Complementing Medical Device Alarms with Animated Guidance

Michael Wiklund and Jonathan Kendler

Caregivers cite medical device alarms as a major annoyance in their work, but also an essential safety net that protects them and their patients from serious harm. When an alarm becomes an annoyance rather than an affordance,[a] it is typically because it does not provide useful information and interrupts important work. False alarms are annoying for obvious reasons, but so are alarm messages that tersely describe problems without hinting at proper ways to resolve them.

Some of the newest medical devices—mainly those with large screens and plenty of computing power—are improving work life for caregivers by guiding them to resolve alarm conditions. For example, an alarm message on a therapeutic workstation might signal the presence of air bubbles in a blood-filled line and provide immediate, step-by-step instructions to remove the air from the blood and restart the therapy. The guidance might even take the form of repeatable animations.

Enhanced guidance, such as animations, can take the stress out of alarm troubleshooting and improve patient care by helping caregivers fix problems quickly.

Slow Progress Toward Better Alarms

Old-school alarm systems, which remain prevalent in clinical environments, have done their best to alert device users to problems by emitting attention-getting tones and perhaps by displaying terse messages on small screens. Often, users disable such alarm systems because they produce too many false alarms or annunciate for invalid reasons given the context of device use (e.g., emitting an air in blood alarm before blood has even flowed into the set). Alternatively, clinicians ignore alarms because of their frequent occurrence and limited value in most scenarios. These problems, most notably alarm fatigue, have led to

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[a] In The Design of Everyday Things (New York, Currency-Doubleday. 1988), Donald Normal defines an affordance as "…the perceived and actual properties of the thing, primarily those fundamental properties that determine just how the thing could possibly be used…affordances provide strong clues to the operation of things…when affordances are taken advantage of, the user knows what to do just by looking: no picture, label, or instruction is required."

several adverse outcomes, prompting a recent series of articles in popular press, including one that reported "Federal investigators concluded that 'alarm fatigue' experienced by nurses working among constantly beeping monitors contributed to the death of a heart patient at Massachusetts General Hospital in January [2010]."[1]

More recently, alarm systems in "smarter" medical devices, such as dialysis machines, integrated patient monitors, and infusion pumps, have done a better job of communicating with users. Alarm tones have become more distinctive by conforming to guidance in the International Electrotechnical Commission's current alarms standard (EIC 60601-1-8:2006[2]), which specifies specific tone sequences based on the device's class (e.g., general, cardiac, artificial perfusion, ventilation) and the alarm's importance (high, medium, or low). For example, the standard suggests that a cardiac-related device emit high priority alarms that include a series of three distinct notes forming a major chord (c-e-g) and quickly follow-up with two more notes (g-c) to emphasize the alarm's high importance. By comparison, the standard suggests that a ventilator should emit audible alarms composed of the musical notes "c," "a," and "f," thereby producing an inverted major chord. Recent studies question clinicians' ability to remember which specific series of notes goes with which device type,[3] but logic suggests that differentiated alarms are better than having every device produce identical "beeps."

Along with enhanced alarm tones, onscreen messages have also become more informative, with devices moving beyond terse and coded messages such as "Error 43" to more informative messages, such as "Air in line. Pump stopped." Some device developers have taken the added step of providing troubleshooting guidance on demand (e.g., a button press), which can substantially improve users' ability to recognize and resolve alarm conditions. Perhaps the simplest way to present troubleshooting guidance is to display text-only instructions for correcting a problem. A small step up from this approach is to include illustrated graphics showing how to perform corrective actions. A larger step up is to animate the corrective actions, which we consider to offer breakthroughs in both effectiveness and appeal to users.

Bringing Guidance to Life

In the not too distant past—let's say the early 2000s—most medical devices lacked the computing power and display size and resolution to present animations. Most medical devices were memory starved and presented information on grayish-green, segmented LCD displays. Their computational poverty constrained developers' efforts to guide the user effectively.

Today (2011), equipment capabilities are no longer the limiting factor, at least not usually. Limiting factors are now more likely to be a lack of developer initiative and a lack of resources—including both time and money—noting that good animations take artistry and a considerable up-front investment. But, the payoff of improved user responses to alarm conditions (i.e., enabling people to fix problems) can be handsome, portending other benefits such as improved device sales and lower demand for customer support.

We have observed the benefits of animated troubleshooting guidance in myriad usability tests of medical devices. In cases where narrative or even illustrated guidance might have left device users struggling to perform corrective actions, an animated demonstration of required actions has enabled test participants to perform the actions with relative ease.

Advantages of Animation

Why bother animating corrective actions instead of showing a video? This is a key question because animations are typically more expensive to produce than videos—perhaps two to three times the cost. After all, you need to engage a graphic artist (visual designer) who also has a good feel for teaching to create the animations. The artistic demands posed by creating an acceptable quality video are arguably lower. Animation is superior to video in most cases because it can be focused more intensely on the most important details.

Animation is superior to video in the same way that drawings are superior to photos—again in most cases—when it comes to delivering instruction. That is why many quick reference guides use graphics (i.e., drawings) instead of photos even though the graphics take more work to produce.

In principle, graphics offer the following advantages:

- Emphasis of important features and subordination or elimination of unimportant ones
- Inclusion of special elements, such as arrowheads or motion lines, to enhance the communication of dynamics
- Inclusion of informative text
- Illustration of features and effects that otherwise are not readily visible
- Elimination of background elements that would create *visual noise* [b]

Let's look at some frames excerpted from an animation of clearing the air from a tube carrying blood from a therapeutic device to an attached patient. Illustrated instructions could use these static images to add clarity to written instructions. However, a continuous animation that includes these sample images makes the discrete steps more coherent, as reflected in the video posted at www.aami.org/HorizonsPlus.

The sample animation was produced on a personal computer using Adobe Flash. However, other applications such as Adobe After Effects, Autodesk Maya, and Swift 3D can also be used to produce equivalent results after investing the varying levels of effort required to learn the applications.

One hallmark of a good animation is that it features simple visuals. Typically, the artist traces reference photos to produce simplified graphical representations of people or body parts and entire devices or specific components. Figure 1 shows this kind of visual translation.

The aforementioned software applications enable the artist to create a motion sequence from one static state to another using a technique that Adobe Flash calls tweening.[c] Figure 2 shows several computer-generated, intermediate frames that "fill the gap" between the end state images created by the artist.

So ask yourself the question: What kind of guidance would you want to receive when responding to an alarm? Your choices in ascending order of preference are likely to be:

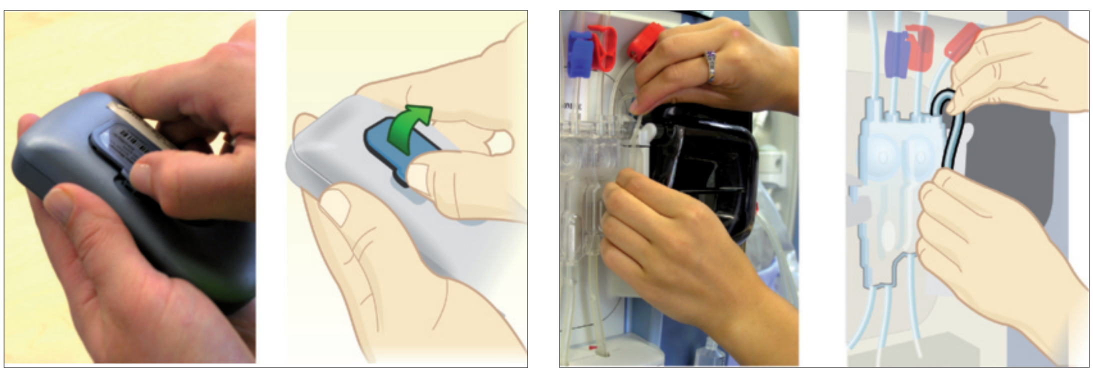

Figure 1. Here, two photos of user-device interactions were converted into colored lined drawings

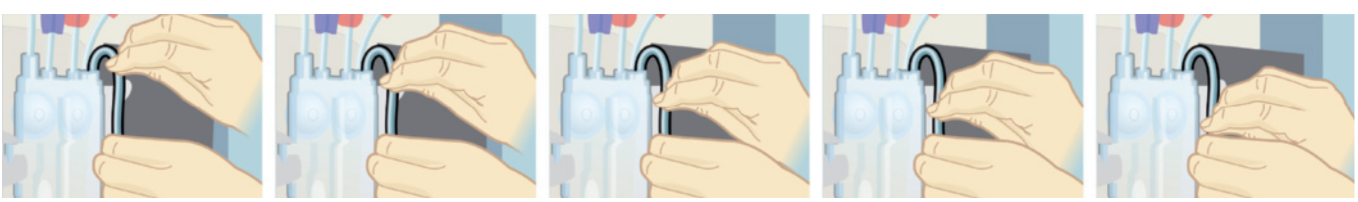

Figure 2. Two original drawings (far left and far right). The others were created by "tweening" and are the material of an animated sequence

[b] Visual noise is distracting, extraneous visual elements that surround important visual elements. It is akin to electronic noise (e.g., static) that can mask the primary electronic signal (e.g., a radio broadcast).

[c] Tweening is the term that Adobe Flash uses to describe the process of graphically interpolating between two visual states, such as two views of an object from different distances and angles.

- Error 43
- Air-In-Line. Pump Stopped.
- Air detected in downstream blood line. Pump stopped. Press Troubleshoot for more guidance.

Note that pressing Troubleshoot, which we'll presume to be a touchscreen button, will automatically play the animation showing how to remove air from the blood line. You probably would choose the last option, particularly if the corrective action involves many steps. Assuming a device featuring animated guidance (i.e., an advanced help system), here's what you would need to do in response to an alarm:

Although animated guidance is a natural complement to alarms, keep in mind that animations are equally well suited to providing procedural guidance.

1. Acknowledge (i.e., silence) the audio alarm.
2. View the animation that shows how to correct the alarm condition.
3. Correct the alarm condition.

It usually makes sense to play an animation upon request because experienced users will not need to view it. But, there certainly are cases when playing the video immediately and repeatedly can be advantageous, such as when delivering guidance to users who do not use the device very often (i.e., novices) or when users might not have an extra hand available to press a Troubleshooting button. That said, some animated guidance might have several parts that require users to press a Continue button (or equivalent) one or more times to view in their entirety. If a cycling video segment is likely to become annoying to some users, developers can set it to play only once and include a Repeat button.

Although animated guidance is a natural complement to alarms, keep in mind that animations are equally well suited to providing procedural guidance. For example, one might complement a linear sequence of device set-up tasks with animated demonstrations of the required tasks, particularly if the tasks will be performed by laypersons or clinicians who will interact with the given device infrequently.

Developing a Good Animation

If you have read this far, you are probably interested in more details about how to produce a good animation. Keep things simple. Ways to do that include:

- Ensure that developers have practiced good human factors engineering to ensure that the user interactions with the given device are not overcomplicated. Of course, this might not be an option if the design is frozen when the time comes to produce the animation.
- Develop a complete understanding of the user's task so that you know exactly what needs to be demonstrated to the user.
- Produce a storyboard (i.e., a hand-drawn, visual outline) of the planned demonstration.
- Take photos of people performing the discrete steps that users must perform. Make sure that the photos are taken from the most effective angle and distance, noting that both wide-angle and close-up images have their place in an animation.
- Generate the computer drawings necessary to produce the animated sequence with "tweening" support from the animation program.

- Evaluate the resulting animation with the presumption that it needs enhancement.
- Repeat the last few development steps until the animation seems as clear as possible.
- Conduct a usability test to evaluate strengths and shortcomings in the animation's ability to assist device users.
- Again, refine the animation based on the test results and possibly retest it. Note that validating the animation by means of usability testing might be necessary if it is cited as a mitigation against a high risk of harm arising due to user-device interactions.

You can also enhance the animation by adding "closed caption" style text below the images and/or playing a spoken voice-over at the same time the animation is playing, the latter option being a feature one might allow users to turn on or off at their discretion.

Animation Design Tips

Here is a short list of tips for designing animations that medical device users are likely to understand and follow:

- Present guidance in logical and small-to medium size chunks. Accordingly, animate one main task at a time.
- Play the animation at a pace that most users will find acceptable. We find that this pace is typically 15-20% slower than the actual time it takes to perform a task. You can determine the right pace by collecting feedback on various paces from intended users who have not seen it before.
- Include brief, 2-3 second pauses after key steps to prepare viewers to notice important details.
- Use fades to create smooth transitions between distinct sections of the animation.
- An animation runtime of 15-30 seconds per distinct step is a good target, lest viewers start to forget important details.
- Start animating with enough drawings so that the level of "tweening" is appropriate. Large jumps between original drawings can make certain actions look jumpy or lacking in essential details.
- Make the drawings realistic to the point that they clearly represent the actual device, but exclude minor details that might distract from more salient ones.
- Zoom in and out to highlight important details.
- Avoid excessive motion and extraneous visual effects, which can distract from key details and overwhelm the viewer. In most cases, animate only two or three on-screen elements at one time, keeping other on-screen elements still.

Conclusion

All medical device users, be they laypersons or highly experienced clinicians, can use help when responding to alarm conditions, particularly those that are infrequent and complicated. Endowing a medical device with animated troubleshooting guidance provides a welcome safety net for users who might otherwise stumble when responding to an alarm. Such animations can be "tuned" to speak a layperson's or clinician's language, sometimes literally if you include a voice-over. Moreover, animations can be set to play automatically when an alarm occurs, or play on demand. Therefore, medical device users can expect to see a lot of animations playing on medical devices in the next five years. Some animations will be better than others based on the artistic and teaching talent brought to bear during their creation, but all are likely to be better than trying to respond effectively to "Error 43" displayed on a thumb-size screen. ■

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References

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