Links between usability flaws, usage problems and negative outcomes in the work system

	Usability flaw			Usage problem			Negative outcome	
	Excerpt	Category	Sub-cat.	Excerpt	Category	Sub-cat.	Excerpt	Category
[22] [29]	"Alert does not provide clear information on relative risk of harm for a given patient" "Although some alerts are categorized by risk, (e.g., some are marked as "significant" and others are "critical"), this notation was not always sufficient for prescribers" ; "Risk rating/degree of risk: Prescribers wanted a more clear indication of risk and suggested that alerts display a quantitative rating" [Inferred: there is no clear risk information in the alert]	Compatibility	Alert content issues	"If there's more than one [alert in a popup window], I don't read through them all, honestly"	Behavioral	Voluntarily ignoring alerts	"Ordering decisions were hampered"; "alerts (…) impeded medication ordering processes.";	Medication management process issues
[22] [29]	"Alert does not provide clear information on relative risk of harm for a given patient" "Although some alerts are categorized by risk, (e.g., some are marked as "significant" and others are "critical"), this notation was not always sufficient for prescribers" ; "Risk rating/degree of risk: Prescribers wanted a more clear indication of risk and suggested that alerts display a quantitative rating" [Inferred: there is no clear risk information in the alert]	Compatibility	Alert content issues	"It's gotten to the point that I don't hardly look at significant (interactions) anymore"	Behavioral	Voluntarily ignoring alerts	"Ordering decisions were hampered"; "alerts (…) impeded medication ordering processes.";	Medication management process issues
[22] [29]	"Alert is not evidence-based, does not provide a reference to evidence that does exist, and/or the actual or perceived level of evidence is low." "The alerts themselves do not present the evidence nor do they provide links to any supporting documentation" "Quality/strength of alert evidence; guidance on actions to take: Prescribers wanted alert to provide: references or links to evidence (...) some alerts were not evidence-based" ."The actual or perceived level of evidence is low"; "unclear if the warnings were "evidence-based"", "extend of evidence is fair, stemming mainly from a few case reports"	Compatibility	Alert content issues	"This lack of information led to prescriber cynicism."	Emotional	Cynicism		
[27]	"erroneous system messaging [about how to solve the problem]"	Compatibility	Alert content issues	"Resorted to trial-and-error behavior exemplified by the extra mouse clicks and keystrokes they needed for locating and executing the right action in response to the message"	Behavioral	Increased workload	"Impaired the ordering efficiency"	Medication management process issues
[27]	"erroneous system messaging [about how to solve the problem]"	Compatibility	Alert content issues	"Physicians were lost »	Behavioral	Users lost	"Impaired the ordering efficiency"	Medication management process issues
[27]	"erroneous system messaging [about how to solve the problem]"	Compatibility	Alert content issues	"Precluding the physicians to understand the problem that generated the alert or how to solve the problem."	Cognitive	Difficulties to understand the alert	"Impaired the ordering efficiency"	Medication management process issues
[29]	"The alert did not provide essential patient information for the prescriber, even though it existed elsewhere in the EHR. For example, decision-making for some drug interaction alerts (e.g, amiloride and lisinopril, which can cause hyperkalemia) depend on patient labs (e.g., potassium). This missing, or more accurately, 'hidden' patient data triggered varying responses."	Compatibility	Alert content issues	"Spent time searching for information in the EHR afterwards to validate their decision."	Behavioral	Increased workload		

	Usability flaw			Usage problem			Negative outcome	
	Excerpt	Category	Sub-cat.	Excerpt	Category	Sub-cat.	Excerpt	Category
[29]	"The alert did not provide essential patient information for the prescriber, even though it existed elsewhere in the EHR. For example, decision-making for some drug interaction alerts (e.g., amiloride and lisinopril, which can cause hyperkalemia) depend on patient labs (e.g., potassium). This missing, or more accurately, 'hidden' patient data triggered varying responses."	Compatibility	Alert content issues	"Others overrode the alert"	Behavioral	Voluntarily ignoring alerts		
[29]	"The alert did not provide essential patient information for the prescriber, even though it existed elsewhere in the EHR. For example, decision-making for some drug interaction alerts (e.g., amiloride and lisinopril, which can cause hyperkalemia) depend on patient labs (e.g., potassium). This missing, or more accurately, 'hidden' patient data triggered varying responses."	Compatibility	Alert content issues	"Made assumptions about the patient history"; "Some prescribers relied solely on their memory of the patient profile"	Cognitive	Increased memory load		
[36]	"Another in-clinic user stated that the system would be more helpful if it gave more detailed information on "how to switch or discontinue drugs.""	Compatibility	Alert content issues	"The system would be more helpful" [currently not sufficiently helpful]	Attitudinal	Questioning usefulness		
[37]	"There were cases in which clinicians reached a dead end within the CR system, with no reasonable option to proceed." "We observed instances in which none of the available options to satisfy the CR applied to the patient or situation."	Compatibility	Alert content issues	"The existence of dead-end scenarios is a barrier to the effective use of the reminders since it impedes the ability to satisfy them"	Behavioral	Ineffective use		
[37]	"There were cases in which clinicians reached a dead end within the CR system, with no reasonable option to proceed." "We observed instances in which none of the available options to satisfy the CR applied to the patient or situation."	Compatibility	Alert content issues	"Additionally, we observed one nurse and one provider become "stuck" trying to satisfy a CR because the appropriate option was not available to them."	Behavioral	Users lost		
[37]	"Options within the dialogue box of the CRs do not always match the patient's response or there is not an appropriate option for indicating why the provider has decided not to order a test, for example."	Compatibility	Alert features issues	"finally, two providers reported using workarounds to satisfy reminders because of the inflexibility of the dialogue options". "Provider arbitrarily selected a date to satisfy the reminder"; "The provider had to leave the reminder unsatisfied."	Behavioral	Workarounds		
[29]	"Alerts cannot be pulled up later, as needed, hindering alert resolution"; "Sometimes, prescribers wanted a way to retrieve an alert that had been displayed, but the alert system did not support this function."	Compatibility	Alert features issues	"Prescribers sometimes forgot what alert(s) appeared"	Cognitive	Information involuntarily missed	"Hindering alert resolution"; "Hinder alert effectiveness"	Technology effectiveness issues
[37]	"The use of CRs automatically generates text that is added to the progress note, but that text is not integrated with the template information and is generally added to the bottom of the note."	Compatibility	Alert features issues	"This integration of the clinical topic addressed by the reminder into the template aligns it more directly into the nurse's workflow, thus facilitating its effective use." [currently not effective use]	Behavioral	Ineffective use		

	Usability flaw			Usage problem			Negative outcome	
	Excerpt	Category	Sub-cat.	Excerpt	Category	Sub-cat.	Excerpt	Category
[10]	"CPOE provides feedback on drug allergies, but only after medications are ordered."	Compatibility	Alert presentation issues	"Some house staff ignored allergy notices (…) and, most important, post hoc timing of allergy information."	Behavioral	Voluntarily ignoring alerts	"House staff claimed post hoc alerts unintentionally encourage house staff to rely on pharmacists for drug allergy checks, implicitly shifting responsibility to pharmacists."	Workflow issues
[24]	"They said that pop-up alerts particularly were annoying or unhelpful if they popped up "too early" in the encounter, or on the wrong screen."	Compatibility	Alert presentation issues	"They said that pop-up alerts particularly were (…) unhelpful"; ""The alerts were most likely to be helpful if they presented when the users were entering orders or were otherwise at the point of making a decision about the issue in question or closely related issues."	Attitudinal	Questioning usefulness		
[24]	"Some acknowledged they were unlikely to respond, or perhaps even be aware of alerts, unless they were intrusive." [Inference: alerts not sufficiently intrusive in this case]	Compatibility	Alert presentation issues	"Some acknowledged they were unlikely to respond, or perhaps even be aware of alerts, unless they were intrusive." [missing an alert]	Cognitive	Information involuntarily missed		
[24]	"They said that pop-up alerts particularly were annoying or unhelpful if they popped up "too early" in the encounter, or on the wrong screen."	Compatibility	Alert presentation issues	"Partly because of the disruption of the thought process"	Cognitive	Users interrupted		
[24]	"However, even some of these users acknowledged that "pop-up" alerts can be very annoying, …"	Compatibility	Alert presentation issues	""Pop-up" alerts can be very annoying"; ""Well, I think anything that keeps recurring to me is [annoying]""	Emotional	Annoyance		
[24]	"They said that pop-up alerts particularly were annoying or unhelpful if they popped up "too early" in the encounter, or on the wrong screen."	Compatibility	Alert presentation issues	""Pop-up" alerts can be very annoying"; ""Well, I think anything that keeps recurring to me is [annoying]""	Emotional	Annoyance		
[25]	"The institutional guideline for heparin administration (…) triggered later in the process when the planing stage of the order is generally completed"	Compatibility	Alert presentation issues	"Six subjects computed, estimated or used a heuristic to get the dose amount at some point before the system-calculated dose presentation"	Behavioral	Workarounds	"Consequently they did not derive all the speed and accuracy benefit and did not reduce their cognitive effort the feature was in part designed to."	Technology effectiveness issues
[28]	"Intrusive alerts presented at the wrong time in the workflow"	Compatibility	Alert presentation issues	"Several prescribers described rapidly overriding these alert types once they recognized that they had seen the alert before. One prescriber noted that she had "memorized the location of the override button" for these situations."	Behavioral	Voluntarily ignoring alerts		
[28]	"Intrusive alerts presented at the wrong time in the workflow"	Compatibility	Alert presentation issues	"These alerts that caused frustrations"	Emotional	Frustration		
[29]	"Technology lags/down- times" "Even 10-15 second computer delays between the order and subsequent alert"	Compatibility	Alert presentation issues	"There were several cases where inadequate alert design (…) disrupted their workflow."	Cognitive	Users interrupted	"Hindering alert resolution"; "Hinder alert effectiveness"	Technology effectiveness issues
[29]	"Technology lags/down- times" "Even 10-15 second computer delays between the order and subsequent alert"	Compatibility	Alert presentation issues	"View as "very troublesome""	Emotional	Annoyance		
[29]	"Technology lags/down- times" "Even 10-15 second computer delays between the order and subsequent alert"	Compatibility	Alert presentation issues	"Place prescribers under pressure"	Emotional	Stress		

Ref	Usability flaw			Usage problem			Negative outcome	
	Excerpt	Category	Sub-cat.	Excerpt	Category	Sub-cat.	Excerpt	Category
[35]	"Too many alerts or alerts at an inappropriate time: "Now we get alerts when we go to charting, which in my workflow is the last step. It's after the patient's gone. Now I get warned they've got some drug interaction. Great!""	Compatibility	Alert presentation issues	"There were numerous complaints about getting too many alerts or alerts at an inappropriate time"	Attitudinal	Negative feelings		
[35]	"Too many alerts or alerts at an inappropriate time: "Now we get alerts when we go to charting, which in my workflow is the last step. It's after the patient's gone. Now I get warned they've got some drug interaction. Great!""	Compatibility	Alert presentation issues	"Or alerts at an inappropriate time" [too late, once the patient is out, the information is missed]	Cognitive	Information involuntarily missed		
[37]	"The CRs appear on this cover sheet but are delayed in loading and displaying (Site 3 reported an average delay of 8 seconds for the CRs to load)."	Compatibility	Alert presentation issues	"We observed providers and nurses use strategies such as clicking on the progress notes tab before the reminders have displayed (…) or report setting a default tab to bypass the cover sheet, thereby lessening the visibility of the reminders"	Behavioral	Workarounds		
[32]	""You do not get the warning again, and there is no button to get it [the second alert] back""	Compatibility	Alerts features issues	"You do not get the warning again" [missed information]	Cognitive	Information involuntarily missed		
[28]	"Prescribers reported that alerts presenting during medication order entry were often (…) difficult to interpret in content and purpose"	Workload	Concision	"Several prescribers described rapidly overriding these alert types once they recognized that they had seen the alert before. One prescriber noted that she had "memorized the location of the override button" for these situations."	Behavioral	Voluntarily ignoring alerts		
[28]	"Prescribers reported that alerts presenting during medication order entry were often (…) difficult to interpret in content and purpose"	Workload	Concision	"Difficult to interpret in content and purpose"; "Some reported difficulty with (…) the length of the text."	Cognitive	Difficulties to understand the alert	"Slowed down their work"	Medication management process issues
[34]	"Pregnancy alerts would be more useful if they showed the category of alert (A, B, C, etc.) rather than narrative information…"	Workload	Concision	""There are too many things popping up at me"; "(alert fatigue)"	Attitudinal	Alert fatigue		
[34]	"Pregnancy alerts would be more useful if they showed the category of alert (A, B, C, etc.) rather than narrative information…"	Workload	Concision	"It's just crying wolf", "Difficult to interpret the validity of many alerts"	Attitudinal	Questioning the validity		
[34]	"Pregnancy alerts would be more useful if they showed the category of alert (A, B, C, etc.) rather than narrative information…"	Workload	Concision	"Many clinicians ignore potentially serious alerts"; "Once you realize that most of the information is useless or superfluous or not relevant, you stop looking at it."	Behavioral	Voluntarily ignoring alerts		
[34]	"Pregnancy alerts would be more useful if they showed the category of alert (A, B, C, etc.) rather than narrative information…"	Workload	Concision	"Trivial alerts often interrupt workflow."	Cognitive	Users interrupted		
[40]	"Every doctor reported that the alerts contained too much text and should be shortened."	Workload	Concision	"If you spend time to read it"	Behavioral	Increased workload		
[40]	"Every doctor reported that the alerts contained too much text and should be shortened."	Workload	Concision	""It pops up so often which can be a very bad thing because you're dismissing it so often that you develop this sort of mechanism""; Most doctors either admitted to not reading the warnings"; "it's so much easier to click that button"	Behavioral	Voluntarily ignoring alerts		

	Usability flaw			Usage problem			Negative outcome	
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[37]	"However, there was no means to cancel the CR without losing the data already inputted for the previous CRs." [inference: the system does not act as the user asks]	Explicit control	Explicit user actions	[inference: user cannot perform the action as he intends to]	Behavioral	Users lost	"Introduces the possibility of losing data previously inputted."	Technology effectiveness issues
[37]	"However, there was no means to cancel the CR without losing the data already inputted for the previous CRs." [inference: the system does not act as the user asks]	Explicit control	Explicit user actions	"A workaround is to select each CR individually from the list rather than using the Next button to navigate through a sequence of CRs."	Behavioral	Workarounds		
[29]	"Interface, which did not adequately support all prescriber types."	Adaptability	Flexibility	"Prescribers unaware that they could turn off some alerts", "Prescribers' ability to act on alerts was impeded by the alert interface"	Behavioral	Ineffective use	"We call the pharmacist and spend time looking up information.";" physicians often come and ask [the pharmacists] about an alert triggered by the combination of amiodarone and simvastatin"; "physicians and nurse practitioners found it helpful, and sometimes necessary, to have real-time, face-to-face communication with clinical pharmacists to be able to interpret and resolve alerts"	Workflow issues
[29]	"Interface, which did not adequately support all prescriber types."	Adaptability	Flexibility	"Prescribers were sometimes unsure (…) what an alert was attempting to convey"; "Language of alerts is difficult for prescriber to interpret "I do not know what that means.""	Cognitive	Difficulties to understand the alert	"We call the pharmacist and spend time looking up information.";" physicians often come and ask [the pharmacists] about an alert triggered by the combination of amiodarone and simvastatin"; "physicians and nurse practitioners found it helpful, and sometimes necessary, to have real-time, face-to-face communication with clinical pharmacists to be able to interpret and resolve alerts"	Workflow issues
[22] [29]	"Overuse of Pop-ups, other, non-medication related pop-ups contribute to prescriber alert desensitization" "- Overuse of other, non-alert pop-up windows may contribute to desensitization"	Guidance	Grouping/d istinction	"Prescriber desensitization", "Even prescribers with a very positive view of the alert system showed signs of desensitization"	Attitudinal	Alert fatigue		
[28]	"Cost and health maintenance alerts that were intrusive to the workflow"	Guidance	Grouping/d istinction	"Viewed as (…) most annoying"	Emotional	Annoyance		
[29]	"Difficult to distinguish different alert types (e.g., duplicate drug versus duplicate drug class alerts)"	Guidance	Grouping/d istinction	"Difficult to distinguish different alert types (e.g., duplicate drug versus duplicate drug class alerts)"	Cognitive	Difficulties to understand the alert		
[32]	"I did not look through the new screen, and then I hit the button and suddenly it was gone"	Guidance	Immediate feedback	« The physician may overlook the second alert, thinking that the override button for the (first) alert has not worked properly"; "thereby unintentionally override the second alert."	Cognitive	Information involuntarily missed	"wrong selection (followed incorrect dose recommendation)"	Patient safety issues

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[22] [26] [29]	"Multiple alerts were grouped together in one pop-up window." "Prescriber confusion when multiple alerts were presented [in the same screen]" "Multiple alerts presented in one pop-up" ""There are times when there are multiple flags [order checks] in the same box [pop-up alerts]""	Workload	Information density	"If there's more than one [alert in a popup window], I don't read through them all, honestly"	Behavioral	Voluntarily ignoring alerts	"Hindering alert resolution"; "Hinder alert effectiveness"	Technology effectiveness issues
[22] [26] [29]	"Multiple alerts were grouped together in one pop-up window." "Prescriber confusion when multiple alerts were presented [in the same screen]" "Multiple alerts presented in one pop-up" ""There are times when there are multiple flags [order checks] in the same box [pop-up alerts]""	Workload	Information density	"It's gotten to the point that I don't hardly look at significant (interactions) anymore"	Behavioral	Voluntarily ignoring alerts	"Hindering alert resolution"; "Hinder alert effectiveness"	Technology effectiveness issues
[22] [26] [29]	"Multiple alerts were grouped together in one pop-up window." "Prescriber confusion when multiple alerts were presented [in the same screen]" "Multiple alerts presented in one pop-up" ""There are times when there are multiple flags [order checks] in the same box [pop-up alerts]""	Workload	Information density	"Prescribers were sometimes unsure (…) what an alert was attempting to convey"; "Language of alerts is difficult for prescriber to interpret "I do not know what that means."	Cognitive	Difficulties to understand the alert	"Hindering alert resolution"; "Hinder alert effectiveness"	Technology effectiveness issues
[22] [26] [29]	"Multiple alerts were grouped together in one pop-up window." "Prescriber confusion when multiple alerts were presented [in the same screen]" "Multiple alerts presented in one pop-up" ""There are times when there are multiple flags [order checks] in the same box [pop-up alerts]""	Workload	Information density	"Prescribers were sometimes unsure (…) what an alert was attempting to convey"; "Language of alerts is difficult for prescriber to interpret "I do not know what that means."	Cognitive	Difficulties to understand the alert	"We call the pharmacist and spend time looking up information."; "physicians often come and ask [the pharmacists] about an alert triggered by the combination of amiodarone and simvastatin"; "physicians and nurse practitioners found it helpful, and sometimes necessary, to have real-time, face-to-face communication with clinical pharmacists to be able to interpret and resolve alerts"	Workflow issues
[22] [26] [29]	"Multiple alerts were grouped together in one pop-up window." "Prescriber confusion when multiple alerts were presented [in the same screen]" "Multiple alerts presented in one pop-up" ""There are times when there are multiple flags [order checks] in the same box [pop-up alerts]""	Workload	Information density	"Many prescribers overwhelmed by (…) multiple alerts presented in one pop-up"	Emotional	Annoyance		
[22] [26] [29]	"Multiple alerts were grouped together in one pop-up window." "Prescriber confusion when multiple alerts were presented [in the same screen]" "Multiple alerts presented in one pop-up" ""There are times when there are multiple flags [order checks] in the same box [pop-up alerts]""	Workload	Information density	"Reading them is ugly"	Emotional	Ugly experience		
[25]	"The institutional guideline for heparin administration, however was embedded in the same alert containing the calculated dose, triggered later in the process when the planning stage of the order is generally completed"	Workload	Information density	""Two subjects did not use the decision support feature because they misidentified the alert as a general guideline reminder and did not notice the dose calculations embedded in text."	Behavioral	System not used at all		
[25]	"The institutional guideline for heparin administration, however was embedded in the same alert containing the calculated dose, triggered later in the process when the planning stage of the order is generally completed"	Workload	Information density	"They misidentified the alert as a general guideline reminder and did not notice the dose calculations embedded in text."	Cognitive	Difficulties to identify alerts' components		

	Usability flaw			Usage problem			Negative outcome	
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[29]	"Extraneous information decreases alert value: Prescribers wanted a brief description of the problem: e.g. "it needs to be 10 words or less"" [Inference: the problem description is too long]	Workload	Information density	"Sometimes, when alerts contain a lot of text, prescribers rely instead on their "own clinical judgment"	Behavioral	System not used at all	"Hindering alert resolution"; "Hinder alert effectiveness"	Technology effectiveness issues
[33]	"Visualization of drug-drug interaction alerts where one drug has interactions with several others" [Inference: too much information in the alert]	Workload	Information density	"They already find it difficult to understand visualization"	Cognitive	Difficulties to understand the alert		
[36]	""It is hard to use the tool when sitting with a patient because it is in paragraph form. It would be better if factoids or outlines and standardized approaches are numbered or outlined and in lists.""	Workload	Information density	"It is hard to use the tool when sitting with a patient"	Attitudinal	Negative feelings		
[36]	""The page is too convoluted. When there are 10 different things on the screen, providers aren't going to read any of it.""	Workload	Information density	"Providers aren't going to read any of it."	Behavioral	Voluntarily ignoring alerts		
[22] [29]	"According to participants, alert displays were problematic since much of the alert text was in all capital letters" "Stylistic interface features support or hinder alert effectiveness: all capital letters …"	Guidance	Legibility	[inference: hard to read the text]	Cognitive	Difficulties to understand the alert	"Hindering alert resolution"; "Hinder alert effectiveness"	Technology effectiveness issues
[22] [29]	"According to participants, alert displays were problematic since much of the alert text was in all capital letters" "Stylistic interface features support or hinder alert effectiveness: all capital letters …"	Guidance	Legibility	"Reading them is ugly"	Emotional	Ugly experience		
[29]	"Lack of spacing between alert text"	Guidance	Legibility	[inference: hard to read the text]	Cognitive	Difficulties to understand the alert	"Hindering alert resolution"; "Hinder alert effectiveness"	Technology effectiveness issues
[22]	"Low alert signal to noise ratio: numerousness of alerts"	Compatibility	Low signal-to-noise ratio	"Prescriber desensitization"; "Even prescribers with a very positive view of the alert system showed signs of desensitization"	Attitudinal	Alert fatigue		
[22]	"Some medication alerts may not be supported by pharmacy data. One pharmacist stated, "Sometimes, a doctor will call me about an interaction. I check in Micromedex®. [Micromedex® is a well-respected medication interaction database] Sometimes, there is no interaction shown in Micromedex® [for that alert]. I tell the doctor, 'I don't know. There is no information on it in the [Micromedex®] database.'"	Compatibility	Low signal-to-noise ratio	"Some prescribers were skeptical of alerts because it was unclear if the warnings were "evidence-based"; also, prescribers sometimes questioned the quality and strength of evidence."	Attitudinal	Questioning the validity		
[22] [29]	"Alert conflicts with VAMC practices that are in place and/or standard medication practices." "Alert conflicts with common medication practices"	Compatibility	Low signal-to-noise ratio	"Influence prescribers' perceptions of the credibility and trustworthiness of the alert system as a whole"	Attitudinal	Questioning the validity		
[22] [29]	"Repeated alerts within the same encounter or over multiple encounters for a given patient"; "alerts were sometimes excessively redundant. (...) The observer noted: we have now seen the same alert 4 times in the last 10 min or less." "Redundant alerts within a given patient encounter. Often triggered by renewing interacting medication pairs. E.g., Same alert appears a 3rd time"	Compatibility	Low signal-to-noise ratio	"If there's more than one [alert in a popup window], I don't read through them all, honestly"	Behavioral	Voluntarily ignoring alerts	"Ordering decisions were hampered"; "alerts (…) impeded medication ordering processes.";	Medication management process issues

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[22] [29]	"Repeated alerts within the same encounter or over multiple encounters for a given patient", "alerts were sometimes excessively redundant. (...) The observer noted: we have now seen the same alert 4 times in the last 10 min or less." "Redundant alerts within a given patient encounter. Often triggered by renewing interacting medication pairs. E.g., Same alert appears a 3rd time"	Compatibility	Low signal-to-noise ratio	"It's gotten to the point that I don't hardly look at significant (interactions) anymore"	Behavioral	Voluntarily ignoring alerts	"Ordering decisions were hampered"; "alerts (...) impeded medication ordering processes.";	Medication management process issues
[22] [29]	"Repeated alerts within the same encounter or over multiple encounters for a given patient", "alerts were sometimes excessively redundant. (...) The observer noted: we have now seen the same alert 4 times in the last 10 min or less." "Redundant alerts within a given patient encounter. Often triggered by renewing interacting medication pairs. E.g., Same alert appears a 3rd time"	Compatibility	Low signal-to-noise ratio	"NP gestures to the screen, "See – three times!""	Emotional	Annoyance		
[22] [29]	"Repeated alerts within the same encounter or over multiple encounters for a given patient", "alerts were sometimes excessively redundant. (...) The observer noted: we have now seen the same alert 4 times in the last 10 min or less." "Redundant alerts within a given patient encounter. Often triggered by renewing interacting medication pairs. E.g., Same alert appears a 3rd time"	Compatibility	Low signal-to-noise ratio	"A nurse practitioner voiced her frustration"	Emotional	Frustration		
[24]	"Repetitive alerts are both annoying and unnecessary."	Compatibility	Low signal-to-noise ratio	"Users complained vociferously »	Attitudinal	Negative feelings		
[24]	"Repetitive alerts are both annoying and unnecessary."	Compatibility	Low signal-to-noise ratio	""Pop-up" alerts can be very annoying"; ""Well, I think anything that keeps recurring to me is [annoying].""	Emotional	Annoyance		
[24]	"However, even some of these users acknowledged that "pop-up" alerts can be very annoying, especially when they are "not right" for some reason."	Compatibility	Low signal-to-noise ratio	""Pop-up" alerts can be very annoying"; ""Well, I think anything that keeps recurring to me is [annoying].""	Emotional	Annoyance		
[26]	"VA's alert system did not match his/her (pharmacist) mental model of how an alert system should be designed (...) sometimes significant order checks really aren't significant (...) Now critical interactions (...) they are so many that are significant."	Compatibility	Low signal-to-noise ratio	"Sometimes significant order checks really aren't significant [interactions] (...) they are so many that are significant"	Attitudinal	Questioning triggering/sorting model		
[26]	"VA's alert system did not match his/her (pharmacist) mental model of how an alert system should be designed (...) sometimes significant order checks really aren't significant (...) Now critical interactions (...) they are so many that are significant."	Compatibility	Low signal-to-noise ratio	"It's gotten to the point that I don't hardly look at significant (interactions) anymore"	Behavioral	Voluntarily ignoring alerts	"Ordering decisions were hampered"; "alerts (...) impeded medication ordering processes.";	Medication management process issues
[26] [29]	"I see it does say "active" though. Technically, the [old] medication [order] isn't "active" because I just changed them to "discontinued"" "Some meds should have been discontinued but were 'active', leading to extra alerts"	Compatibility	Low signal-to-noise ratio	""Did it accept my changes?"" [doubts]	Attitudinal	Questioning the behavior		
[26] [29]	"I see it does say "active" though. Technically, the [old] medication [order] isn't "active" because I just changed them to "discontinued"" "Some meds should have been discontinued but were 'active', leading to extra alerts"	Compatibility	Low signal-to-noise ratio	"This order check [appearing now for a second time] might freak someone out"	Emotional	Annoyance		

	Usability flaw			Usage problem			Negative outcome	
	Excerpt	Category	Sub-cat.	Excerpt	Category	Sub-cat.	Excerpt	Category
[28]	"Alerts (…) repeatedly encountered"	Compatibility	Low signal-to-noise ratio	"Several prescribers described rapidly overriding these alert types once they recognized that they had seen the alert before. One prescriber noted that she had "memorized the location of the override button" for these situations."	Behavioral	Voluntarily ignoring alerts		
[29]	"Same alerts appear for a patient across one or more med renewals; E.g., Alert says 'Previous adverse reaction to antidepressants.'…Phys types in override reason, 'Has been on venlafaxine for 5 yrs now.'"	Compatibility	Low signal-to-noise ratio	"Phys types in override reason, 'Has been on venlafaxine for 5 yrs now.'"	Behavioral	Voluntarily ignoring alerts		
[29]	"Number of alerts is problematic"; "Potential problems are overdetected or underdetected"	Compatibility	Low signal-to-noise ratio	"Many prescribers overwhelmed by (…) multiple alerts presented in one pop-up"	Emotional	Annoyance		
[31]	"When the physician used CPOE in the office area, a medication alert appeared saying 'duplicate order', which indicated that the patient was getting iron from both VA and non-VA sources (i.e. over-the-counter or non-VA pharmacy). Upon seeing this alert, the physician stated, "That's not true to my knowledge. The patient doesn't like to take it; I doubt he's taking it [from a non-VA source]."	Compatibility	Low signal-to-noise ratio	"That's not true to my knowledge. The patient doesn't like to take it; I doubt he's taking it [from a non-VA source]."	Attitudinal	Questioning the validity		
[31]	"When the physician used CPOE in the office area, a medication alert appeared saying 'duplicate order', which indicated that the patient was getting iron from both VA and non-VA sources (i.e. over-the-counter or non-VA pharmacy). Upon seeing this alert, the physician stated, "That's not true to my knowledge. The patient doesn't like to take it; I doubt he's taking it [from a non-VA source]."	Compatibility	Low signal-to-noise ratio	"The physician proceeded with the order and went back to the exam room to talk with the patient, where s/he confirmed that the patient was not obtaining iron from an outside source."	Behavioral	Increased workload	"The physician (…) talk[s] with the patient, where s/he confirmed that the patient was not obtaining iron from an outside source."	Workflow issues
[32]	"too low dose limits"	Compatibility	Low signal-to-noise ratio	"Could further add to alert fatigue"; "Remarks suggesting alert fatigue"	Attitudinal	Alert fatigue		
[32]	Furthermore, residents referred to other aspects that could further add to alert fatigue: (…) DDIs that should be suppressed because of low incidence of adverse events"	Compatibility	Low signal-to-noise ratio	"Could further add to alert fatigue"; "Remarks suggesting alert fatigue"	Attitudinal	Alert fatigue		
[32]	Furthermore, residents referred to other aspects that could further add to alert fatigue: (…) DDIs that should be suppressed because of low incidence of adverse events"	Compatibility	Low signal-to-noise ratio	"If I have to consider every DDI, than I am busy with it, all day, and that is not my job."	Behavioral	Increased workload		
[32]	Furthermore, residents referred to other aspects that could further add to alert fatigue: (…) DDIs that should be suppressed because of low incidence of adverse events"	Compatibility	Low signal-to-noise ratio	"I am often inclined to rapidly click them away; you get all those DDIs reported; you simply skip them."	Behavioral	Voluntarily ignoring alerts		
[32]	"There are so many drug–drug interactions that are irrelevant, that I am often inclined to rapidly click them away [resident in internal medicine].	Compatibility	Low signal-to-noise ratio	"I am often inclined to rapidly click them away; you get all those DDIs reported; you simply skip them."	Behavioral	Voluntarily ignoring alerts		
[32]	Furthermore, residents referred to other aspects that could further add to alert fatigue: (…) DDIs that should be suppressed because of low incidence of adverse events"	Compatibility	Low signal-to-noise ratio	"All those drug–drug interactions and all those things you get reported drive you mad."	Emotional	Annoyance		

	Usability flaw			Usage problem			Negative outcome	
	Excerpt	Category	Sub-cat.	Excerpt	Category	Sub-cat.	Excerpt	Category
[33]	"Reminder alerts that should be given the last day of hospitalization (*i.e.*, bacteriological tests), a day the system cannot forecast. This leads to an alert every day."	Compatibility	Low signal-to-noise ratio	"This leads to an alert everyday and therefore to (…) alert fatigue."	Attitudinal	Alert fatigue		
[33]	"Alerts once entered in the system can be outdated. The processes how to keep them up-to-date is not yet implemented (*i.e.* for patients who were carrier of methicillin-resistant staphylococcus aureus (MRSA) and who are now readmitted to the hospital)."	Compatibility	Low signal-to-noise ratio	"Some brought up issues make the CPOE less utile"	Attitudinal	Questioning usefulness		
[33]	"Reminder alerts that should be given the last day of hospitalization (*i.e.*, bacteriological tests), a day the system cannot forecast. This leads to an alert every day."	Compatibility	Low signal-to-noise ratio	[inference: alerts voluntarily ignored]	Behavioral	Voluntarily ignoring the alert	"low compliance rate"	Lowering alerting system expected effectiveness
[34]	"According to clinicians, the sensitivity of alerts was often set too high while the specificity was too low."	Compatibility	Low signal-to-noise ratio	"There are too many things popping up at me"; "(alert fatigue)"	Attitudinal	Alert fatigue		
[34]	"Alerts are often fired for drug combinations that conform to clinical guidelines and are recommended by specialist colleagues. Examples include aspirin with angiotensin converting enzyme inhibitors in patients with heart disease or diabetes."	Compatibility	Low signal-to-noise ratio	"There are too many things popping up at me"; "(alert fatigue)"	Attitudinal	Alert fatigue		
[34]	"Appropriate polypharmacy is not acknowledged" "In psychiatric care, mood stabilizers are often used intentionally in combination or "augmentation" therapy with antidepressants."	Compatibility	Low signal-to-noise ratio	"There are too many things popping up at me"; "(alert fatigue)"	Attitudinal	Alert fatigue		
[34]	"Pregnancy alerts would be more useful (…) if they were suppressed for male patients and women of non-child-bearing age."	Compatibility	Low signal-to-noise ratio	"There are too many things popping up at me"; "(alert fatigue)"	Attitudinal	Alert fatigue		
[34]	"Within-class interactions typically reflect an out-of-date medication list – such as an antibiotic interacting with another antibiotic – rather than a true interaction."	Compatibility	Low signal-to-noise ratio	"There are too many things popping up at me"; "(alert fatigue)"	Attitudinal	Alert fatigue		
[34]	"According to clinicians, the sensitivity of alerts was often set too high while the specificity was too low."	Compatibility	Low signal-to-noise ratio	"It's just crying wolf"; "Difficult to interpret the validity of many alerts"	Attitudinal	Questioning the validity		
[34]	"Alerts are often fired for drug combinations that conform to clinical guidelines and are recommended by specialist colleagues. Examples include aspirin with angiotensin converting enzyme inhibitors in patients with heart disease or diabetes."	Compatibility	Low signal-to-noise ratio	"It's just crying wolf"; "Difficult to interpret the validity of many alerts"	Attitudinal	Questioning the validity		
[34]	"Appropriate polypharmacy is not acknowledged" "In psychiatric care, mood stabilizers are often used intentionally in combination or "augmentation" therapy with antidepressants."	Compatibility	Low signal-to-noise ratio	"It's just crying wolf"; "Difficult to interpret the validity of many alerts"	Attitudinal	Questioning the validity		
[34]	"Since most pediatric drugs are used off-label, pediatricians find it difficult to interpret the validity of many alerts."	Compatibility	Low signal-to-noise ratio	"It's just crying wolf"; "Difficult to interpret the validity of many alerts"	Attitudinal	Questioning the validity		

	Usability flaw			Usage problem			Negative outcome	
	Excerpt	Category	Sub-cat.	Excerpt	Category	Sub-cat.	Excerpt	Category
[34]	"Within-class interactions typically reflect an out-of-date medication list – such as an antibiotic interacting with another antibiotic – rather than a true interaction."	Compatibility	Low signal-to-noise ratio	"It's just crying wolf"; "Difficult to interpret the validity of many alerts"	Attitudinal	Questioning the validity		
[34]	"According to clinicians, the sensitivity of alerts was often set too high while the specificity was too low."	Compatibility	Low signal-to-noise ratio	"Many clinicians ignore potentially serious alerts"; "Once you realize that most of the information is useless or superfluous or not relevant, you stop looking at it."	Behavioral	Voluntarily ignoring alerts		
[34]	"Alerts are often fired for drug combinations that conform to clinical guidelines and are recommended by specialist colleagues. Examples include aspirin with angiotensin converting enzyme inhibitors in patients with heart disease or diabetes."	Compatibility	Low signal-to-noise ratio	"Many clinicians ignore potentially serious alerts"; "Once you realize that most of the information is useless or superfluous or not relevant, you stop looking at it."	Behavioral	Voluntarily ignoring alerts		
[34]	"Appropriate polypharmacy is not acknowledged" "In psychiatric care, mood stabilizers are often used intentionally in combination or "augmentation" therapy with antidepressants."	Compatibility	Low signal-to-noise ratio	"Many clinicians ignore potentially serious alerts"; "Once you realize that most of the information is useless or superfluous or not relevant, you stop looking at it."	Behavioral	Voluntarily ignoring alerts		
[34]	"Pregnancy alerts would be more useful (…) if they were suppressed for male patients and women of non-child-bearing age."	Compatibility	Low signal-to-noise ratio	"Many clinicians ignore potentially serious alerts"; "Once you realize that most of the information is useless or superfluous or not relevant, you stop looking at it."	Behavioral	Voluntarily ignoring alerts		
[34]	"Within-class interactions typically reflect an out-of-date medication list – such as an antibiotic interacting with another antibiotic – rather than a true interaction."	Compatibility	Low signal-to-noise ratio	"Many clinicians ignore potentially serious alerts"; "Once you realize that most of the information is useless or superfluous or not relevant, you stop looking at it."	Behavioral	Voluntarily ignoring alerts		
[34]	"According to clinicians, the sensitivity of alerts was often set too high while the specificity was too low."	Compatibility	Low signal-to-noise ratio	"Trivial alerts often interrupt workflow."	Cognitive	Users interrupted		
[34]	"Alerts are often fired for drug combinations that conform to clinical guidelines and are recommended by specialist colleagues. Examples include aspirin with angiotensin converting enzyme inhibitors in patients with heart disease or diabetes."	Compatibility	Low signal-to-noise ratio	"Trivial alerts often interrupt workflow."	Cognitive	Users interrupted		
[34]	"Appropriate polypharmacy is not acknowledged" "In psychiatric care, mood stabilizers are often used intentionally in combination or "augmentation" therapy with antidepressants."	Compatibility	Low signal-to-noise ratio	"Trivial alerts often interrupt workflow."	Cognitive	Users interrupted		
[34]	"Pregnancy alerts would be more useful (…) if they were suppressed for male patients and women of non-child-bearing age."	Compatibility	Low signal-to-noise ratio	"Trivial alerts often interrupt workflow."	Cognitive	Users interrupted		
[34]	"Within-class interactions typically reflect an out-of-date medication list – such as an antibiotic interacting with another antibiotic – rather than a true interaction."	Compatibility	Low signal-to-noise ratio	"Trivial alerts often interrupt workflow."	Cognitive	Users interrupted		
[35]	"There are too many [alerts]."	Compatibility	Low signal-to-noise ratio	"Physicians ignoring alerts because there are too many"	Behavioral	Voluntarily ignoring alerts		

	Usability flaw			Usage problem			Negative outcome	
	Excerpt	Category	Sub-cat.	Excerpt	Category	Sub-cat.	Excerpt	Category
[37]	"Clinicians (…) faced with a long list of them for each patient."	Compatibility	Low signal-to-noise ratio	"Become desensitized to the CRs"	Attitudinal	Alert fatigue		
[37]	"Clinicians reported that they faced situations in which CRs could not be removed and therefore continued to appear."	Compatibility	Low signal-to-noise ratio	"CRs could not be removed"	Behavioral	Users lost	"CRs (…) continued to appear"	Technology effectiveness issues
[38]	"Reminders did not always apply given the context of a particular patient." ; "The third barrier to following the advice of a clinical reminder was inapplicability to the specific situational context. For example, a recommendation to begin Highly Active Anti-Retroviral Therapy (HAART) was not followed because the patient had experienced multiple intolerances to the medication in the past."	Compatibility	Low signal-to-noise ratio	"Clinical reminders were not [always] used"	Behavioral	System not used at all		
[40]	"Most prescribers believed that most (alerts) were redundant."	Compatibility	Low signal-to-noise ratio	"Some doctors recognized that they had become desensitized to the alerts."	Attitudinal	Alert fatigue		
[40]	"Most prescribers believed (…) that they received too many alerts …"	Compatibility	Low signal-to-noise ratio	""It pops up so often which can be a very bad thing because you're dismissing it so often that you develop this sort of mechanism"", Most doctors either admitted to not reading the warnings", "it's so much easier to click that button"	Behavioral	Voluntarily ignoring alerts		
[41]	"excess alerts - e.g., asthma and opiate, warfarin and paracetamol""	Compatibility	Low signal-to-noise ratio	"The physician reported that specific features of the system (…) were hindering the use"	Behavioral	Ineffective use		
[41]	""Too low triggering threshold with drug interaction alerts""	Compatibility	Low signal-to-noise ratio	"I never bother to read them"	Behavioral	Voluntarily ignoring alerts		
[41]	"excess alerts - e.g., asthma and opiate, warfarin and paracetamol"	Compatibility	Low signal-to-noise ratio	"Irritating drug interaction and contraindication alerts"	Emotional	Annoyance		
[22] [29]	"(…) scrolling were problematic" [Inference: user needs to scroll to see the whole information]; "poor screen display; alert display does not support alert resolution and/or prescriber workflow" "they have to manipulate the alert to see all of the information"	Workload	Minimal action	"There were several cases where inadequate alert design prompted prescribers to take extra steps in the medication ordering process. For example, prescribers sometimes had to manipulate the alert to see all of the information"	Behavioral	Increased workload	"Hindering alert resolution"; "Hinder alert effectiveness"	Technology effectiveness issues
[22] [29]	"(…) scrolling were problematic" [Inference: user needs to scroll to see the whole information]; "poor screen display; alert display does not support alert resolution and/or prescriber workflow" "they have to manipulate the alert to see all of the information"	Workload	Minimal action	"There were several cases where inadequate alert design (…) disrupted their workflow."	Cognitive	Users interrupted	"Hindering alert resolution"; "Hinder alert effectiveness"	Technology effectiveness issues

Ref	Usability flaw Excerpt	Usage problem Category	Usage problem Sub-cat.	Usage problem Excerpt	Usage problem Category	Usage problem Sub-cat.	Negative outcome Excerpt	Negative outcome Category
[22] [29]	"(…) scrolling were problematic" [Inference: user needs to scroll to see the whole information]; "poor screen display: alert display does not support alert resolution and/or prescriber workflow" "they have to manipulate the alert to see all of the information"	Workload	Minimal action	"View as "very troublesome""	Emotional	Annoyance		
[29]	"Time needed to resolve alerts: Justification requirement often viewed as time burden" [Inference: justify an the irrelevance of an alert requires several actions that take time]	Workload	Minimal action	"Justification requirement often viewed as time burden"	Attitudinal	Negative feelings		
[30]	"Some had difficulty identifying the patient's risk factors for the interaction. Successfully answering this question required clicking on the Risk Factors tab to reveal the data (see Figure 3)." "The most commonly cited design concerns were the unnecessary use of tabs (7 subjects)"	Workload	Minimal action	"Had difficulty identifying the patient's risk factors for the interaction"	Cognitive	Difficulties to understand the alert	"Successfully answering this question (…) required clicking on the Risk Factors tab" [error in answering a clinical question]	Patient safety issues
[32]	"Necessity for scrolling down the whole alert text to find the conclusion"	Workload	Minimal action	"Could further add to alert fatigue"; "Remarks suggesting alert fatigue"	Attitudinal	Alert fatigue		
[32]	"Necessity for scrolling down the whole alert text to find the conclusion"	Workload	Minimal action	"Necessity for scrolling down" [increased workload]	Behavioral	Increased workload		
[32]	"Necessity for scrolling down the whole alert text to find the conclusion"	Workload	Minimal action	« The physician may overlook the second alert, thinking that the override button for the (first) alert has not worked properly"; "thereby unintentionally override the second alert."	Cognitive	Information involuntarily missed	"wrong selection (followed incorrect dose recommendation)"	Patient safety issues
[32]	"Necessity for scrolling down the whole alert text to find the conclusion"	Workload	Minimal action	"Misinterpretation (…) high numbers of wrong or inapplicable rules and reasoning."	Cognitive	Misinterpretation of alerts' content	"wrong selection (followed incorrect dose recommendation)"	Patient safety issues
[37]	"Five nurses and two providers were observed to skip all or some of the reminders and explained that this was because they perceived that they did not have enough time to "satisfy" the reminders by entering data."; "Completing the CRs creates "double documentation" burdens for some providers (…) as they generally keep track of this information without the CRs (e.g., in a health maintenance list within the progress note)."[Inference: satisfy the reminders requires time]	Workload	Minimal action	"Completing the CRs creates "double documentation" burdens for some providers (…) as they generally keep track of this information without the CRs"	Behavioral	Increased workload		
[37]	"Five nurses and two providers were observed to skip all or some of the reminders and explained that this was because they perceived that they did not have enough time to "satisfy" the reminders by entering data."; "Completing the CRs creates "double documentation" burdens for some providers (…) as they generally keep track of this information without the CRs (e.g., in a health maintenance list within the progress note)."[Inference: satisfy the reminders requires time]	Workload	Minimal action	"Five nurses and two providers were observed to skip all or some of the reminders"	Behavioral	Voluntarily ignoring alerts		
[38]	"At all sites, at least one provider never satisfied reminders that were not clinically relevant, which required data entry such as when a patient received a vaccine at another hospital." [data entry cumbersome] "additional workload"	Workload	Minimal action	"Lack of time to follow documentation procedures within the CR noting why the reminder's advice was not followed."	Behavioral	Increased workload		

	Usability flaw			Usage problem			Negative outcome	
	Excerpt	Category	Sub-cat.	Excerpt	Category	Sub-cat.	Excerpt	Category
[38]	"At all sites, at least one provider never satisfied reminders that were not clinically relevant, which required data entry such as when a patient received a vaccine at another hospital." [data entry cumbersome] "additional workload"	Workload	Minimal action	"At least one provider at all eight sites conducted documentation activities, including satisfying clinical reminders (…), after the patient had left the room. (…) at least one provider conducted documentation activities after the clinic closed, normally within 36 hours. (…) case managers documented clinical reminders (…) after the physicians did not."	Behavioral	Workarounds		
[41]	"Reminders' texts are sometimes too strict in the short version. If you don't move the cursor over the text and see the whole reminder, the wording doesn't work.'"	Workload	Minimal action	"If you don't move the cursor over the text and see the whole reminder (…)"	Behavioral	Increased workload		
[41]	"Reminders' texts are sometimes too strict in the short version. If you don't move the cursor over the text and see the whole reminder, the wording doesn't work.'"	Workload	Minimal action	"(…) the wording doesn't work"	Cognitive	Difficulties to understand the alert		
[36]	"Several users in the simulation-based testing did not notice the arrows under the clinical recommendations or did not realize they provided additional, more detailed information about the basic recommendation when clicked on." [inference: the arrow is not intuitive enough]	Significance of codes	Non intuitive icons	"Several users did not notice the arrows under the clinical recommendations or did not realize they provided additional more detailed information about the basic recommendation when clicked on."	Cognitive	Difficulties to identify alerts' components		
[37]	"When defaulting past the cover sheet, feedback for the presence of due CRs is signified by a question mark icon in the upper right corner of the display. We observed three providers misinterpret this question mark to indicate that the patient had no CRs due, when in actuality it meant the system was still evaluating data to determine which CRs were due." [inference: non intuitive enough symbol]	Significance of codes	Non intuitive icons	"We observed three providers misinterpret this question mark"	Cognitive	Difficulties to identify alerts' components		
[24]	"Yeah, you see it, but you have to do something to even find out what it means. "" [Inference: passive alerts are not sufficiently informational to support a quick triage]	Significance of codes	Non intuitive wording	"Users said they would like more information available with less effort so they can evaluate and act on alerts and reminders more easily."	Behavioral	Increased workload		
[27]	"Use of abbreviations and expressions that were not understandable by physicians, confusing terminology in labelling of buttons"	Significance of codes	Non intuitive wording	"Precluding the physicians to understand the problem that generated the alert or how to solve the problem."	Cognitive	Difficulties to understand the alert	"Impaired the ordering efficiency"	Medication management process issues
[27]	"Use of abbreviations and expressions that were not understandable by physicians, confusing terminology in labelling of buttons"	Significance of codes	Non intuitive wording	"Physicians became frustrated"	Emotional	Frustration		
[36]	"A user thought that the appearance of the "stamp" window implied that the patient had a chronic pain problem or diagnosis. In actuality, the "stamp" indicated that the patient had a scheduled appointment within a 5-day window and that ATHENA-OT had recommendations available should the provider consider OT for that patient." [inference: stamp wording not intuitive enough]	Significance of codes	Non intuitive wording	"A user thought that the appearance of the "stamp" window implied that the patient had a chronic pain problem or diagnosis" [misinterpretation]	Cognitive	Misinterpretation of alerts' components		

	Usability flaw			Usage problem			Negative outcome	
	Excerpt	Category	Sub-cat.	Excerpt	Category	Sub-cat.	Excerpt	Category
[39]	"Two participants misinterpreted the meaning of "When" to represent the current patient received the intervention instead of the frequency the intervention is due for all patients."	Significance of codes	Non intuitive wording	"Two participants misinterpreted the meaning of "When""	Cognitive	Misinterpretation of alerts' components		
[23]	All alerts include an acknowledgement comment field, only some alerts are marked as requiring acknowledgement. Even those alerts which require acknowledgement only require that the acknowledgement button be pressed, not that a comment be left, although clinicians may have misinterpreted the directive."	Guidance	Prompting	"although clinicians may have misinterpreted the directive."	Cognitive	Misinterpretation of alerts' content	"The absence of a specific order critique in this alert, combined with the required acknowledgement, may be related to the relatively high proportion of content free comments"	Technology effectiveness issues
[24]	"It was somewhat surprising that users did not always seem to understand how to use and manage the alerts effectively."Inference: alert's management is not intuitive]	Guidance	Prompting	"Not always seem to understand how to use and manage the alerts effectively"	Behavioral	Ineffective use	"This resulted in some unnecessary repetition of alerts"	Technology effectiveness issues
[24]	"It was somewhat surprising that users did not always seem to understand how to use and manage the alerts effectively."Inference: alert's management is not intuitive]	Guidance	Prompting	"This (…) contributed to user frustration."	Emotional	Frustration		
[26]	"The programmers' mental model, as reflected in the system image, did not adequately match prescribers' mental models (…): Physician (MD) orders [VA] aspirin - 162 mg. An order check [alert] appears. Says duplicate drug order. Non-VA ASPIRIN. [Alert] mentions 325mg....MD is looking at it also and [appears] confused"	Guidance	Prompting	"MD clicks through [the alert] [accepts order]" (accepts without understanding the alert)	Behavioral	Advice blindly followed	"MD goes back to the medication list. Aspirin is now listed both under VA list and non-VA medication list" [double order of aspirin]	Patient safety issues
[26]	"The programmers' mental model, as reflected in the system image, did not adequately match prescribers' mental models (…): Physician (MD) orders [VA] aspirin - 162 mg. An order check [alert] appears. Says duplicate drug order. Non-VA ASPIRIN. [Alert] mentions 325mg....MD is looking at it also and [appears] confused"	Guidance	Prompting	"This led to confusion during the prescribing process", "MD to Observer: What's it going to do? Is it going to switch the patient to 325mg?"	Cognitive	Difficulties to understand the alert	"MD goes back to the medication list. Aspirin is now listed both under VA list and non-VA medication list" [double order of aspirin]	Patient safety issues
[27]	"unclear information or guidance" in the messages	Guidance	Prompting	"Resorted to trial-and-error behavior exemplified by the extra mouse clicks and keystrokes they needed for locating and executing the right action in response to the message"	Behavioral	Increased workload	"Impaired the ordering efficiency"	Medication management process issues
[27]	"unclear information or guidance" in the messages	Guidance	Prompting	"Physicians were lost »	Behavioral	Users lost	"Impaired the ordering efficiency"	Medication management process issues
[27]	"unclear information or guidance" in the messages	Guidance	Prompting	"Precluding the physicians to understand the problem that generated the alert or how to solve the problem."	Cognitive	Difficulties to understand the alert	"Impaired the ordering efficiency"	Medication management process issues
[28]	"Prescribers reported that alerts presenting during medication order entry were often (…) difficult to interpret in content and purpose"	Guidance	Prompting	"Several prescribers described rapidly overriding these alert types once they recognized that they had seen the alert before. One prescriber noted that she had "memorized the location of the override button" for these situations."	Behavioral	Voluntarily ignoring alerts		

	Usability flaw			Usage problem			Negative outcome	
	Excerpt	Category	Sub-cat.	Excerpt	Category	Sub-cat.	Excerpt	Category
[28]	"Prescribers reported that alerts presenting during medication order entry were often (…) difficult to interpret in content and purpose"	Guidance	Prompting	"Difficult to interpret in content and purpose"; "Some reported difficulty with (…) the length of the text."	Cognitive	Difficulties to understand the alert	"Slowed down their work"	Medication management process issues
[29]	"Prescribers unaware that they could turn off some alerts"	Guidance	Prompting	"Prescribers unaware that they could turn off some alerts"; "Prescribers' ability to act on alerts was impeded by the alert interface"	Behavioral	Ineffective use		
[29]	"Salience: Alert visibility and distinction: Prescriber wanted more visual emphasis on high risk alerts" [Inference: no sufficient visual emphasis on high risk alerts]	Guidance	Prompting	"Difficult to distinguish different alert types (e.g., duplicate drug versus duplicate drug class alerts)"	Cognitive	Difficulties to understand the alert		
[30]	"Two areas of minor criticism were the layout of buttons and checkboxes" ; "Some users did not see the tab or did not realize it was selectable."[Inference: they are not salient enough to be seen]	Guidance	Prompting	"Had difficulty identifying the patient's risk factors for the interaction"	Cognitive	Difficulties to understand the alert	"Successfully answering this question (…) required clicking on the Risk Factors tab" [error in answering a clinical question]	Patient safety issues
[30]	"Many [users] missed a question regarding data in the alert that should reduce the level of clinical concern ('attenuating information')" [rephrasing: this information is missed because of the organization of the information in the alert: it is outside the center of the alert]	Guidance	Prompting	"Many missed a question regarding data in the alert that should reduce the level of clinical concern ('attenuating information')."	Cognitive	Information involuntarily missed	"the patient had been taking both medications for many years and most physicians would be reassured by this fact. However, only 58% of subjects made this connection." [error in understanding patient data]	Patient safety issues
[32]	"The interviews suggest that both unclear alert texts and texts read incompletely play a role."; alert presentation was unclear (two DDI alerts in one screen provoking oversight)	Guidance	Prompting	« The physician may overlook the second alert, thinking that the override button for the (first) alert has not worked properly", "thereby unintentionally override the second alert."	Cognitive	Information involuntarily missed	"wrong selection (followed incorrect dose recommendation)"	Patient safety issues
[32]	"The interviews suggest that both unclear alert texts and texts read incompletely play a role."; alert presentation was unclear (two DDI alerts in one screen provoking oversight)	Guidance	Prompting	"Misinterpretation (…) high numbers of wrong or inapplicable rules and reasoning."	Cognitive	Misinterpretation of alerts' content	"wrong selection (followed incorrect dose recommendation)"	Patient safety issues
[33]	"Some alerts are out of the visual focus region when using the system"	Guidance	Prompting	[inference: alert unnoticed]	Cognitive	Information involuntarily missed	"Leading to low response levels to the alerts"	Technology effectiveness issues
[41]	"Reminders' texts are sometimes too strict in the short version. If you don't move the cursor over the text and see the whole reminder, the wording doesn't work.'"	Guidance	Prompting	"If you don't move the cursor over the text and see the whole reminder (…)"	Behavioral	Increased workload		
[41]	"Reminders' position on the left side of the screen" [Inference: position outside their focal visual field]	Guidance	Prompting	"The physician reported that specific features of the system (…) were hindering the use"	Behavioral	Ineffective use		
[41]	"Reminders' texts are sometimes too strict in the short version. If you don't move the cursor over the text and see the whole reminder, the wording doesn't work.'"	Guidance	Prompting	"(…) the wording doesn't work"	Cognitive	Difficulties to understand the alert		

| Ref | Usability flaw | | | Usage problem | | | Negative outcome | |
	Excerpt	Category	Sub-cat.	Excerpt	Category	Sub-cat.	Excerpt	Category
[22] [26] [29]	"Language of alerts is difficult for prescriber to interpret: E.g., Alert says remote order checking unavailable. (See Figure 1.) Phys: "I do not know what that means.""	Error management	Quality of error messages	"Prescribers were sometimes unsure (…) what an alert was attempting to convey"; "Language of alerts is difficult for prescriber to interpret "I do not know what that means.""	Cognitive	Difficulties to understand the alert	"We call the pharmacist and spend time looking up information.";" physicians often come and ask [the pharmacists] about an alert triggered by the combination of amiodarone and simvastatin"; "physicians and nurse practitioners found it helpful, and sometimes necessary, to have real-time, face-to-face communication with clinical pharmacists to be able to interpret and resolve alerts"	Workflow issues
[10]	"The CPOE system does not display information available on other hospital systems. For example, only the pharmacy's computer provides drug interaction and lifetime limit warnings."	Compatibility	Tasks and control distribution issues	"The CPOE system does not display information available on other hospital systems. For example, only the pharmacy's computer provides drug interaction and lifetime limit warnings." [missing information]	Cognitive	Information involuntarily missed	"Pharmacists call house staff to clarify questionable orders"	Workflow issues
[29]	"Prescribers unsure if pharmacists review these (override justifications) or find them useful"	Compatibility	Tasks and control distribution issues	"Unsure if pharmacists review these [override justifications]"	Attitudinal	Questioning the behavior		
[37]	"CR system is currently insufficient for supporting transmission of reminder results from nursing intake to provider examination"	Compatibility	Tasks and control distribution issues	"Paper-based workarounds were employed to alert providers to positive findings from the screening, including printing the nursing note for the provider (Site 1), placing a post-it note or using handwritten abbreviations on the patient's routing form (Sites 2 and 4), and marking a check box next to the appropriate item on a "green card" that the patient then gave to the provider (Site 3)."	Behavioral	Workarounds		
[22] [29]	"Alert system does not adequately reveal its capabilities/limitations to the prescriber; full functionality of the alert system is ambiguous." "System capabilities and limitations are ambiguous: Prescribers confused about whether the system could evaluate non-formulary, non-VA medications"	Compatibility	Transparency issues	""I am not confident it's checking all the interactions that I want it to check."", "No, I'm not clear. I'm not clear what the triggers are".	Attitudinal	Questioning triggering/sorting model		
[22] [29]	"Alert system does not adequately reveal its capabilities/limitations to the prescriber; full functionality of the alert system is ambiguous. "System capabilities and limitations are ambiguous: Prescribers confused about whether the system could evaluate non-formulary, non-VA medications"	Compatibility	Transparency issues	"Prescribers unaware that they could turn off some alerts"; "Prescribers' ability to act on alerts was impeded by the alert interface"	Behavioral	Ineffective use	"We call the pharmacist and spend time looking up information.";" physicians often come and ask [the pharmacists] about an alert triggered by the combination of amiodarone and simvastatin"; "physicians and nurse practitioners found it helpful, and sometimes necessary, to have real-time, face-to-face communication with clinical pharmacists to be able to interpret and resolve alerts"	Workflow issues

	Usability flaw			Usage problem			Negative outcome	
	Excerpt	Category	Sub-cat.	Excerpt	Category	Sub-cat.	Excerpt	Category
[24]	"There are instances where users expect the system to "be aware" of and utilize patient information that exists in the database."	Compatibility	Transparency issues	"There are instances where users expect the system to "be aware" of and utilize patient information that exists in the database, to more accurately target eligible patients."	Attitudinal	Questioning triggering/sorting model		
[25]	"Three subjects expressed their need for better understanding of the dose calculation by the system. (...) users would not be able to "validate" the system's reasoning without resorting to calculation that is more complicated" [Inference users are not sure that the system based its recommendation on the same assumptions they would have made]	Compatibility	Transparency issues	"Subjects wanted to be sure that the system based its recommendation on the same assumptions they would have made"	Attitudinal	Questioning the behavior		
[26]	"A specific medication alert did not appear, even though the pharmacist was expecting it to come up for a patient. (...) Pharmacist: "The patient is 85yrs old. It's not good if he is on a full dose of aspirin and Plavix. These are both anti-platelets [medications]..." [later, while ordering medications for this patient] An order check appears [after the] pharmacist change[s] [the] aspirin dose. [Alert] says duplicate drug class - hydrocodone. This was the only order check alert listed in the window. Pharmacist: "This is because the patient is on hydrocodone. It pulled-up that one, but not the Plavix [alert] which is interesting."" "Programmer and prescriber mental model mismatches were evident when a prescriber expected an alert to appear, but the system did not display that alert: (...) physician [is] ordering [renewing] naproxen... No order check [alerts] appear."	Compatibility	Transparency issues	« The pharmacist was expecting it to come up for a patient."	Attitudinal	Questioning triggering/sorting model		
[29]	"Ambiguity about alert management; need for closed-loop feedback; E.g., Phys: "I want [the alert system] to have user control. I am not confident it's checking all the interactions that I want to check.""	Compatibility	Transparency issues	""I am not confident it's checking all the interactions that I want it to check."", "No, I'm not clear. I'm not clear what the triggers are".	Attitudinal	Questioning triggering/sorting model		
[29]	"System capabilities and limitations are ambiguous"	Compatibility	Transparency issues	""I am not confident it's checking all the interactions that I want it to check."", "No, I'm not clear. I'm not clear what the triggers are".	Attitudinal	Questioning triggering/sorting model		
[29]	"System capabilities and limitations are ambiguous"	Compatibility	Transparency issues	"Prescribers unaware that they could turn off some alerts", "Prescribers' ability to act on alerts was impeded by the alert interface"	Behavioral	Ineffective use	"We call the pharmacist and spend time looking up information.";" physicians often come and ask [the pharmacists] about an alert triggered by the combination of amiodarone and simvastatin"; "physicians and nurse practitioners found it helpful, and sometimes necessary, to have real-time, face-to-face communication with clinical pharmacists to be able to interpret and resolve alerts"	Workflow issues

	Usability flaw			Usage problem			Negative outcome	
	Excerpt	Category	Sub-cat.	Excerpt	Category	Sub-cat.	Excerpt	Category
[33]	"some express doubts on whether the system has up-to-date information (for instance for weight-based drug dosage alerts in pediatrics or drug interactions in cardiology where they often introduce new drugs)."	Compatibility	Transparency issues	"Some express doubts on whether the system has up-to-date information "	Attitudinal	Questioning the validity		
[38]	"Users were uncertain how long the reminders would be turned off for each dialog option."	Compatibility	Transparency issues	"Users were uncertain how long the reminders would be turned off for each dialog option"	Attitudinal	Questioning the behavior		
[42]	"The reason for this is that the registration of an allergy is based on the ATC code, and the same drug can be registered under several codes if the drug has various indications." "The older version of the CPOE system only warns the user if the same drug code appears twice and not if the same drug (registered under different ATC codes) appears twice. "[Inference: there would be no alert for a medication]	Compatibility	Transparency issues	[inference: users are unaware of gaps in the data]	Cognitive	Misinterpretation of alerts' content	"There are various examples of complex registration that lead to medication errors"	Patient safety issues