In recent years, academia and industry organizations have been focusing very closely on medical software’s usability. This is particularly true as regards medical error. While computers have been touted as a means to reduce error, a featured article in the Journal of the American Medical Association showed how poor design of a CPOE (computer-based practitioner order entry) system at the University of Pennsylvania caused many medical errors. In general, the software development world has seen an upsurge in applied usability, referencing the work of academics and industry experts such as Alan Cooper, Jakob Nielsen, Donald Norman, and Edward Tufte.

First, we lay out the specific literature on information design, and the related domain of user interaction design (usability, human factors, user interface design, process design),

Wikipedia says Information Design is the art and science of preparing information so that it can be used by human beings with efficiency and effectiveness. It goes on to say the term has come to be used specifically for graphic design that has the purpose of displaying information effectively, rather than just attractively, or for the purpose of self expression by the designer as artist.

Action-Oriented Information Design is information design that drives actions, such as the care of a stroke patient or MI patient in the ED or a patient in a National Disaster Medical System (NDMS) Disaster Medical Assistance Team (DMAT) field hospital. It aims to decrease error, to remind us to do those things that we know to do but might forget, and to improve compliance with established guidelines, while not forcing us into rigid protocols. Action-oriented information design also tries to educate us about optimal ways to perform as we move through our daily tasks.

If this sounds like the goal of standing orders for common medical conditions, there is a strong correlation. Those who are writing standing orders are, know it or not, practicing action-oriented information design.
Many information design principles evolved long before personal computers or the World Wide Web. A few examples follow. These have been used in the analysis that follows and constitute a basic reading-list for information design practitioners (or critics):

- the layout of type on a printed page or a computer screen, discussed in Bringhurst’s seminal *Elements of Typographic Style* (Figs. 1-2).3

- the layout used in *graphic design*; a computer-oriented presentation may be found in the Sun textbook, *Designing Visual Interfaces* (Fig. 3).4

- the science and art of color, found most accessibly in Itten’s books (Fig 4).5,6

- the art and science of presenting scientific and other data in comprehensible form, which finds its most profound expression in the published works of Yale’s Edward Tufte (Fig. 5).7,8,9,10

- forms design; those with deep pockets and much money at risk (national tax agencies, large insurance companies) have funded research into forms design that has saved them billions of dollars in improved usability, and these usability pearls are found in Barnett’s focused and knowledgeable book *Forms for People*11

- more specifically, the EMR “tracking board” can be classed as an information dashboard; though it differs from a typical business dashboard, still much can be learned from works such as Few’s outstanding *Information Dashboard Design* (Fig. 18).12

### Usability and Performance

In his college textbook, *Usability Engineering* (Fig. 6),13 guru Jakob Nielsen (useit.com) lays out a branching diagram for software suitability analysis (Fig. 7). The right side lists the components of usability. In the clinical setting – when we are sleep-deprived and frequently interrupted with urgent concerns, particularly in the emergency department (ED) – usability becomes even more important.14,15 The ED is quite analogous to a DMAT deployment – usability becomes a much bigger concern, not only from the viewpoint of

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user acceptance, but as a means to prevent medical error.

We also learn from Nielsen about system performance (Fig. 8). If you are an average computer user, once you click something on the screen, you will wait for one (1) second before turning to something else. In a busy clinical setting (Fig. 9), we can reasonably suspect that you won’t wait nearly so long. Once you turn to something else, your train of thought is derailed, which provides an opening for cognitive error. The role of such distraction in fomenting error is well-documented, and James Reason’s book *Human Error* serves as an essential reference to this well-recognized scientific discipline (Fig. 10).

**ANALYSIS TECHNIQUES**

Design is art and intuition. Usability analysis is sanding. Alan Cooper says: To me, usability methods seem like sandpaper. If you are making a chair, the sandpaper can make it smoother. If you are making a table, the sandpaper can also make it smoother. But no amount of sanding will turn a table into a chair. Yet I see thousands of well-intentioned people diligently sanding away at their tables with usability methods, trying to make chairs. Nonetheless, we will look at a few engineering principles and heuristics that we can use to analyze and improve a design.

Using a phrase and concept originated by Edward Tufte, we can analyze the ink on a

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17. Cooper A. The inmates are running the asylum. Indianapolis, IN: Sams; 1999.
piece of paper – or the pixels on a computer screen – in terms of data ink and data pixels. How many pixels actually convey needed data? How many don’t convey data? What is the ratio?

In Nielsen and Tahir’s *Homepage Usability* (Fig. 11)\(^\text{18}\), they analyze 50 representative home pages, including some of the most well-known, in terms including data-pixel ratios. While they break down the screen real estate into multiple categories, for our use here – which is primarily a usability assessment – the main division is Tufte’s classic data pixels vs. non-data pixels, related specifically to the clinician’s task at hand (Fig 12).

A classic example is the display of lab values. Clinicians – and focusing now on emergency physicians as the some of the most narrowly task-focused people around – want to have the essential data in front of them right away. For example, when taking a quick look at a CBC, they aren’t interested in the MCV, MCHC, or a variety of other information beyond the basic WBC, Hg, Hct, and platelet counts. If they want more information, for example the differential, they are happy to click on something to find this out.

Indeed, a good general principle for medical software is to design for the ED as a worst-case scenario. If the system works there, it will likely work anywhere. Quoting from a recent presentation Dr. Conover gave for HIMSS\(^\text{19}\): Emergency physicians are majorly stressed and working at max capacity already.

**Darwinian selection means that ED staff (this is from the Critical Incident Stress Management literature):**

- have obsessive/compulsive personality traits
- like to be in control
- are risk oriented
- are action-oriented
- “need to be needed”
- are dedicated

Thus, those in the ED are intolerant of systems that waste their time. (Look at Fig. 9 again; note the number of users of the handwritten whiteboard vs. the computer-based one.) This is why IT traditionally hates the ED, and why IT projects fail in the ED more frequently than in other units. Nonetheless, striving to make things work in the ED is a path to success throughout the hospital.

And, if we’re looking for an analogy for the work environment of a DMAT field hospital, whether dealing with acute or chronic patients,
it is – in terms of interruptions,\textsuperscript{20,21} information overload, and stressed, tired users – much more like a busy ED than an ambulatory care or inpatient setting.

Figure 13 shows a laboratory data display from one install of the leading niche “best-of-breed” ED information system (KLAS\textsuperscript{22} overall rating of 8.24). This is the output from the laboratory system, available as a more-or-less unparsed data feed. (ED information systems can provide better-formatted lab data, provided they are provided the proper data feed to parse.)

If we mask those pixels that are not directly related to our needs – seeing the basic CBC results (Fig. 14) – we see data scattered about the page, buried in a mass of data irrelevant to the current task (seeing the basic CBC).

Compare with the dashboard design by Dr. Larry Nathanson of Harvard’s Beth Israel-Deaconess Medical Center (Fig 15). In the Beth Israel example, the lab values are grouped together, so that we don’t have to scan through haystacks of data to find the few needles of data they need.\textsuperscript{23}

The remainder of the screen also shows information that is relevant to the acute-care clinician, compared to the more detailed laboratory report from the leading EDIS, which nonetheless has fewer data pixels related to the clinician’s needs. Those with a programming background may see parallels with the object-oriented programming concepts of data-hiding and encapsulation.

\textsuperscript{20} Chisholm CD, Collison EK, Nelson DR, Cordell WH. Emergency department workplace interruptions: are emergency physicians “interrupt-driven” and “multitasking”? Acad Emerg Med 2000;7:1239-43.


\textsuperscript{22} www.klasresearch.com, a leading healthcare software rating organization

\textsuperscript{23} We know that central (foveal) vision subtends an angle of only six degrees – for the author’s 21” monitor at his usual viewing distance of 27”, this means that he can only read in a 2.5” circle on the screen. To find information outside this circle, we must scan the screen – slowing us down and inviting error. As surprising as it seems, our vision is a veritable blur outside the 6 degree foveal circle. Of interest, peripheral vision is also color-blind, but very good at picking up motion, so movement is better than color or shape to indicate an urgent on-screen message.
Realtors speak of “location, location, location” and this is true of the computer screen as well. Western viewers tend to read the screen in a predictable fashion, giving pride of place to things displayed in the upper left or the center of the screen. Figure 16, from the previously-mentioned Information Dashboard Design, illustrates this. A simple heuristic is to inspect program screens to see if critical information gets the best place, or if those places are reserved for corporate logos or artwork.

Finally – and getting a bit theoretical – we can delve into cognitive psychology to see what we can learn about screen design. There is no better place to start than Colin Ware’s scholarly yet practical text, Information Visualization (Fig. 17).24

A briefer and more accessible source of the relevant information is found in Few’s previously-mentioned Information Dashboard Design (Fig. 18), where he presents a précis of the most relevant points of Ware’s text. The following excerpt gives the flavor of Few’s presentation:

Preattentive processing, the early stage of visual perception that rapidly occurs below the level of consciousness, is tuned to detect a specific set of visual attributes. Attentive processing is sequential, and therefore much slower.

The difference is easy to demonstrate. Take a moment to examine the four rows of numbers in Figure 4-1 [our Fig. 19, and try to determine as quickly as you can the number of times the number 5 appears in the list.

How many did you find? The correct answer is six. Whether you got the answer right or not, the process took you a while because it involved attentive processing. The list of numbers did not exhibit any preattentive attributes that you could use to distinguish the fives from the other numbers. Now try it again, this time using the list of numbers in Figure 4-2 [our figure 20].

Much easier this time, wasn’t it? In this figure the fives could easily be distinguished from the other numbers, due to their differing color intensity (one of the preattentive attributes we’ll discuss below): the fives are black while all the other numbers are gray, which causes them to stand out in clear contrast. Why couldn’t we easily distinguish the fives in the first set of numbers (Figure 4-1 [our figure 19]) based purely on their unique shape? Because the complex shapes of the numbers are not attributes that we perceive preattentively. Simple shapes such as circles and squares are preattentively perceived, but the shapes of numbers are too elaborate.

In Information Dashboard Design, Few notes several attributes that can be processed preattentively, as shown in Figures 22-26. A clever designer could, for example, use a combination of these specific elements to preattentively highlight out-of-bounds and panic levels of lab tests. In applications where we have trouble remembering graphical icons, icons could be replaced with symbols designed using these preattentive attributes.

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Figure 22. Preattentive Attributes

Figure 23. Additional Preattentive Attributes

Figure 24. Additional Preattentive Attributes

Figure 25. Additional Preattentive Attributes

Figure 26. Preattentive Attributes and Quantity
Some are of particular interest to the previously-mentioned action-oriented information design, particularly standing orders and computer-based practitioner order entry (CPOE). There are sections relevant to the display of data, too.

To separate entries in data tables, as seen in list of patients in the EMR Patient Dashboard, Barnett recommends the use of dotted lines; Tufte also argues for de-emphasizing lines (non-data pixels) by gray tint; and Barnett suggests that the best is to tint alternate lines with bars of faint gray (for printed forms, as seen in the example from the UPMC Mercy DEM MI orders dosing for Integrilin, Figure 21) or a pastel color, as seen in financial programs such as Quicken. Adding pastel bars behind alternate entries in the Patient Dashboard would improve readability.

Another suggestion, from both from Barnett and Nielsen – de-emphasize everything except things directly relevant to the task at hand. There may be requirements for certain logos or boilerplate text on a page, but, by decreasing contrast and color saturation of such “non-data pixels,” this allows us to focus on critical data on the screen. The examples of the UPMC Mercy MI floor orders (Fig. 27) and ED MI orders in a new format (Fig. 28), based on information design principles – such as having checkboxes and text right-justified (decreases error) also show the de-emphasis of non-critical elements to avoid “sign pollution” (Fig. 29).

This is an area in which the design of the EMR excels – there is no applied ornamentation, and screens are clear of superfluous graphic elements.

FORMS DESIGN

The previously-mentioned *Forms for People* is full of useful evidence – some applicable to paper forms, some to computer-based input forms.
**DISCOUNT USABILITY TESTING**

Jakob Nielsen (useit.com) promotes the idea of “discount usability testing” – usability testing that doesn’t require expensive usability labs and a large staff of usability experts. He recommends a simple method that others call the “anthropological field survey” method. We simply sit behind a naïve user with a notebook, observing the user attempting to accomplish common tasks using the program. We ask the user to describe what he or she is doing or thinking, but not to ask questions about how the program works, or how to accomplish a task. We note how the user interacts with the program, when and where the program prevents the user from accomplishing the task, and the efficiency of the process. There are standard checklists for what to watch for, posted at useit.com. This method was used at College Station to analyze the NDMS EMR in actual use.

**NDMS EMR ANALYSIS AND RECOMMENDATIONS**

**OVERVIEW**

With only a brief chance to use the NDMS EMR (Fig. 30) in actual practice, this was not a full-scale user-interaction analysis. However, it was an opportunity to have someone with user-interaction expertise, working with others with domain expertise, do a brief usability study. As a result of this we present several recommendations that should allow major improvements in the EMR, in many cases with minimal recoding.

It should be noted that those providing input to this analysis (multiple members of the clinical staff at the Federal Medical Station set up at College Station, TX for Hurricane Gustav) were emphatic in their insistence that, though portions of the EMR were usable, other portions were very difficult to use, or ineffective. Those using the system, and those studying those using the system, had a general consensus of the following.

- If a single user is using a single laptop, then registration, triage, vital signs and history and physical, take about 3 to 5 times as much of clinician’s time as using a paper record, but are usable as is.

The consensus was that there needs to be a significant recoding before the system can be used widely without creating a major impact on efficiency and morale.

**MANY USERS, FEW LAPTOPS**

One major issue noted by users was that there are many more users than laptops. This means that users must log in or log out frequently, which slows the process down quite a bit. It also provides many opportunities for error as users tend to turn away from a laptop for a few minutes, then turn back to it, only to find out that someone else had been using it in the interim. As a break in workflow, this is an invitation to medical error. It also seems likely to result in invalid data, as users – either accidentally, or simply to avoid a log-out and log-in – enter data under someone else’s logon.

It would be possible to run multiple instances of the EMR on a single laptop, but when we try to do this, it is difficult to tell at a glance which instance belongs to which user: the user name in the header bar does not stand out from the background, nor are there any preattentive signals next to the user’s name. Nor is it easy to switch between users.

It takes up valuable screen real-estate, and would need to be tested, but we could have multiple “instances” within the application itself, and an always-visible bar with current logged-in users. We could then push a radio button at...
the bottom to return to our place in the EMR application, and continue working where we left off. Look at the screenshot of the Allergies section of the EMR (Fig. 31), and the modified version with the addition of a user panel at the bottom (Fig. 32). This is just a rough mockup using Photoshop, and is an inefficient use of screen real estate, but gives some idea of what such a functionality might look like.

TO SAVE OR NOT TO SAVE?
A standard paradigm for computer database entry is to fill in form fields on a screen, review the screen for correctness, then press SAVE (Fig. 33). However, many modern programs that are not primarily data-entry applications – take Microsoft Outlook or Quicken for examples – save data as it is entered. There is no need to press SAVE. Indeed, in his seminal book *About Face: Essentials of User Interface Design*, Alan Cooper points out this need to tell the computer to save your data is an outdated relic of early computer systems and has no place in modern software design. The presence of Save and Continue within the EMR suggests it is designed for database-entry clerks and not busy clinicians, who may be called away or distracted at any second. The EMR should save data as entered. In accordance with Cooper’s recommendations, the EMR should, instead of a SAVE button, offer a multiple-level undo/redo function, similar to that in Microsoft Word, available on all data-entry screens.

PARALLEL PROCESSING
When web-based stores such as amazon.com first started, they invested much time and money in making it easy to buy things from them. One thing they learned is that users got confused about where they “were” in the purchasing process as they moved through screen after screen. Dot-coms adopted methods that gave us a geographic sense of moving through a linear process, and this became common on many websites. The registration > triage > treatment > discharge sequence line shown in the EMR is an adaptation of this method to provide a sense of geographic situational awareness (Fig. 34).

While this linear geographic metaphor is excellent in its place – linear website purchasing or similar data entry tasks – it is ill-suited to the work processes in an ED or a DMAT tent-hospital. Indeed, one of the recent great advances in improving ED throughput is to change the ED process from a serial one (first A, then B, then C, then D) to parallel processing, where A and B and C and D all go on simultaneously. One of the terms associated with this is bedside registration, which captures at least part of the idea of parallel processing. EDs used to have a serial registra-
tion > triage > treatment > discharge workflow for all but the most critical patients, who were brought back to a room right away. But in an era of crowded EDs looking for efficiency, and taking lessons from industrial process management, things have changed. (Those interested may read about maverick Toyota engineer Taiichi Ohno, lean production, short feedback loops, and other modern industrial advances in *The machine that changed the world: how Japan’s secret weapon in the global auto wars will revolutionize western industry.*\textsuperscript{25} Fig. 36.) Today, if a bed is available, and a patient presents, the patient is brought back to the bed right away. A nurse, or doctor, or registration clerk, or indeed anyone can then enter some basic information in the EMR – name and age and chief complaint – just enough to get started. Then, whoever is available first – doctor, nurse, registration, medic – comes to the patient in the room and starts doing his or her thing. This has resulted in striking increases in efficiency when it is used.

To accommodate this type of parallel workflow, the EMR should be modified to get away from a linear model and employ more of a parallel model. It’s not possible to provide any one simple fix to make this happen; it requires careful redesign of many screens. However, there are metaphors (e.g., color, shape, typface, preattentive-recognition icons) than can provide us with a sense of geographic orientation in a parallel-processing EMR system. One is the *breadcrumb trail*, as seen in the screenshot from amazon.com’s “my account” pages (Fig. 36). While this may look like the linear process shown in Fig. 34, it instead shows one’s position in a branching, treelike hierarchical structure rather than a position along a linear process.

**REGISTRATION**

To find something using the Google search engine, or a location using Google Maps, or to find patient from Cerner Millenium FirstNet\textsuperscript{26}, we must simply type, in a single search box, either “Lastname, Firstname” or “Firstname Lastname.” Then, we are presented with a list of matches, with information such as SSN and birthdate, that we can use to identify the correct patient. Simple. Elegant. (One of the better features of FirstNet, which sadly lags behind the market leaders in many other forms of usability.) The ease, efficiency and popularity of searching from a single search box and then picking from a list of choices has not only made Google one of the richest companies in the world, but is now the expectation of the public. And, as Donald Norman notes in his bestselling book *The Design of Everyday Things*\textsuperscript{27} (Fig. 37), we need to follow standards, even if we don’t entirely agree with them. Otherwise, people will try to apply their standard computer habits and there will be usability problems when they don’t work.

If we are trying to find a patient in the existing EMR, we have to type in the patient’s last name (Fig. 38). And then, to enter a first name, switch to another field, either tabbing – provided we know about tabbing between fields, which studies show is a poor expectation – or having to click on the second field with


\textsuperscript{26} A fairly common ED IS, linked to the Cerner hospital-wide information system.

a finger or
the mouse,
which slows
us down.

As we’ve
learned from
Google, it’s
more efficient
to simply let
us (especially
those who are
two-finger
typists) type the information into a single field
and then let us choose the best search result.

LOOKUP BY TYPING;
SWITCHING MODES

When entering list items such as medica-
tions or allergies in the EMR, we must start
typing, then move our eyes from the search box
to another box (losing efficiency),
then click
on the item,
then click on
an arrow to
“move” this
from the pick
list to the list
of medica-
tions. In us-
ability terms,
this process
has a very high cognitive friction. It takes us a
while to get through it, and demands more at-
tention than is really needed. (And, in a busy and
chaotic ED or DMAT field hospital, our attention
is a scarce resource that, to prevent medical error,
program designers must religiously conserve.)

And, as we’ve learned from Google and
particularly the “Awesome Bar” in the new 3.0
version of the FireFox browser, auto-complete is
very powerful. Allowing us to type into a search
box, offering greyed text beyond the cursor with
the most likely match that can be confirmed with
the Enter key, or a dropdown box of other pos-
sibilities that can be chosen with the arrow keys
+ Enter or the mouse, is a very fast and effective
way to choose items. The EMR should offer an
auto-complete feature similar to the FireFox 3
Search Bar (Fig. 40) and “Awesome Bar” (Fig. 41)
and, with a more detailed structured lookup page
as a usually-hidden last resort.

Typing is an input mode. Using the mouse is
an input mode. Using a touchscreen is an input
mode. Each mode is a bit different – it’s hard to
draw pictures with the keyboard, but not that
hard with a mouse; it’s hard to enter text with a
mouse, or even a touchscreen, but a keyboard al-

But from a user interaction standpoint, we
must also look at mode transitions. Every time we
have to switch from mouse to keyboard, or from
keyboard touchscreen, we have to slow down.
And, we are distracted from the task at hand by
the mode-switch, so mode switches are an invita-
tion to error. In user interaction terms, mode
switches induce cognitive friction. Applications
such as the EMR should be carefully surveyed, by
watching actual users at work, to detect when we
feel compelled to switch modes, and those cogni-
tive “rough spots” should be smoothed over. For
example, once we are typing on a keyboard, we
should be allowed – and, given how many people have at least basic touch-typing skills these days, even encouraged – to continue using the keyboard. We should see visual affordance (visual hints) that we can continue to use the keyboard – for example fields prominently highlighted when they are active, and offering non-intrusive suggestions to use the tab or arrow key between fields, such as a small arrow just outside the bottom border of the text box (Fig. 42).

We should be able to accomplish common tasks without changing input modes. We should be able to move through their tasks using fingers on a touchscreen, typing on a keyboard, or using the mouse, without ever being forced (even if just by ignorance of the tab key to switch fields) to switch modes. “Discount usability testing,” described earlier, can be used to observe this in action and identify points where the system should be changed to prevent us from feeling the need to switch modes.

**TRIAGE**

Driven by the Department of Health and Human Services, a new triage system is taking hold in EDs across the country. Called ESI (emergency severity index), it has been found both easy and effective. This is not triage in the multi-casualty in-the-field sense, but is a system for triaging patients arriving at a medical facility in terms of how urgently they need to be seen – something very appropriate to many DMAT operations. Currently at Version 4, the ESI system has been refined over the years and is now a mature system supported by the medical literature. The AHRQ ESI Implementation Handbook is available at http://www.ahrq.gov/research/esi/.

As more and more EDs move to using the Federally-recommended ESI system, those with the DMAT at College Station felt that the Federal EMR system should support this system as well. AHRQ provides excellent ESI educational materials that could easily be used for training PHS and NDMS personnel.

Especially if we have a “DMAT in the parking lot” working in concert with one of the many hospital EDs using the ESI, we should have at least an option to use the same triage system as they do, else our interoperability will suffer.

**CLEVER VITAL SIGNS**

A subtle but clever and effective design in the Vital Signs portion of the Triage screen is that the finger-touch buttons for the various vital signs then populate with the actual vital signs once they are entered. Those who designed and coded this deserve kudos for such a clever and effective design. It keeps tight integration between data entry and data display, allowing fairly dense data display despite the constraints of a touchscreen display.

**ORDER ENTRY/FULFILLMENT**

One of the chief complaints at Texas A&M regarded the ordering of medications. The pharmacists complained that they couldn’t tell when there was an order on the system. They would have to go to the laptop, scroll down to the bottom of a list of orders, and manually inspect for possible new orders. Suggestions:

- Allow (but do not require) an audible signal when a new order arrives.
- Have new orders appear at the top of a list that is nearly always visible.
Use preattentive signals, preferably multiple of them (see above) to differentiate new orders from old, fulfilled orders.

Pharmacists also complained that, even though they were able to contact pharmacies to clarify patient’s existing medications, they did not have permissions to enter this information based on their logins. This should be easy to fix.

From “discount usability testing” done during the Hurricane Gustav deployment, the order entry screen was a major stumbling block for us. It is difficult to offer specific redesign advice. However, we might keep in mind Alan Cooper’s dictum: popping up a dialog box is equivalent to walking through a door into another room – only require us to do this if there is no reasonable alternative. A redesign should require fewer clicks/touches/keystrokes and fewer dialog boxes, high-light relevant elements and de-emphasize less-relevant items. It should have a more “intuitive” design that strongly reflects clinicians’ underlying mental model of order-entry.

One feature that confounded all of us was the ordering buttons labeled “New” “Complete” and “Evaluate” – which didn’t correspond with our mental models of the usual order entry process. We were very uncertain as to what these buttons actually meant or did. This was universal. Thus, this requires a design change rather than user education.

That these words made sense to the coders but not to us is not entirely unexpected. In the first edition of About Face,28 one of the first usability texts, Cooper speaks of the difference between the coder’s mental model of the program (“implementation model”) and the user’s mental model (Figure 45). One of the jobs of a designer is to help users create a simple and effective mental model of the program’s functions. Perhaps New/Complete/Evaluate is too close to the implementation model and not close enough to our mental models of the medical ordering process.

In his early book Tog on Interface,29 (Fig. 46) Bruce Tognazzini, the first Apple User Interface Evangelist (his official title at Apple Computer) discusses what has come be known as Tognazzini’s Paradox: sometimes the simplest elements of the user interface, often simply the wording, can be the biggest design problem, and paradoxically consume more time and effort than other, seemingly-more-important elements of the interface. He describes his discovery thus:

I experienced my most pathological example of Tognazzini’s paradox while Dave Eisenberg and I were working on “Apple Presents ... Apple” back in 1979, the first time an in-box tutorial had been written for a micro. We had earmarked certain sections of the program as being hopelessly difficult, while others were hardly worth testing. Test subjects found most of the “hopelessly difficult” sections perfectly easy, while the one area

we knew would have no problems at all proved fantastically difficult:

**Problem:** In “Apple Presents ... Apple, An Introduction to the Apple II Plus Computer,” find out if the user is working with a color monitor.

**User profiles:** New owner, customer in a computer store, or member of a class learning to use Apple computers.

**Test user profiles:** Customers in a computer store, non-computerists in a classroom environment, friends, and relatives.

**First design:** A color graphic would be displayed.

**PROMPT:** “Are you using a color TV on the Apple?”

**ANTICIPATED PROBLEM:** Those who were using a monochrome monitor in a classroom or computer store situation wouldn’t know whether the monitor was black and white or was color with the color turned off. We reiterated the design.

**Second iteration:** A color graphic was displayed.

**PROMPT:** “Is the picture above in color?”

**FAILURE RATE:** 25%

**REASON:** As anticipated, but incorrectly overcome, those seeing black and white thought their color might be turned down. They didn’t answer the question wrong; they turned around and asked one of the authors whether the monitor in question was color or not. A decision was made that the authors could not be shipped with each disk.

**Third iteration:** A smaller graphic with color names, each in its own vivid color was substituted:

GREEN BLUE ORANGE MAGENTA

**PROMPT:** Are the words above in color?”

**FAILURE RATE:**

- color TV users: none
- black and white monitor users: 20%
- green-screen monitor users: 50%

**REASONS:** The black and white monitor users who answered incorrectly admitted that they did so on purpose. (Our methods for wringing their confessions shall remain proprietary.) 50% of the green-screen folk considered that they were looking at both black and green-two colors—and answered the question accordingly.

**Fifth iteration:** Same display of graphic and colored text

**PROMPT:** “Are the words above in several different colors?”

**FAILURE RATE:**

- color TV users: none
- black and white monitor users: 20%
- green-screen monitor users: 25%

**REASONS:** By this time, the authors were prepared to supply everyone who bought an Apple...
II with a free color monitor, just so we would not have to ask the question. It turns out that around 20% of the people were not really reading the question. They were responding to the question “Are the words above several different colors?”

Sixth iteration:

Same display of graphic and colored text

PROMPT: “Do the words above appear in several different colors?”

FAILURE RATE: none

This was a highly interactive tutorial typically taking twenty minutes to complete. This was the only interface issue that required more than one iteration to correct. No matter how many engineers we had crowded into a room to discuss with what areas users were or were not going to have trouble, we would have never hit upon this as the major problem in the application. Had we not tested, we would have had a disaster on our hands: Instead of users having a wonderful first experience, they would have walked away thinking both they and our computer were awfully stupid.

“New/Complete/Evaluate” may be an example of Tognazzini’s Paradox. Rather than using Tognazzini’s testing methods, however, one could use the Nielsen “discount usability testing” described above to more rapidly hone in on an appropriate set of words. Recommend modeling after existing niche ED Information Systems’ order entry functions. Note also that “users” in this case are clinicians and not unit secretaries used to detailed order entry screens on hospital information systems. “New Order” “Order Completed” and “Results Reviewed” might work but again this must be tested.

DISCHARGE INSTRUCTIONS

Clinicians rightly believe that proper care by a DMAT includes providing high-quality, clinically-relevant discharge instructions. Indeed, among EDs, the most prevalent form of IS system is a discharge instruction package. There is evidence that good discharge (good in quality of information, specificity of information instructions for the patient’s condition, and readability, for instance, compliance with EasyRead) improves patient compliance and understanding and likely their medical conditions. Although only about 30% of EDs have a comprehensive ED IS system, probably over 50% have some sort of electronic discharge instructions. Leading providers of high-quality discharge instructions have editorial boards that constantly review and update their instructions, and may contract to provide these instructions to be used in other systems. These instructions include a great variety of conditions - hundreds of them - and both support and supplement verbal discharge instructions. Having pre-written instructions also allows providers to be much more efficient. Simply printing the instructions for, say, myoclonus, and having an EMT review the written instructions for the patient, saves the clinician a great deal of time.

Such a capability should be included in the EMR, and it should be a comprehensive package with a large number of high-quality instructions.

GRACEFUL FAILURE

At the 2007 International Symposium on ED Information Systems in New Orleans, Dr. Keith Conover (this paper’s author) and Dr. James Aiken (Chair of the Charity Hospital ED during Hurricane Katrina) moderated a discussion forum on the role of healthcare IT in disaster. Participants included academics, leading healthcare IT vendors, hospital and DMAT staff members, even some from foreign equivalents of DMATs. A strong consensus was developed on the following points.

35. e.g., Logicare, ExitCare, ExitWriter
• Healthcare IT systems do fail for mechanical reasons during disasters, but more common are general system failure due to workflow overload.

• When faced with too few staff and too many patients, staff have to choose between treating patients or charting – and treating patients always wins. Electronic systems that are inflexibly demanding of our time are suddenly and completely abandoned.

• Systems used for tracking and charting should allow graceful degradation during a disaster.

When the press of patients starts to overwhelm staff, they push the “Disaster Mode 1” button on the computer screen. This then strips the workflow of less-essential elements. For example, ED nurses can now skip “screening” and charting for domestic violence and immunization status, and there is no need to enter ICD-9 codes, though if information is directly relevant to the chief complaint, it can be included.

The “Disaster Mode 1” button-press also tags patient records as being done during a disaster, to validate that the lack of information is due to situation-appropriate degradation.

When things get worse, the “Disaster Mode 2” button strips the system down even more: for example, we no longer need to obtain a complete medication list.

When things get even more out-of-control, the “Disaster Mode 3” button strips the requirements down to essentials: name, chief complaint, a bit of clinical information, diagnosis and a bit of the care rendered. In any Disaster Mode we may, if we wish, add additional information to any record.

The disaster modes require progressively less and less information, allowing us to take shortcuts and still continue using the system, at least a bit, rather than being forced to abandon it entirely. In other words the system bends rather than breaking: it’s not brittle.

Once the patient flow diminishes, and more staff is available, the system can gradually ramp back up to normal operations mode.

A labor relations observation may inform this EMR “disaster mode” concept. When teamsters or air-traffic controllers cannot strike, but want to stage a work slowdown, they follow the rules. All the rules. Truckers come to a complete stop at all stop signs; they obey all speed limits. Air traffic controllers follow every rule in the (very big) book. Result? The systems grind to a halt.

In daily life, when we get hurried, we take little shortcuts. We’re very good at deciding which shortcuts to take when.

When we have washed our car, and we go to move it from in front of the garage into the garage (a distance of what? maybe 20 feet?), do we put on the seatbelt? Or do we just ignore the car’s “ding-ding-ding” and pull the car into the garage? A quick (and usually unconscious) judgment – comparing the miniscule time and effort to put on the seatbelt, vs. the even more miniscule risk of not wearing a seatbelt – may lead us to skip the seatbelt.

We may feel a bit guilty – is this a bad example for the kids? am I going to form a bad habit? – but most people (at least in an informal survey) will skip the seatbelt. This is discussed in more detail in Donald Norman’s 1998 book *The invisible computer: Why good products can fail, the personal computer is so complex, and information appliances are the solution.*

So, a “one-size-fits-all” EMR, one that doesn’t understand disaster modes, one that demands that we gather epidemiologic data no matter however overwhelmed with patients we are, and doesn’t allow shortcuts when things get busy – well, such a system will fail.

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36. Norman DA. *The invisible computer: Why good products can fail, the personal computer is so complex, and information appliances are the solution.* Cambridge, Mass.: MIT Press; 1998.

37. A personal note: during Katrina, a strike team was faced with so many patients that their records, such as they were, consisted of a piece of blank paper on a clipboard, with one line for each patient.
Overwhelmed medical personnel can't continue to use an EMR when we have to, metaphorically, stop at all the stoplights, drive under the speed limit, and follow every rule in the book.

The EMR needs to be supple and flexible, not brittle. When subjected to stress, it must bend, not break.

**SUMMARY**

Overall, the EMR is a good first try. It avoids many egregious user-interaction errors found in many current production EMR systems. The EMR already has many feature of which usability dweebs would approve - such as the use of the touch-screen, the lack of applied ornamentation, and in particular the Vital Signs input/display.

Specific recommendations:

- Go through all the screens of the program, increase data pixels, decrease non-data pixels, and de-emphasize non-data pixels with decreased contrast and saturation.
- Go through all the screens, to see where we may encapsulate data (e.g., date, source, medication orders that are the same, subsidiary data from CBC) so as to fit more relevant data on each screen.
- Get rid of all of the SAVE buttons and replace them with multi-level UNDO and REDO buttons. Save all data as it is entered.
- Replace the underlying serial-processing workflow model with a parallel-processing model, where registration and triage and nurse assessment and physician/CRNP/PA assessment occur in parallel. Implement as follows:
  - Replace the existing linear visual geographic metaphor with other geographic metaphors, including but not limited to a breadcrumb trail, and distinctive, preattentively-processed color/icon combinations for different areas of the EMR system.
- Allow multiple simultaneous users on a single laptop, similar to what is shown in Figure 32.
- Improve patient lookup, as with Cerner – a single search bar which will accept “firstname lastname” or “lastname, firstname” or simply “lastname” and then present the user with a pick list with other identifying information from which to choose.
- Improve lookup within medications, allergies and other similar listboxes, offering an intelligent autocomplete feature that not only allows standard autocomplete but offers a dropdown box of the most common selected matching options, as with FireFox 3.
- Implement the ESI as an alternative triage method.
- Redesign the order-entry and fulfilment functions to take advantage of preattentive processing. Reorganize the order-entry screen to match closely with clinician-user’s existing mental models of the ordering process.
- Contract with one of the providers of high-quality ED discharge instructions to provide this capability within the EMR.
- Provide multiple “disaster modes” for when the press of patients is overwhelming.

One would hope that, after changes made based on these and other observations, additional “discount usability testing” as described by Nielsen could be performed. We would hope that, eventually, this EMR could pass the most stringent of real-world usability tests: the “sleep-deprived intern” test. Start with an intern who was on call last night, and who has never used the system. Sit the intern down in front of the system, give 30-60 seconds of instruction, and see if the intern can use the system effectively. While this may sound facetious, it truly is the best test of a system, and some systems used in EDs (e.g., the original DOS-based Logicare Checkout discharge instruction system) have passed this test.

When teaching about past medical information system failures (which are, in fact, quite...
Once upon a time, a large HIS (hospital information system) vendor sold a hospital a charting system for cardiologists to use in charting cardiac catheterizations. One of the physicians employed by the HIS vendor was a cardiologist. He visited the hospital to see how the cardiologists were doing with the charting application.

Much to his surprise, the hospital’s cardiologists were up in arms about the product – they said it was so klunky as to be unusable. They said that, if they were to use the charting program for all of their caths, they’d have to stay an extra 1-2 hours at the end of each day just to complete the cath reports.

The cardiologist who worked for the HIS vendor went to his boss, a vice-president of the company, and told him of the problem, saying “We have to do something for these guys! The product is basically unworkable.”

The VP stared at him coldly for a minute. Then the VP said “those aren’t our customers.” (Meaning that the customers were not the end-users like cardiologists, but the Chief Information Officers and others who actually made purchase decisions.)

This informs the observation made by some of the users of the EMR during the Hurricane Gustav deployment. “It’s not a bad system, but it needs to be more usable. If we’re inundated with patients, and I have a choice of spending a couple of hours at the end of the shift completing EMR entries, or sleeping a few hours so I can get ready to see patients again, I know which I’ll choose!”

This paper was created based on observations by many of the clinical staff of the RI-1 DMAT and backfill personnel from other DMATs, who deserve credit for their willingness to use the EMR and spend time and effort offering constructive and detailed criticism. Any errors in representing their views are due entirely to the author of this paper.

Thanks to the NDMS for the opportunity to work with, and the invitation to comment on, this exciting new system. It was the hope of all working with the NDMS EMR that it will continue to develop and become a valuable and treasured resource for NDMS.