at point of prescribing, integrated with CPOE.	Previous real life experience with system.
Chua et al., 2018, Singapore [35]	Qualitative	Tertiary care teaching hospital	*N* = 39, *n* female = 22	Junior physicians (*n* = 29), senior physicians (*n* = 10)	Existing system. Provides patient-specific antibiotic recommendations at point of prescribing.	Previous real life experience with the system.
Chung et al., 2017, USA [36]	Qualitative	Children's hospital	*N* = 22	Medial leaders (*n* = 5), pediatric emergency attending faculty (*n* = 5), pediatricians (*n* = 6), physician assistant (*n* = 1), nurse practitioner (*n* = 3)	Existing system. System delivers ASP recommendations at point of care through the existing medical record system. Gives alerts and advice about antibiotics prescribing.	Previous real life experience with system.
Collins et al., 2012, Singapore [37]	Qualitative	Hospitals	*N* = 41	Consultants (*n* = 13), pharmacists (*n* = 28)	System does not yet exist. Aim is to create a starting point for developing an oncology CDSS.	Attitudes and knowledge of physicians and pharmacists to a CDSS in oncology in general.
Cornu et al., 2014, Belgium [38]	Survey	University hospital	*N* = 164, *n* female = 75	Prescribers	Existing systems. Several types of basic CDSSs for drug prescribing. Functions such as drug-drug interaction check, dosage information support, presented as passive information/non-interruptive alerts.	Previous real life experience with the system.
Day et al., 2011, Australia [39]	Qualitative	Teaching hospital	*N* = 19	Medical, nursing and pharmacy staff	Existing system. Electronic medication management system with decision support in the form of alerts.	Previous real life experience with the system.
De Vries et al., 2013, The Netherlands [40]	Survey	Heart failure clinics	*N* = 162, *n* female = 110, *M* age = 48, *M* work experience = 14 years	Cardiologists (*n* = 36), heart failure nurses (*n* = 126)	Existing systems. No specific system, different CDSSs used in the heart failure domain.	Previous real life experience with their own system.
Dodson et al., 2019, USA [41]	Qualitative	Local health care systems	*N* = 10	Nurse practitioners (*n* = 10)	Several existing systems. Clinical decision support tools and mobile applications for prescriptive purposes	Previous real life experience with system.
Feldstein et al., 2004, USA [42]	Qualitative	Health maintenance organization	*N* = 20, *n* female = 10, *M* work experience = 9 years	Physicians (*n* = 17), physician assistants (*n* = 2), nurse (*n* = 1)	Existing system. System provides drug specific alerts and reminders. Alerts and reminders regarding overdue health maintenance procedures. Access to evidence-based guidelines.	Previous real life experience with system.
Feldstein et al., 2005, USA [43]	Qualitative	Health maintenance organization	*N* = 20	Primary care prescribers	Existing system. System provides drug specific alerts and reminders. Alerts and reminders regarding overdue health maintenance procedures. Access to evidence-based guidelines.	Hypothetical cases.
Glassman et al., 2002, USA [44]	Survey	Large VA health care system	*N* = 168, *n* female = 61, *M* age = 48.5	Physicians, nurse practitioners, physician assistants	Existing system. A comprehensive electronic medical record including provider order entry. Provides automated drug alerts.	Previous real life experience with system.
Goodspeed et al., 2019, USA [45]	Qualitative	Mental Health Center	*N* = 16	Physicians and nurse practitioners	System developed in this study. Mental health CDSS integrated in HER. Development based on these focus groups.	Wishes and preferences for the new system.
Hellden et al., 2015, Sweden [46]	Qualitative	Two primary healthcare centers	*N* = 7	General practitioners	System was developed for this study. Web-based system. GP	Previous real life experience with the system.

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Table 1 (*continued*)

Authors, year published, country	Study type	Setting	Participant info	Clinician type	CDSS	Questions about
					must press a button to receive alerts, drug lists etc.	
Henshall et al., 2017, UK [47]	Qualitative	The Oxford Health NHS Foundation Trust & general practice	$N = 23$, n female $= 14$	Consultant psychiatrists ($n = 12$), primary care general practitioners ($n = 6$), nurses ($n = 5$)	System is in development. Allows clinicians and patients to enter simple demographic and clinical variables (i.e. age, gender, severity) and discuss the relevance of the different side effects.	Their wishes for such a tool.
Hobbs et al., 1996, UK [48]	Survey	Fourteen primary care practices	Not mentioned	General practitioners	Existing, rule based system. Sends several prompts, for instance reminder to ask for medication history and to insert a cholesterol level. Advice is then given on appropriate management of the patient, based on a protocol.	Previous real life experience with the system.
Hor et al., 2010, Ireland [49]	Survey	Multiple general practitioners	$N = 98$	General practitioners	Existing systems. Whichever CDSS the GP was already using. Not one specific system is studied.	Previous real life experience with their own system.
Hum et al., 2014, USA [50]	Survey	Four academically affiliated NICUs	$N = 46$	NICU attending physicians ($n = 12$), neonatology fellows ($n = 5$), residents ($n = 18$), house physicians ($n = 2$), nurse practitioners ($n = 9$)	System developed for this study. Algorithm based. Provided antimicrobial prescribing recommendations.	General real life experience.
Jindal et al., 2018, India [51]	Qualitative	Five community health centers	$N = 10$	Nurses ($n = 5$), physicians ($n = 5$)	Developed in this study. CDSS for management of hypertension, diabetes and comorbid conditions.	Real life experience with system during 4 month pilot.
Johansson-Pajala et al., 2019, Sweden [52]	Qualitative	Two nursing homes	$N = 8$, n female $= 7$, median age $= 45$, median work experience $= 11$ years	Registered nurses ($n = 8$)	Web-based decision support system designed for use by healthcare professionals for drug prescribing and reviews. Quality reports provide information about inappropriate drugs, potential drug-drug interactions, contraindications, and possible adverse drug reactions, all in relation to each individual patient.	Real life experience with the system.
Johnson et al., 2015, UK [53]	Qualitative	Two hospital trusts in provincial city	$N = 8$	Cardiologists ($n = 4$), specialist cariology nurses ($n = 3$), cardiac psychologist ($n = 1$)	Developed in this study. Web-based computerized CDSS to support investigation and medication decisions for patients with new onset stable chest pain.	Real life experience with the system for 4 months.
Jung et al., 2013, Netherlands, Argentine, Denmark, France, Ireland, Switzerland, Bulgaria, Austria, Greece [54]	Survey	Multiple hospitals	$N = 1018$	Physicians	Existing systems. All hospitals used different systems with varying levels of decision support.	Previous real life experience with their own system.
Kappen et al., 2016, Netherlands [55]	Mixed methods (interview and survey)	University medical center	N survey $= 53$, N interviews $= 8$	Anesthesiologists, physicians	Developed for this study. A prediction model has been made for predicting PONV (postoperative nausea and vomiting). This model presented the PONV risk to the clinician.	Previous real life experience with this system.
Kazemi et al., 2009, Iran [56]	Qualitative	Teaching general hospital	$N = 19$	Specialists/sub-specialists ($n = 12$), residents ($n = 3$), interns ($n = 4$)	Prototype of the CDSS function in existing CPOE. CDSS would concern dose and interval decision support.	Prototype was shown and opinions about it immediately asked.
Lapane et al., 2008, USA [57]	Mixed methods (focus groups and survey)	64 different primary care practices	N survey $= 157$, N focus groups $= 276$	Physicians or residents ($n = 128$), physician assistants ($n = 13$), nurse practitioners ($n = 19$)	Six different existing e-prescribing systems with drug alerts.	Previous real life experience with the different systems.
Litvin et al., 2012, USA [58]	Qualitative	Nine different primary care practices	$N = 39$	Physicians ($n = 27$), nurse practitioners ($n = 6$), physician's assistants ($n = 6$)	Developed for this study. CDSS tool reflects guidelines. Recommendations based on patients' predominant presenting symptoms and the patients' age. Once diagnosis	Real life experience with the system for the past 15 months.

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Table 1 (*continued*)

Authors, year published, country	Study type	Setting	Participant info	Clinician type	CDSS	Questions about
					has been made prompts regarding appropriate antibiotic use are given.	
Martens et al., 2008, Netherlands [59]	Qualitative	53 GPs	$N = 6$	General practitioners	Developed for this study. Based on prescribing recommendations from multidisciplinary guidelines. Computerized reminders regarding prescribing behavior.	Real life experience with the system for 12 months.
Meulendijk et al., 2013, Netherlands [60]	Survey	Numerous GPs	$N = 184$	General practitioners	Proposed system, has not yet been developed. Would be integrated in CPOE, GPs would be advised on how to prescribe in patient-specific cases.	Details about proposed system presented and opinions asked.
Mulder-Wildemors et al., 2020, Netherlands [61]	Qualitative	Pharmacies	$N = 10$	Pharmacists	Web-based CDSS. Gives pop-up alerts for patients older than 70 years taking certain medications.	Real life experience with the system for 1 year.
Murphy et al., 2020, Ireland [62]	Qualitative	14 GPs	$N = 14$	General practitioners	Developed in this study. CDSS delivered tailored recommendations to the GP.	Real life experience during the pilot.
Omar et al., 2017, Sweden [63]	Qualitative	Hospital	Not mentioned	Pediatricians, resident physicians, pediatric surgeons, neonatologists	Existing system. Offers information of drugs and enables pediatricians to use prefilled drug orders and prescribe in a standardized manner.	Previous real life experience with the system.
Peiris et al., 2009, Australia [64]	Mixed methods (survey and interviews)	Eight teaching general practices and three Aboriginal Medical Services	$N = 21$, n female $= 9$	General practitioners	Developed for this study. System uses an algorithm to predict a 5-year risk of a first cardiovascular disease event.	Real life situations.
Pirnejad et al., 2011, Netherlands [65]	Qualitative	Tertiary academic hospital	$N = 12$	Nurses ($n = 4$), physicians ($n = 6$), project leaders ($n = 2$)	Two existing systems. System 1: CPOE which can generate drug alerts. System 2: Designed specifically to provide decision support and plan chemotherapy doses based on patient's biometric indexes.	Previous real life experience with the systems.
Ramanathan et al., 2016, Singapore [66]	Qualitative	Urban academic medical center	$N = 16$	Nurses ($n = 8$), general surgery residents ($n = 6$), nurse practitioners ($n = 2$)	Existing system. CDSS through EMR including alerts and order-sets.	Previous real life experience with the system.
Reynolds et al., 2019, USA [67]	Qualitative	Two health systems	$N = 20$	Nurses	Handheld decision support device in pediatric intensive care settings. Helps calculate dosage, detects unsafe doses etc.	Real life experience with system during pilot.
Rieckert et al., 2018, Germany [68]	Qualitative	Multiple GPs	$N = 21$, n female $= 14$, M age $= 53$, M work experience $= 16$ years	General practitioners	Developed for this study. GP enters data and presses medication review button. System then provides a comprehensive medication review based on current best evidence.	Previous real life experience with the system for 1 year.
Robertson et al., 2011, Australia [69]	Qualitative	Numerous GPs	$N = 27$, n female $= 15$	Experienced general practitioners ($n = 18$), trainees ($n = 9$)	Existing systems. Different systems used by different GPs.	GPs were asked to describe specific situations which they had encountered at any point.
Russ et al., 2009, USA [70]	Qualitative	Five outpatient primary care clinics	$N = 20$	Physicians, nurse practitioners, pharmacists	Existing system. Alerts appear in the Computerized Patient Record System as a pop-up window and require prescriber action to be resolved.	Interviews right after real life observations.
Santucci et al., 2016, Australia [71]	Qualitative	Teaching hospital	$N = 20$	Senior doctors ($n = 7$), junior doctors ($n = 13$)	Existing system. Computerized alerts at point of prescribing, pre-written orders and a reference material search tool.	Interviews right after real life observations.
Sedlmayr et al., 2013, Germany [72]	Survey	Tertiary care acute hospital	$N = 9$	Senior physicians ($n = 2$), specialist in internal medicine ($n = 1$), junior physicians ($n = 6$)	Developed for this study. CDSS integrated within hospital's HER. Medication safety checks and embedded drug information system.	Previous real life experience with the system.
Seidling et al., 2016, England, France, Portugal,	Qualitative	13 hospitals in 12 countries	$N = 20$	Research pharmacists and clinical pharmacists	Existing systems. Different systems in each hospital. Each	Previous real life experience with their own system.

(continued on next page)

Table 1 (*continued*)

Authors, year published, country	Study type	Setting	Participant info	Clinician type	CDSS	Questions about
Switzerland, The Netherlands, Austria, Denmark, Canada, Norway, Spain, Sweden, USA [73]					with some form of decision support integrated.	
Short et al., 2003, UK [74]	Qualitative	Nine general practices	*N* = 15, *n* female = 2, *M* age = 45, *M* work experience = 16 years	General practitioners	Developed for this study. Markov models examining the decision to (not) prescribe.	Familiarizing with the system and then opinions were asked.
Trafton et al., 2010, USA [75]	Qualitative	Local primary care clinics	*N* = 20	Psychiatrists (*n* = 3), physicians (*n* = 15), nurse (*n* = 1), nurse practitioner (*n* = 1)	Developed for this study. CDSS provides evidence based recommendations at the point of care. Based on patient health information.	Simulated usage and in-clinic usage.
Trinkley et al., 2019, USA [76]	Qualitative	Primary care within a large health system	*N* = 21	Physicians (*n* = 13), pharmacist (*n* = 4), advanced practice provider (*n* = 4)	No system yet. To provide context, CDS for chronic heart failure (HF) medications in primary care was used as a case study during the focus groups.	Perceptions regarding beneficial features of CDS.
Tsopra et al., 2014, France [77]	Survey	Various general practitioners' associations	*N* = 38	General practitioners	Developed for this study. Participants didn't use the system before. Gives advice about recommended antibiotics and treatment.	Hypothetical cases presented and opinions asked.
Wannheden et al., 2017, Sweden [78]	Qualitative	Outpatient clinic for HIV patients	*N* = 14, *n* female = 10	Physicians (*n* = 4), nurses (*n* = 10)	Prototype developed for this study. Gives active guidance to support treatment decisions, passive guidance to support monitoring decisions, alerts and an adverse drug reaction browser.	Demonstration of prototype and questions about opinions.
Weingart, Massagli et al., 2009, USA [79]	Qualitative	Hospital	*N* = 25, *n* female = 9, *M* work experience = 25 years	Physicians (*n* = 21), nurse practitioners (*n* = 3), physician assistant (*n* = 1)	Existing system. Commercial e-prescribing system with a variety of drug allergy and interaction alerts.	Previous real life experience with the system.
Weingart, Simchowitz et al., 2009, USA [80]	Mixed methods (survey and focus groups)	Ambulatory care setting	*N* survey = 184, *N* focus groups = 25, *n* female = 85, *M* work experience = 22 years	Physicians (*n* = 138), nurse practitioners (*n* = 33), physician assistants (*n* = 3), clinical nurses (*n* = 3)	Existing system. Commercial e-prescribing system. desktop and hand-held system that uses drug allergy and interaction alerts.	Previous real life experience with the system.
Wipfli et al., 2011, Switzerland [81]	Qualitative	Teaching hospital	*N* = 9	Deputy heads (*n* = 5), physicians (*n* = 2), residents (*n* = 2)	Existing systems. Several systems in several departments which give medication alerts to clinicians.	Interviews after real life observations.
Yu et al., 2011, Australia [82]	Survey	General practice and pharmacies	*N* = 329, *n* female = 144	General practitioners (*n* = 191), community pharmacists (*n* = 138)	No specific system is being assessed.	Questions about how they would like to see drug interaction alerts to be presented to them.
Zaidi et al., 2013, Australia [83]	Qualitative	Hospital	*N* = 42	Junior medical staff (*n* = 18), senior medical staff (*n* = 12), pharmacists (*n* = 12)	Existing system. General CDSS that offers clinical guidelines in a decision support format at the point of care regarding antibiotic prescribing.	Previous real life experience with the system.

facilitators = 1) and *completeness* (*n* unique barriers = 8, *n* unique facilitators = 1). Examples included redundant alerts, irrelevant alerts and information presentation. Related to System Quality, *efficiency* (*n* unique barriers = 5, *n* unique facilitators = 8), *ease of use* (*n* unique barriers = 12, *n* unique facilitators = 6), *usefulness of system features and functions* (*n* unique barriers = 5, *n* unique facilitators = 20) and *flexibility* (*n* unique barriers = 9, *n* unique facilitators = 14) were the most-often-reported evaluation measures and concerned, for example, saving time and the amount of clicks.

3.2.2. Human

Both factors regarding the Human component of HOT-fit were present in the included articles. System Use was mostly encountered in barriers (*n* total barriers = 72, *n* total facilitators = 12), while User Satisfaction was mostly visible in reported facilitators (*n* total barriers = 5, *n* total facilitators = 11). The most-often-reported evaluation measures related to system use are *expectation/belief* (*n* unique barriers = 16, *n* unique facilitators = 3), *training* (*n* unique barriers = 4, *n* unique facilitators = 2) and *reluctance/resistance* (*n* unique barriers = 8, *n* unique facilitators = 0). Examples included dependence on the system and not receiving adequate training.

3.2.3. Organization

Reported barriers and facilitators were related to both categories in the Organization component of HOT-fit: both Structure (*n* total barriers = 24, *n* total facilitators = 5), and Environment (*n* total barriers = 6, *n* total facilitators = 2) were most often encountered in barriers. Related to Structure, the evaluation measure *clinical process* (*n* unique barriers = 7, *n* unique facilitators = 3) was most often represented, concerning, for instance, the workflow of the clinician.

Table 2
Summary of the most frequently found evaluation measures.

HOT-fit dimension	Evaluation measure	Examples from included studies
Information quality	Usefulness (*n* = 40, B = 15, F = 25) [21,22,23,24,27,28,30,34,35,40,42,43,47,50,54,57,58,63,64,68,71,78,79,80,81,82,83]	*Barrier:* System shows redundant alerts (e.g. an interaction so well known that it provides little added value) [23,28,71,80] *Facilitator:* Patient-safety alerts were considered useful [22,42,43]
	Relevance (*n* = 37, B = 34, F = 3) [23,24,35,37,38,42,44,49,51,53,54,57,63,64,69,70,71,76,77,79,80,81,82]	*Barrier:* Too many irrelevant alerts (e.g. worries about alert fatigue because of the large amount of irrelevant alerts such as a lactation alert for a 60 year old patient) [23,24,28,36,38,42,44,54,69,70,71,76,79,80,82] *Facilitator:* Not all information is shown at once, user can ask for elaboration [42,43,54,75]
	Format (*n* = 31, B = 6, F = 25) [21,23,27,30,33,35,38,42,43,44,45,46,54,75,76,78,81,83]	*Facilitator:* Prioritizing information with highlights and colors [23,30,75] *Barrier:* Alerts are presented out of the visual focus region [35,43,81]
	Conciseness (*n* = 23, B = 15, F = 8) [21,24,25,27,28,30,36,42,43,45,46,51,66,69,71,75,76,77,80]	*Barrier:* System fires too many alerts [25,27,28,30,36,66,71,80] *Barrier:* Alerts are too long (i.e. too much text) [23,51,75]
	Reliability (*n* = 11, B = 8, F = 3) [23,35,37,38,64,70,77,79,80]	*Barrier:* Recommendations based on out-of-date or false information [64,79,80] *Facilitator:* System provides evidence on which alert is based [35,38,77]
	Completeness (*n* = 10, B = 9, F = 1) [23,42,44,54,69,70,77]	*Barrier:* Missing contextualization of the alerts [54]
	Evaluation measures encountered less than 10 times: Accuracy (*n* = 6, B = 6, F = 0), Legibility (*n* = 4, B = 3, F = 1), Timeliness (*n* = 2, B = 1, F = 1) Evaluation measures not encountered: Importance, Data entry methods	
System quality	Efficiency (*n* = 57, B = 30, F = 27) [22,23,25,31,35,36,38,40,42,45,46,47,49,50,52,54,56,58,62,63,64,66,67,68,69,71,72,74,75,76,77,78,80,83]	*Barrier:* System usage is time-consuming [22,23,31,35,36,38,40,42,45,54,56,62,64,66,67,68,72,75,77,78] *Facilitator:* System saves the clinician time [25,47,50,52,63,69,76,83]
	Ease of use (*n* = 41, B = 18, F = 23) [23,24,30,31,33,36,38,39,41,45,46,47,51,52,58,63,65,67,70,72,74,76,77,78]	*Facilitator:* System is easy to use and simple [31,33,36,38,41,45,46,47,63,65,67,74,77,78] *Barrier:* Too many clicks needed [39,77]
	Usefulness of system features and functions (*n* = 30, B = 5, F = 25) [31,32,40,45,46,47,50,52,62,63,65,67,76,78,80,82]	*Facilitator:* System shows patient history [32,40,47,63,80]
	Flexibility (*n* = 32, B = 14, F = 18) [23,36,38,44,45,51,57,58,64,65,76,78]	*Facilitator:* Possibility to make minor adaptions to the system tailored to personal preferences [38,58,78] *Facilitator:* Providers can set their own level of sensitivity for alerts [23,57]
	Evaluation measures encountered less than 10 times: Availability (*n* = 9, B = 9, F = 0), Data accuracy (*n* = 7, B = 4, F = 3), Database contents (*n* = 6, B = 5, F = 1), Ease of learning (*n* = 4, B = 2, F = 2), Reliability (*n* = 4, B = 1, F = 3), Response time (*n* = 8, B = 6, F = 2), Technical support (*n* = 3, B = 3, F = 0) Evaluation measures not encountered: Data currency, Security, Resource utilization, Turnaround time	
Service quality	Evaluation measures encountered less than 10 times: Follow up service (*n* = 1, B = 0, F = 1), Quick responsiveness (*n* = 2, B = 0, F = 2), Technical support (*n* = 3, B = 2, F = 1) Evaluation measures not encountered: Assurance, Empathy	
System use	Expectation/belief (*n* = 37, B = 34, F = 3) [22,23,33,35,36,37,38,40,45,47,49,53,54,55,56,63,68,69,76,78,81]	*Barrier:* Concern that clinicians become too dependent on the CDSS [33,38,47,54,78,81] *Barrier:* Concern that a CDSS reduces clinicians' decision making power [22,23,36,38,49]
	Training (*n* = 14, B = 10, F = 4) [23,24,25,33,41,42,58,69,71,72,83]	*Barrier:* Too little or no training about working with the CDSS provided [23,25,72,83]
	Reluctance/resistance (n = 14, B = 14, F = 0) [24,25,40,51,53,58,63,67,68,69]	*Barrier:* Prefer to ask a colleague for advice rather than use the system [25,63,69]
	Evaluation measures encountered less than 10 times: Acceptance (*n* = 6, B = 3, F = 3), Attitude (*n* = 3, B = 2, F = 1), Knowledge/expertise (*n* = 3, B = 3, F = 0), Motivation to use (*n* = 3, B = 3, F = 0), Recurring use (*n* = 2, B = 2, F = 0), Report acceptance (*n* = 1, B = 1, F = 0), Use by whom? (*n* = 1, B = 0, F = 1) Evaluation measures not encountered: Amount/duration, Actual vs. reported use, Nature of use, Purpose of use, Level of use, Percentage used, Voluntaries of use	
User satisfaction	Evaluation measures encountered less than 10 times: Decision making satisfaction (*n* = 5, B = 1, F = 4), Overall satisfaction (*n* = 1, B = 0, F = 1), Perceived usefulness (*n* = 8, B = 2, F = 6), Satisfaction with specific functions (*n* = 1, B = 1, F = 0), Software satisfaction (*n* = 1, B = 1, F = 0) Evaluation measures not encountered: Enjoyment	
Structure	Clinical process (*n* = 20, B = 16, F = 4) [24,33,36,38,39,42,44,52,58,61,66,76,78]	*Barrier:* System usage does not fit into workflow [36,39,42,61,66,78]
	Evaluation measures encountered less than 10 times: Autonomy (*n* = 3, B = 2, F = 1), Culture (*n* = 1, B = 1, F = 0), Leadership (*n* = 3, B = 3, F = 0), Management (*n* = 1, B = 1, F = 0), Planning (*n* = 1, B = 1, F = 0) Evaluation measures not encountered: Nature, Culture, Strategy, Communication, Top management support, Medical sponsorship, Champion, Mediator, Teamwork	
Environment	Evaluation measures encountered less than 10 times: Financing source (*n* = 2, B = 2, F = 0), Inter-organization relationships (*n* = 4, B = 2, F = 2), Politics (*n* = 2, B = 2, F = 0) Evaluation measures not encountered: Government, Localization, Competition, Population served, External communication	
Net benefits	Clinical outcomes (*n* = 21, B = 2, F = 19) [25,39,42,44,46,47,49,54,57,62,68,74,78,80]	*Facilitator:* CDSS is beneficial to patient safety [42,44,46,54,57] *Facilitator:* CDSS improves quality of care [39,49,80]
	Error reduction (*n* = 14, B = 1, F = 13) [49,54,56,65,73,79,80]	*Facilitator:* CDSS prevents prescription error [49,54,56,73,79,80]
	Communication (*n* = 12, B = 0, F = 12) [36,47,58,64,74,79]	*Facilitator:* CDSS stimulates discussion between patient and clinician [36,47,58,64,74,79]
	Clinical practice (*n* = 12, B = 0, F = 12) [25,31,40,46,47,56,65,68,77,78,79]	*Facilitator:* Clinicians no longer have to remember everything by heart [56]
	Evaluation measures encountered less than 10 times: Cost (*n* = 3, B = 3, F = 0), Decision making quality (*n* = 8, B = 0, F = 8), Effectiveness (*n* = 3, B = 1, F = 2) Evaluation measures not encountered: Efficiency	

In this table, *n* represents the total amount of barriers and facilitators encountered, B represents the total amount of barriers and F represents the total amount of facilitators.

3.2.4. Net benefits

The last HOT-fit component, Net Benefits, was also recognized repeatedly within the included papers, mainly in reported facilitators (*n* total barriers = 7, n total facilitators = 66). The most-often-encountered evaluation measures related to Net Benefits were *clinical outcomes* (*n* unique barriers = 2, *n* unique facilitators = 10), *error reduction* (*n* unique barriers = 1, *n* unique facilitators = 4), *communication* (*n* unique barriers

= 0, *n* unique facilitators = 4) and *clinical practice* (*n* unique barriers = 0, *n* unique facilitators = 10), with barriers and facilitators such as patient safety and prescription errors.

3.2.5. Outside of HOT-fit

Besides the aforementioned classification of barriers and facilitators within the HOT-fit model, the included papers also yielded some barriers and facilitators that did not fit into the HOT-fit model (*n* total barriers = 22, *n* total facilitators = 24). A total of 8 barriers and 5 facilitators were related to the context in which the CDSS was used. For instance, clinicians mentioned as a barrier that the CDSS was not useful on a specific ward such as the intensive care unit or the emergency department [83]. Furthermore, 6 facilitators were related to the system having an educational role; this was a facilitator because the system has the potential to increase clinicians' knowledge [25,33,57,77,79,83].

4. Discussion

4.1. Main findings

This systematic review aimed to identify barriers and facilitators for medication-related CDSS acceptance as indicated by clinicians. Our review revealed that the included studies mostly focused on barriers and facilitators related to the Technology component from HOT-fit, and more specifically to Information Quality and System Quality. Barriers and facilitators about *efficiency* and *ease of use* of the system, and *usefulness* and *relevance* of the information were most often reported. Systems being time consuming was the most often encountered barrier, and ease of use was the most often encountered facilitator. The other HOT-fit components, Human, Organization and Net Benefits, were encountered less often. *Context* was identified as an important new factor.

4.2. Interpretations, implications and impact

The evaluation measure *efficiency* was most often encountered in all of the barriers and facilitators. Clinicians often mentioned time constraints as an impeding factor and the system saving them time as a facilitator. While designing a CDSS, developers should keep in mind that system usage should not be time-consuming or ideally even time-saving. *Ease of use* was also a frequently occurring theme and should be closely monitored while developing new CDSSs. Clinicians often indicated that a simple, easy-to-use system facilitates usage. Complex systems with hard-to-find information inhibited usage according to clinicians.

Furthermore, *usefulness* and *relevance* of the information presented were also often mentioned. If clinicians perceived the advice as useful, this facilitated usage. On the other hand, redundant alerts, e.g. if the presented information is already well known, were indicated as a barrier. Similarly, irrelevant alerts were seen as a major barrier, for instance if an alert regarding pregnancy was shown for a male patient. In practice, this means that the content of the alerts should be critically evaluated. Only truly useful and relevant information should be presented to the clinician.

A common theme in the factors discussed above is that clinicians agree that certain factors inhibit or facilitate usage, but have different views on how to achieve this. Clinicians for instance agreed that useful information facilitates usage, but had different visions on which information is useful. Therefore, during development, clinicians from the system's target group should be involved. User-centered design could be a suitable method for this, as research has shown its ability to make CDSSs more effective and easy to use [84]. This will allow system developers to make sure that the CDSS's features overcome barriers and facilitate acceptance of the system before implementation.

Some aspects of the HOT-fit model were found less frequently in our results; specifically, User Satisfaction, Service Quality, and Environment. We defined User Satisfaction as remarks specifically about satisfaction, and not remarks from other categories implying satisfaction, thus it not surprising that this is rarely used. Likewise, it is logical that when discussing their interaction with a CDSS, clinicians may not spontaneously discuss the organization- and government-level factors related to Environment, or mention Service Quality unless asked directly about those factors. Further research is needed to determine if these factors nonetheless play an important role in CDSS acceptance.

From the barriers and facilitators that could not be categorized into HOT-fit, one clear theme arose: *context*. Clinicians indicated that a CDSS's success was dependent on the context in which it was used; some systems were only considered useful in certain specialties. *Context* is relevant for non-medication-related CDSSs as well; for example, systems that aid in the diagnosis of disease are inherently specialty-specific, as well as preventative care reminders etc. Therefore, *context* is a theme that should be taken into account when developing a CDSS. However, we also see this in studies of other health information systems. Electronic Health Record (EHR) adoption has been shown to significantly correlate with physician specialty, suggesting context is also important in these systems [85]. Therefore, adding *context* to the HOT-fit model can make it more complete and useful for future studies.

HOT-fit provides a useful lens for viewing the results of this review, but they could be interpreted in light of other models as well. The Two-Stream Model views a CDSS's interaction with a user as two decisions: deciding what advice to present and deciding how to present it [86]. In this model, barriers such as "Guidelines did not always pertain to all of the patients" (*usefulness*) [58] would be grouped under Clinical Knowledge, while "Skepticism of the accuracy of described data and information" (*data accuracy*) [45] would be seen as reflecting problems with data and/or the encoded logic of the CDSS. Other models could provide different views, and thus different insights, on the data identified by our review.

4.3. Comparison to other studies

The results of this systematic literature review are complementary to previously-conducted reviews. Kilsdonk and colleagues [87] conducted a review of factors influencing CDSSs' success, using the HOT-fit framework. Similar to our results, they found that organizational HOT-fit factors were underrepresented in the included literature. However, Kilsdonk and colleagues focused on "mid-level guideline-based CDSSs" (thus not focusing on medication and excluding "simple" CDSSs such as drug dose, allergy, interaction). Their review also differed methodologically; our review focuses on opinions of end users (clinicians), while the Kilsdonk review did not differentiate between opinions of the system users and opinions of the authors or development team.

In 2013, Roshanov and colleagues [88] performed a meta-analysis of factors reported by the authors of published randomized controlled trials and their association with the efficacy of the systems under study. The findings of this study have surprisingly little overlap with our findings. Unsurprisingly (but in contrast to Roshanov et al.), the studies in our review report integration with the workflow and at the time of decision-making as a facilitator, e.g. "Alerts during medication prescribing were generally viewed as more helpful" [43]. Likewise, although Roshanov showed a negative association with success for CDSSs integrated in the EHR, lack of integration with other systems is reported as a barrier. Roshanov reported positive findings for systems that offered advice to patients and systems that require professionals to enter a reason for overriding advice; these were not mentioned in our studies, although data entry in general is seen as a barrier. These contrasting findings illustrate that qualitative and quantitative techniques are complimentary, and offer different insights on the same problem.

Lastly, our findings are in line with the prior review by Van Dort and colleagues [12]. However, our review includes far more studies and therefore provides a more complete overview of barriers and facilitators.

4.4. Strengths and limitations

There are several methodological strengths of this systematic review. Firstly, the search strategy was made in collaboration with an expert in systematic literature searches and performed in multiple databases. Reference lists were cross-checked to ensure no papers were missed. Furthermore, every record was screened by at least two coders in title/abstract and full text inclusion. This reduces the chance of missing eligible papers. Lastly, the data extraction sheet was created and tested in an iterative process with multiple authors (LW, GB, JW, SM), ensuring reliability of the data extraction process.

The HOT-fit model was considered a useful model for categorization of the barriers and facilitators, and this systematic categorization is a strength of our review. However, the authors of the HOT-fit model provide explanations regarding its main components (e.g. Information Quality, System Use etc.), but the underlying evaluation measures are merely named and not defined. Other systematic reviews using HOT-fit have also reported this issue [87,12]. Additional clarification about how to use and interpret the evaluation measures would make categorization more reliable. Furthermore, even though the categorization was thoroughly discussed by a team of four authors (LW, GB, JW, SM), the entire list was not independently coded by a second person. Applying this approach in the future might also enhance reliability of the categorization.

Furthermore, the results of this review showed some gaps in the literature, as some of the HOT-fit dimensions were barely present in the extracted data. However, our results only show which dimensions are missing, but not why they are missing. The question remains whether these dimensions are understudied, or whether they are simply not as relevant in a CDSS context. Whether a barrier or facilitator emerges in the results of a study depends on what questions were asked, particularly in closed-question survey studies. A limitation of closed-question survey studies is that they direct respondents to select or report items. Surveys with open questions and qualitative studies allow more freedom in responses. Thus a barrier or facilitator might not be mentioned frequently because it is not important to the participants, or because they were focused on other themes. It is important to keep this limitation in mind when interpreting the results of this study. Although a list of common barriers and facilitators is valuable for the design and implementation of future systems, it is not a substitute for the involvement of users in the development process.

4.5. Future research

This study focused on medication-related CDSSs; future research could compare overlap in barriers and facilitators between this and other domains, and assess the reasons behind these differences. It can also be assessed whether some barriers or facilitators are universal for all CDSSs or if there are domain-dependent patterns. Furthermore, it could be interesting to look at how barriers and facilitators might vary per user group and per context. Splitting up the results for different groups in this way can create valuable additional insights. This could eventually lead to guidelines for developing specific kinds of CDSSs.

Overall, the findings of the current review are especially relevant for medication-related CDSS developers. More specifically, in the near future the findings will be used in the development of a medication-related CDSS for general practitioners to reduce older patients' medication-related fall risk. During the development of this system, and also of other future CDSSs, the barriers and facilitators found in this review can suggest specific features and functions that will help overcome barriers and facilitate usage.

4.6. Conclusion

In short, this review provides valuable insight into a broad range of barriers and facilitators for accepting a medication-related CDSS as perceived by clinicians. The Technological HOT-fit component predominated, and clinicians named many barriers and facilitators related to System Quality and Information Quality, for instance regarding *efficiency*, *usefulness* and *ease of use*. We also found *context* to be an important additional factor. To our knowledge, the current review is the first large systematic review of barriers and facilitators for medication-related CDSSs. The barriers and facilitators identified by this study can be used as a starting point for designing high-quality CDSSs, although they should not be considered a substitute for involvement of end-users during the development. Furthermore, future research should explore similar overviews of barriers and facilitators for usage in different CDSS domains. Eventually this will contribute to the development of more effective CDSSs and ultimately improve patient care.

Authors' contributions

LW, KP, GB, AL, JW, NV, SM contributed to the conception and design of the study. JD conducted the search strategy. LW, KP, LS, SG and KV independently screened titles and abstracts for eligibility. LW, KP, SG and KV screened full texts for inclusion. SM was consulted in case of disagreement between coders. LW prepared the original draft, KP, GB, AL, JW, JD, NV, HW, AA and SM reviewed the final manuscript.

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Summary table

What was already known on the topic

- Medication-related Clinical Decision Support Systems (CDSS) offering advice to clinicians can prevent medication errors and thereby improve patient safety and healthcare quality.
- Even though evidence of its effectiveness exists, a high percentage of CDSS systems are not used, and alerts are overridden or ignored by clinicians.
- Individual studies have investigated clinicians' reasons for accepting or not accepting medication-related CDSSs, but no attempt has been made to systematically summarize the evidence base of reported barriers and facilitators of medication-related CDSS acceptance.

What this study added to our knowledge

- This review provides a valuable, systematic insight into a broad range of barriers and facilitators for medication-related CDSS acceptance as perceived by clinicians.
- Data categorization provides a clear overview of frequently found themes and gaps in the literature.
- The common barriers and facilitators identified by this study can be used as a starting point for the design of high-quality CDSSs, although they should not be considered a substitute for involvement of end-users, preferably from the start of the design process.

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Declaration of Competing Interest

The authors report no declarations of interest.

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Appendix A. Supplementary data

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