Using Magic to Throw Light on Tricky Healthcare Systems: Patient Safety Problem Solving

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Abstract

The illusions that occur in healthcare are inadvertent, certainly unintended, and unfortunately accepted as an aspect of practice with which clinicians have to cope. There are inadvertent illusions and unintended magic in medical devices, software, and in the healthcare environment generally. The engineer, programmer, manufacturer, or architect may not recognize the unintended magic in his or her own designs. Yet the clinician is seen as responsible when the illusion results in unexpected harm to a patient. By being unwilling to suspend disbelief in the face of illusion when it isn’t clear what’s real, clinicians can end the magic. It is possible to use magic and illusion to show the value of human factors engineering and ergonomics (HFE) in identifying and solving patient safety issues. HFE experts with this ability are equipped to unmask illusion and reveal magic at work in healthcare. Clinicians may see unmasking illusion as equivalent to accurate diagnosis of system ills and the first step in being able to treat system illness. In considering the state of healthcare culture, the use of simple magic tricks brings heightened awareness of tricky medical systems in need of repair and the need for tool-based problem solving native to HFE. © 2011 Wiley Periodicals, Inc.

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1. INTRODUCTION

“The essence of magic is fundamental deception” (Blackstone, 1985). “My object is to mystify and entertain. I wouldn’t deceive you for the world” (Thurston quoted in Steinmeyer, 2003). “The conjurer demonstrates that things are not always as they seem” (Stodare in Steinmeyer, 2003). There are many inadvertent illusions and unintended magic in medical devices and software (Gosbee, 2003).

There are inadvertent illusions and unintended magic in medical devices, software, and in the healthcare environment generally. Engineers, programmers, and architects may not recognize the unintended magic in their own designs. In healthcare, it is the healthcare worker (HCW) who is seen as responsible when the illusion results in unexpected harm to a patient. By being unwilling to suspend disbelief in the face of illusion, when it isn’t clear what’s real, HCWs can help end the magic.

Knowing how magic and illusion exploit vulnerabilities in human conscious thought (Macknik et al., 2008) allows the design of critically important healthcare devices to compensate—or at least to avoid creating inadvertent illusions and trickiness. Human factors engineering and ergonomics (HFE) researchers and practitioners are equipped to unmask illusion and reveal magic at work in healthcare. Tools that are commonplace in the field of HFE are effective in dispelling magic. Clinicians may see unmasking illusion as equivalent to accurate diagnosis of system ills and HFE
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Figure 1 Select one card, focus on your card. Memorize it. It will disappear.

research and tools as surprisingly effective treatments for system illness.

Harry Blackstone, Jr., said, “The essence of magic is fundamental deception. You know you’re being deceived, and thus the outcome, the product of magic is fun, entertaining, educational, enlightening, spiritual” (Blackstone, 1985). Magic and illusion are fun when practiced in the appropriate venue. Anyone found to be practicing illusion outside of an entertainment venue is more likely to be distrusted. The illusions that occur in healthcare, however, are inadvertent, certainly unintended, and unfortunately accepted as an aspect of practice with which HCWs have to cope.

2. THE CULTURE

What purpose is served by maintaining the sense of magic present in the status quo? There is certainly a high regard for the HCWs with recognized expertise—those who handle machines and equipment deftly, as if the machine or device is an extension of their own bodies. The more complex and mysterious the device, the more impressive is the mastery.

Overcoming illusion to achieve skillful use of challenging instruments, devices, and procedures is expected—it is the norm. Certifying boards for medical specialties have stated competencies that set the minimum level of required skill (American Board of Medical Specialties, 2010). The standard in healthcare is that clinicians know the patient’s medical history and current health status, understand medications and interactions, have mastered devices and equipment, and will correctly interpret results and produce safe and effective outcomes—having somewhere along the line achieved the ability to perform differential diagnosis (Riegelman, 1991).

Considering that the knowledge and skills that contribute to expertise are gained through education and training, patient safety will improve when HCWs recognize that illusions are present, acquire skills like basic usability testing (Anderson, Wagner, Bessesen, & Williams, 2011), and work with HFE experts to remove illusions. Consider the illusion created in a card trick (Figure 1).

3. DISPELLING ILLUSION

Without application of HFE, overcoming illusion is a lonely battle requiring that individual clinicians become masters of and experts on every device and situation that he or she might possibly encounter. The expectation is that every clinician will either know or have time to learn (to the level of expert) how devices work—and how the current version differs in function (although it may not differ in appearance) from the one previously in use. Medical equipment, devices, drugs—even healthcare architecture—contain illusions that trick practitioners with regard to function or outcomes (Aiken, Clarke, & Sloane, 2008; Casey, 2007; Gosbee and Gosbee, 2007; Williams, 2005).

Maintaining a level of vigilance to safely deliver healthcare in a tricky environment is at least stressful (Warm, Parasuraman, & Matthews, 2008), if not impossible (Maruenda, 2004). Through application of HFE expertise and research, many individuals can join in the effort to reveal illusion and demand design that is appropriate for safe use by humans, even by novices. Seeing magic at work provokes discussion of tricky medical devices (Figure 2).

HFE demands that design adhere to certain principles based on how a human body is built and how a human brain functions. It shouldn’t come as a surprise that a skilled magician uses those principles as well as an HFE expert does (Macknic, 2008).

Selecting just a few basic HFE design principles and usability standards illustrates their opposition to trickery and illusion. Things that are well designed have a “simple and natural dialogue” with the user (Nielson, 1992); minimize the users memory load.
providing recognition rather than expecting recall; balance user control and freedom; have flexible and efficient use; provide feedback; help users recognize and diagnose errors and have excellent error recovery; have affordances that direct correct use, provide progressive levels of detail as needed, have readable and understandable labels and warnings (Nielsen, 1992); and don’t lie to the user (Gosbee and Gosbee, 2007).

An example of a lie (compare with Figure 1): You successfully made a card disappear (Figure 3).

Revealing an illusion that works because of the way our brains are wired, any card selected (Figure 1) will be missing (Figure 3)—because these are five different cards. We miss this because we don’t maintain awareness of the whole set of possible face cards in a full deck of cards.

An illusion similar to the magic card trick occurs in healthcare, although with risk beyond momentary puzzlement (Figure 4).

A clinician familiar with a model that doesn’t require the addition of water to the chest drain may not be aware that there are five choices, most of which do require water. The instructions for use may obfuscate.

“With balanced pneumonectomy drainage no suction is connected and the suction control stopcock should remain open. Also the suction control chamber does not need to be filled. The water seal is filled to the 1 cm level, instead of the normal 2 cm. The depth of the water in the water seal determines the maximum amount of positive pressure in the chest. With a 1 cm water seal, the maximum amount of positive pressure is +1 cmH2O. With a 1 cm water seal, pleural negativity cannot exceed approximately −17 cmH2O. If patient intrathoracic pressure begins to increase to approximately −17 cmH2O, air at a lesser negative pressure will pass through the water seal and enter the pleural space. This will reduce the negative pressure in the pleural space.”

- Instructions for use of chest drain

Another example of the need to be aware of the entire set of possibilities is seen in a pediatric case study. A missing value creates an illusion, and reveals that dispelling illusion is not always difficult.

The patient is a 7-month-old baby girl with fever. She is seen on Sunday by her pediatrician. The diagnosis is viral illness. Because the patient is young, a blood sample is drawn for a count. The baby doesn’t appear ill. Her physician expects to see at least 40% neutrophils. On the following Tuesday, the baby arrives for a follow-up examination; it is then revealed that, with a white count of 8,400 (71% lymphocytes, 24% monocytes, 5% eosinophils and zero neutrophils), the baby had been at risk of serious infection—in essence defenseless in the face of infection. Because the percentage of neutrophils was zero, it did not appear on the laboratory report.
How the magic works: In this instance, the pediatrician originally assessed 71% of lymphocytes (8,400 × 71% = 5,964) as adequate immune system protection against infection and didn’t see the missing neutrophil percentage as zero.

The hospital modified the report format to stipulate number and percentage of neutrophils including bands, even when there is a 0% value. This action to dispel illusion is consistent with understanding that humans are “pattern mad supposing machines” (Ackerman, 2004). Without the clear listing of neutrophils the humans mind is free to extrapolate – filling in with the expected and present value to replace the missing value.

3.1. It Is a GAG

It is not reasonable to ask clinicians to maintain awareness of all possibilities. Consider this GAG: Sodium hyaluronate is a glycosaminoglycan (GAG). It has a high molecular weight. It is a straight chain polymer basically composed of a repeating unit of disaccharide. It is also the simplest GAG; a typical polymer might contain 104 disaccharides. Its structure imparts viscosity to solutions and rigidity to tissues.

This is a useful substance. It is tasteless, odorless, and readily soluble in water. In water it is extremely viscous, even at a 1% concentration. It is present in many human tissues—umbilical cord, the aorta, tendons, skin and skeletal tissue, synovial fluid, and the vitreous of the eye.

GAG has many useful forms. These two drugs are not the only two choices. These, however, have the same generic name and same concentration, and both are typically stored under refrigeration. They are manufactured in two countries by two different companies. Coincidentally, both companies have similarly designed white and blue packaging (Figure 5).

They have differing viscosities, but it is unfair to ask the ophthalmic surgeon to assess viscosity to determine what labeling and packaging should readily reveal. Achieving continuous awareness of all options is better done with supportive aids, clear labels, and logical, sensible names.

3.2. The Magic Rope

In the magic rope trick, three dissimilar lengths of rope combine and redistribute their lengths without cutting...
or sewing to transform into equal lengths (Figures 6 and 7).

The Institute for Safe Medication Practices (ISMP, 2010a) offers an eight-page, double-columned list of drug names frequently confused to provide narrative material for the magician doing this trick.

It is desirable for proprietary names for drugs to sound efficacious, safe, and reliable. An unfortunate combination of English language syllables could negatively affect sales of an otherwise useful product. In the example in Figure 8, these three different medications have been confused in the ordering process, in the dispensing process, and in the administration process (ISMP, 2010a) due to their efficacious, safe-sounding names.

Fosphenytoin is an anticonvulsant. Celecoxib is a nonsteroidal anti-inflammatory drug. Citalopram is an antidepressant. They are manufactured by three pharmaceutical companies, and one is marketed by a fourth company. The naming occurred without intention of confusion, but based on syllable sounds and visual appeal to suggest efficacy and safety. An interim measure to assist with revealing differences is evident on the ISMP’s list of confusing names. Syllables that are different are noted with tall man lettering to make detection a bit easier (ISMP, 2010b), for example, CeleBREX, CeleXA.

### 3.3. The Disappearing Ball

In the disappearing ball trick, the ball is removed from the chalice, but reappears unexpectedly, making us uncertain as to the real status (Figure 9). Is it present because it was never removed, was it restored to its place, or is this a new, different ball? Medical devices without clear status indicators or progress indicators are

**Figure 6** Different.

**Figure 7** Different transformed to same.

**Figure 8** Three different things easily mistaken for one another.

**Figure 9** The magician removes the ball from the chalice, and then reveals it to be in place in the chalice.
similarly troubling but with dire consequences. Consequences are devastating for clinicians who assume that the blame belongs to the human using the machine or device when, in fact, it belongs with the design of the tricky machine.

The real-life healthcare version of this illusion is well described by Steven Casey in his chapter “Set phasers on stun” about the Therac-25 (Casey, 1993). A human radiology technologist repeatedly pushes a button in the face of uncertainty. Without tactile or other perceptible feedback as to its state or the state of the machine, the button invites repeated efforts. The machine delivered successive doses of damaging radiation.

Another machine with an inadvertently missing next step indicator is a ventilator stuck in precheck mode (Figure 10) while the patient waits, needing assistance from the ventilator to breathe. The instruction to “press ↓ to start” was inadvertently overwritten with an update to the machine’s programming code.

### 3.4. Visual Illusion

In certain laparoscopic surgical procedures, the use of monitors and reflective devices reveal work in progress. The method is much less traumatic to the patient than is abdominal surgery. The risk is creation of an illusion similar to the frog and penny trick (Figure 11).

In this visual illusion, the penny appears near the top of the dome. When the dome is removed we can see that the penny rests at the bottom of the dish (Figure 12). Unlike the ease with which one can dispel the penny illusion, surgeons see an image that consistently appears to be correct. This optical illusion occurs in laparoscopic bile duct surgery accounting for 97% of injuries during surgery (Johnston, Low, & Das, 2003; Way et al., 2003). The perceptual illusion was inadvertently created by traction on the gallbladder at the start of the procedure. The rearrangement of anatomy replaced, to visual appearance, the cystic duct with the common bile duct. It “mimicked the surgeon’s mental model of the relationship between the cystic duct and the gallbladder” (Way et al., 2003).

“The videotapes of operations literally show the operators deliberately, intentionally cutting the common bile duct, believing that they were cutting the cystic duct. The
surgeons believe what they see. But the appearance of the image on the television screen is deceiving. Only later, sometimes much later, does it become apparent that it was the common and not the cystic duct that was being cut. Then it becomes clear that the surgeon was seeing what he or she believed. The clarity at the moment of injury was a delusion” (Cook, 2003).

3.5. An Illusory Resuscitation Bag
Prior to compression, this bag looks like other resuscitation bags ready for use to rescue a patient having difficulty breathing. When compressed, however (Figure 13), it fails to recover shape sufficiently to allow for the minimum tidal volume to be delivered, with the result that the patient isn’t adequately ventilated.

3.6. Luer Connections
Luer lock connectors make healthcare safer by preventing leakage and disconnection. The illusion is created that things that fit together belong together (Figure 14). The illusion is heightened in an intensive care unit where a patient may have many lines and tubes for a variety of life-saving purposes. Lines that support breathing are dangerously at risk for misconnection with lines that support nutrition (U.S. Food and Drug Administration, 2010). The illusion is heightened by our experience handling connectors for devices like cell phone chargers and computers. Cell phones have specific, designated connections—sometimes frustratingly so. Their narrowly specific connections create the illusion that they are unique for some reason other than supporting the cell phone industry. The opposite illusion is created for a patient with a variety of tubing entering various natural or created portals. Incorrect connections are easy to make and can be catastrophic (Guenter et al., 2008).

For added convenience in healthcare, there are adapters with graduated increases in diameter that allow connections between various sizes of tubing (Figure 15). The illusion is created that it is okay to use these handy devices. In reality, they make all sorts of misconnections possible, making them extremely dangerous.
3.7. Born Blind

Our keen ability to perceive details and recognize patterns leads us to believe that we take in the reality present around us. The phenomenon of not seeing what is plainly evident is termed inattentional blindness (Chabris and Simons, 2010; Macknik et al., 2008; Most et al., 2001). In healthcare, clinicians are often asked to do what is nearly impossible (Curry, Meyer, & McKinney, 2006). They must perceive the patient’s status and remain aware constantly; analyze information from diverse sources; act on information and status changes; and converse with patients, families, and other HCWs. Maruenda (2004) writes of a similar impossibility for referees making a correct off-side call in soccer, describing the anatomy and physiology that makes it impossible.

Even when fatigued, sleep deprived, ill, or hungry (all normal human conditions), HCWs are asked to be constantly vigilant. Vigilance is not only impossible to sustain, but the demand is stressful, and it requires hard mental work (Warm et al., 2008). In healthcare, the mental work would be better devoted to patient recovery of health rather than in compensating for faulty design of the healthcare environment and devices.

It seems a dream to imagine what is already possible—a supportive healthcare environment that integrates feedback from various devices, revealing trends in the patient’s vital signs, fluid intake, and output; progressive imaging studies; and other information presented in a way that allows quick assessment, freeing the human to analyze and respond. Making that dream come true requires dispelling magic and illusion.

4. CONCLUSION

Simple magic tricks and illusions can be mastered by a human willing to consult an instructional magic book or visit a magic store. “Magic combines multiple principles of attention, awareness, trust, and perception to both overtly and covertly misdirect the audience” (Macknik et al., 2008). Excellent design combines those same principles to direct the user to correct use and error recovery.

One can set out to combat inadvertent illusions in healthcare by studying how magicians accomplish illusion and by using HFE to dispel trickery. Mastery of simple magic tricks may serve as an effective educational strategy to persuade HCWs to apply their keen perception to identify illusions using basic HFE tools such as usability testing (Shapiro and Fox, 2001; Sojourner, Aretz, & Vance, 1993). Making the case for hiring HFE experts either as full-time staff or under contract for specific project work can be argued by HCWs equipped with the evidence from cognitive science and neuroscience. Attention can be focused using simple magic tricks to illustrate human perceptual and conceptual vulnerabilities.

Persons in healthcare unfamiliar with the expertise offered by HFE may be surprised by the extent of HFE research and capabilities. HFE experts may be surprised at the tolerance of clinicians for tricky devices and illusions that are present in the work environments where healthcare is delivered.

Whenever observation, heuristic evaluation, or usability testing indicates that the interface is tricky and therefore not safe, the system or device in question reveals itself to be a potential hazard (Samore et al., 2004; Small, 2004). The complexity of the solution needed to dispel magic and repair the hazard defines and justifies the need for consultation with HFE experts.

References

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