Supplementary Table S1 Human factors principles in medication decision support

Adherence to human factors guidelines is associated with improved usability, reduced prescriber workload, and reduced prescribing errors. Usability is defined as "the extent to which specified users can use a system, product or service to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use"[24] is impacted by many factors, and the gold standard for improving usability includes utilizing user-centered design and performing usability testing. Advise was created based on a validated tool called I-MeDeSA.[25]
Below is the guidance of the human factors principles:
Section 1: Timing of the Alert
- When several alerts appear for one order, **the most severe alert should appear first**
- Alerts should appear while the order is placed (i.e., entering the drug, frequency, or route).
o However, if the drug interaction is severe, an alert should appear **during and at the signing**
Section 2: Visual Aspects of the Alert
- The alert should be **visually distinct** from the rest of the screen. This can be achieved in the following ways:
o Alerting appearing as a pop-up
o Use of different colors and/or symbols and icons
o Larger and bolder font
o Use of a signal word such as "warning," "caution," etc.
- When the alert appears, it should present **directly in the line of sight** of the prescriber
Section 3: Severity of the Alert
- In addition to the alert being distinctive, the **alert's severity** should also be represented.
o Ways in which this can presented include (but are not limited to):
o Use of a color-coded system
o Symbol or icon
o Combination of colors and symbols
Section 4: Content of the Alert
- Differentiating between generic and brand names of drugs, along with the use of Tallman lettering, helps ensure the correct medication is being chosen during ordering
- If the drug interaction is presented in sentence form, the two interacting drugs should be located at the beginning of the sentence so that the prescriber can immediately identify the subjects of the alert
- In addition to visual aspects of an alert that represent the severity of the alert, a signal word such as "Warning" or "Danger" can also be helpful to prescribers
- The following text-based information is recommended to be within the alert:
o The drug interaction
o An instruction statement that details how to avoid ordering these two drugs in the future

o A list of recommended tasks that reflect the order of required actions
o Consequence statement that notifies prescribers of what may occur if the order is placed.
Section 5: Actions (How to Resolve the Alert)
- The recommended action in response to an alert should be located within the same window of the alert itself so that the prescriber does not have to navigate out of the alert
- Once the alert is accepted, some systems can **automatically** make the intended change (i.e., discontinue the medication, change the dose, etc.); this is also an example of corrective action
o This ensures that the prescriber not only acknowledges the alert but it also captures the prescriber's intended action
- Given the severity of these drug-drug interaction alerts, there should be some safeguards in place to prevent these drugs from being prescribed together
Section 6: Irrelevant Information in or Surrounding the Alert
- To ensure that the alert has strong saliency and is effective, other low-priority alerts should not be presented in the same window or in the same manner

Supplementary Table S2 List of changes made to the I-MeDeSA for the development of the human factors assessment

Original I-MeDeSA Items	Changes Made for Human Factors Assessment
Alarm Philosophy 1i. Does the system provide a general catalog of unsafe events, correlating the priority level of the alert with the severity of the consequences?	Did not include in human factors assessment because we were unsure if a clinician would know the answer to this question.
Placement **2i.** Are different types of alerts meaningfully grouped? (ie, by the severity of the alert, where all level 1 alerts are placed together, or by medication order, where alerts related to a specific medication order are grouped together) **2ii.** Is the response to the alert provided along with the alert, as opposed to being located in a different window or in a different area on the screen? **2iii.** Is the alert linked with the medication order by appropriate timing? (ie, a DDI alert appears as soon as a drug is chosen and does not wait for the user to complete	For item 2i, we did not include in the human factors assessment because we were unsure if a clinician would know the answer to this question. Item 2ii was included in section 5 of the human factors assessment, "Action (How to Resolve the Alert." If clinicians selected that the response to the alert was not located within the same window of the alert, a follow up question was asked about where the recommended action was located (different window separate from the alert or different area of the screen). Item 2iii was moved to section 1 of the assessment, "Timing of the Alert" and the wording of the question changed to

the order and then alert him/her about a possible interaction) **2iv.** Does the layout of critical information contained within the alert facilitate quick uptake by the user? Critical information should be placed on the first line of the alert or closest to the left side of the alert box. **2v.** Critical information should be labeled appropriately and must consist of: (1) the interacting drugs, (2) the risk to the patient, and (3) the recommended action.	"When does the alert appear during the workflow?." Item 2iv was not directly included in the assessment, but we did add a new section called "Visual Aspects of the Alert." The main question in this section was, "How was the alert visually distinct from the rest of the screen?," and we provided several check-box options for clinics to choose from. Item 2v was not directly included in the assessment, as its content was similar to the text-based information questions that we ask in the assessment.
Visibility **3i.** Is the area where the alert is located distinguishable from the rest of the screen? This might be achieved through the use of a different background color, a border color, highlighting, bold characters, occupying the majority of the screen, etc. **3ii.** Is the background contrast sufficient to allow the user to easily read the alert message? (ie, dark text on a light background is easier to read than light text on a dark background) **3iii.** Is the font used to display the textual message appropriate for the user to read the alert easily? (ie, a mixture of upper and lower case lettering is easier to read than upper case only)	All items in this section were condensed into one question into one question in section 2 of the assessment, "How is the alert visually distinct from the rest of the screen?." Clinics were provided 6 choices in check-box format so that they could choose multiple choices. The choices were: • Alert appears as a pop-up • Different color • Font (i.e., larger and bolder) • Use of a signal word • Use of a symbol or icon • Other, please explain: _____
Prioritization **4i.** Is the prioritization of alerts indicated appropriately by color? (ie, colors such as red and orange imply a high priority compared with colors such as green, blue, and white) **4ii.** Does the alert use prioritization with colors other than green and red, to take into consideration users who may be color blind?	Items 4i – 4iv were condensed into one question in section 3 of the human factors assessment (Severity of the Alert), "How is the severity of the alert presented?." The following options in check-box format were presented to clinicians to choose from: • Use of a color-coded system only • A symbol or icon only • Combination of colors and symbols • Other, please explain: _____

4iii. Are signal words appropriately assigned to each existing level of alert? For example, 'Warning' would appropriately be assigned to a level 1 alert and not a level 3 alert. 'Note' would appropriately be assigned to a level 3 alert and not a level 1 alert **4iv.** Does the alert utilize shapes or icons to indicate the priority of the alert? (ie, angular and unstable shapes such as inverted triangles indicate higher levels of priority than regular shapes such as circles) **4v.** In the case of multiple alerts, are the alerts placed on the screen in the order of their importance? The highest priority alerts should be visible to the user without having to scroll through the window.	For item 4v, we moved this question to section 1 of the assessment (Timing of the Alert). The wording of the question was changed to, "Did multiple alerts appear for this medication order?," and then clinics were asked to select "yes" or "no." If clinics selected the "yes" option, a follow up question asked if the most severe appear first ("yes" or "no").
Color **5i.** Does the alert utilize color-coding to indicate the type of unsafe event? (ie, drug–drug interaction (DDI) vs allergy alert) **5ii.** Is color minimally used to focus the attention of the user? As excessive coloring used on the screen can create noise and distract the user, there should be less than 10 colors.	For these items we incorporated this into sections 2 and 3 of the survey where ask about the use of color as making the alert visually distinct from the rest of the screen and indicating the severity of the alert. Since for this pilot we only assessed drug-drug interaction alerts, this question was no applicable.
Learnability and Confusability 6i. Are the different severities of alerts easily distinguishable from one another? For example, do major alerts possess visual characteristics that are distinctly different from minor alerts? The use of a signal word to identify the severity of an alert is not considered to be a visual characteristic.	Item 6i, along with items 4i – 4iv were condensed into one question in section 3 of the human factors assessment (Severity of the Alert), "How is the severity of the alert presented?." The following options in check-box format were presented to clinicians to choose from: • Use of a color-coded system only • A symbol or icon only • Combination of colors and symbols • Other, please explain: _____

Text-Based Information **7i.** A signal word to indicate the priority of the alert (ie, 'note,' 'warning,' or 'danger') **7ii.** A statement of the nature of the hazard describing why the alert is shown. This may be a generic statement in which the interacting classes are listed, or an explicit explanation in which the specific DDIs are clearly indicated. **7iia.** If yes, are the specific interacting drugs explicitly indicated? **7iii.** An instruction statement (telling the user how to avoid the danger or the desired action) **7iiia.** If yes, does the order of recommended tasks reflect the order of required actions? **7iv.** A consequence statement telling the user what might happen, for example, the reaction that may occur if the instruction information is ignored.	All items in this section were condensed into one question in section 4 of the human factors section (Content of the Alert): "Which of the following text-based information is included in the alert?." The follow response options were provided in check-box format: • Drugs in question • Instruction statement • List of recommended tasks • Consequence statement
Proximity of Task Components being Displayed **8i.** Are the informational components needed for decision making on the alert present either within or in close spatial and temporal proximity to the alert? For example, is the user able to access relevant information directly from the alert, that is, a drug monograph, an 'infobutton,' or a link to a medical reference Web site providing additional information?	For this item, we did not directly include it in the assessment as we felt that it was covered in text-based information question we asked in section 4 of the assessment (Content of the Alert).
Corrective Actions **9i.** Does the system allow corrective actions that serve as an acknowledgment of having seen the alert? For example, 'Accept' and 'Cancel' are corrective actions, while 'OK' is an acknowledgment.	This section of I-MeDeSA was condensed into one question, where corrective action was an answer choice. The question was included was section 5 of the assessment (Action (How to Resolve the Alert), and question was, "What happens when the prescriber accepts the recommendations

	9ia. If yes, does the alert utilize intelligent corrective actions that allow the user to complete a task? For example, if warfarin and ketoconazole are co-prescribed, the alert may ask the user to 'Reduce the warfarin dose by 33–50% and follow the patient closely.' An intelligent corrective action would be 'Continue with warfarin order AND reduce dose by 33–50%.' Selecting this option would simultaneously over-ride the alert AND direct the user back to the medication order where the user can adjust the dose appropriately. **9ii.** Is the system able to monitor and alert the user to follow through with corrective actions? Referring to the previous example, if the user tells the system that he/she will reduce the warfarin dose but fails to follow through on that promise, does the system alert the user?	of the alert?." The two answer choices were either: • Options for how to resolve the alert was presented to the prescriber • The system automatically makes the recommended changes (Corrective Action)