

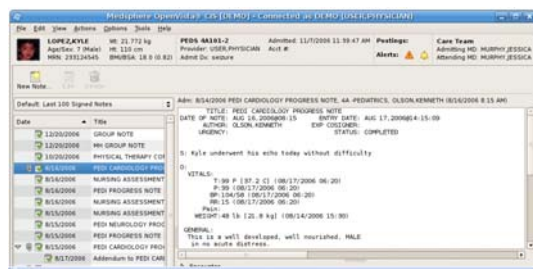
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Deputy CIO, Nursing Informatics
NIH Clinical Center

Building Safety into CPOE Systems Using Human Factors Engineering Principles

E-Cigarettes: Are they safe?



Clinical Information Systems – Are They Safe?



Clinical Information Systems – Are They Safe?



The Evidence Says CPOE is Safe

- Effects of computerized physician order entry and clinical decision support systems on medication safety; A systematic review by Kaushal, Shojania & Bates (2003)
- Error reduction in pediatric chemotherapy computerized order entry and failure modes and effects analysis by Kim, et. al. (2006)

The Evidence Says CPOE is Safe

- Medication errors: a prospective cohort study of hand-written and computerized physician order entry in the intensive care unit by Shulman, Singer, Goldstone & Bellingan (2005)
- Randomized trial to improve prescribing safety during pregnancy by Raebel et. al. (2007)

The Evidence Says CPOE is Not Safe

- Role of computerized physician order entry systems in facilitating medication errors by *Koppel, et. al. (2005)*
- Unexpected increased mortality after implementation of a commercially sold computerized physician order entry system by *Han, et. al. (2005)*

The Evidence Says CPOE is Not Safe

- Types of unintended consequences related to computerized provider order entry by *Campbell, Sittig, Ash, Guappone and Dykstra (2006)*
- Medication errors related to computerized order entry for children by *Walsh (2006)*

What is the truth?

- Critical Appraisal of the evidence - tools
 - CONSORT - Randomized controlled trials
 - QUOROM – Systematic Reviews/Meta Analysis
 - TRENDS – Non-randomized designs
 - STROBE – Observational studies
 - CHERRIES - E-Surveys

Lack of Standards

- Research methodology
- Definition of medication error
- Definition of types of medication errors
- Definition of cause of medication errors
- Definition of severity of medication errors
- Acknowledged heterogeneity of systems
- Poor generalizability

Slow Adoption – Are we surprised?

- Cost
- Complexity
- No evidence to prove that they really reduce errors

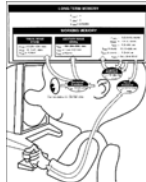
Common Theme

- Human-computer interaction issues
- Interface design/redesign needs
- Cognitive complexity of human-computer interaction
- Usability issues
- Human-machine interface flaws
- Heavy cognitive demands



Human Factors

- Term used to describe the relationship between humans and machines
- Human Factors concepts in relation to computers:
 - Human Computer Interaction (HCI)/Usability
 - Ergonomics



Human-Computer Interaction

- The study of how people design, implement, and use interactive computer systems and how these systems affect individuals, organizations and society (Myers, Hollan & Cruz, 1996).

Nursing Informatics Competency

- NI Specialists - Apply human factors and ergonomics to the design of the computer screen, location and design of devices, and design of software.
- Results of a Delphi study to determine informatics competencies for nurses at four levels of practice final master list of nursing informatics competencies© Staggers, Gassert & Curran, 2002

Human Factors - Example



Human Factors - Example



Human Factors - Example



Human Factors - Example



Safe CPOE Design?



Nielsen's Usability Heuristics

- General principles for user interface design.
- They are called "heuristics" because they are more in the nature of rules of thumb than specific usability guidelines.
- Heuristic evaluation is the most popular of the usability inspection methods.
- Heuristic evaluation is done as a systematic inspection of a user interface design for usability.
- The goal of heuristic evaluation is to find the usability problems in the design so that they can be attended to as part of an iterative design process.

Heuristic #1

- Visibility of system status** - The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.



VS



Heuristic #2

- Match between system and the real world** - The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.

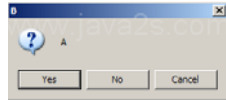


"User-Designer Mismatch"

- Users ascribe a meaning to a data label differently from what is assumed by the system designer.
- Day, Time - Example
- "Total Volume" - Example
 - Total volume to be infused?
 - Total volume for the IV bag being ordered?
- Matching of workflow processes

Heuristic #3

- **User control and freedom** - Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.



Heuristic #4

- **Consistency and standards** - Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.

Keep Order Forms Standard

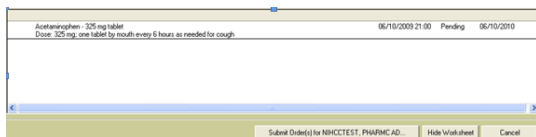
- Placement of fields
- Data labels
- Navigation tools
- Should look the same and behave the same



Heuristic #5

- **Error prevention** - Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.

Confirmation of Right Patient



Building in Safety

- FMEA studies
- **Error reduction in pediatric chemotherapy: computerized order entry and failure modes and effects analysis** by Kim, Chen & Arceci (2006)
- **A risk analysis method to evaluate the impact of a computerized provider order entry system on patient safety** by Bonnabry, et. al, (2008)

Building in Safety

Frequency: every 4 hours Default Times: 01:00, 05:00, 09:00, 13:00, 17:00, 21:00

Start Date: * Priority/Time: Stop After: * Clear

Juxtaposition Errors

PRN Reason:

- agitation *
- allergy symptoms
- anxiety
- blood glucose monitoring results
- bronchospasm
- chest pain
- congestion
- constipation
- cough
- diarrhea

Juxtaposition Errors

Current List	Case	Select All Patients	16 Views	View Selected Patients									
Patient Name	Assigned Location	Visit Type	Visit Date	Temporary Location	Provider	Check (Drop)	Flag	Check (Drop)	Miss (Drop)	New (Drop)	New (Drop)	To (Drop)	Admitting Provider
NHCCTEST_PATIENTEE A4E	CC-CADRE	Inpatient	ADM	Bratelsky, Gerri	■	■	■	■	■	■	■	■	79C-0111
NHCCTEST_PATIENTFR 222	CC-CADRE	Outpatient	ADM	Platz, Paul H	■	■	■	■	■	■	■	■	91 CC-0117
NHCCTEST_PATIENTG 555	CC-CADRE	Inpatient	ADM	Raines, Joseph J	■	■	■	■	■	■	■	■	09 DA-0437
NHCCTEST_PATIENTM NNN	CC-CADRE	Inpatient	ADM	Sameretti, Mauro	■	■	■	■	■	■	■	■	91 CC-0117
NHCCTEST_PATIENTN NNN	CC-CADRE	Inpatient	ADM	Bratelsky, Gerri	■	■	■	■	■	■	■	■	86 CC-0062
NHCCTEST_PHARMN NNN	CC-CADRE	Inpatient	ADM	Olman, Jaleel W	■	■	■	■	■	■	■	■	91 CC-0117
NHCCTEST_PHARMN NNN	CC-CADRE	Outpatient	ADM	Luenberg, Steven	■	■	■	■	■	■	■	■	90 CC-0168
NHCCTEST_PHARM ADULT	CC-CADRE	Inpatient	ADM	Luenberg, Steven	■	■	■	■	■	■	■	■	92 CC-0181
NHCCTEST_PHARM ADULT	CC-CADRE	Inpatient	ADM	Luenberg, Steven	■	■	■	■	■	■	■	■	90 CC-0168
NHCCTEST_TESTATV TEST	CC-CADRE	Inpatient	LOA	Heron, David W	■	■	■	■	■	■	■	■	95 CC-0123
NHCCTEST_TESTATV D	CC-CADRE	Outpatient	ADM	Abu-Jaoudeh, Nad	■	■	■	■	■	■	■	■	06 AT-0016
NHCCTEST_TESTATV NNN	CC-CADRE	Inpatient	ADM	Abu-Jaoudeh, Nad	■	■	■	■	■	■	■	■	92 CC-0094
NHCCTEST_TESTATV NNN	CC-CADRE	Inpatient	ADM	Abu-Jaoudeh, Nad	■	■	■	■	■	■	■	■	92 CC-0094
TEST_PATIENT LAB INPATIENT	CC-CADRE	Inpatient	ADM	Luenberg, Steven	■	■	■	■	■	■	■	■	91 CC-0117
TEST_PATIENT LAB INPATIENT 1	CC-CADRE	Inpatient	ADM	Ogborne, Frederick	■	■	■	■	■	■	■	■	91 CC-0117
TEST_PATIENT LAB OUTPATIENT	CC-CADRE	Outpatient	ADM	Luenberg, Steven	■	■	■	■	■	■	■	■	94 CC-0130

Juxtaposition Errors

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NHCCTEST_TESTATV NNN	CC-CADRE	Inpatient	ADM	Abu-Jaoudeh, Nad	■	■	■	■	■	■	■	■	92 CC-0094
NHCCTEST_TESTATV NNN	CC-CADRE	Inpatient	ADM	Abu-Jaoudeh, Nad	■	■	■	■	■	■	■	■	92 CC-0094
TEST_PATIENT LAB INPATIENT	CC-CADRE	Inpatient	ADM	Luenberg, Steven	■	■	■	■	■	■	■	■	91 CC-0117
TEST_PATIENT LAB INPATIENT 1	CC-CADRE	Inpatient	ADM	Ogborne, Frederick	■	■	■	■	■	■	■	■	91 CC-0117
TEST_PATIENT LAB OUTPATIENT	CC-CADRE	Outpatient	ADM	Luenberg, Steven	■	■	■	■	■	■	■	■	94 CC-0130

Oral Contrast Contraindicated?

Oral Contrast Contraindicated * IV Contrast Contraindicated *

Explain Contraindication, if any:

Is it OK to Administer Oral Contrast?

Is it OK to administer ORAL contrast? Yes No

Is it OK to administer IV contrast? No

Using Clinical Decision Support to Reduce Errors

- Clinical Decision Support Alerts
 - Drug – Allergy Checking
 - Drug – Drug Interaction Checking
 - Duplicate Drug Orders
 - Drug – Lab Checking
 - Display of alert at time of ordering with ability to recover

Examples from Literature

- Complete med list on one screen
- Do not display drug dosages based on pharmacy supply
- Display the calculation used for drug calcs
- Minimize information on the screen.
- Design interfaces that match workflow patterns of clinicians
- Don't force users to navigate through too many screens.

Heuristic #6

- **Recognition rather than recall** - Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.

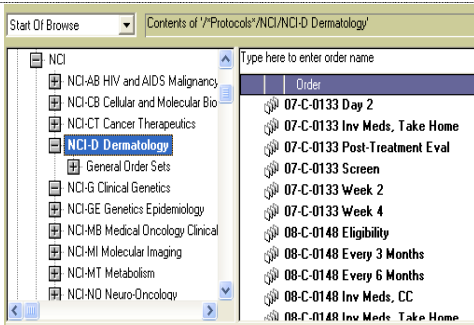
Don't Make Users Rely on Memory

- Have pertinent lab values pull into appropriate ordering screens.
 - PT/PTT/INR for Anticoagulant orders
 - BUN/Creat/eGFR for contrast orders or orders for aminoglycosides

Heuristic #7

- **Flexibility and efficiency of use** - Accelerators -- unseen by the novice user -- may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.

Efficiency of Use – Order Sets

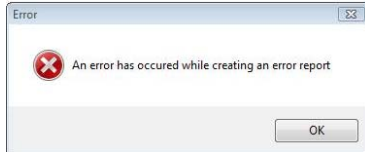


Heuristic #8

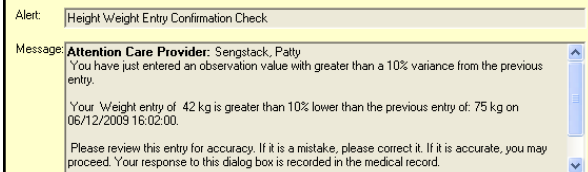
- **Aesthetic and minimalist design** - Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.
- KISS

Heuristic #9

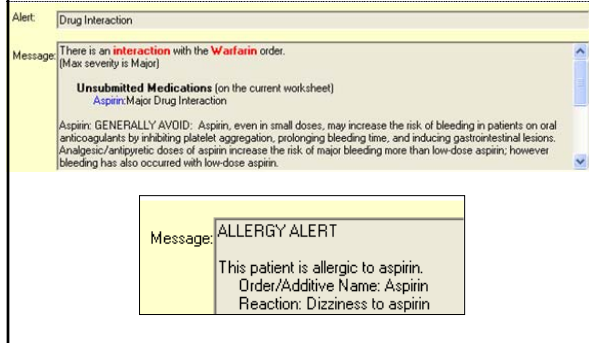
- Help users recognize, diagnose, and recover from errors - Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.



Example Error Warning



Example Error Warning



Heuristic #10

- Help and documentation - Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

How to Correct an Error 😊



What Needs To Be Done

- More research!
- Use of standard taxonomy for medication error outcomes research
- Use of similar study methodologies
- More attention to human factors engineering
- Build usability evaluation into our iterative system changes and updates

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Questions?