



The Patient Safety
Education Program™
CANADA

Module 2: Human Factors Design: Applications for Healthcare

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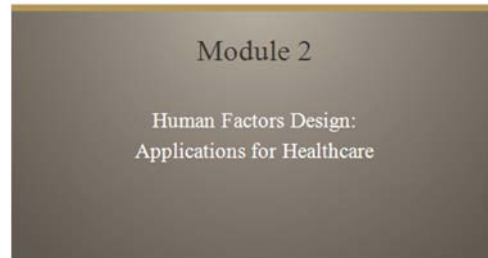
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PSEP - Canada Objectives	Related CPSI Safety Competencies
<p>The knowledge requirements include an understanding of:</p> <ul style="list-style-type: none"> • Human factors engineering • The relationship between human factors and patient safety <p>The performance requirements include the ability to:</p> <ul style="list-style-type: none"> • Apply the principles of human factors and ergonomics • Justify the importance of considering human factors for all planned institutional changes 	<p>Domain: Optimize Human and Environmental Factors</p> <p><i>3. Health care professionals who appreciate the impact of the human/technology interface on safe care are able to:</i></p> <p>3.1. Define human factors and human factors engineering and understand their application in health care environments</p> <p>3.2. Describe the role of usability assessment in the safe application of technology</p> <p>3.3. Recognize the importance of ergonomics in safety design</p>

Abstract

Slide 1



This module defines human factors as the discipline concerned with uncovering and addressing areas of mismatch between people, the tools they have to work with and the systems in which they work. By correcting these areas of mismatch we can improve patient safety, efficiency, the user experience, technology adoption and reduce the need for user training. Human factors focuses on changes to technologies and systems to support people and does not try to change the human condition. Several examples, case studies and interactive exercises are included to teach you how to apply human factors to your healthcare institution.

Keywords

Human factors, humanistic, mechanistic, Human-Tech Ladder, system-oriented, person-oriented, cognitive engineering, memory, attention, cognitive bias, fatigue, workload, automation, physical ergonomics, work-related musculoskeletal disorders (WMSDs), user-centred design, heuristics, hierarchy of effectiveness, Reason's Swiss cheese model, active failure, latent failure, hazard, adverse event, lapse, slip, mistake, violation

Teaching methods

Interactive lecture, case-based teaching

Learning objectives

Slide 2

Knowledge requirements

- Be able to understand:
 - human factors engineering
 - the relationship between human factors and patient safety

Slide 3

Performance requirements

- Apply the principles of human factors and ergonomics
- Justify the importance of considering human factors for all planned institutional changes

Knowledge requirements

The knowledge requirements include an understanding of:

- human factors engineering, and
- the relationship between human factors and patient safety.

Performance requirements

The performance requirements include the ability to:

- apply the principles of human factors and ergonomics, and
- justify the importance of considering human factors for all planned institutional changes.

Clinical case on trigger tape

Slide 4

Trigger tape



A patient has just barely survived an emergency resuscitation after being transported to the Intensive Care Unit (ICU) from another unit in the hospital. The ICU staff, including the physician who was admitting the patient, failed to catch the patient's rapid deterioration because they were focused on the information presented by the transport monitor, which showed stable vital signs. The physician had been on call every other night leading up to the event and the ICU nurse notes how stressful and busy the unit can be. The physician feels he should have known better than to just trust what the monitor was telling him and that he should have realized the patient's condition was deteriorating. After the patient was stabilized, the ICU nurse, who has had a similar experience in the past, catches the source of the error: the monitor was set on "demo mode."

Case discussion points

One point illustrated by the case is whether the physician should be held accountable for not recognizing his patient was deteriorating even though the monitor showed the patient had a normal sinus rhythm

People often blame themselves when something goes wrong. It is natural to think "I should have known better", or, "I should have been paying closer attention", or, "I should have noticed the warning signs", which often seem clear after the fact. But in reality, there are many things that influence how we behave, how we think and how we make decisions.

People may be tempted to blame the physician for not noticing that his patient was deteriorating, and from the trigger tape, even the physician blamed himself. However, there are other factors to consider such as:

- What if a different patient monitor was being used on the unit?
- What if the patient monitor displayed a warning that indicated it was in demo mode?

- What if the button to put the monitor into demo mode was difficult to press?
- What if the physician had not been on call every other night leading up to the event?
- What if the environment was not a stressful place in which to work?
- What if the nurse had noticed the monitor was in demo mode?
- What if the physician had previous experience putting this monitor into demo mode?
- What if the technology was viewed as being unreliable by the physician?

When we start thinking about some of the factors that could have played a role in leading up to a failure to detect the patient's deteriorating condition, it becomes much more difficult to simply hold the physician accountable. There were many other upstream factors such as the type of patient monitor used on the floor, the design of the monitor's user interface, and the physician's lack of sleep, for example, that ultimately came together to produce the situation the physician found himself in. Since healthcare delivery is so complex, involving multiple people and technologies, it is important to consider the relationships and not simply the individual people involved in delivering safe care.

Suggested key sections

The sections of material in this module are intended to be flexibly packaged depending on the purpose and goals of the presenter. The Introduction to Human Factors is the backbone of this module and its content belongs in most learning settings. The remaining sections, including the Human Error and Applying Human Factors sections build on the Introduction to Human Factors section and provide additional material. A case study is presented that reviews all the concepts covered in the entire human factors module.

Introduction to human factors

Section objectives

This section aims to:

- define human factors engineering;
- provide examples of good and bad design;
- describe the systems versus person approach; and
- discuss the benefits of applying human factors engineering to healthcare.

Good and bad design

Slide 5

Good and bad design

- ▢ What features do you think make these good or bad designs?
- ▢ What is it about the design that makes it difficult to use?
- ▢ What would you add to it, or take away from it to make it easier to use?

If confronted with the cook top in Figure 1 below, how would someone turn the front left-most burner on?

Figure 1



If someone instead were confronted with the cook top shown in Figure 2, how would he/she go about turning the front left-most burner on?

Figure 2



The same principals can be applied to elevators. In Figure 3, how would someone get to the second floor and then hold the door open for someone who was running to catch the elevator before the doors closed?

Figure 3



Using Figure 4 as an example, how would someone get to the second floor and hold the door open for someone who was running to catch the elevator before the doors closed?

Figure 4



Comparing the elevator button panels in Figures 3 and 4, it is clear that the panel shown in Figure 3 would be easier to use than the panel in Figure 4. People generally think of a building as being made up of multiple floors that are numbered from lowest to highest and that are stacked one on top of the other. The elevator button panel in Figure 3 matches the expectations of how a building is arranged and so it is fairly easy to know what to do. To get to the second floor in this building, a person would press the number “2”. However, the elevator button panel in Figure 4 would be more difficult to figure out. If a person knew he/she needed to get to the second floor and had not been inside this building before, he/she probably would not know where to start. The person would likely have to ask someone or could just start pressing buttons to see where the elevator ended up. In the case of navigating a building, having to ask someone or going to the wrong floor by accident would not be a critical mistake. It could perhaps be an inconvenience, but overall, the impact would not be terrible.

In healthcare, people are confronted with new types and new models of medical devices that they must interact with in time-sensitive and stressful situations. If these devices are confusing, and users would have difficulty knowing where to start, such as the elevator panel in Figure 4, life threatening outcomes may be experienced by the patient. In life or death situations there is rarely enough time to ask someone how to use a device, read instructions or attempt to use a device through trial and error.

Summary

Below are some potential observations of Figures 1 and 2.

Figure 1

- Figure 1 is more complex than Figure 2, with 6 instead of 4 burners
- Each knob has an image associated with it so the user can map which burner is controlled by which knob
- Arrow around each knob indicates the direction in which the knob should be turned
- A slightly different symbol (extended arrow) is present around the knobs controlling the bottom left and right most burners, which are different from the other burners

Figure 2

- Figure 2 only has 4 burners, yet it would be more difficult to determine how to turn the intended burner on
- No images to map which burner controls which knob
- Unsure whether knobs should be turned clockwise or counter clockwise

Both figures

- What is it about the design that makes it difficult to use?
- What would you add to it, or take away from it to make it easier to use?

What is human factors?

Slide 6

What is human factors?

“We cannot change the human condition, but we can change the conditions under which humans work” (Reason 1997)

- Goals of human factors in healthcare environments are to improve:
 - patient safety efficiency
 - technology adoption user experience
 - reduce the resources required for user training
- Can be applied to any system

Human factors is a discipline dedicated to uncovering and addressing elements of mismatch between people, the tools they have to work with and the environments in which they work. As James Reason, the eminent British psychologist and human factors expert said, “we cannot change the human condition, but we can change the conditions under which humans work” (Reason, 1997). Given this, human factors focuses on improving technologies and systems to work optimally for people rather than attempting to change how people behave. The goals of human factors in healthcare environments are to:

- improve patient safety;
- improve efficiency;
- improve technology adoption;
- improve the user experience; and
- to reduce the resources required for user training.

Human factors is applied in many domains, from aerospace to nuclear to healthcare to consumer product development. Although only fairly recently applied to the field of healthcare, human factors has been applied to industries such as aviation since the 1940's. Human factors can be applied to any system, either prospectively to consider potential areas of mismatch between system components, or retrospectively to consider harmful incidents from a system-level perspective.

Human factors versus ergonomics

In Canada, the terms “human factors”, “human factors engineering” and “ergonomics” are often used interchangeably. Some human factors professionals, however, make a distinction between human factors and ergonomics with human factors describing cognitive aspects of the field and ergonomics describing physical aspects of the field. According to the International Ergonomics Association (IEA):

“Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance” (IEA, 2000).

In Canada, the Association of Canadian Ergonomists and the Human Factors Association of Canada serve as professional societies for human factors and ergonomics specialists. The Human Factors and Ergonomics Society (HFES) is the American equivalent professional society. Organizations such as the University Health Network carry out significant research in advancing human factors in healthcare. Additionally, The Canadian Human Factors in Healthcare Network, supported by the Canadian Patient Safety Institute, promote partnerships between healthcare organizations, research institutions and industry to increase patient safety in Canada. (<http://www.patientsafetyinstitute.ca/en/toolsResources/Human-Factors-Network>)

Some common misconceptions about human factors

Slide 7

Common misconceptions

- Applying human factors:
 - attempting to change factors that are human
 - the straight application of checklists and guidelines
 - can be achieved by using yourself as a model
 - is just applying common sense
 - can compensate for all the human factors issues in a system

It means attempting to change factors that are human

Although people need to have an understanding of human limitations to be able to design technologies and environments that fit well with people, the goal of human factors is not to learn about and to try to change the limitations of humans. Instead, the focus of human factors is to understand and design systems that take human limitations into account, supporting people in areas we know to be challenging and capitalizing on human strengths.

It means the straight application of checklists and guidelines

Although checklists and guidelines can be useful human factors tools, both in terms of design and reducing the need for people to rely on their memory, they are just two examples of many tools that can be applied in a given situation. There is no one magic guideline or checklist that can be applied to a system to solve all the human factors related issues. Sometimes checklists and guidelines are not the right solution at all.

It can be achieved by using yourself as a model

Sometimes people believe that if they do not have any trouble interacting with a piece of technology, others will also find it easy to use and that it has been designed well. Many people have already encountered this, such as not finding a device easy to use however others do not seem to have any difficulty figuring it out. Often those who design and purchase equipment do not involve the users of this equipment or consider the environments in which the technologies will be used. For example, a tall engineer may install new patient monitors in a unit so they are easy for him to see and reach. However, a short nurse may have a lot of trouble accessing and seeing the monitors if they have been installed too high.

It is just applying common sense

Although many human factors principles and recommendations may seem obvious, identifying how and when to apply them is not always straightforward, especially in a complex system such as healthcare. This is why there are many examples where human factors principles are violated. One example is the elevator panel in Figure 4. This may seem to be an obvious example of a poor design, but when people first see it, they probably do not think the panel looked too bad unless they were thinking like human factors professionals. In addition, common sense can often be contradictory, which could lead to a flawed design. For example, a designer may think that using the colour red on a button will be a good way to represent a “stopping” function. Although in our culture, red is often associated with stopping, in other cultures the colour red predominantly has a positive connotation. Additionally, those who are colour blind may not be able to appreciate the “common sense” symbolism represented by the colour of the button.

It can compensate for all the human factors issues in a system

Although a shortage of human resources can contribute to the occurrence of a patient safety incident, especially if people are working beyond their means (e.g., are tired, untrained, stressed,), simply adding additional people to share in the workload will not solve all the human factors-related issues in the system. For example, if a nurse is interacting with an infusion pump that has a menu which is confusing to navigate, adding two more nurses to help alleviate the first nurse’s workload will not have an impact on how difficult or easy it is for the nurse to navigate the infusion pump menu.

Person approach versus systems approach

Slide 8

Systems versus person approach

- Person approach
 - safety interventions are generally targeted at individual people
- Systems approach
 - person as a part of the whole system
 - consider all factors that may have contributed to the harmful event

As described in the Patient Safety Education Program Canada (PSEP - Canada) Module 1: Systems Thinking: Moving Beyond Blame to Safety, the traditional approach to dealing with harmful incidents in healthcare centred around blaming and shaming those most directly involved in an incident. If a professional made an error they would be blamed, told not to make the same mistake again, provided with training or potentially disciplined by the organization or their professional body. In this module’s trigger tape,

the physician blamed himself and clearly felt terribly that he had not noticed the patient's deteriorating condition. Most healthcare professionals enter the field out of a desire to help others. Rarely do we see "bad apples" who intend to do harm. In a person approach to system safety, safety interventions are generally targeted at individual people.

Although that specific person would be careful never to make the same mistake again, other people are likely to find themselves in similar situations, making the same or a similar mistake. With the person approach, improving safety takes a long time, many patients are harmed in the process and people working in the system tend to develop a fear of making mistakes as well as low worker morale.

The systems approach, in contrast, considers the person as a part of the whole system. We know that as people we have certain strengths and certain limitations to our abilities. As a result, the tools and environments we interact with should be designed to capitalize on our strengths and help us with things that we find challenging. The systems approach is a holistic way to view the world and one in which the relationships between the various system elements are important. From the trigger tape, a systems approach would be to consider all the factors that may have contributed to the physician not realizing his patient was deteriorating. For example: the physician was likely tired since he had been on-call every other night; the "demo mode" button was easy to press; and it was difficult to tell when "demo mode" had been activated on the patient monitor. The systems approach has the potential to achieve a sweeping improvement; with a systems approach no matter who was put into a given situation, they would each perform well because of a good fit between the person and the tools they had to work with to achieve their goal.

The mechanistic-humanistic divide

Slide 9

Mechanistic-humanistic divide

- "Divide and conquer" mentality
 - can be problematic as only learn from one focused perspective of a person or group
- Division between human sciences and technical sciences
 - a gap exists - human factors serves to help fill this gap

As a society, people have historically learned about our world using a reductionist approach. In other words, to understand how things work, people employ a "divide and conquer" mentality and have a person or group of people focus in very closely on a topic to understand how that area of the topic works. As a society, people are able to learn a lot about specific phenomena, but only from the focused perspective of the person or group who studied it. This can be problematic because the world is not a number of separately existing entities, but an interactive aggregate of these entities. People tend to spend time

looking at individual problems without stepping back to see how all the individual pieces fit together in the larger scheme of things.

As a result, within the sciences, there has historically been a division between the human sciences, such as cognitive psychology, and the technical sciences, such as computer programming and engineering. Those coming from the human sciences perspective (“Humanists”) know about how people think and those coming from the technical sciences perspective (“Mechanists”) know how to make technology work. A gap exists between the Humanists and the Mechanists in that we know how people think, and we know how to make technology work, but until recently few put the two together.

Human factors serves to help fill this gap by ensuring we take what we know about how people think and act and what we know about how technology works and put them together such that the technology is able to complement how people tend to think and act. In the real world people do not exist without technology and technology does not exist without people, so it is important to consider what happens to people and technology when we put them together.

Hard and soft technologies

Although people often think of technologies as being limited to devices consisting of hardware or software or both, there also exist “softer” technologies such as work schedules, paper forms and team coordination. These aspects of technology also must be taken into account when considering systems, because they affect how “hard” technologies such as hardware and software are used by people.

The Human-Tech Ladder

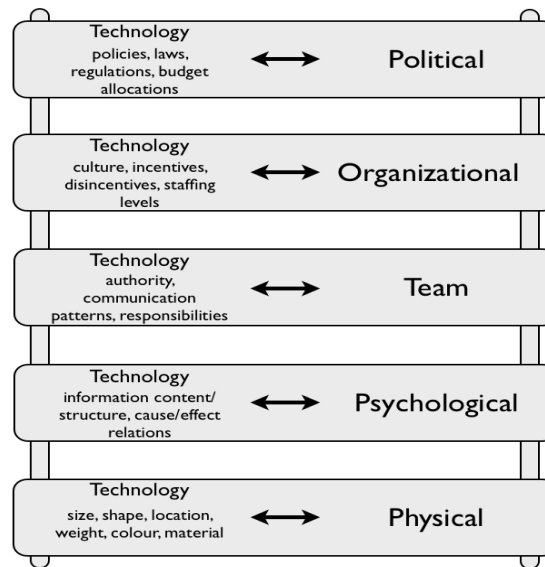
Slide 10

The Human-Tech Ladder

- ▢ Technologies must:
 - fit well with the physical abilities of people
 - fit well with the cognitive abilities of people
 - facilitate communication
 - fit well with organizational characteristics
 - fit well with people at a political level

To address the Mechanistic-Humanistic divide, it helps to consider people and technologies together as part of a system. The Human-Tech Ladder from Vicente (Figure 5) is a useful model that represents the relationship we have with technology from a number of perspectives.

Figure 5



The bottom-most rung of the Human-Tech Ladder asks people to think of how they interact with technologies on a physical level. If something is too heavy to lift or too far away to reach, on a physical level there is a mismatch between how the technology was designed and the people who use it. An example of this is Figure 6. If a cardiac monitor is placed too high for the team to see, a poor fit will exist between the person and the technology at a physical level.

Figure 6



Moving up one rung to the psychological level, technologies must also fit well with the cognitive abilities of people. If a technology requires a user to remember a series of numbers or is counter-intuitive, again, a mismatch will exist between the technology and the people who were meant to use it. Considering Figure 6, if a nurse was trying to adjust

a setting on the monitor but could not figure out how to access the menu item, a poor fit would exist between the person and the technology at the psychological level.

At the team level, technologies must facilitate communication and allow multiple people to work towards a common outcome. For example, if the patient monitor was placed in the room such that only the anaesthesiologist was able to view it, even though the surgeon also wanted to see this information, poor communication about the patient's condition could result and the two team members could end up working counterproductively with one another.

Technologies must also fit well with organizational characteristics such as culture, work schedules, incentives and disincentives. For example, if the patient monitor was out of view of the surgeon, depending on the culture of that particular operating room (OR), it may be culturally unacceptable for the surgeon to ask the anaesthetist regularly for patient vitals updates or for the monitor to be repositioned. This difficulty could result if the surgeon was a junior staff member or if the personalities of those involved in the operation made it difficult to work towards a common goal with the technology. PSEP – Canada Module 5: Organization & Culture provides additional detail on the importance of having a positive organizational culture.

Finally, technologies must fit well with people at a political level. This level considers basic attributes like public opinion, laws and budgets. For example from Figure 6, before these patient monitors could have been selected for the Operating Room, they would have had to receive a Health Canada license.

A good technology must exhibit a good fit between all the relevant levels on the Human-Tech Ladder. A technology may match a person well at the physical level in that the components may be reached and manipulated, but if that technology requires the user to remember 14 different numbers that must be entered into a subsequent interface, the technology would not be a good fit for the user at the psychological level. This module focuses on the bottom two rungs of the Human-Tech Ladder: physical and psychological. Other modules, such as PSEP – Canada Module 4: Teamwork: Being an Effective Team Member and Module 5: Organization and Culture touch on some of the higher levels of the Human-Tech Ladder, such as the team level and organizational level. Different systems require the consideration of different levels of the Human-Tech Ladder.

Human-Tech Ladder in application

Below is an example of a case where the Human-Tech Ladder could be applied:

A patient was transferred to a step-down unit from the ICU. The patient required 3 litres/minute (31%) oxygen and was attached to an adult Venturi mask. A Venturi mask (Figure 7) is used to allow air that is inspired by a patient to mix with a fixed concentration of oxygen, in order to increase a patient's oxygen

intake. Venturi masks generally come in fixed oxygen concentrations and are colour coded accordingly.

Figure 7



The patient who had previously occupied the bed required a heated humidity setup for a tracheostomy, which consisted of a humidifying device connected with tubing to an adjustable oxygen diluter. The oxygen diluter was then connected to a compressed air flow meter, which was connected to the compressed air wall outlet.

Normally, when a patient with a heated humidity setup is discharged, the respiratory therapist (RT) is paged to remove the compressed air flow meter from the wall. When the patient with the tracheostomy was discharged the RT was not paged. This procedure was not formalized with a policy, but all the nurses knew to call the RT upon patient discharge. Upon discharge of the patient with the tracheostomy, a compressed air flow meter was connected to the compressed air wall outlet and an oxygen flow meter was connected to the oxygen wall outlet.

After the nurse had attached the patient to the Venturi mask and had attached the correct white diluter jet to the mask, the nurse connected the oxygen tubing to the compressed air flow meter instead of the oxygen flow meter.

Over the next 3 shifts, the patient desaturated below 90% and the RT was paged. Initially the RT attached a different diluter jet to increase the flow of oxygen to the patient. The patient continued to desaturate, so the RT decided to switch to a high flow oxygen delivery system. In the process of switching the patient to the high-flow oxygen delivery system the RT noticed the original setup had been connected to the compressed air flow meter. As a result, over the course of 36 hours the patient received air when they should have been receiving oxygen.

Some of the issues the case presents include:

- the points where there was a good a poor fit between people and technology;
- the events leading to this patient safety incident; and
- how to prevent a similar type of incident from occurring again.

The rungs of the Human-Tech Ladder can be used to identify some of the ways in which the technology (Venturi mask, diluters, flow meters, wall outlets, etc.) did not support the people (nurse, RT, patient).

Physical: The oxygen tubing easily fit the compressed air flow meter; the compressed air flow meter was attached to the compressed air wall outlet and thus was available as a connection to the nurse.

Psychological: Even though compressed air flow meters generally include black/white elements and oxygen flow meters generally include green elements, the colour differences between the two were difficult to perceive on the glass; similarly, flow meters usually had a colour-specific nipple attachment (yellow and light green Christmas tree-looking plastic attachments), with black being used for compressed air and green being used for oxygen. However, in the case of this institution, black, white, yellow and green nipples were available and were often interchanged by staff; the RT assumed the patient was connected to the oxygen flow meter.

Team: The RT usually disconnected the compressed air flow meter, but the nurse never informed the RT that the patient had been discharged.

Organizational: The organization did not have a policy that outlined the nurse was responsible for calling the RT when a patient who required compressed air was discharged; the organization did not enforce colour coding rules for the nipples used on the different flow meters; the relative placement of the compressed air wall outlets to the oxygen wall outlets was not standardized across the organization and often differed from room to room.

Political: There is no regulatory body responsible for standardizing compressed air flow meters or oxygen flow meters, therefore, flow meters with the same purpose often look different.

Summary: By considering how people interact with technologies from a number of perspectives (physical, psychological, team, organization and political) we can uncover some of the ways in which the technologies and system in place did not support those people working in the system.

Principles of design for understandability and usability

Slide 11

Principles of design ...

- ▢ Designs should give visual clues about how to interact with them
- ▢ Conceptual models
 - used by people as a means of trying to understand systems
- ▢ Mappings
 - links that people make, based on cues provided by the design that connect what they want to do with what appears to be possible

From the examples of good and bad stovetop or elevator button design, it is clear that designs matter. When people approach things in the environment, they automatically start looking for clues about how to interact with them. Norman (1998) gives an example of approaching a door, and although as a society people are familiar with doors and know that they open and close, people still need clues about how to go about opening or closing the particular door. Should the door be pushed, pulled or slid to the side? Will the door open automatically? On which side of the door should one push or pull to get it to move?

Clues in the design can help this decision. A handle, a push plate or hinges can indicate which side of the door to put a hand on and whether to push or pull the door. As a result, people may make a mistake when trying to go through the door in Figure 8. The clues indicate that the door needs to be pushed since there is only a push plate and no handle, but it is unclear at first glance whether the user should place their hand on the left side or right side of the door. Designs should give visual clues about how to interact with them.

Figure 8



To navigate their surroundings, humans use conceptual models, mappings, affordances and feedback. Conceptual models are used by people as a means of trying to understand systems. For example, when approaching a door, a strategy is conceived about how to interact with the door based on a person's training, instruction and previous experience

going through other doors. A conceptual model might include information like: doors open and close, one must push or pull on the door to get it to move and some doors slide. People simulate going through the door based on the parts that they see and the implications that they have.

Mappings are links that people make, based on cues provided by the design that connect what they want to do with what appears to be possible. Even though people use mappings when trying to interact with technologies, designers do not always create devices to make these mappings true. For example, considering the door in Figure 8, people may think that by pushing on the left most push-plate, the door will open, when in reality, it will only open when the right side is pushed.

Slide 12

... Principles of design

- ▢ Affordances
 - perceived and actual properties of technologies that determine how they might be used
- ▢ Bad design
 - make it difficult for people to apply conceptual models, mappings or affordances

Affordances are perceived and actual properties of technologies that determine how they might be used. For example, if someone sees a button, he/she assumes it must be pressed rather than trying to slide or turn a button to get it to work.

As people interact with technologies, they are continuously collecting sensory information to serve as feedback. They need to assess where they currently are with a technology, compare that to where they need to be and then adjust their approach to get closer to where they need to be. This process of collecting feedback guides everyone when interacting with technologies.

Bad designs are those that make it difficult for people to apply conceptual models, mappings or affordances or that cause people to assign erroneous conceptual models, mappings or affordances to figure out how to interact with the technology. People are bound to come across technologies they have never seen before, but the design should provide good enough visibility to allow those new to the technology to understand how the technology should be approached for proper operation.

These principles can also be applied to electronic patient record systems and medical devices, and similar questions can be asked regarding the design. For example, does the device provide a good conceptual model? Is it easy to use? Does it provide correct mappings? (i.e. the user knows exactly what will happen if they press a button on an

infusion pump). Does it provide enough affordances? (e.g. symbols on a medical device that are easy to interpret and don't cause confusion) The idea of affordances, conceptual models, and mappings apply to physical equipment as well as digital technologies.

Impact of technology on society

Most people think of technology as helping to further our society. Technology is meant to make life easier, but when technology is designed poorly, users can have extreme difficulty and often blame themselves when they struggle with a device. More technology as well as more advanced technology is not always better. Technologies can be useful when they are carefully designed to solve a societal problem and when they are designed to fit well with people's capabilities and limitations.

Why apply human factors to healthcare?

Human factors is a discipline dedicated to uncovering and correcting elements of mismatch between people, the tools they have to work with and the environments in which they work. By identifying and correcting elements of mismatch between system elements, an improvement in patient safety, efficiency, technology adoption and user experience, as well as a reduction in the need for user training can be achieved. To reiterate James Reason, , "we cannot change the human condition, but we can change the conditions under which humans work" (Reason, 1997).

Application of human factors principles has significantly improved the quality of work in domains such as aviation and nuclear power plants. Better understanding of cognitive capabilities and limitation of pilots and nuclear power plant operators led to changes in task procedures, training, and physical and digital equipment design and has resulted in safer work practices. In 2000, the Institute of Medicine published their famous report, "To Err is Human", to draw attention to the human element for improving health care. (Donaldson, Corrigan, & Kohn, 2000). Applying human factors principles in health care can improve the quality of care significantly and increase patient safety. This can be achieved by understanding strengths and weakness of people and by creating work environment and work practices that eliminate the mismatch.

Cognitive engineering

Section objectives

This section aims to:

- define engineering psychology and cognitive engineering;
- explain how humans process information;
- list four limits of human attention;
- explain the limits of human memory;
- describe five types of cognitive bias;
- explain how both high and low workloads can affect human performance; and
- describe some of the pros and cons of automation.

Introduction to cognitive engineering and human performance

Slide 13

Cognitive engineering and human performance

- Cognitive engineering
 - branch of human factors
 - studies the cognitive capabilities and limitations of humans
- How people interact with their surroundings
 - sensory information reaches the brain
 - information is perceived (top-down, bottom-up)
 - decide what should be done and execute action

Cognitive engineering is a branch of human factors that attempts to understand the cognitive capabilities and limitations of humans so the design of systems, including environments, tools, equipment and jobs, can be informed to reduce errors and fatigue and enhance productivity and efficiency.

The Human-Tech Ladder: psychological

The Human-Tech Ladder (Figure 5) allows us to consider the psychological fit between people and technologies within a system. How people perceive, process and react to information is influenced both by cognitive capabilities as well as by factors like how much sleep the perceiver has had and the other things that are going on around him/her. Cognitive engineering is concerned with this rung on the Human-Tech Ladder.

Human factors considers how people interact with their surroundings

Initially people receive information about their surroundings through their senses (Figure 9). This physician is receiving visual information from the computer screen.

Figure 9



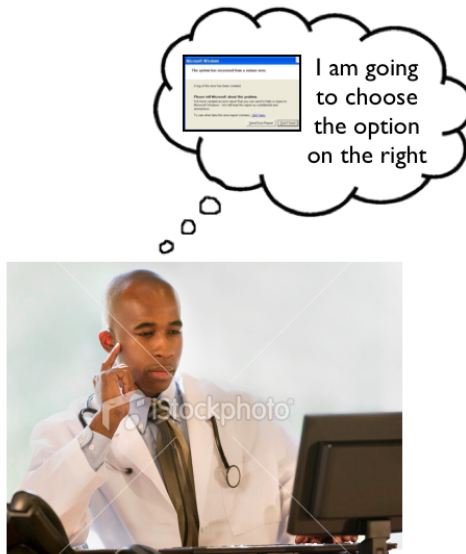
This **sensory** information reaches the brain and is stored there for a varying amount of time depending on several factors. Next this information is **perceived**, meaning it is interpreted and given meaning to the information that is sensed. People give meaning to this information using both a bottom-up (e.g., sensory information taken in) and a top-down (e.g., memory and past similar experiences) approach, and people typically do this without giving it too much thought. Represented in Figure 10, the physician is using bottom-up processing (seeing the error message on the screen) and then top-down processing (comparing what he sees with what he remembers seeing in the past) to assign meaning to the information sensed.

Figure 10



Next working and long-term memories are used to process the information that has been perceived. This requires time and effort, and especially attentional resources. It is then decided what should be done and execute the action, which is often a physical response requiring muscle movement and coordination (Figure 11).

Figure 11



Additional sensory information, or feedback, is collected which helps determine whether the response that was chosen had the desired effect. Depending on what is perceived, an adjustment may have to be made to the selected action and re-execute the action.

For example, if an infusion pump was sounding its alarm as a result of a line occlusion, a nurse would hear the alarm and this auditory information would be stored in her brain. She would then combine the auditory information she just received (bottom-up processing) with past experience (top-down processing) to know the sound she was hearing was an infusion pump alarm and based on the perceived sound she might be able to determine what the alarm was for. Next she would decide how to respond to the situation. In this case, she might decide to respond to the alarm and execute the response by walking over to the pump to figure out what to do about the alarm.

Limits of cognition

Slide 14

Limits of cognition ...

- Human performance is constrained by known principles of cognitive and physical performance
- Short term memory
 - working memory ("scratch pad")
 - 7 ± 2 units of information remembered
- Long term memory
 - facts and how to do things
 - use mental models to store this information

People generally are good at cognitive tasks like finding and interpreting patterns and that we struggle with things like mental arithmetic and remembering lists of information. Even though people know how to perform these more challenging cognitive tasks such as mental arithmetic and mathematical conversions, they are still quite prone to making errors. They are able to identify these challenging tasks based on experiments whereby data is collected about how quickly and accurately various goals can be achieved and about the types of errors that are committed. Just as the electrical and mechanical properties of technologies are constrained by the laws of physics, human performance is also constrained by known principles of cognitive and physical performance.

Examples of cognitive limits

Below is an example of a question that may or may not be simple:

Stuart took a test consisting of 20 questions in which each correct answer was awarded 10 points and each incorrect answer deducted 5 points. If Stuart scored 110 on the test and answered all the questions, how many questions did he get incorrect?

The answer is six. If Stuart had gotten all the questions right, he would have scored 200 points. He scored 110 meaning he lost 90 points. For each incorrect answer, 5 points are deducted, but he also loses the 10 points he would have gotten had the question been answered correctly. As a result he lost 15 points per question and 90 points divided by 15 points is 6 questions.

Even though this question involves simple arithmetic, it can sometimes be challenging to get the correct answer.

Another example is the following passage, adapted from the Food and Drug Administration (2010):

During use of the device for a cardiopulmonary bypass procedure, the user reported the heater cooler made a high pitch noise which caused alarms to be activated.

Unscrambled, the passage reads as follows:

During use of the device for a cardiopulmonary bypass procedure, the user reported the heater cooler made a high pitch noise which caused alarms to be activated.

In summary, people are good at finding and interpreting patterns, and in this case, even when the middle letters of these words are mixed around, they can still make out what the passage says because they are familiar with patterns when reading.

Short term memory

Memory is where information collected from our environment is stored. Working memory is where temporary information is stored, and it also serves as a “scratch pad” where different mental representations of that information can be examined, evaluated, transformed and compared. Working memory is limited, and when attention is drawn elsewhere, it can be especially vulnerable. Studies have shown that people can generally only remember seven +/- two units of information in their working memory at once. Often, people rely on working memory without even realizing it during the workday, which can be problematic given the number of things that have to be remembered as well as the many distractions, interruptions and tasks going on at once.

An example of short term memory

Healthcare workers have to rely on working memory over the course of the workday. It might be trying to pull up a patient record using a medical record number (MRN), or when transcribing a medication order given verbally by the physician.

- How do you remember things like medical record numbers or verbal orders?
- What do you think would happen if you were interrupted or distracted while remembering these things?
- Why do you think you forget this information?

Another example is memorizing a five digit number then counting backwards from 700 by 7's. Afterward, many people struggle to recall the number. When people are distracted, interrupted or focused on another task, it is often challenging to correctly recall information that was stored in the working memory.

To overcome the limitations of short term memory, the load on short term memory should be minimized. For example, if the number of procedures to be kept in memory is

large, they should be written instead of trying to keep them from memory. Another strategy that can be used is called “chunking”. Chunking refers to grouping similar items which improves recall. A well known example for the chunking technique is that it is easier to remember two chunks of information like 451-1423 than a sequence of 4-5-1-1-4-2-3.

Long term memory

Initially, information is stored in working memory, but through learning or training, some of this information moves into long term memory. Long term memory is where people store facts about the world and how to do things. Mental models are used to store this information and it can be retrieved either by recalling it, such as being able to recite a phone number, or by recognizing it, such as being able to identify a friend's number out of a list of phone numbers. Forgetting or being unable to retrieve information correctly can have negative consequences and can lead to errors or an increased time to complete a task in the event information has to be located or confirmed.

One limitation of long term memory is that information in long term memory is vulnerable to decay over time. We forget over time especially if we don't use the information regularly. Procedures for non-common situations can easily be forgotten, which may pose a risk in ensuring patient safety. Regular training and learning is therefore important because the more frequently and recently a piece of information is retrieved from long term memory, the easier it will be to remember. For example, people can easily recall procedures and tasks immediately after a training program. To keep things fresh in long term memory, frequent training and simulations should be carried out. This is why in domains such as aviation, pilots go through regular training programs to strengthen their long term memory on procedures that need to be carried out in uncommon situations. Furthermore, memory aids, such as written procedures can be used for tasks that are carried out infrequently.

Attention

Slide 15

... Limits of cognition ...

- ▢ Attention is the ability to concentrate on someone or something
- ▢ what we do not pay attention to will go unnoticed
- ▢ 4 elements of attention:
 - attentional blindness
 - selective attention
 - focused attention
 - divided attention

Attention describes the ability to concentrate on someone or something. Attention is limited and so those stimuli that are ignored will never get processed by the brain. Instead what is ignored will go unnoticed and will not be remembered. In daily life, people are bombarded with visual and auditory information like phones ringing and data on computer screens, and depending on what else is going on, the things that are right in front of us may not be noticed.

Attentional blindness

When people are paying attention to one thing, other things that might seem obvious to others, or that might seem obvious after the fact, can happen right in front of everyone without anyone even realizing it. For example, administering incorrect dose of medication when the label clearly states the dose can be considered as an attentional blindness.

Selective attention

Selective attention, which is also known as cognitive tunnelling, occurs when people focus on the things that stand out the most and not necessarily on what is most useful. For example consider two alarms going off in a patient's room at the same time: one indicating the patient's temperature reading was ready for review by the nurse, and the other indicating the patient's oxygen level had fallen below 70%. If the alarm for the patient's temperature was louder than the alarm indicating the patient's oxygen level had fallen below 70%, even though the nurse would likely want to attend to the patient's oxygen level first, he or she may attend to the patient's temperature first simply because the louder alarm would be more salient.

Focused attention

Focused attention occurs when someone is trying to concentrate on a single stimulus, but other things in the environment make it difficult to focus, causing distraction.

Divided attention

Divided attention occurs when one attempts to focus on more than one stimulus at once, fully intending to process both stimuli. For example, a physician may listen to a nurse who is briefing her about a deteriorating patient at the same time she reads the patient monitor to determine the patient's oxygen saturation. Depending on the type of stimuli that are presented, people are often able to divide their attention to address two or more tasks at hand. The mental resources that we require to conduct these tasks will depend on how difficult the tasks are for us to do and how much effort is required to complete the tasks.

Cognitive biases

Slide 16

... Limits of cognition

- Cognitive biases
 - confirmation bias
 - groupthink
 - omission bias
 - framing effect
 - status quo bias
 - recency bias

We are wired to see things in a certain way, and as a result we often draw conclusions that are incorrect about information we are being presented with. We acquire these biases as a result of our tendency to use heuristics, or rules of thumb, which decrease the cognitive load on our brains but increase the chance of introducing errors to our thought process. For example, a study by Jones et al. (2016), found that interviewed nurses almost uniformly agreed that cutting corners undermined patient safety, but they also believed that when they cut corners, they were not risking the safety of their patients.

There are many known cognitive biases including: confirmation bias; groupthink; omission bias; framing effect; status quo bias; and recency bias.

Confirmation bias

A confirmation bias is the tendency for people to seek out or to interpret information that confirms their preconceived thoughts or beliefs. For example, initial diagnosis of a patient may lead up to seeking evidence that confirms the diagnosis and ignoring evidence that is against the initial diagnosis. Confirmation bias can be a problem especially in a busy environment like emergency departments where nurses and physicians tend to stick with their initial diagnosis (Pines, 2006). To overcome confirmation bias, several techniques can be used. One of them is using checklists. Even

if the person is suffering from confirmation bias, checklists can remind them of the other possibilities.

Groupthink

Groupthink is the tendency for a group with similar interests to come to a consensus in order to minimize conflict within the group, even when there is no evidence to support the consensus chosen. Examples of groupthink can be seen in political space (for example, the Iraq War and the false consensus within the US intelligence community on the existence of the chemical weapons). Regarding patient safety, groupthink can show itself as being in a consensus with a charismatic leader in the team and hesitating to express controversial ideas.

Omission bias

An omission bias is the tendency for people to believe that a harmful action is worse than or less moral than an equally harmful inaction. An example of omission bias is the reluctance to vaccinate (Ritov & Baron, 1990) where parents may think that not vaccinating a child is better than vaccinating due to possible adverse effects.

Framing effect

The framing effect describes the tendency for people to draw different conclusions from information depending on how the information is presented. This may be important in communication between healthcare personnel (e.g. between a nurse and a physician) and during handoffs. The way a patient's condition is described can lead to biased interpretations rather than objective assessment.

Status quo bias

Similar to omission bias, a status quo bias is the tendency for individuals to want to avoid change and maintain the status quo. For example, most people tend to stick to their current service providers (status quo) and don't switch to others even if switching would benefit them. In healthcare settings, Abernethy et al. (2005, p.1498) gives the following case as an example of status quo bias: "...For example, consider a patient with pneumonia who is in the ICU, has convalesced, and is in stable condition for transfer to the medical floor. If the patient is found to have a blood glucose level of 500 mg/dL, some clinicians might opt to keep the patient in the ICU until the hyperglycemia is resolved, whereas they would not transfer an equivalent patient from the medical floor to the ICU as a result of the same finding." Here, the physician maintains status quo by not transferring the patient to the ICU.

Recency bias

A recency bias is the tendency for people to place greater importance on something that has been observed recently. For example, after a successful treatment, the doctor may assign a greater value to the effectiveness of the treatment even if that particular treatment is not the best strategy most of the time.

Many of these biases are very common in health care. One way to deal with these biases is to understand and know about them. The best way to become aware of cognitive biases is learning and developing critical thinking skills (Croskerry, 2013). Another approach is to use tools and technology that help reduce these biases. For example, using checklists can act as a reminder of all the other options if the person is biased toward a particular option. As well as the biases mentioned in this section, Croskerry (2003) lists more than 30 cognitive biases that can occur in diagnosis.

External factors affecting cognition

Slide 17

External factors affecting cognition ...

- ▢ Alertness and fatigue
- ▢ Alarm fatigue
- ▢ Workload
- ▢ Multitasking
- ▢ Mindfulness

Alertness and fatigue

When people are tired, it is challenging to perform at their best. Although people require between six and eight hours of sleep every night, most do not get nearly that much, which can affect performance while they are awake. Going without sleep for 24 hours or going an entire week with only four to five hours of sleep per night induces a level of impairment that is equivalent to having a blood alcohol level of 0.1% (Czeisler, 2006). The Institute of Medicine (IOM) has made clear that healthcare professionals suffering from a lack of sleep are a major concern for patient safety, and rules have been implemented in the US to limit the number of consecutive hours residents can work. After 16 consecutive hours on duty, residents must have five consecutive hours of sleep to ensure they can get the rest they need and to better protect patients from errors (IOM, 2008). Our circadian rhythm can also greatly affect our performance. Our bodies naturally have periods of tiredness and alertness and when doing shift work, especially at night, our natural rhythm can be disturbed. Taking frequent breaks can reduce negative

effects of fatigue. This is especially important for critical monitoring tasks which require alertness and attention.

Alarm fatigue

Alarm fatigue is when the constant barrage of sounds (sometimes hundreds every day) emitted by monitors, infusion pumps, ventilators and other devices causes sensory overload and leads to desensitization to alarms. Many of these sounds do not require action, resulting in clinicians missing the true alarms. Alarm fatigue has been the ERCI Institute's (www.ecri.org) top health technology hazards for several years.

Due to the sheer number of false alerts and the lack of standardization of alarm sounds between device manufacturers, caregivers may have difficulty in distinguishing between different alarms, become insensitive, and miss the important alarms (Jones, 2014). To address alarm fatigue, healthcare providers and manufacturers should collaborate to reduce false alarms and increase salience of important alarms by selecting a narrower range of conditions to prompt alarms. The first step in addressing alarm fatigue is understanding the situation at your institution (Karnik & Bonafide, 2015). For example, collecting data on the types of alarms and the frequency of firing in each unit, and interviewing nurses about how they manage alarms will help you understand which alarms cause alarm fatigue, and which ones should be prioritized.

Workload

It is important to consider the workload that is expected of people because it can affect performance, cause stress and can cause people to get burnt out or to experience other negative personal effects. Having a heavy workload, however, does not automatically mean a person will not perform well. In some cases, when workers have a low workload and experience boredom, fatigue and/or sleep loss, poor performance can also result.

Generally, people working under high mental demands are more prone to making errors. Frequent rests can help to deal with high workload. Also, developing mental strategies can be useful. For example, when the task demand is high, the person may try to reduce background noise (such as going to a quiet area before dealing with some important information).

Multitasking and Interruptions

Related to workload, an important factor that affects cognitive performance is multitasking. Healthcare environment is fast paced where nurses and physicians may need to attend to multiple patients and activities simultaneously. One study found that nurses multitask 34% of the time (Kalisch, & Aebersold, 2010). Overall studies show that multitasking (essentially task switching) is detrimental to performance. Interruptions lead to necessary multitasking at times, which can further affect cognitive performance negatively. An outcome of frequent interruptions is that people tend to rely on heuristics (which will be discussed further in the module) and biases when they are dealing with

multiple situations, which can lead to cognitive errors as discussed in the previous section.

Dealing with Stress: Mindfulness

Influx of patients, frequent alarms, interruptions, heavy workload and multitasking can lead to high levels of stress and result in increased burnout, absenteeism, and lower job satisfaction among healthcare workers, and decreased quality of care. Controlling stress is a difficult process and can deplete the person's mental resources that are critical in ensuring patient safety. A recent approach, mindfulness, started to gain popularity as a strategy to deal with stress. Mindfulness refers to bringing one's attention to the moment and is often achieved through meditation exercises. Mindfulness can be a powerful tool to manage stress, as shown by numerous studies. A study found that providing mindfulness training through a continuing education course reduced burnout and increased mental well-being (Goodman & Schorling, 2012) among healthcare workers. Similarly, a Mindfulness-Based Stress Reduction program (MBRS) resulted in decreased stress and burnout among nurses (Bazarko, Cate, Azocar, & Kreitzer, 2013). The techniques used in this study included guided mindfulness meditation sessions, group discussions, and yoga. The positive effects of this mindfulness program lasted 4 months after the program ended. This shows that mindfulness education can have significant benefits to healthcare personnel, which in turn, can increase quality of care and patient safety. A review of the studies published in this field also showed that mindfulness-based programs decrease anxiety and stress and increase empathy towards patients (Dharmawardene et al., 2016). The Institute for Healthcare Improvements provides several mindfulness exercises for healthcare workers (IHI, 2018)

Automation

Slide 18

... External factors affecting cognition

Automation

- use of computers or mechanical systems to assist people
- can help people by freeing them up to perform other tasks
- when designed and implemented poorly, can increase the complexity of a system
- advantages and disadvantages of automation

Automation describes the use of computers or mechanical systems to assist people. Typically automation is preferred for:

- acquiring information;
- interpreting information;

- integrating information;
- repetitive tasks;
- uncomfortable tasks; and
- dangerous tasks.

When designed and implemented well, automation can:

- help people by freeing them up to perform other tasks;
- help people to be more efficient;
- improve performance; and
- increase overall system productivity, especially in high stress or time sensitive environments.

When designed and implemented poorly, however, automation may increase the complexity of a system because:

- people may not understand what the automated system is doing;
- people may not know how to communicate with the automated system;
- people may not trust the automated system;
- people may trust the automated system too much; and
- people may not monitor the system for abnormalities.

An example of some of the advantages and disadvantages of automation is the patient monitor from the module's trigger tape. A patient monitor such as this one displays measurements of a patient's vitals such as heart rate, blood pressure and oxygen saturation as a series of numerical values and waveforms. This automated system frees physicians and nurses from having to discretely measure heart rate, blood pressure and oxygen saturation and in this way they are able to spend more time providing other forms of patient care. Also, in time sensitive situations physicians and nurses can simply glance at the monitor to get an understanding of how a patient is doing rather than having to separately measure each vital. Although patient monitors can improve performance, from the trigger tape, it is clear to see they may also increase the complexity of a system. From the trigger tape, too much trust was put in the technology, the automated system was not clearly understood by those involved and the systems' automation design was flawed because of how easy it was to put the monitor into demo mode.

The Institute for Safe Medication Practices Canada (2016) recommends several measures that need to be taken when deploying automated systems:

- The limitations of automated systems should be clarified during training;
- Ideally trainees should experience automation failures during training to better understand the capabilities and limitations; and.
- Risk analyses such as failure mode effects analysis (FMEA) should be conducted to identify limitations of automation and situations where errors can occur.

Additionally, the framework developed by Borycki and Kushniruk (2017) can be useful in assessing the fit of automation to the workplace. Borycki and Kushniruk recommend testing new technologies (and automation) in three stages before implementing health information technologies in an organization, namely during procurement, pre-implementation and post-implementation.

Inspections during procurement helps to select the technologies (and automation) that would be the best fit in terms of usability. During pre-implementation stage, usability analysts (human factors practitioners) can analyze the devices systematically by using the usability heuristics (discussed later in the module). Simulations can be carried out to see if people can use the new device effectively. And lastly, after implementation, user complaints and workflow issues can be monitored, and incident reporting systems can be established.

Situation Awareness

Slide 19

Situation Awareness

- Three levels:
 - Level 1: Perception
 - Level 2: Comprehension
 - Level 3: Projection
- Situation Awareness is key to successfully handle complex situations in high-paced environments

Situation awareness is defined as "perception of the elements of the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future" (Endsley, 1988, p. 97). In simple terms, situation awareness refers to "knowing what's going on". The concept of situation awareness was born from aviation where pilots had to deal with enormous amount of information and make decisions very quickly. Since then, the concept has been applied to many other safety-critical domains. Situation awareness (SA) entails 3 levels:

Level 1 – Perception: The most basic level of situation awareness. This level refers to detecting and being aware of the objects, events, people, tools, situations around the person. For example, in an operating room, level 1 situation awareness includes noticing machine displays (e.g. heart rate of the patient), patient's situation (e.g. sweat), other members of the team such as nurses, and physical objects such as surgical equipment and drugs.

Level 2 – Comprehension: Comprehension refers to understanding the meaning of the things noticed. This level requires analyzing and synthesizing information. For example,

in the operating room, identifying the situation of the patient by integrating vital signs is considered as level 2 situation awareness.

Level 3 – Projection: The highest level of situation awareness. This level refers to being able to predict what will happen in the near future, given the understanding of the situation and the expertise of the person. For example, in the operating room, this may refer to predicting how a patient will react to a drug, and how the vitals will change as a result of a particular surgical procedure.

At any given point, the person can operate at any of these levels. However, ideally, obtaining and maintaining a level 3 situation awareness is critical, especially in high pace environments. Breakdowns in lower levels can make it very difficult to obtain level 3 situation awareness. For example, if a vital sign has not been noticed (Level 1 error), it may lead to misidentification (level 2) of the situation. Likewise, given all the information and vital signs, mischaracterizing the situation of the patient (Level 2 error) may lead to incorrect actions and future projections (Level 3).

By breaking down situation awareness into multiple levels, we can analyze the work environment, physical and digital devices, teams and communication at different levels of information needs. Consider the case presented earlier in the module. The physician failed to identify the deteriorating condition of the patient (Level 2 SA) because the physician could not obtain the information necessary to make the correct judgement (Level 1) because the device was on “demo mode”.

Communication with team members is also critical for developing higher level situation awareness because team members usually have the key information required to have the complete picture of the situation, as is often the case in operating rooms and emergency departments.

Situation awareness can be measured in a variety of ways. One common method is using situation awareness questionnaires. These questionnaires include questions that can target a specific level of situation awareness, such as whether the person has noticed certain information, whether they can make sense of the situation, and what they expect will happen in the near future.

Lack of situation awareness is often detrimental and has been found as an underlying cause of many accidents and incidents in the past. To deal with loss of situation awareness, technology and tools should provide important information in a timely manner. For example, better clinical displays and computer software can provide information necessary to make correct assessment of the situation and predictions into the future. Parush et al. (2017) implemented such a display in emergency departments to improve resuscitations. These “situation displays” integrated important and critical information used for resuscitation. They found that such a display not only improved situation awareness of the staff, but also led to more team communication. Having a high level of situation awareness as a team is critical as most of the communication between team members are susceptible to information loss (for example, in operating rooms;

Parush et al. 2011). “Being on the same page” is critical for healthcare teams to succeed, and therefore attention should be paid to whether team members accurately and timely share relevant information.

Communication and Handoffs

Slide 20

Communication and Handoffs

- Communication breakdown caused by:
 - Busy environment
 - Time pressure
 - Interruptions
 - Lack of clear handoff procedures
- Standardized handoff procedures
 - SBAR: Situation, Background, Assessment, and Recommendation

The limitations discussed previously not only apply to individual work but also to teamwork and communication. Communication breakdowns during handoffs are one of the most important causes of patient safety related incidents. Handoffs occur when a patient is transferred from one healthcare entity to another (for example, from one clinician to another). A study conducted by Johner et al. (2012) in Canadian acute care surgery services found that 83% of the residents handed over the care of the patients at least once a day. During handoffs, communication errors may happen. A busy and noisy environment can lead to distractions and less effective communication. Similarly, time pressure can result in less than ideal communication and some of the details may be skipped over. Interruptions can also result in communication failures. As discussed in the previous section, multitasking due to interruptions is a very poor mental strategy and can result in cognitive errors such as forgetting important information.

Handoff procedures should ideally be standardized. Additionally, good practices should be followed for handoff procedures. Gleicher and McGhee (2014) implemented standardized patient handover procedures including a formal time out and checklists for handovers from cardiovascular operating room to cardiovascular intensive care unit. They observed significant improvements in handover processes such as less variability in handover content. Similarly, I-PASS Study Group implemented I-PASS handoff techniques (Inpatient Settings Accelerating Safe Sign-outs) in nine hospitals across Canada and the US over 6 months and found that medical error rate decreased by 23% and the rate of patient safety incidents decreased by 30%. (Starmer et al., 2014).

A SBAR toolkit developed by the Toronto Rehabilitation Institute and the Canadian Patient Safety Institute provides comprehensive tools to facilitate communication during handoffs. This toolkit allows practitioners to articulate **S**ituation, **B**ackground,

Assessment, and Recommendation clearly during handoffs. More information about SBAR, teams and communications are also covered in the PSEP – Canada Module 4: Teamwork: Being an Effective Team.

Why cognitive engineering is important in healthcare

A lot of knowledge exists about how people perceive, and process information and this knowledge should be incorporated into healthcare systems to enhance the fit between people and the system in which they work. People have limited memory and attention and interpret the world using a number of cognitive biases. Other factors such as how much sleep we get, our workload and the automation of systems can also affect how we perform cognitively.

The importance of cognitive engineering in healthcare becomes more obvious as more and more incidents are analyzed. For example, a poster published by the Institute for Safe Medication Practices Canada (2017) analyzing 403 medication incidents revealed that issues contributing to these incidents involved confirmation bias, heavy workload, and environmental distractors. <https://www.ismp-canada.org/download/posters/PPC2017Poster-Metforim.pdf>

Looking at patient safety and work practices from a cognitive engineering lens allows us to identify the mismatch between the system (device, medication, procedure) and human capabilities and limitations, and take appropriate measures to increase patient safety.

Physical ergonomics

Section objectives

This section aims to:

- define physical ergonomics;
- provide examples of good and bad physical fit between people and tools;
- explain how a poor physical fit between people and tools can result in injury or discomfort; and
- identify the impact of human variability on the design of technologies.

Introduction to physical ergonomics

Slide 21

Intro to physical ergonomics

- The design and arrangement of equipment within an environment such that people can interact with it in a safe, comfortable and efficient manner
- The Human-Tech Ladder: physical anthropometry
example: surgical tools

Physical ergonomics is a discipline concerned with the design and arrangement of equipment within an environment such that people can interact with it in a safe, comfortable and efficient manner. Physical ergonomics is informed by an understanding of biomechanics, anatomy, anthropometry and physiology.

Every day, people often do not think twice when they interact physically with the world. In the morning for example, consider the many physical feats necessary just to get out of bed (sitting up, pulling off the covers, placing feet on the floor and pushing off the bed and into a standing position).

People are used to performing these types of tasks. They are able to make use of physical capabilities in order to interact with the world. People are able to grab onto handles to open things, manipulate their fingers to grasp things and use their strength to lift things. It would be different getting out of bed if the objects that were interacted with did not support the needed capabilities. What if the bed was 6 feet off the ground? This may seem silly, but in reality there are some bad designs that do not match our physical capabilities. For patients, these features can be all important in preventing falls.

Examples of physical ergonomics

There are everyday things that people interact with that are difficult to physically use. They could be things that are:

- hard to reach, like items on top shelves;
- difficult to open, like medication bottles;
- hard to press, like levers to adjust hospital beds;
- heavy to lift, like infusion pumps; or
- tough to disconnect, like intravenous infusion tubing.

The Human-Tech Ladder: physical

The Human-Tech Ladder (Figure 5) focuses on the physical fit between people and technologies within a system. Characteristics and capabilities of the human body should be taken into account when considering technologies, to ensure that people can safely and efficiently interact with them. An understanding of the range of physical dimensions of intended users, as well as an appreciation for how users can vary is essential. The discipline that focuses on measurements of the human body is called **anthropometry**. Textbooks full of measurement data exist, which designers can reference to ensure their designs will be proportionate to their intended users.

Although the physical measurements of people vary, designers must still take into account the range of physical dimensions of the intended users. For example, many surgical instruments are designed for use by male hands; however more recently, female surgeons have become much more prevalent. Female surgeons have had to cope with tools that are too large and that require excessive force or sometimes even two hands to use. Using surgical tools that do not fit the surgeon's hand can make performing surgical procedures more challenging and may also lead to injury. Offering differently sized tools or redesigning surgical tools such that they are adjustable can help accommodate a wider range of users.

Examples of physical parameters that should be taken into account by designers include things like reach, strength, dexterity, hand size, height, balance and visual acuity. In addition to the physical characteristics of the intended users, environmental parameters such as lighting, temperature, humidity, vibration and noise can also affect a person's physical abilities. For example, a pharmacist may have no trouble verifying a paper order before entering it into the patient's medication record when lighting in the area is good, however, in dimly lit conditions, the same pharmacist will have much more difficulty being able to see and verify the same paper order.

Consequences of a poor fit (people and technologies)

Slide 22

Consequences of a poor fit

- Injuries or discomfort may occur
 - work-related musculoskeletal disorders (WMSDs)
 - repetitive strain injuries (RSIs)

When a poor fit between a person and a technology exists, injuries or discomfort may occur. Work-related musculoskeletal disorders (WMSDs), also commonly referred to as repetitive strain injuries (RSIs), describe a collection of injuries affecting nerves, muscles and tendons with some examples being tendonitis and carpal tunnel syndrome. WMSDs often result from the postures and movements required on the job and can be affected by how repetitive tasks are, how quickly tasks are carried out and the forces involved with the task at hand. In addition, vibration and temperature can exacerbate the potential for experiencing a WMSD. Musculoskeletal disorders are the most common forms of lost-time injury and generate the largest worker compensation costs in Canada. The estimated cost of musculoskeletal diseases to Canada is \$22 billion each year (Canadian Institutes of Health Research, 2014).

Lower back pain is also commonly experienced, especially by nurses. A study by Vieira (2006) found that 58% of ICU nurses and 65% of orthopaedic nurses experience debilitating lower back pain at some point during their careers. Nurses often have to turn and transfer patients as well as lift and move equipment. These types of lifting tasks are repeatedly performed throughout the course of a shift and can lead to back injuries. Minimizing the need for nurses to perform these tasks by implementing patient lifts, putting equipment on booms and/or de-cluttering patient rooms for improved access to medical equipment may help to reduce the prevalence of lower back pain.

The safety of a lifting task can be assessed using the guidelines developed by The National Institute for Occupational Safety and Health (NIOSH; Waters et al. 1994). Canadian Centre for Occupational Health and Safety (CCOHS) also recommends using NIOSH guidelines to assess the safety of lifting tasks. According to these guidelines, lifting tasks can be made safer by reducing the frequency of lifting, eliminating awkward postures such as twisting the body, keeping the equipment close to the body and reducing how far the equipment is lifted. To achieve these, physical

environments should be designed accordingly. CCOHS provides comprehensive guidelines and courses on preventing musculoskeletal disorders and increasing workplace safety.

Other examples of poor fit

Other examples can be found during a regular shift at the hospital. There are specific actions that could lead to a WMSD or to lower back pain, such as regularly having to lift or transfer patients, moving equipment or carrying out repetitive actions like prepping and priming IV lines. PSEP – Canada Module 9: Methods for Improving Safety has more information on how to conduct an FMEA so potential mitigating strategies to these issues can be identified.

Why physical ergonomics is important in healthcare

A good match between people and the physical environment is essential to ensure healthcare professionals are comfortable, safe and efficient while carrying out their daily tasks. Tools that have not been designed to match the dimensions and physical capacities of people will be difficult to use and when a poor physical fit between a person and a technology exists, injuries or discomfort may result.

An understanding of physical ergonomics is not only important to clinicians. With the increase in home care among patients, it is important that clinicians are also communicating with patients and caregivers regarding physical care interactions and how to manage safety risks and plan safer care. One study found that the prevalence of physically demanding work among homecare workers was as high as 56%, which demonstrated a significant association with a six-month incidence of musculoskeletal disorders (Kim, 2010).

Design and evaluation

Section objectives

This section aims to:

- explain how applying the Human-Tech Ladder can help create systems that fit well with people;
- describe the user-centred design (UCD) approach and why it is helpful;
- apply design heuristics to consider the usability of healthcare-related technology; and
- explain why training and policies are less effective than forcing functions.

Introduction to design and evaluation

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Design and evaluation

- Human factors methods have the most impact when employed in the design stage
- Using the Human-Tech Ladder to evaluate technologies
 - user-centred design
 - heuristics
 - hierarchy of effectiveness

A good fit between people and tools is imperative to ensure:

- an improvement in patient safety;
- an improvement in efficiency;
- an improvement in technology adoption;
- an improvement in user experience; and
- a reduction in the resources required to train users.

Human factors methods have the most impact when they are employed in the design stage because technologies will then be designed with the target user and system in mind. In addition to being applied at the design stage, human factors is also frequently used to analyze technologies or environments that are already in use. Applying human factors in this way can uncover potential issues and solutions so that users become well supported when using those technologies within the system.

Using the Human-Tech Ladder to evaluate technologies

The Human-Tech Ladder, which was introduced earlier in the Introduction to Human Factors section, is a useful way to categorize the many levels on which people interact with technology. By considering the fit of people and technology at each of the five levels: physical, psychological, team, organization and political, it is easier to select technologies that are designed to complement the abilities of people rather than requiring people to adapt to the technologies they are presented with.

One example would be a smart pump implementation. Starting at the physical level, one must consider whether the interface is mounted within reach, whether everyone can press the buttons accurately and whether everyone can move the pump if required.

The psychological level considers whether everyone is able to figure out how to get the pump to operate in the wide range of circumstances required, whether everyone has to keep critical information in our working memory from one screen to the next and whether or not the alarms associated with the pump can be heard.

Moving up another rung to the team level, this pump needs to be evaluated for how might it work within a team, perhaps a clinical unit in this case. Is it easy to tell where an alarm is coming from and what it is indicating when several of these pumps are close to each other and, are other nurses on the unit able to easily figure out what is going on with another nurse's patient's infusion pump if they are covering? Additionally, the drug library should be designed by all the required stakeholders such as pharmacy and IT, and the needs of each unit should be taken into account in the drug library design.

Moving up to the fourth rung (the organizational level), any disincentives to using the pump should be considered, such as whether the pumps significantly increase the nurses workload, or whether the culture on the unit is generally not welcoming of new technologies.

Finally, at the political level, has the design has received regulatory approval from Health Canada? For more information about approval of medical devices in Canada, see PSEP – Canada Module 6: Technology: Impact on Patient Safety.

To create good Human-technology systems, a number of tools exist to evaluate the fit between people, technologies and systems. **User-centred design, heuristics** and the **hierarchy of effectiveness** are three such tools that focus design and evaluation mainly at the bottom two rungs of the Human-Tech Ladder: physical and psychological (Figure 5). These tools are often most effectively applied at the design or technology selection stage. However, they may be used in your own healthcare institution at any point to evaluate how well technologies and systems match the needs of the user.

The Human-Tech Ladder in your institution

The Human-Tech Ladder can be applied to any tool or technology that is used in the context of your healthcare organization (the environment in which it is used should be considered) to learn about how the technology fits with people at the physical, psychological, team, organizational and political levels.

User-centred design

Slide 24

User-centred design ...

- Methods that promotes the interaction of designers, users of technology and the technology itself throughout the design process from inception to completion



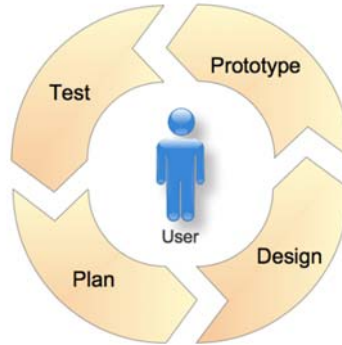
Slide 25

... User-centred design

- Use a pen and paper drawing to gather feedback from users
 - could occur multiple times before the next step
- Apply feedback to the next prototype
- Persuasive design
 - motivate users through design

User-centred design (UCD) is a method that promotes the interaction of designers, users of technology and the technology itself throughout the design process from inception to completion. Having the intended users of the technology participate in this way allows information to be collected about what works well and what doesn't before having to commit to a final design. Figure 12 shows the UCD process, which cycles through the steps of planning, designing, prototyping and testing with representative end users involved at every step. This cycle is often repeated several times until the prototype fits well with the user's capabilities and preferences in the intended environment.

Figure 12

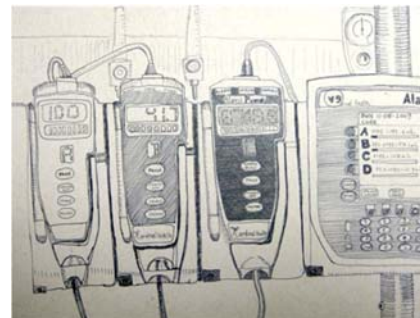


Figures 13, 14 and 15 illustrate the UCD process. These Figures represent how one might go about the UCD process for an infusion pump. Figure 14 is a pen and paper drawing, which can be a useful and economical way to get an initial idea of the components and layout of a design.

Figure 13



Figure 14



A drawing such as this would then be shown to intended users to gather feedback before moving onto the next prototyping stage. Users might be asked to explain how they would complete a number of tasks given the drawing, and in this way, information about how people would physically and cognitively interact with the proposed device can be collected. The process of creating a pen and paper drawing and showing it to users to gather feedback could occur multiple times before moving on to development of the next type of prototype. The strength of this approach is that the designs are easy to discard, as little effort has been put into their creation. Figure 15 represents a computer-drawn prototype that would be developed based on user feedback from the hand-drawn version. This prototype would again be shown to intended users, and then feedback would be collected and applied to the next prototype.

In user testing, a procedure called think-aloud technique can be used to identify how well people can understand how to use the device. This technique requires the user to think aloud while interacting with the device. This can help the designers to identify problems users can experience when using the actual product. For example, if a user says that they don't understand the meaning of a symbol on the device screen, this is an important sign that perhaps there was not enough clarity or affordances on the symbol.

Figure 15

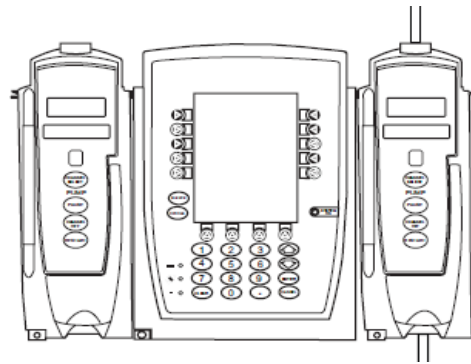


Figure 13 represents the final product, by which time several prototypes (including hand drawn, computer drawn and tangible prototypes) would have been reviewed by users. Feedback collected from users as they interacted with each prototype would have been incorporated into the final design. UCD enables technologies to be designed that support users because users were involved and gave input about their needs from the beginning.

Persuasive Design

A recent development in the field of design and human factors is persuasive design. Persuasive design refers to approaches that change user behaviour by making a technology more engaging (and fun) using design principles. This approach goes beyond usability of technologies, and it aims to encourage users to change their behaviours by providing motivational design elements (Fogg, 2009; Oinas-Kukkonen, Harjumaa, 2009). In a recent study, St-Maurice et al. (2017) used persuasive design techniques to improve electronic medical record systems by motivating clinicians to enter data in a complete and timely manner. They provided clinicians statistics about their data entry activities over a month and showed how timely they entered patient records on the new electronic medical record system interface. For complete and timely entries, clinicians earned rewards in the form of badges and awards. They found that adding these simple changes to the electronic medical record system interface increased the same-day entries of patient records by almost 10%. These results are promising and suggest that persuasive design can be successfully used in designing healthcare technology that creates positive behaviour change and increase patient safety.

Heuristics

Slide 26

Heuristics ...

- 14 heuristics that can be applied to medical devices
 - consistency and standards
 - visibility of system state
 - match between system and world
 - minimalist
 - minimize memory load
 - informative feedback

Zhang, 2003

Slide 27

... Heuristics

- 14 heuristics (continued)
 - flexibility and efficiency
 - good error messages
 - prevent errors
 - clear closure
 - reversible actions
 - use user's language
 - users in control
 - help and documentation

Zhang, 2003

Heuristic evaluation can be used to identify issues with technology designs by comparing the technology in question against general “rules of thumb” that outline good design principles. Zhang has developed 14 heuristics that can be applied to medical devices based on previous work by Jakob Nielsen and Ben Shneiderman (Zhang, 2003). These heuristics allow us to consider how well technologies have been designed to fit the capabilities of people especially from a physical and cognitive human factors perspective.

1. Consistency and standards

Conventions should be present so users do not have to wonder whether similar words or symbols mean the same or different things. If standards exist that are relevant to the technology, they should be incorporated into the design of the technology

2. Visibility of system state

Users should always be able to determine what is happening within a system through the use of feedback.

3. Match between system and world

The system should show the user things they will understand and would expect to see from their everyday experiences rather than showing the complexities of how a system is operating in the background, especially if it will not mean anything to the user.

4. Minimalist

Information displayed to the user should be relevant to the task at hand. If extra information is included on a user interface that is rarely needed or used, it competes with the remaining useful information, which could make seeing the relevant information more challenging.

5. Minimize memory load

Minimize the information users must retain in their working memory by making things visible and using cues to guide their actions along the way. Ensure users do not have to remember information as they go from one screen or task to another and that instructions can easily be accessed by the user as they are completing their task.

6. Informative feedback

Feedback that is prompt and informative should be provided to users to help them determine the impact their actions have had on the system.

7. Flexibility and efficiency

Technologies should be easy and efficient to use both for novices and experts. Incorporating the ability for experts to use shortcuts, especially for commonly performed tasks can help cut down on interaction time and can minimize user frustration.

8. Good error messages

Language used to identify an error should be clear and concise and should help guide the user towards an acceptable solution.

9. Prevent errors

Situations where users can easily get into error prone situations should be minimized or eliminated. If errors cannot be eliminated, ensure users are aware an error exists either via an error message or by having them confirm their action with the understanding that it may lead to an error.

10. Clear closure

Information should be provided to the user about the start and finish of a task so the user has an understanding of when a task has been completed

11. Reversible actions

Users should have the ability to exit from a function that was chosen by mistake and to recover from errors without having to go through a complicated process to undo an action.

12. Use users' language

The language used on an interface should always support understanding by the intended users.

13. Users in control

Users should always feel that they are in control of the system, not that the system is in control of them.

14. Help and documentation

Documentation meant to assist the user should be clear, concise and easy to search. Help should be focused on the user's task, should be broken down into a number of discrete steps and should be visible to the user as they are troubleshooting so they do not have to remember a list of steps while trying to navigate the device.

Heuristics in practice

Two bottles of adrenaline are shown in Figure 16. The bottle shown on the left is an injectable version, while the bottle shown on the right is a topical version.

Figure 16



1. Consistency and standards

Information required on the labels of medication bottles is outlined in the Canadian Standards Association CAN/CSA-Z264.2-99 (Canadian Standards Association, 1999) standard for labelling of drug ampoules, vials and pre-filled syringes. In this case, colour is the most obvious distinguishing feature between the injectable and topical versions of the drug. Colour standards to represent injectable versus topical medications do not exist in Canada and as a result, practitioners may not relate colour to whether the medication is injectable or meant for topical use. Consistency between the two bottles of adrenaline does not exist for concentration with the injectable version having larger blue text than the topical version.

2. Visibility of system state

It is difficult to tell how much medication is left in these bottles because the containers are opaque. Also, it would be challenging to identify the difference between the injectable and topical adrenaline, especially if both medications were stored standing up in a drawer. From the top, both versions of the medication look virtually identical and practitioners might not notice any difference between the topical and injectable versions.

3. Match between system and world

Since the option exists for a user to puncture the lid of the adrenaline meant for topical use with a needle and draw the medication up into a syringe, a good match between the system and the real world does not exist. If the design prompted users to interact with it in the desired way, for example if there was a screw cap that could not be punctured with a needle, a better match between the system and the real world would exist.

4. Minimalist

The labels on the bottle look busy with different styles, sizes and colours of text. It is difficult to know where to look first, however the medication name, coloured rectangle and name of the company are the predominant features on the label. It would likely be difficult for a healthcare professional glancing quickly at the medication bottle to discern the important information on the bottle. Information such as the address of the manufacturer could be removed to unclutter the label.

5. Minimize memory load

Although the label does indicate injectable versus topical use, this information is not readily visible to the user, especially if considering one of the bottles in isolation of the other. People may not remember there are two versions and as a result, may not look for this distinguishing information on the label.

6. Informative feedback

The medication bottles do not provide a means of feedback, especially if the adrenaline meant for topical use is drawn into a syringe. It is up to the healthcare practitioner to recognize the note on the label and refrain from injecting the topical adrenaline. This is made especially challenging by the design of the bottle of the medication meant for topical use, which allows a user to draw the medication into a syringe. Considering a top view of the medication bottles, if they were stored upright in a drawer, the user would receive little feedback about the difference between the two versions of the medication.

7. Flexibility and efficiency

The flexibility to puncture the lid with a needle or to open the bottle using the metal tab is dangerous in this case. Users should not be provided with the flexibility to choose how to access the medication given the consequences will be dire if topical adrenaline is administered via injection.

8. Good error messages

There is no error message afforded by the design of these medication bottles. If a user were to draw the topical adrenaline into a syringe, there would be no means of communicating the error to the user. This design relies on user vigilance in reading and understanding the label, which is clearly not ideal.

9. Prevent errors

This design does not prevent user error. Instead, the bottle with the medication meant for topical use encourages user error because the rubber stopper on the top of the bottle can be punctured with a needle and is similar to the top of the bottle for injectable adrenaline.

Considering a top view of the two medication bottles, there is little difference between the injectable and topical versions of adrenaline.

10. Clear closure

Considering these two medication bottles, the user should be able to tell when they have started and finished their task, however, the user will not know whether the task was done correctly.

11. Reversible actions

Technically a user would be able to refrain from injecting topical adrenaline into a patient if they happened to notice the label said for topical use, however since there is no feedback about errors available to practitioners, it is unlikely this error would be noticed if it had already been drawn into a syringe.

12. Use users' language

Language used on medication labels often must be useful to multiple users including pharmacists, physicians and nurses. The language used on labels must also comply with the CAN/CSA-Z264.2-99 (Canadian Standards Association, 1999) standard for labelling of drug ampoules, vials and pre-filled syringes. Since so many user groups' needs must be met through the language used on the label, it is inevitable that extra information, not required by some of the user groups will be listed. This goes against the heuristic for "minimalist".

13. Users in control

Users are likely to feel they are in control of this system, however, a false sense of security may be provided by the apparent simplicity of the medication bottle designs. Users may not appreciate how problematic the design of the bottle with medication meant for topical use is.

14. Help and documentation

Users may not be aware of the difference between the two medication bottles and as such, may not seek out help or documentation when they come into contact with the design. Generally people seek out help and documentation when they hit a road block and cannot figure out what to do next. Since the design of the bottle containing medication meant for topical use seems straight forward to use and does not provide any way for users to diagnose an error, it is unlikely help and documentation would be sought out.

Heuristics in your institution

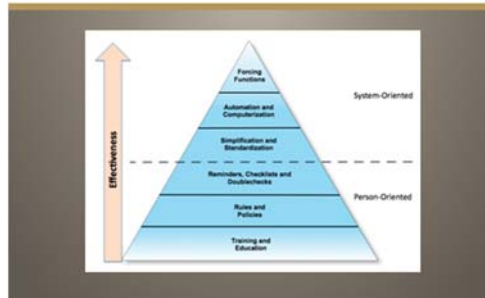
The above example can be applied to any piece of equipment or product that is used in a healthcare institution. The analysis on it can identify whether potential design issues

exist. If it becomes clear there are concerns with the equipment or product, a FMEA should be conducted (covered in PSEP – Canada Module 9: Methods for Improving Safety).

Hierarchy of effectiveness

Slide 28

Hierarchy of effectiveness ...



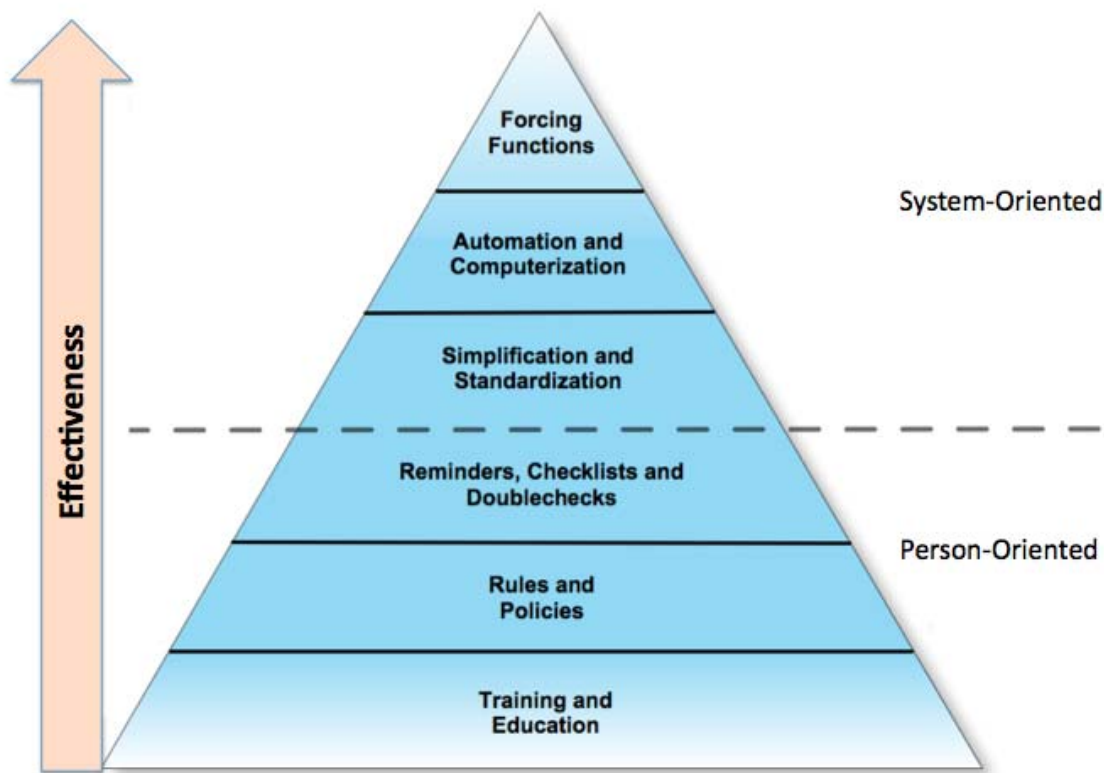
Slide 29

... Hierarchy of effectiveness



The hierarchy of effectiveness (Figure 17) is a toolbox that can be used to consider how effective a design or error mitigating strategy will be based on what we know about the physical and cognitive strengths and limitations of people.

Figure 17



The hierarchy of effectiveness includes both person-oriented and system-oriented strategies to error prevention with the effectiveness of each strategy improving as we move up towards the pinnacle of the triangle. Person-oriented strategies can assist in preventing errors, however, these strategies still rely on vigilance. Even when people have the best of intentions, errors can occur. The system-oriented strategies focus more on how systems have been designed to help guide users within the system. System-oriented strategies are typically more robust than person-oriented strategies because they are meant to support the decisions and actions of people and minimize the requirement for people to behave and act perfectly.

It may be surprising to learn that training and education, shown at the bottom of Figure 17, is not one of the more effective ways to minimize errors. Training is often used to familiarize people with technologies and systems and is an important part of becoming familiar with a new device or system. Training is also a great way to practice skills required to safely carry out a job because of the repetition involved. However, when training is implemented in response to a poor device or system design, or to reinforce proper device usage after an incident, it is not effective. Training that is meant to mitigate a poor device or system design opens us up once again to the issue of vigilance. For example, even if a user was trained how to get around a problematic device feature, it

would still be possible for the user to err depending on the other cognitive pressures being experienced at the time.

Rules and policies are often implemented in healthcare organizations because they can be broadly disseminated and serve to guide employees about appropriate conduct in the workplace. Rules and policies are often put into place as a result of an incident in order to control how people behave and act, but they do not always stop an action from being performed and do not get at the system level factors that contributed to an incident. Depending on the demands placed on a worker, rules may not always be followed or followed correctly and sometimes the rules and policies implemented do not really fit the workflow of the healthcare professional.

Reminders, checklists and double-checks can help to prevent errors by assisting people to remember things and by involving multiple people in a process. Although these tools may be useful, people can easily become desensitized when a checklist is routinely filled out or a reminder is routinely seen. When it comes to double-checks, often they are not done independently, and even when they are, we are all still susceptible to cognitive biases such as attentional blindness and confirmation bias. It is not uncommon for more than one person to make the same mistake. Reminders, checklists and double-checks may help in identifying errors, however, they do not prevent errors from occurring.

Simplification and standardization is more of a system-oriented strategy to preventing errors because it focuses on tailoring systems to match what people are used to, or what they might expect. Having a single device model instead of several versions of the same device type would mean that people would only have to be familiar with a single device. Reducing complexity by simplifying and standardizing can help people to focus on the important parts of a task instead of trying to sort through a collection of information. Although simplification and standardization can help in preventing errors, it is not an ideal solution because people are still prone to slips and only some of the issues within a system will be accounted for.

Automation with computerization is another system-oriented strategy that can shift some of the tasks we know to be potentially problematic for people, to computers. Those tasks that require people to memorize, calculate or monitor can be transferred to computers, which are reliable at performing these actions. Although automation can support the abilities of people, it is possible for errors to be introduced upstream of the automated step, since people design computer systems, and these errors could go undetected by people because they are computerized or automated.

Forcing functions are design features that force or prevent a user from carrying out an action that could lead to an error. They are considered the most robust method of preventing errors because by preventing people from continuing down the path of making an error, it is unlikely for that error to occur. Although forcing functions are considered to be robust, it can sometimes be difficult to design-in forcing functions because of the wide range of tasks for which devices can be used. Also, in some cases it may be necessary for

an “override” function to exist, which may encourage people to sidestep forcing functions. An example of a forcing function would be the gas line shape coding on anaesthesia machines. The nozzles for each gas line are designed to fit only in the matching socket.

In application

The hierarchy of effectiveness could be applied to the trigger tape such that the adverse event could have been avoided. There are pros and cons of using each level of the tool in the context of the scenario.

Training and education

The physician could have been taught during in-service training about how easily the monitor could be put into demo mode.

Pros: The physician might have been better tuned to looking for this potential issue when the patient appeared to be doing poorly but the monitor showed the patient had a normal sinus rhythm.

Cons: The physician still may not have realized the monitor was in demo mode even if he had been trained to recognize this monitor state. Also, even if training had been implemented for the device, the physician may not have received training or may not have remembered this training if it was delivered in the past. Training can also be time consuming and resource intensive.

Rules and policies

A policy could have been implemented to remind employees to verify this particular monitor was not in demo mode each time they looked at the screen.

Pros: The physician might have been able to determine the monitor was in demo mode, shortening the amount of time the patient was in ventricular fibrillation.

Cons: The physician might not have known this policy existed or might not have remembered to follow this policy since hospitals often have thousands of employee policies.

Reminders, checklists and double-checks

The physician could have used a checklist or a reminder to verify whether the monitor was in demo mode. Alternately, the physician could have had someone else double check the monitor to identify what the problem was.

Pros: A checklist or reminder could have prompted the physician to verify whether the monitor was in demo mode. Alternately, a second person double checking the correct operation of the monitor could have helped to identify the monitor was in demo mode.

Cons: The physician may not have remembered to use a checklist, or may not have seen or been prompted by a reminder. In this case, using a checklist, reminder or double check may not be practical due to the resource intensive nature of this type of activity. Also, depending on the type of check implemented, it may not be clear whose responsibility it is to verify correct operation of the monitor.

Simplification and standardization

A single model of patient monitor could have been used in the hospital, which might have allowed the physician to become an expert user of the device since there would have only been a single device like it in use. Alternately, industry partners could get together to identify consistent standards for all patient monitor displays so all monitors would have the same warning for being in demo mode or the same set of steps required to enter demo mode. Finally, if demo mode was not a standard mode of operation, but instead required a specific series of key presses, it would greatly reduce the chance for the monitor to be in demo mode.

Pros: If all monitors in the hospital were the same or if industry partners got together and decided upon standards for patient monitors, the physician might have realized the monitor was in demo mode because he would have been more of an expert at using the device. Also, if demo mode was not a standard mode of operation, it would be unlikely the monitor would have entered into demo mode.

Cons: Even if all monitors in the hospital were the same or if industry partners created a standard for patient monitors, if a demo mode was still available as an option, it may still have been accidentally selected by the physician.

Automation and computerization

The monitor could have been designed such that if demo mode was entered, it would automatically revert back to the patient monitoring mode after a couple of minutes.

Pros: Even if the monitor was put into demo mode, the monitor would automatically revert back to patient monitoring mode after a few minutes, limiting the length of time a patient would not be monitored.

Cons: The patient could still potentially not be monitored for a couple of minutes while the monitor was in demo mode.

Forcing functions

The monitor could have been designed without a demo mode so the user would not have been able to select it by accident.

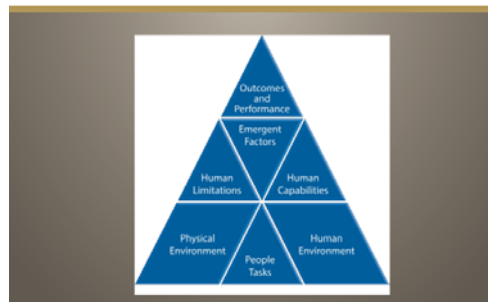
Pros: The monitor would not have been in demo mode at all and so the length of time the patient experienced ventricular fibrillation would have been greatly reduced.

Cons: The monitor may require a demo mode and in some instances, an override may be necessary. Whenever an override exists, it provides an opportunity for users to side-step forcing functions, essentially defeating the purpose of these error mitigating strategies.

HF-MARC Framework

Slide 30

HF-MARC Framework



Slide 31

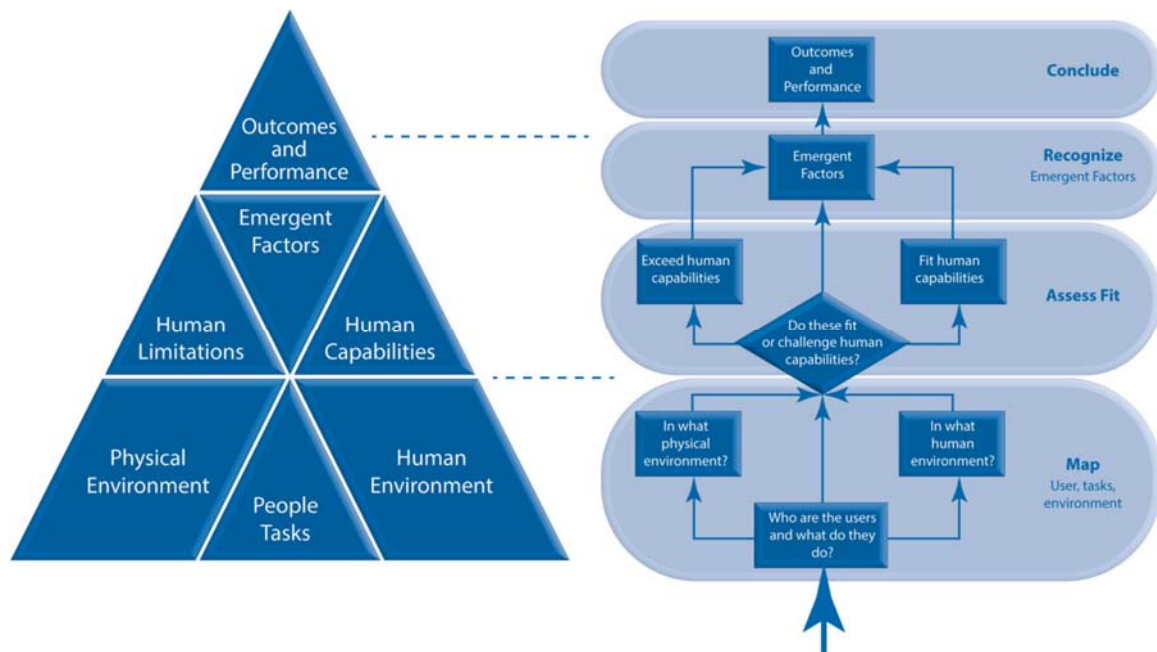
HF-MARC Framework

- ▣ **Map** - Understand people, tasks, goals, physical environment
- ▣ **Assess** – Assess human capabilities and limitations
- ▣ **Recognize** – Identify factors emerging from task demands and human limitations
- ▣ **Conclude** – Predict and understand performance and outcome

A recent framework developed by Parush et al. (2017) provides a powerful and systematic way of analyzing incidents as well as proactively assessing systems, equipment and procedures.

HF-MARC stands for Human Factors Conceptual Framework to Map-Assess-Recognize-Conclude. The framework is a comprehensive and systematic guide to evaluate technology, situations and processes in healthcare.

Figure 18



The HF-MARC framework consists of 4 steps:

In the first step, “Map”, people involved in the situation, their goals, tasks and physical environment are defined. In this step, the analyst identifies **people** involved in the site, situation, or process. Then the analyst identifies the **tasks** people do, and their goals. Finally, the analyst identifies the **environmental setting**: physical environment, organizational factors, tools and devices.

In the next step, “Assess”, the analyst analyzes the situation and tasks, identifies cognitive requirements and task demands, and assesses human **capabilities** and **limitations** (topics discussed throughout this module). For example, the analyst lists all the relevant cognitive limitations that may play a role in the situation.

In the next step, “Recognize”, the analyst identifies **emerging factors** in the situation, given task demands on one side and human capabilities on the other. In this step, the analyst could identify factors such as stress, high workload, and communication issues.

In the final step, “Conclude”, the analyst takes the insights generated in previous steps and analyzes the predicted performance and outcomes of the situation.

Based on the outcomes (Conclude step), recommendations are generated that address issues uncovered in the analysis. The complete method and step-by-step guide can be found in Parush et al. (2017).

Why design and evaluation are important in healthcare

People should not have to adapt to technologies and systems, but instead technologies and systems should be designed to support people. Most have access to a number of tools that allow those involved to consider whether a good fit is achieved at the design stage, before implementing a new technology or to evaluate technologies that are already in use. By applying tools such as user-centred design, heuristics and the hierarchy of effectiveness, areas of mismatch that could lead to patient safety issues, poor efficiency, poor technology adoption, a negative user experience or increased training requirements can be identified. These areas of mismatch can then be addressed using some of the techniques outlined in PSEP – Canada Module 9: Methods for Improving Safety, such as FMEA. Although these tools can be useful in identifying problematic designs and error mitigating strategies, **no approach is failsafe**. Designs and error mitigating strategies need to be considered from all levels of the Human-Tech Ladder to ensure they are as effective at supporting the needs and expectations of people as possible.

Human error

Section objectives

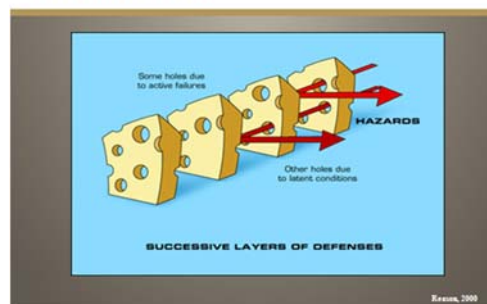
This section aims to:

- apply Reason's Swiss cheese model of error to a healthcare system to describe how hazards can become harmful incidents;
- explain the difference between active and latent failures;
- provide an example of a slip, a lapse and a mistake; and
- explain the difference between a near miss and an adverse event.

Introduction to human error

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Human error

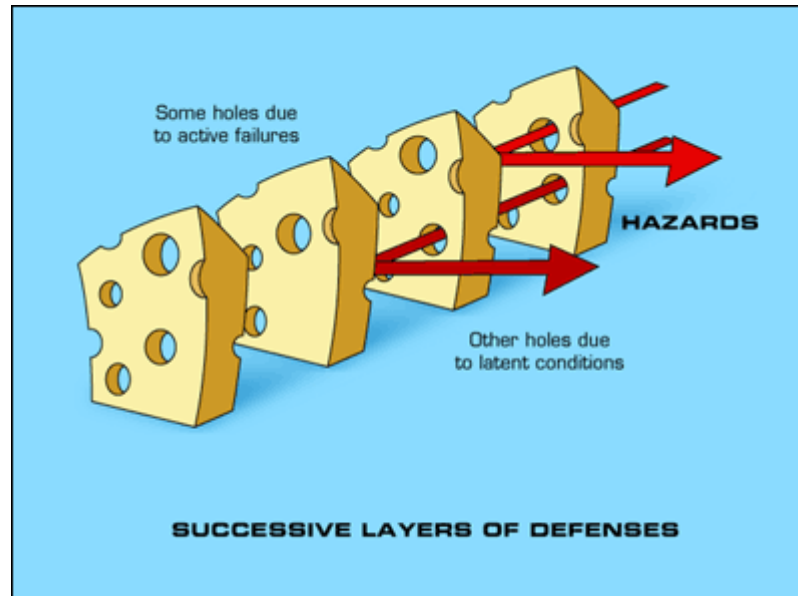


The trigger tape for this module illustrated that when an error occurs, even though the first reaction may be to hold a person directly involved accountable, there are many upstream factors that also need to be taken into account. In the case of the trigger tape, thinking about things like the physician's lack of sleep, and what effect a different patient monitor might have had on the situation, help us to consider that it was not simply the physician failing to notice his patient was deteriorating that resulted in this event, but instead a series of upstream decisions and actions that contributed to this occurrence. Had different decisions and actions been made about things like scheduling, selection of monitors for the unit and design features of the monitor, this particular adverse event may never have occurred.

To consider how errors can propagate from the decisions and actions that were made upstream all the way to the patient, we can use Reason's Swiss cheese model (Reason, 2000). This model, an adaptation of which is shown in Figure 19, can be used to describe how even when we have many barriers in place to try to prevent errors from occurring, each barrier, no matter how well intentioned, has inherent weaknesses that will ultimately align to create opportunities where hazards can propagate through the system, becoming harmful incidents. These weaknesses can come from a number of sources along all the

rungs of the Human-Tech Ladder. Physical, psychological, team, organizational and political areas of mismatch between people and systems can create hazards and weaknesses in the healthcare system.

Figure 19



In Reason's model, which is also described in PSEP – Canada Module 1: Systems Thinking: Moving Beyond Blame to Safety, each slice of cheese represents a barrier put in place to try to make the healthcare system safer. Each safeguard inherently contains a number of weaknesses, which are represented by the holes in the cheese. The holes in the slices of cheese are continuously moving around and often a subsequent barrier is able to stop a hazard from reaching the patient, but when the holes line up in certain combinations, hazards have the opportunity to sneak through the safeguards that have been put in place and find their way to the patient.

The holes at the end of the system, which come into contact with the patient, are termed *active failures* and generally involve those at the sharp end of patient care: nurses, physicians, surgeons, anaesthesiologists, pharmacists etc.

Active failures may surface due to a number of mechanisms including *lapses*, *slips*, *mistakes* or *violations*. A *lapse* occurs when you experience a temporary failure of concentration, memory or judgment such as if you forgot to check a patient's wristband or if you were to check a patient's medications against their chart twice because you weren't sure whether you had already verified them. A *slip* occurs when you interpret perceived information correctly and intend to carry out the correct response, but end up performing the wrong action accidentally. An example would be if someone just saw Mr. Smith and then picked up Mr. Jones' chart when he/she meant to pick up Mr. Smith's chart. A *mistake* occurs when you do not correctly interpret information, which can lead to an incorrect action. An example would be if a patient were misdiagnosed because someone incorrectly interpreted their symptoms and then selected the wrong treatment

for the patient based on the misdiagnosis. A *violation* occurs when someone intentionally chooses to act in a way that goes against accepted protocol, such as if a person knew that he/she were supposed to document a patient's medication but was busy and decided not to include this information in the patient's chart or if you were in an emergency situation and had no time to document this information. The culpability model, which is described in PSEP – Canada Module 1: Systems Thinking: Moving Beyond Blame to Safety can be used to determine whether an action resulting in a failure was intentional (violation) or accidental (mistake, slip, lapse).

The holes in the slices of cheese that do not come into direct contact with the patient are termed *latent failures* and generally result from designs and decisions made upstream from those at the sharp end. Latent failures can take on many forms such as administrative decisions, policies, budgets, staffing levels and schedules.

Depending on the hazard in question and the active and latent factors at play, a patient safety incident may occur. A patient safety incident is an event or circumstance which could have resulted, or did result, in unnecessary harm to the patient. A near miss is an event that, gone unnoticed, could have resulted in patient harm. For example, an incident would have occurred if a patient received epinephrine meant for topical use as an injection, while a near miss would have occurred if a nurse drew the epinephrine meant for topical use into a syringe and then before administering the adrenaline via syringe to the patient, the nurse noticed the bottle said “for topical use only” and so did not give the injection to the patient.

Everyday applications

Reason's Swiss cheese model can be applied to situations like the trigger tape in order to figure out:

- what the active and latent failures were;
- whether the active failures were slips, lapses, mistakes or violations; and
- whether this was an adverse event or a near miss.

In the case of the trigger tape, the active failures include:

- physician/nurse did not notice his patient was deteriorating, and
- physician/nurse did not notice the monitor was in demo mode.

The latent failures include:

- the patient monitor did not show it was in demo mode;
- the demo mode button was easy to press;
- the physician was tired since he had been on call every other night;
- the unit was a stressful place to work;

- the process used to select patient monitors may not have considered the monitors in the context of the unit;
- the manufacturer may not have incorporated UCD into their product;
- the physician had no previous experience with a monitor going into demo mode; and
- the physician trusted the technology.

Slip, lapse, mistake or violation

The physician made a mistake because he thought his patient was alright to be transferred when his patient was suffering from ventricular fibrillation.

Harmful event or near miss

This would be considered a harmful event because although the patient did survive and they were experiencing ventricular fibrillation before any intervention by the physician, the patient was in ventricular fibrillation for an extended period of time. The patient wouldn't have ordinarily been in ventricular fibrillation for such an extended period of time, except it was unknown that the monitor was in demo mode. Had the physician noticed the monitor was in demo mode before the patient showed signs of V-tach, such that the patient's ventricular fibrillation was diagnosed and addressed right away, the event would have been considered a near miss.

Harmful Events in healthcare

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Harmful events in healthcare

- Errors may occur anywhere in the healthcare system
- Generally errors result from an imperfect system rather than irresponsible or careless people

The occurrence of harmful incidents in hospitals is remarkably prevalent. Each year, approximately 185,000 people experience an adverse event in Canadian hospitals, 70,000 of which are potentially preventable (Baker, 2004). A more recent study estimated that patients suffered harm in 138,000 hospitalizations in Canada in 2014-2015, a reduced rate compared to the 2004 study but still very concerning (CIHI, 2016). Between 9,000 and 23,000 people in die in Canada annually as a result of harmful incidents (Baker, 2004). Errors may occur anywhere in the system and are often classified according to type. Errors pertaining to medications, transfusions, surgeries, suicides, restraints, falls, burns,

pressure ulcers and patient mix-ups are common (IOM, 1999). Errors generally result from decisions and actions made by people working within imperfect systems and not from people who are being irresponsible or careless.

Why human error is important to consider in healthcare

A common mentality in healthcare is one of “I can handle it” or “this is nothing, you should have seen what I had to do on my last shift”. This is a dangerous mindset because although we can often handle these types of situations on a good day, when we are well rested and when other safeguards put into place are effective at preventing a hazard from propagating, there will be times when circumstances align, allowing a hazard to become a patient safety incident. Reason’s Swiss cheese model illustrates how latent failures upstream of where patient care is delivered ultimately have an impact on patient safety. Healthcare professionals, although extremely intelligent, vigilant and caring, are not super-human, and so we cannot rely on our abilities to ensure we always perform perfectly. When we experience a slip, lapse or a near miss it is important to know that others around us are likely to experience the same issues. By bringing these experiences forward, awareness can be brought to the system-level concerns that need to be addressed and this can help prevent the same error or near miss from happening to others.

System-oriented strategies are typically more robust than person-oriented strategies at mitigating errors because they are meant to minimize the requirement for people to behave and act perfectly. We can use what we know about people’s strengths and weaknesses to determine whether a design or a strategy meant to prevent errors will be successful.

Applying human factors

Section objectives

This section aims to:

- identify four human factors tools you can apply to your own healthcare institution;
- identify four performance limitations that play a role in determining whether a good fit exists between people and technology;
- explain why it is so important to report near misses; and
- describe the benefits of applying human factors in healthcare environments.

Introduction to applying human factors

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Intro to applying human factors

- Tools that can be applied to our healthcare systems
 - Human-Tech Ladder
 - principles of design
 - heuristics
 - hierarchy of effectiveness
 - HF-MARC Framework
- Consider human performance limitations

There are many tools available that are helpful in supporting us to view our world from a human factors perspective. Being able to identify good versus bad designs can help us to see areas where the needs of people are or are not being met by the technologies and systems around them. Tools including the Human-Tech Ladder, principles of design, heuristics and the hierarchy of effectiveness can all be applied to our healthcare systems to view them from a human factors perspective. Humans have performance limitations, such as limited memory and attentional resources and are prone to interpreting the world according to a number of cognitive biases. The physicality of tasks and consideration of anthropometric measurements can also play a role in how well daily activities are performed.

A new human factors view of the world can be put to excellent use within any healthcare institution. The perspective prompts consideration of some of the everyday things used in a completely new light, wondering how, up until now, it was never noticed how challenging or frustrating these things were to use.

What can I do?

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What can I do?

- Report patient safety incidents and near misses
- Reporting enables learning

When harmful incidents, near misses, or items of concern occur, it is important to report these incidents so others may learn from them. Harmful incidents and near misses can be reported in a number of ways including to your hospital's incident reporting system, to your manager, or through a number of online databases such as the Institute for Safe Medication Practices' (ISMPs) Canadian Medication Incident Reporting and Prevention System (CMIRPS).

Near misses provide an opportunity to learn about the weaknesses in our system without the associated cost of, or negative effect on human life. Thinking back to Reason's Swiss cheese model (Figure 19), a near miss would be considered a hazard that made it through one or more barriers (slices of cheese) due to the weaknesses (holes) in the slices of cheese, but that was stopped before finding its way through the final barrier (slice of cheese) protecting the patient. Near misses are often underreported for a number of reasons including: people may not realize they have been involved in a near miss; they may think that since nothing went wrong that it is not worth reporting; or that since no one else is any the wiser, there is no need to let others know what you almost did wrong.

Those involved in a near miss may feel embarrassed or ashamed, but it should be remembered that people are fallible, and if an error just occurred or was caught right before it occurs, given the right set of circumstances others will likely commit that error too.

By reporting these harmful incidents and near misses, people are able to learn about the hazards and weaknesses in our healthcare system, and by investigating these incidents, effective safeguards can be put into place. Two methods that are often used in healthcare to investigate harmful incidents and near misses are root cause analysis (RCA) and failure mode and effects analysis (FMEA). RCA is generally used to investigate harmful incidents in a retrospective manner, while FMEA is used to prospectively consider what could go wrong in a system. Additional information about these techniques can be found in PSEP – Canada Module 9: Methods for Improving Safety.

Additionally, the Canadian Incident Analysis Framework can be used to understand how and why incidents occur, and more importantly, how to improve safety in the organization and in work practices. This framework provides a comprehensive set of tools (including Reason's Swiss Cheese model) to analyze an incident and generate insights and recommendations that will improve the patient safety. More information about Canadian Incident Analysis Framework can be found in the PSEP – Canada Module 16: Canadian Incident Analysis Framework.

Benefits of applying human factors

In addition to acquiring information about where our systems are weak and where improvements can be made, there are other benefits to applying human factors. Human factors can improve patient safety, improve the user's experience, improve efficiency, improve the adoption of technology and reduce the need for training. Additionally, institutions can see a return on investment when human factors principles are incorporated into the design of medical devices. Wiklund (2005) estimates (based on a fictional smart pump device) that the return on investment when incorporating human factors processes and design principles could be as much as 7:1 when using a conservative estimate. Incorporating human factors can lessen the time to market, allow for the development of less complex learning tools, increase sales, reduce the user's reliance on customer support, extend the life of a design and reduce the impact of product liability protection, among other things.

Medical device regulations

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Medical device regulations

- FDA requires incorporation of human factors processes and design principles into designs of medical devices (US)
- Health Canada requires that medical devices meet certain usability standards established by ISO and Standards Council of Canada (SCC).

In the US, the FDA now requires manufacturers of medical devices to incorporate human factors processes and design principles into their designs, and although the same requirements do not currently exist in Canada, Health Canada publishes and updates a list of recognized standards. This list includes several usability related standards for medical

devices (<https://www.canada.ca/en/health-canada/services/drugs-health-products/medical-devices/standards/list-recognized-standards-medical-devices.html>). If a manufacturer applying for a license for a device subject to these standards, they must show evidence that the device meets or exceeds these standards. In addition to these human factors processes and design principles, other regulations must also be met when it comes to medical devices, such as electrical and mechanical integrity. A Medical Devices Regulations document available on the Department of Justice website outlines medical device requirements for manufacturers of healthcare-related technology. Additional information about medical device regulation can be found in PSEP – Canada Module 6: Technology: Impact on Patient Safety.

Summary

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Summary

- We must apply human factors to ensure that our technologies and systems support our needs
- Our goal is to improve:
 - patient safety
 - efficiency
 - technology adoption
 - the user experience
 - reduce the need for user training

As James Reason said “we cannot change the human condition, but we can change the conditions under which humans work”. Healthcare professionals, although extremely intelligent, vigilant and caring, are not super-human, and so we cannot rely on our abilities to ensure we always perform perfectly. To improve patient safety, efficiency, technology adoption, the user experience and to reduce the need for user training, the user must apply human factors to ensure the technologies used and systems involved support our needs. By reporting both near misses and harmful incidents, people are able to learn about the types of things that can go wrong in healthcare environments so that the healthcare system can be made more robust.

Potential pitfalls

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Potential pitfalls

- ❑ Blaming people for their mistakes (physical and cognitive capabilities are limited!)
- ❑ Targeting individuals rather than systems
- ❑ Not reporting near misses and harmful events
- ❑ Believing that you cannot make a difference by simply noticing and reporting human factors-related concerns

1. Blaming people for their mistakes (physical and cognitive capabilities are limited!)
2. Targeting individuals rather than systems
3. Not reporting near misses and harmful events
4. Believing that you cannot make a difference by simply noticing and reporting human factors-related concerns

Pearls

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Pearls

- ❑ Systems should support users. If you're having trouble, others are likely having trouble as well
- ❑ Applying human factors can improve patient safety, efficiency, technology adoption, the user experience and can reduce the need for user training
- ❑ Reporting near misses and harmful events will have a positive impact on our Canadian healthcare system


1. Systems should support users. If you're having trouble, others are likely having trouble as well
2. Applying human factors can improve patient safety, efficiency, technology adoption, the user experience and can reduce the need for user training
3. Reporting near misses and harmful incidents will have a positive impact on our Canadian healthcare system

Toolkits and outcome measures

Refer to the Toolkit and Resource Compendium (PSEP - Canada Appendix 1c) for more details on the following toolkits.

- **Hand Hygiene Human Factors Toolkit:** Canadian Patient Safety Institute, in conjunction with 3M and the University Health Network.
<http://www.patientsafetyinstitute.ca/en/toolsResources/pages/human-factors-toolkit.aspx> 
<http://www.patientsafetyinstitute.ca/fr/toolsresources/pages/human-factors-toolkit.aspx> 
- **Canadian Root Cause Analysis Framework:** In 2006, the Canadian Patient Safety Institute partnered with Saskatchewan Health and the Institute for Safe Medication Practices Canada (ISMP Canada) to co-author the Canadian Root Cause Analysis Framework.
<http://www.patientsafetyinstitute.ca/English/toolsResources/rca/Pages/default.aspx> 
<http://www.patientsafetyinstitute.ca/french/toolsresources/rca/pages/default.aspx> 
- **Canadian Failure Mode and Effects Analysis Framework©:** ISMP Canada. (2006, December 23). *Failure Mode and Effects Analysis: Proactively Identifying Risk in Healthcare*. ISMP Canada Bulletin 2006, 6(8).
- <https://www.ismp-canada.org/fmea.htm> 
- **Canadian Incident Analysis Framework.** Canadian Patient Safety Institute, in collaboration with Institute for Safe Medication Practices Canada, Saskatchewan Health, Patients for Patient Safety Canada (a patient-led program of CPSI), Paula Beard, Carolyn E. Hoffman and Micheline Ste-Marie; 2012.
<http://www.patientsafetyinstitute.ca/en/toolsResources/IncidentAnalysis/Pages/incidentanalysis.aspx> 
- **CAPHC Paediatric Trigger Tool (CPTT):** Canadian Association of Paediatric Health Centres. <https://www.caphc.org/about-caphc-programs/> 
- **Safety Briefings IHI:** Langley GL, Nolan KM, Nolan TW, Norman CL, Provost LP. The Improvement Guide: A Practical Approach to Enhancing Organizational Performance. The Plan-Do-Study-Act cycle was developed by W. Edwards Deming (Deming WE. The New Economics for Industry, Government, Education.).
<http://www.ihi.org/knowledge/Pages/Publications/ImprovementGuidePracticalApproachEnhancingOrganizationalPerformance.aspx>
- **Patient Safety Toolbox for States:** Portland, ME: National Academy for State Health Policy. <http://psnet.ahrq.gov/resource.aspx?resourceID=3190>
- **A Toolkit for Redesign in Health Care:** AHRQ Publication No. 05-0108-EF, September 2002. Agency for Healthcare Research and Quality, Rockville, MD.
<http://www.ahrq.gov/qual/toolkit/>
- **Device Use – Safety Briefing Model:** Institute for Healthcare Improvement: Iowa Health System.



<http://www.ihl.org/resources/Pages/Tools/DeviceUseSafetyBriefingModelIHS.aspx>

- **Failure Modes and Effects Analysis Tool:** Institute for Healthcare Improvement: East Alabama Medical Center. Opelika, AL.
<http://www.ihl.org/resources/Pages/Tools/FailureModesandEffectsAnalysisTool.aspx>
- **Safety Assessment Code (SAC) Matrix:** Safety Assessment Code (SAC) Matrix: US Department of Veteran Affairs, 2007.
<https://www.patientsafety.va.gov/professionals/publications/matrix.asp>
- **How to Investigate and Analyse Clinical Incidents: Clinical Risk Unit and Association of Litigation and Risk Management:** BMJ 2000; 320:777-781 (18 March) Charles Vincent, Sally Taylor-Adams, E Jane Chapman C, David Hewitt, Pam Strange, Ann Tizzard. How to investigate and analyse clinical incidents: Clinical Risk Unit and Association of Litigation and Risk Management protocol. British Medical Journal 2000; 320:777-781.
<http://www.bmj.com/content/320/7237/777>
- **Safety Huddle Results Collection Tool:** Institute for Healthcare Improvement: Iowa Health System.
<http://www.ihl.org/resources/Pages/Tools/SafetyHuddleResultsCollectionTool.aspx>
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<https://archive.ahrq.gov/professionals/quality-patient-safety/patient-safety-resources/resources/toolkit/index.html>
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<https://archive.ahrq.gov/professionals/quality-patient-safety/patient-safety-resources/resources/mistakeproof/index.html>
- **SBAR: A Shared Structure for Effective Team Communication (2nd Edition):** Based on the project “*Enhancing Effective Team Communication for Patient Safety*” co-funded by the Canadian Patient Safety Institute and the Toronto Rehabilitation Institute. 2010 
http://www.uhn.ca/TorontoRehab/Education/SBAR/Documents/SBAR_Toolkit.pdf

Resources

Refer to the Toolkit and Resource Compendium (PSEP - Canada Appendix 1c) for more details on the following resources.

- **Alberta Health Services Human Factors Resources,**  <https://www.albertahealthservices.ca/info/page10880.aspx>
- **BC Patient Safety & Quality Council Knowledge Centre,**  <https://bcpsqc.ca/knowledge-centre/>
- **Canadian Centre for Occupational Health & Safety OSH Answers Fact Sheets**  <http://www.ccohs.ca/oshanswers/>
- **Canadian Standards Association,** <http://www.csagroup.org/> 
- **Engaging Patients in Patient Safety – a Canadian Guide**  <http://www.patientsafetyinstitute.ca/en/toolsresources/patient-engagement-in-patient-safety-guide/>
- **Keeping Patients Safe: Transforming the Work Environment of Nurses.** Institute of Medicine. National Academy Press; 2004.
- **Minerva Canada Safety Management Education - Human Factors in Workplace Safety and Design Teaching Module,**  <http://safetymanagementeducation.com/teaching-resources/teaching-modules/>
- **Patient Safety: Achieving a New Standard for Care.** Institute of Medicine. National Academy Press; 2004.
- **Preventing Medication Errors.** Institute of Medicine. National Academy Press; 2007.
- **The Canadian Human Factors in Healthcare Network**  <http://www.patientsafetyinstitute.ca/en/toolsResources/Human-Factors-Network/>
- **The Society for Technical Communication's Usability Toolkit:** <http://www.stcsig.org/usability/resources/toolkit/toolkit.html>
- **To Err is Human.** Institute of Medicine. National Academy Press; 2000.
- **Usability First:** www.usabilityfirst.com
- **Using Human Factors Engineering to Improve Patient Safety.** Gosbee JW, Gosbee LL. Oakbrook Terrace, IL: Joint Commission Resources, 2005.
- **WISHA Services Division, Washing State Department of Labor and Industries.** Office Ergonomics Practical Solutions for a Safer Workplace; 2002. <http://www.lni.wa.gov/IPUB/417-133-000.pdf>
- **World Health Organization Patient Safety Publications,** <http://www.who.int/patientsafety/publications/en/>
- **Armstrong Institute Center for Health Care Human Factors,** https://www.hopkinsmedicine.org/armstrong_institute/centers/human_factors_engineering/
- **Institute for Healthcare Improvement – Human Factors and Safety Online Course,** <http://app.ihi.org/lms/coursedetailview.aspx?CourseGUID=0d1d53a1-1ec4-4065-8250-56247132fb9e&CatalogGUID=6cb1c614-884b-43ef-9abd-d90849f183d4&LessonGUID=00000000-0000-0000-0000-000000000000>
- **Nielsen Norman Group Usability Website:** <https://www.nngroup.com/>


- **Department of Justice – Medical Device Regulations** <http://laws-lois.justice.gc.ca/eng/regulations/SOR-98-282/>
- **United States Food and Drug Administration Human Factors Section:** US Food and Drug Administration Human Factors Section: Department of Health and Human Resources. <https://www.fda.gov/MedicalDevices/DeviceRegulationandGuidance/HumanFactors/default.htm>
- **The National Institute for Occupational Safety and Health (NIOSH),** <https://www.cdc.gov/niosh/index.htm>
- **Health and Safety Executive in UK,** <http://www.hse.gov.uk/humanfactors/>
- **NASA, Man-Systems Integration Standards NASA-STD-3000,** NASA, Washington D.C., 1994
- **The Federal Aviation Administrations’ Overview of Human Factors:** <http://www.hf.faa.gov/Webtraining/Usability/usability1.htm>
- **The U.S. Department of Health & Human Services’ guide to building a usable website:** <https://www.usability.gov/>
- **Association of Canadian Ergonomists:** Suite 1003, 105-150 Crowfoot Crescent, NW, Calgary, Alberta, Canada T3G 3T2 <https://ace-ergocanada.ca/>  
- **ACM/Special interest group on computer human interaction (SIGCHI)** <http://www.sigchi.org>
- **Usability Professionals Association:** <http://uxpa.org/>
- **Ergonomics Society:** The Ergonomics Society, Elms Court, Elms Grove, Loughborough LE11 1RG, UK. <http://www.ergonomics.org.uk/>
- **Human Factors and Ergonomics Society:** www.hfes.org
- **International Ergonomic Association:** www.iea.cc
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Additional case study: fluorouracil incident root cause analysis

Read the following case study and use the questions provided to consider this adverse event from a human factors perspective.

Denise Melanson, a 43 year-old mother of three was receiving outpatient chemotherapy treatment for advanced nasopharyngeal cancer, from which she was expected to recover. On July 31st, she went to the Cross Cancer Institute (CCI) in Edmonton, Alberta to receive her treatment. At 9:30 am she received pre-hydration and pre-medications followed by cisplatin and post-hydration over the course of approximately 5 hours, as per protocol. The nurse then programmed an ambulatory infusion pump to deliver fluorouracil to Denise continuously over four days as had been ordered by her physician.

In order to program the pump, the nurse had to calculate the rate of medication delivery and used the electronic order and label prepared by pharmacy on the bag of medication to do so.

The order was for 5-Fluorouracil 5250 mg (at 4000 mg/m²) to be given by continuous intravenous infusion over 4 days. The nurse had to figure out how many mL of medication had to be administered per hour.

When the nurse did the calculation, she got 28.8 mL/h. She then asked a second nurse to verify her calculation. The second nurse, who couldn't find a calculator, did both a mental calculation and a calculation on paper. The second nurse then verified the rate that had been programmed into the pump and locked the pump. Both nurses signed off on the medication administration record and the first nurse electronically signed off on the total

dose to be administered to the patient. The nurse initiated the patient's infusion and explained the functionality of the pump to Denise, telling her to return in four days so the CCI could disconnect the pump. Denise left the CCI with a friend around 2:30 pm and returned to Compassion House, the supportive residence she was staying at while she received her treatment.

Four hours later Denise noticed her infusion pump was beeping and when she opened the fanny pack in which her pump was being stored, she found the bag of fluorouracil was empty. A volunteer from Compassion House drove Denise and a friend back to the CCI where the nursing supervisor disconnected the pump, contacted the physician on call and explained to the Denise that nothing could be done about the overdose because there was no antidote. The nursing supervisor advised Denise to come back the following day. The nursing supervisor filled out an incident report and the pump was sequestered for review by the unit manager.

Over the next 23 days Denise's condition worsened and she eventually suffered multi-organ failure. Denise was taken off life support on August 22 with the coroner's report indicating the cause of death was "sequelae of fluorouracil toxicity".

Unfortunately, this is not the first time an incident like this has occurred, nor was it the last. After Denise Melanson's tragic death it was found that the same type of adverse event had occurred in other healthcare institutions, also resulting in patient deaths.

Discussion questions: fluorouracil incident root cause analysis

Icebreaker

What are your initial thoughts and feelings about this case?

Introduction to human factors

Did Dr. Tony Fields and the administration at the Cross Cancer Institute take a person or a systems approach, and what did you think about his reaction to this adverse event?

- Tony Fields took a systems approach
- Moving towards a "just" culture and away from "blame and shame" (see PSEP - Canada Module 5: Organization and Culture)
- He wants others to learn from this mistake so no one else is harmed in this way
- He supported the nurses involved in the incident and did not reprimand them
- He wants to change the system so that even when people make mistakes, patients will not be harmed

Cognitive engineering

Did cognitive biases play a role in this incident, and if so, what types of cognitive biases might have been present?

- Yes, cognitive biases did play a role
- Confirmation bias: the value 28.8, which the nurse calculated, was present on the label; the second nurse did not do an independent double-check
- Attentional blindness: nurses concentrating so much on completing the calculations they missed the important step of dividing the dosage per day by 24 hours a day
- Recency bias and confirmation bias: many of the medication delivery rates for other medications in the unit were in and around 28.8 mL/h and so this value would have been a familiar one
- Framing Effect: this may have played a role in how the nurse interpreted the information on the label since the rate 28.8 mL/24 h was shown first (when reading from left to right), the nurse may have found this value to be more salient. Perhaps if the rate 1.2 mL/h had been the first value on the line when reading from left to right, the nurse would have noticed a discrepancy between the calculation and the label and recalculated her rate.

What other cognitive factors might have played a role in this adverse event?

- Attention: there was a lot of information that was unnecessary for the nurse on the medication label, which made the information required by the nurse less salient; the second nurse was on her way to do another task when she was asked to check the first nurse's calculation
- Memory: the nurse had to do a mental calculation in which she would have stored some of the values in her head
- Alertness and Fatigue: if the nurses had been on-call, or working long or double shifts, they may have been negatively affected by fatigue and may not have been as alert

Could automating the medication delivery process have prevented this type of adverse event?

- Possibly, because we know that people are not good at calculations. In this case, the nurses had to carry out 3 calculations to convert mg into a rate of mL/h.
- Using a calculator may have helped the second nurse to arrive at the correct infusion rate
- Using a “smart pump” with pre-programmed drug library having upper and lower limits for fluorouracil may have prevented this adverse event, however, with smart pumps it is still possible to program infusions outside of the drug library

Design and evaluation

Use heuristics to consider the medication label in Figure 29.

1. Consistency and standards

There were many different types of information present on the medication label including: the total volume, final concentration, dose per 4 days, dose per 24 h, rate per 24 h, rate per h, the length of time the medication bag would last, the remaining volume of medication after 4 days, the physician's name, prescription number, when it was prepared, when it would expire, pharmacy name and pharmacist's name. Several of the values included on the label were redundant, as they described the same type of information (such as dose or rate), but over different durations.

2. Visibility of system state

This label relies on the vigilance of those handling the medication to correctly calculate and check calculated values, such as rate, against the label. This label does not provide feedback to the user as the user would have to recognize the value they calculated among a host of options, which opens up the opportunity for the user to experience a cognitive bias.

3. Match between system and world

Even with the numerous values included on the label, the nurse was still required to conduct a complex calculation in order to confirm the values for pump programming. Also, because this label is used by different types of healthcare personnel, including nurses and pharmacists, some of the information present on the label would not have matched all of the user's expectations and only could have been useful for either nurses or pharmacists.

4. Minimalist

There is a huge amount of information shown on the label and the label is extremely cluttered. After the nurse had calculated the rate per hour, she compared her calculated value with the label and saw a match. Having so much information on the label provided the opportunity for the nurse to experience a confirmation bias because what was calculated happened to match one of the many values on the label.

5. Minimize memory load

The nurse had to remember how to conduct the calculation to get from 5-Fluorouracil 5250 mg (at 4000 mg/m²) to mL/h. Also, the second nurse didn't have easy access to a calculator which would have increased the load on her working memory as she had to remember several numerical values in order to do a mental calculation.

6. Informative feedback

The label on the medication bag does not provide feedback to the user and instead relies on user vigilance to check any calculated values against the information on the label.

Additionally, because there is so much information present on the medication label, the opportunity for users to experience a cognitive bias while checking exists.

7. Flexibility and efficiency

Users may find this label difficult to navigate because there is so much information present. If users were looking for a particular piece of information, such as dosage or rate, it could be challenging to quickly locate these values.

8. Good error messages

This medication label does not provide any discernible error messages to the user. A mismatch between a calculated value and the label may prompt a user to redo a calculation, however as we know, relying on user vigilance and our ability to perform complex calculations can be problematic.

9. Prevent errors

This label does not minimize the chance for users to get into error prone situations. The nurse had to perform a complex calculation to convert dosage to a rate of mL/h. Those involved were not aware an error had been committed as there was no discernable feedback provided to the users from the label.

10. Clear closure

The nurses would have known when to start using the label and when to stop using the label, but there was no way to determine whether the label had been used correctly during the checking process.

11. Reversible actions

No discernable feedback was provided to the users through the medication label and so there was no way to know a mistake had occurred. Had the error been identified early enough, the pump could have been reprogrammed with the correct mL/h rate found on the label.

12. Use users' language

Some of the information on the medication label supported some of the users, but a lot of the information would have been superfluous in nature. Some of the information would have been useful for the pharmacists while some of the information would have been relevant for the nurses.

13. Users in control

It is unknown whether the users felt they were in control of the system, but because the label was a static interface (unlike the dynamic and interactive interfaces of many

electronic devices), it is likely the users would have felt in control of interacting with the label.

14. Help and documentation

Help and documentation were not available and there was no known antidote to a fluorouracil overdose.

Use the hierarchy of effectiveness to consider the following:

ISMP conducted an in-depth RCA of the Denise Melanson case and identified a number of recommendations, some of which include:

- Use pumps with safeguards such as preset maximum rates
- Standardize orders such that mL/h, not mL/ 24 h is included on the order
- Incorporate checklists and calculations into the medication administration record and order forms
- Include a “mental estimation” step as part of training and orientation about how to check medication related calculations

Where does each recommendation fall on the hierarchy of effectiveness? Discuss the potential efficacy of implementing this recommendation.

1. Use pumps with safeguards such as preset maximum rates

Automation/computerization:

- The pump would warn the user when a preset maximum rate had been exceeded

Forcing functions:

- If the pump did not allow the user to enter a rate higher than the preset maximum rate

This recommendation could bring the user’s attention to a calculation error; however, if users are able to decide whether or not to heed the warning, overdoses could still occur.

2. Standardize orders such that mL/h, not mL/ 24 h is included on the order

Simplification and standardization:

- Orders would only include information about mL/h

This recommendation could assist the user because extra information that could compete for the user’s attention would be removed. Additionally, having only the “mL/h” rate would have removed the opportunity for the nurses to experience a confirmation bias in this case.

3. Incorporate checklists and calculations into the medication administration record and order forms

Reminders, checklists and double checks:

- A checklist would be filled out by nurses as part of their documentation requirements

Rules and policies:

- This would be a new requirement for those involved in the procedure

In this case, a checklist or calculation included as part of the medication administration record would be unlikely to prevent this adverse event. The second nurse completed a calculation on paper and still arrived at the incorrect medication rate.

4. Include a “mental estimation” step as part of training and orientation about how to check medication related calculations

Reminders, checklists and double checks:

- A mental calculation would serve as a double check for your own calculation

Rules and policies:

- An explicit mental estimation would be a new requirement for those involved in this process

Training and education:

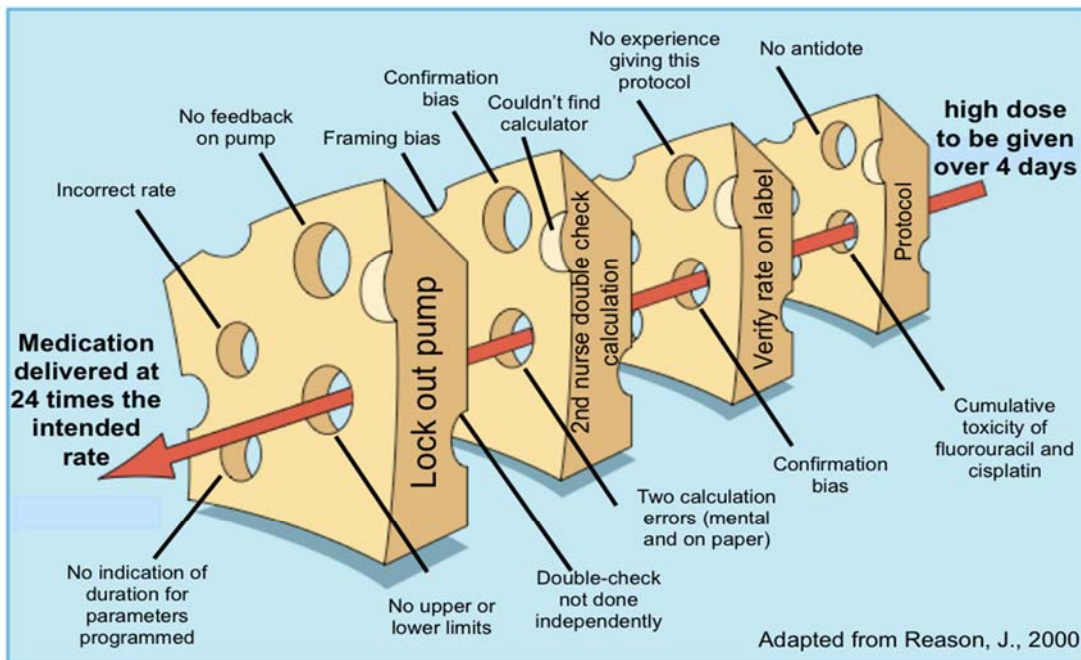
- This new requirement would be taught to nurses during training and orientation

It is unclear whether a mental estimation would have prevented the calculation error in this case. The new requirement to complete a mental estimation would be relayed to nurses during training and orientation and so there is no guarantee nurses would remember to complete this step as part of their medication administration processes.

Ensuring this step is completed by nurses relies on vigilance. In some cases, nurses may not perform this mental calculation if they think they have correctly calculated the rate or if they are pressed for time. Additionally, even when carrying out a mental calculation, if the value calculated was present on the label, order or in the medication administration record, it is likely this confirmation, even if incorrect, would serve as a confirmation bias. Slips, lapses and mistakes are also possible when completing calculations. An example of a lapse would be if you forgot to complete a step of a calculation. An example of a slip would be if you were supposed to multiply, but instead you divided two numbers to convert a value. An example of a mistake would be if you thought you were supposed to use the drug concentration in a calculation but instead you were supposed to use the rate.

Human error

Consider the Denise Melanson case using Reason's Swiss cheese model. What were the hazards, barriers, latent failures and active failures in this case?



The Swiss cheese model of how defences, barriers, and safeguards may be penetrated by an accident trajectory

Hazards:

- The high medication dose, which is meant to be delivered over 4 days, can be lethal if delivered too quickly

Barriers:

- Chemotherapy protocol
- Verify calculated rate against label to confirm match
- Double check rate calculation
- Double check pump programming and lock out pump

Latent failures:

- No antidote to fluorouracil or cisplatin overdose
- Cumulative toxicity of fluorouracil and cisplatin
- First nurse was inexperienced at administering this protocol
- Confirmation bias
- Could not find a calculator
- Two calculation errors (mental and paper calculations)
- Framing bias

- Double check was not truly independent

Active Failures:

- No feedback on pump
- No upper or lower medication delivery rate limits
- Incorrect rate entered
- No integrated feedback to inform nurse of duration of infusion

Did Denise's nurse experience a slip, a lapse or a mistake?

Denise's nurse experienced a mistake because she miscalculated the infusion rate even though she had the correct information available to her. This mistake led to an incorrect rate being programmed into the ambulatory infusion pump. Forgetting to divide by 24 could also be considered a lapse as this step was omitted by the nurse.

How might you report an adverse event or a near miss in your own institution?

You could report an adverse event or a near miss to your manager, through your institution's incident reporting system, or to CMIRPS.

Why is it so important to report near misses?

It is important to report near misses because they provide an opportunity to learn about the weaknesses in our system without the associated cost of, or negative impact on human life. Near misses are often underreported because people may not realize they have been involved in a near miss, they may think that since nothing went wrong that it is not worth reporting, or that since no one else is any the wiser, there is no need to let others know what you almost did wrong. By reporting near misses (as well as harmful incidents) we can learn about the hazards and weaknesses in our healthcare system and then by investigating these events we can put effective safeguards into place.

Applying human factors

How could you analyze this adverse event if you wanted to learn about the contributing factors and identify recommendations?

Root Cause Analysis (RCA) (See PSEP – Canada Module 9: Methods for Improving Safety)

Principal message

This module provides an understanding of Human Factors Engineering (HFE) and how HFE relates to patient safety. The single most important message your audience should come away with is that *applying HFE to healthcare systems design improves performance and safety*.

Module overview

The science of HFE has often been misunderstood with the result that it has been poorly applied in patient safety. HFE is primarily concerned with methods to discover and understand how people perform in different environments and circumstances so that better ways can be developed that allow people to perform at their best. This module explains what HFE is and what it is not. It gives examples from outside healthcare as well as within healthcare to demonstrate the principles. In addition to explaining the elements of HFE this module shows how to use HFE design principles in the workplace.

Preparing for a presentation

1. Assess the needs of your audience

Choose from the material provided in the syllabus according to the needs of your expected participants. It is better for participants to come away with a few new pieces of information, well learned, than to come away with a deluge of information from which they can remember little or nothing.

2. Presentation timing

The suggested timing for each part of this module is:

Introduction	2-3 minutes
Trigger tape & discussion	5-7 minutes
Presentation	30 minutes
<u>Summary</u>	<u>2-3 minutes</u>
Total	40-45 minutes

3. Number of slides: 39

4. Preparing your presentation

The text in the module was not designed to be used as a prepared speech. Instead, the text provides material you may want to use. The slides have been designed to trigger your presentation. Although the slides closely follow the text of the module, they do not contain all of the content. Their use presumes that you have mastered the content.

You may want to make notes on the slide summary pages to help you prepare your talk in more detail and provide you with notes to follow during your presentation.

Remember that you can adjust the slides to suit your presentation content, your style, and to make it feel fully familiar and your own.

Practice your presentation using the slides you have chosen, and speaking to yourself in the kind of language you expect to use, until it is smooth and interesting and takes the right amount of time. The most accomplished presenters and teachers still practice prior to a presentation; don't miss this step.

5. Preparing a handout for participants

The module text and slides were designed to be reproduced and provided to participants as a handout. Take the portion you need; they can be used in their entirety, module by module, or for just one specific topic. Please ensure to acknowledge the source of the material, the PSEP – Canada Acknowledgment Page at the front of the module provides the formal citation.

6. Equipment needs

- Screen, computer and projector
- Flipchart and markers for recording discussion points

Test your equipment beforehand to ensure that it works.

Review your video to assess which portions you would like to use.

Have a back-up plan so that if there is any equipment failure you can move without panic to your back-up plan. For instance, have in mind that:

- if the video fails, you can read the vignette of the trigger tape story;
- if the slides cannot be shown, you can refer to the hand out slides; and
- if the markers do not work, you can have participants list items on their hand outs that you would have written up for all to see.

Making the presentation

1. Introduce yourself

If you have not already done so, introduce yourself. Include your name, title, and the organization(s) you work for. Briefly describe your professional experience related to the information you will be presenting.

2. Introduce the topic

Show the title slide for the module. To establish the context for the session, make a few broad statements about the importance of the topic as a patient safety matter. Tell participants the format and time you will take to present the session. Identify the teaching styles that you intend to use.

3. Review the session objectives

Show the slide with the session objectives listed. Read each objective and indicate those that you are planning to emphasize.

4. Show the trigger tape

After reviewing the objectives for the session, show the trigger tape. It has been designed to engage the audience and provide an appropriate clinical context for the session. It was not designed to demonstrate an ideal interaction, but to “trigger” discussion.

Trigger tape content

A patient has just barely survived an emergency resuscitation after being transported to the ICU from another unit in the hospital. The ICU staff, including the physician who was admitting the patient, failed to catch the patient’s rapid deterioration because all were focused on the transport monitor which showed stable vitals. The physician, who is visibly shaken, is discussing this near miss with an ICU nurse. The nurse admits that she has experienced a similar situation where the transport monitor was set to “demo mode”, and emphasizes that everyone makes mistakes, particularly when relying on technology.

Keep in mind that the facilitator may choose to use any one of the trigger tapes. Since the vignettes are rich and overlap in their teaching points, it may make sense to do this, for instance if an audience has seen the trigger tape already or if a trigger tape from another module is easier for the audience to identify with.

A teachable moment: discussion after the trigger tape

After the trigger tape, ask the participants for their comments about the issues and the interaction they have just seen. To affirm what they contribute, consider recording the important points on a flipchart or whiteboard.

If the discussion is slow to start, you may want to ask more direct questions, like:

- What parts of the narrative do you think relate to a design problem?
- Are you able to identify in your own work environment how HFE might apply?
- Do you think applying HFE thinking would make a difference to your work? If so how?
- What is challenging about HFE?

Use the discussion to set the stage for the material to follow. Do not let the discussion focus on a critique of the technical quality of the video or how “real” the players seemed. If the participants do not like something that was said or done in the video, acknowledge that there is always room for improvement and ask them how they would do it themselves.

Setting limits to discussion time

It is usually best to limit discussion of the video to no more than five minutes, then move on to the presentation. To help move on if the discussion is very engaged, try saying something like:

- let’s hear two last points before we move on, and
- now that you have raised many of the tough questions, let’s see how many practical answers we can find.

For the more advanced facilitator who is very confident of both the patient safety material and his or her pedagogic skills, it is possible to use the trigger tape as a form of case-based teaching and to facilitate the discussion to draw out the teaching points of the module. The hazard of this approach is that the discussion will not yield the desired teaching points. Feel free to return to the slides if this happens. If this approach is used, it is essential to write up the points on a flip chart as they arise, to fill in any gaps and to summarize at the end. Again, use this method with caution and only if you are really ready.

5. Present the material

Recommended style: interactive lecture

An interactive lecture will permit you to engage your audience, yet cover your chosen material within the time.

Ask the participants what their major concerns regarding HFE and to give you an example where HFE might have helped a particular situation. Once you find a case that resonates with the group, you may choose a focus. Have a back up case from your own experience in case you there are reasons to not go into the ones from the audience. The module gives many examples that you can use for group discussion. Choose the focus so that you can deliver specific content you have prepared.

Alternative style: case based teaching

One way to use case-based teaching is to use the trigger tape case. Expand on the case with your audience to bring out your teaching points.

Alternatively, use the following case as an interactive exercise. First ask a participant to read the case description below. Then facilitate discussion to bring out your teaching points.

Case Description

A patient is receiving an infusion of 10 cc of fentanyl that was scheduled to take 14.3 hours. After only six hours of infusion, the syringe was empty. But the pump indicated that 4.16 cc was infused and that 5.84 cc remained. The patient had received the entire dose in less than half the anticipated time. The patient, so far, was experiencing no adverse reactions.

What happened? Had the nurse made an error in programming the pump? An on-the-spot analysis revealed that a “general purpose” syringe pump was configured to infuse 10 cc of fentanyl at a rate of 0.7 cc/hour. At this rate, an anticipated total infusion time of 10/0.7 or 14.3 hours was expected. Presuming a pump malfunction, staff tested the pump using saline, but found that the pump seemed to operate correctly. After an internal incident report was filled out, the pump was sent to the biotechnology (biotech) department with a note attached to “see if you can figure what went wrong.”

(Draper S, Nielsen GA, Noland M. Using "no problem found" in infusion pump programming as a springboard for learning about human factors engineering. *Jt Comm J Qual Saf*. 2004 Sep;30(9):515-20.)

Interactive exercise

Perform a root cause analysis on the above case. Participants should break into groups of 3-5 and try to identify possible causes for the pump malfunction. Allow time for group discussion of possible causes. You may then choose to reveal the “actual” cause of the error, which is the operator might have overridden the standard syringe size to indicate a syringe size identical to the dosage size, resulting in a faster rate of plunger travel and subsequent overinfusion. Ask the participants to think about how this error could occur, and what steps could be taken to prevent it, with particular focus on human factors principles. During group discussion, be sure to draw out the following points from the audience:

- this error could occur due to:
 - incorrect understanding of the difference between the dosage and syringe sizes, or
 - accidentally pressing the up/down arrows on the pump, thereby inadvertently changing the syringe size; and
- disability of the “size override” function could prevent this error.

Possible discussion questions

Some possible discussion questions include:

- What would you do when the biotech department reported “no problems found”?
- Do you think perhaps someone else might have had the same problem?
- Where would you look to see if similar events had occurred in other institutions?
- What might a HFE task force think about to prevent similar incidents in the future?
- What changes might you implement in your institution as a result?
- Do you use design guidelines in your institution?
- What would you recommend about how to use HFE in the healthcare setting?

6. Key take-home points

1. Applying human factors design improves performance and safety.
2. Patient safety problems are the result of interaction between people and systems.
3. Cognitive performance diminishes with increased mental load and increased fatigue; do not rely on individual vigilance.
4. All elements of the system should support the user’s performance.
5. If a system is not easy to use, it is not well designed.
6. A system is not necessarily well designed just because it works.
7. Human factors is not simply common sense.

7. Summarize the discussion

Briefly, review each part of the presentation. Recap two or three of the most important points that were discussed.