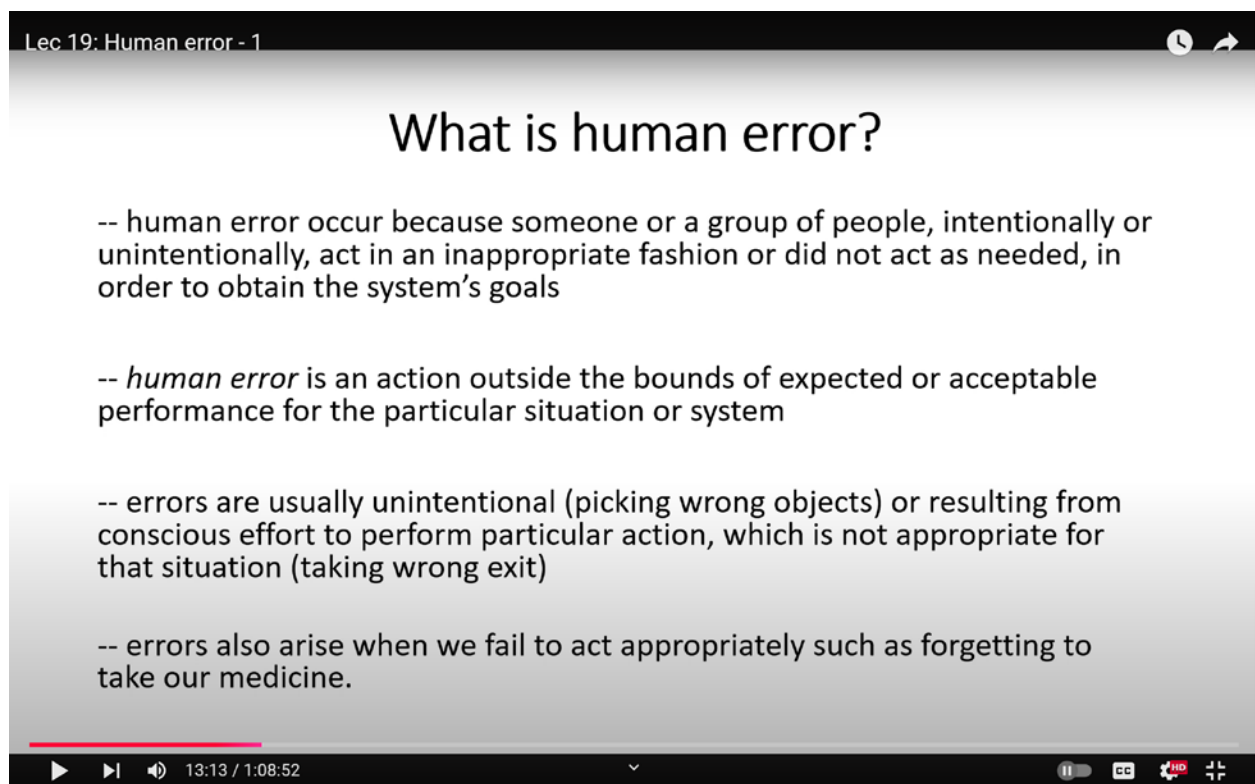


Engineering Psychology
Prof. Naveen Kashyap
Department of Humanities and Social Sciences
Indian Institute of Technology, Guwahati
Week-08
Lecture-19
Human error - 1

The topic for today's discussion will be human error. We have often heard the saying, "To err is human, and to forgive is divine." The first part of this statement holds significance for our lecture today. Human beings, by their very nature, are prone to making errors. In contrast, machines exhibit limited error rates and have a higher tolerance for issues.

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Lec 19: Human error - 1

What is human error?

- human error occur because someone or a group of people, intentionally or unintentionally, act in an inappropriate fashion or did not act as needed, in order to obtain the system's goals
- *human error* is an action outside the bounds of expected or acceptable performance for the particular situation or system
- errors are usually unintentional (picking wrong objects) or resulting from conscious effort to perform particular action, which is not appropriate for that situation (taking wrong exit)
- errors also arise when we fail to act appropriately such as forgetting to take our medicine.

13:13 / 1:08:52

Many machines can identify and resolve their own problems, thus fostering a more effective relationship between the operator and the machine. However, it is important to remember that

machines are dependent on human operators for their functionality. Human beings are constrained by their knowledge and experiences in the world, and along with their physiological and cognitive capabilities and limitations, they are susceptible to making mistakes. As an engineering psychologist, one of our primary functions is to identify where and when these errors can occur.

Once we understand where errors are likely to happen, we can design systems to mitigate most of them. Certain types of errors, such as those involving decision-making, can be particularly challenging for machines to manage. In these instances, training and learning can be provided to human operators to significantly reduce the likelihood of errors. Human errors can lead to accidents, which may result in loss of life, property damage, and various other issues.

In today's discussion, we will define human error, explore the different types of errors that can exist, clarify what constitutes an error, classify these errors, and examine techniques for addressing them. Additionally, we will look at models that assist us in studying human errors and predicting where they may occur in the process flows that enable human-machine systems to function effectively.

It is often observed that machines do not make errors; rather, humans are typically held responsible for mistakes. I will also address the misconception that humans are the primary source of errors. While it is true that human actions can lead to errors, many times, the underlying cause is a flawed system design that results in human operators misinterpreting the system's output, leading to erroneous actions.

To illustrate how human errors can occur, let me present a scenario involving Ganesh, who owns a small tea stall where he sells tea and snacks. Ganesh is well-liked and known for his excellent cooking skills, and he serves numerous customers throughout the day. Having worked in this capacity for several years, most of his customers are satisfied. However, there have been a few incidents in which negligence, either on Ganesh's part, that of his co-workers, or due to the equipment and cooking processes he utilizes, has resulted in problems.

On one particular day, two groups of customers arrive at Ganesh's tea stall, each ordering different types of meals. One customer requests a vegetarian meal, while the other orders a non-vegetarian option. Ganesh prepares the meals and places them at the counter, where he often manages orders

and engages in conversation with other customers. While serving the food, he unintentionally hands the non-vegetarian meal to the vegetarian customer and vice versa. At a glance, the two dishes appear similar. However, once the customers begin eating, they recognize the mistake and voice their complaints. Ganesh attempts to resolve the situation by offering alternatives, but an error has already occurred, which could lead to negative repercussions.

Furthermore, Ganesh relies on various tools and equipment to operate his stall. On this particular day, he discovers that his cooking cylinder is empty. He decides to use an electric stove to continue cooking but notices that both of the electrical outlets he typically uses are occupied. In a hurry, he locates an electrical distribution box, connects it to one of the terminals, and plugs the cooking appliance into that terminal. Soon after, he realizes that there is a fault in the circuit, causing a power outage. Ganesh has made an error by connecting a high-voltage appliance to a low-capacity outlet, resulting in an overload and a short circuit.

The question arises: Whose error should be recorded? Is it Ganesh's error for incorrectly plugging a high-capacity cooking appliance into a low-capacity outlet, or is it a design flaw in the outlet and cooking equipment that failed to indicate that the appliance should only be connected to high-capacity outlets?

Several other incidents could also be discussed where many would assign blame to Ganesh as the potential source of errors. In the first case, the error was unintentional. Although he had the food prepared, his attention was distracted, leading him to serve the wrong meals to different customers. In the second scenario, while Ganesh performed an action, it was incorrect because he failed to notice the warning signs on the stove, which ultimately led to an electrical failure.

These examples illustrate different notions of error: in the first case, a slight attentional lapse could have been resolved with better problem-solving, while in the second case, improved warning signs could prevent unnecessary incidents. The first error is minor and can be rectified, but the second error, a potential electrical failure, could have catastrophic consequences, such as a fire that could cause injury or loss of property.

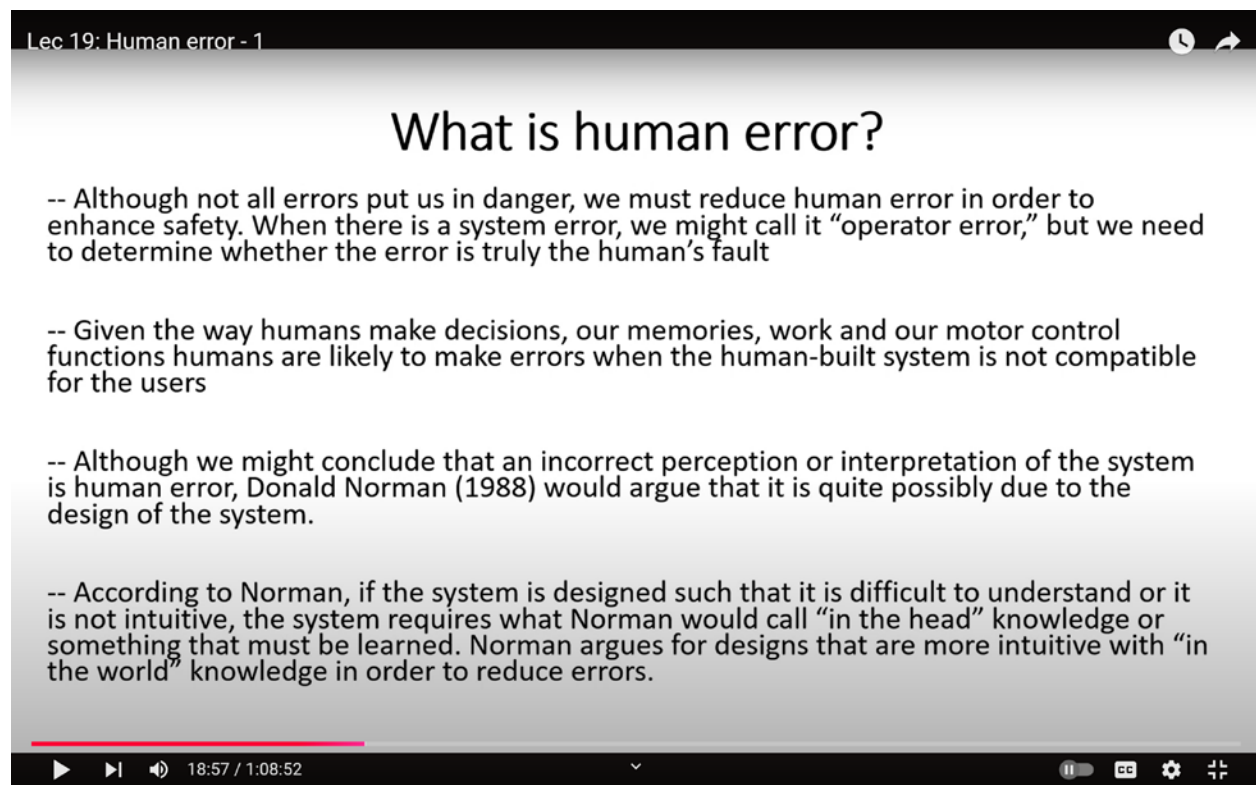
So, what can be done to mitigate such problems? Let me begin by explaining what errors are and how they can be classified. Human error occurs when an individual or group intentionally or

unintentionally acts inappropriately or fails to act as needed to achieve the goals of a system. In our two scenarios, there were distinct goals: the first was to serve the correct meal to each customer, and the second was to successfully operate the electric stove to resume cooking.

Regardless of whether the actions are intentional or unintentional, if individuals perform actions that are unnecessary or incorrect in a given context, leading to failure in achieving the system's goals, this can be classified as an error.

Human error refers to actions that fall outside the expected or acceptable performance levels for a given situation or system. Every system and human has specific behaviors and performance metrics aligned with the goals of that system. An error occurs when an action deviates from or exceeds the bounds of expected behavior or performance. Typically, errors are unintentional, such as picking up the wrong object, or they may result from a conscious decision to perform an action that is inappropriate for the situation. As previously defined, errors can arise from inattention.

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Lec 19: Human error - 1

What is human error?

- Although not all errors put us in danger, we must reduce human error in order to enhance safety. When there is a system error, we might call it "operator error," but we need to determine whether the error is truly the human's fault
- Given the way humans make decisions, our memories, work and our motor control functions humans are likely to make errors when the human-built system is not compatible for the users
- Although we might conclude that an incorrect perception or interpretation of the system is human error, Donald Norman (1988) would argue that it is quite possibly due to the design of the system.
- According to Norman, if the system is designed such that it is difficult to understand or it is not intuitive, the system requires what Norman would call "in the head" knowledge or something that must be learned. Norman argues for designs that are more intuitive with "in the world" knowledge in order to reduce errors.

18:57 / 1:08:52

For example, consider two objects on a table: a glass of water and a mobile phone. While talking to a friend, I reach for the mobile phone but unintentionally grab the glass of water instead. Upon realizing my mistake, I set the glass down, causing some water to spill and wetting the desk. This constitutes an unintentional action. In contrast, a conscious decision, such as making an incorrect turn while driving, can also lead to problems. For instance, while traveling from my office to my home, I have multiple route options. If I choose a particular turn and later realize that a previous turn would have allowed me to accomplish a task or two and reach home on time, my wrong turn results in unnecessary driving to complete those tasks before returning home.

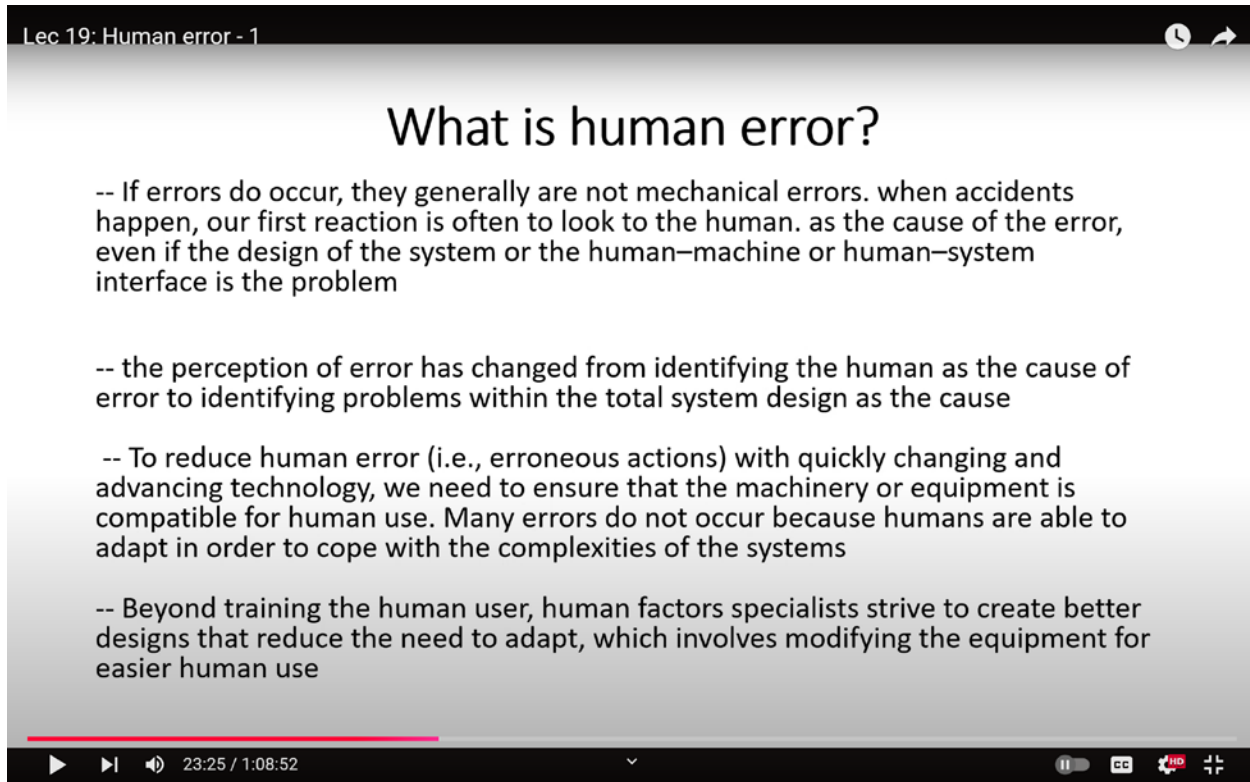
In both scenarios, an error has occurred. In the first case, it is unintentional; in the second case, it involves an intentional choice that leads to an incorrect outcome. Errors can also occur when individuals fail to act appropriately, such as forgetting to take their medication. Certain errors arise from lapses in memory, indicating that human memory function or failure can contribute to errors. While not all errors pose a danger, minimizing human error is crucial for enhancing safety. When an error occurs within a system, it might be labeled as an operator error, but it is essential to determine whether it truly falls under human accountability.

Many believe that most errors lead to accidents or undesirable situations, but this is not entirely accurate. Several errors may result in discomfort without being life-threatening. Therefore, it is vital to explore methods for avoiding these errors. As previously mentioned, system errors are often regarded as operator errors, with the assumption that the system itself cannot be at fault. Machines are designed to perform repetitive tasks without critical thinking. However, humans are not always the source of errors; sometimes, the design of the system output contributes to misunderstandings of the machine's output, leading humans to take actions that result in errors.

Given the nature of human decision-making, memory functioning, and motor control capabilities, individuals are likely to make mistakes when a human-built system does not align with user requirements. One reason humans are prone to errors is that both cognitive and physiological systems have limitations. When machine output does not accommodate human limitations, errors are likely to occur. While it may be tempting to conclude that an incorrect perception or interpretation of the system is a human error, Donald Norman argues that these issues often stem from the system's design. Although humans are frequently blamed for errors, it is often the design

of the system that leads to imperfect or suboptimal output, which in turn results in errors.

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Lec 19: Human error - 1

What is human error?

- If errors do occur, they generally are not mechanical errors. when accidents happen, our first reaction is often to look to the human. as the cause of the error, even if the design of the system or the human-machine or human-system interface is the problem
- the perception of error has changed from identifying the human as the cause of error to identifying problems within the total system design as the cause
- To reduce human error (i.e., erroneous actions) with quickly changing and advancing technology, we need to ensure that the machinery or equipment is compatible for human use. Many errors do not occur because humans are able to adapt in order to cope with the complexities of the systems
- Beyond training the human user, human factors specialists strive to create better designs that reduce the need to adapt, which involves modifying the equipment for easier human use

23:25 / 1:08:52

According to Donald Norman, if a system is designed in such a way that it is difficult to understand or lacks intuitiveness, it requires what he terms "in-the-head knowledge," which must be learned. Norman asserts that designers should aim for "in-the-world knowledge," which allows for reduced errors. He identifies two approaches to interacting with systems: one involving in-the-head knowledge, where human operators must rely on their knowledge to make decisions, and the other involving in-the-world knowledge, where system outputs are intuitive and self-explanatory, requiring minimal conscious skill to operate. This latter approach facilitates increased performance and improved human-machine interaction.

Human factors specialists should prioritize in-the-world knowledge, enabling machines to communicate in a language that humans can understand. For example, when a Windows system encounters an error, it might display a message indicating an error in memory area 0. A typical user would likely find this message unhelpful, as it does not convey actionable information. In

contrast, an effective system would provide clear guidance on the nature of the problem and the necessary steps to resolve it.

When errors do occur, they are generally not mechanical failures. Our instinctive response when accidents happen is to attribute blame to the human involved, even when the underlying issue may lie within the system design or the human-machine interface. As previously noted, when errors arise in human-machine interactions, we often blame the human operator. However, many times, it is the system and its interface that produce outputs that are not meaningful enough for humans to comprehend, which prevents them from taking appropriate actions, thus resulting in errors.

The perception of error has shifted from identifying humans as the primary cause to recognizing issues within the overall system design as the root cause. From this newer perspective, it is not humans who are the sole source of errors; rather, it is the system design that can create conditions for error to arise. To reduce erroneous actions, particularly with rapidly advancing technology, it is crucial to ensure that machinery and equipment are compatible with human use. We should design systems that effectively communicate with humans using in-the-world knowledge.

Many errors can be avoided because humans have the capacity to adapt and cope with the complexities of various systems. Often, even when a system presents an error message, individuals can use their adaptive features and experiences to navigate the system successfully, thereby minimizing errors. By leveraging their knowledge and experience, humans can circumvent potential errors in their interactions with technology.

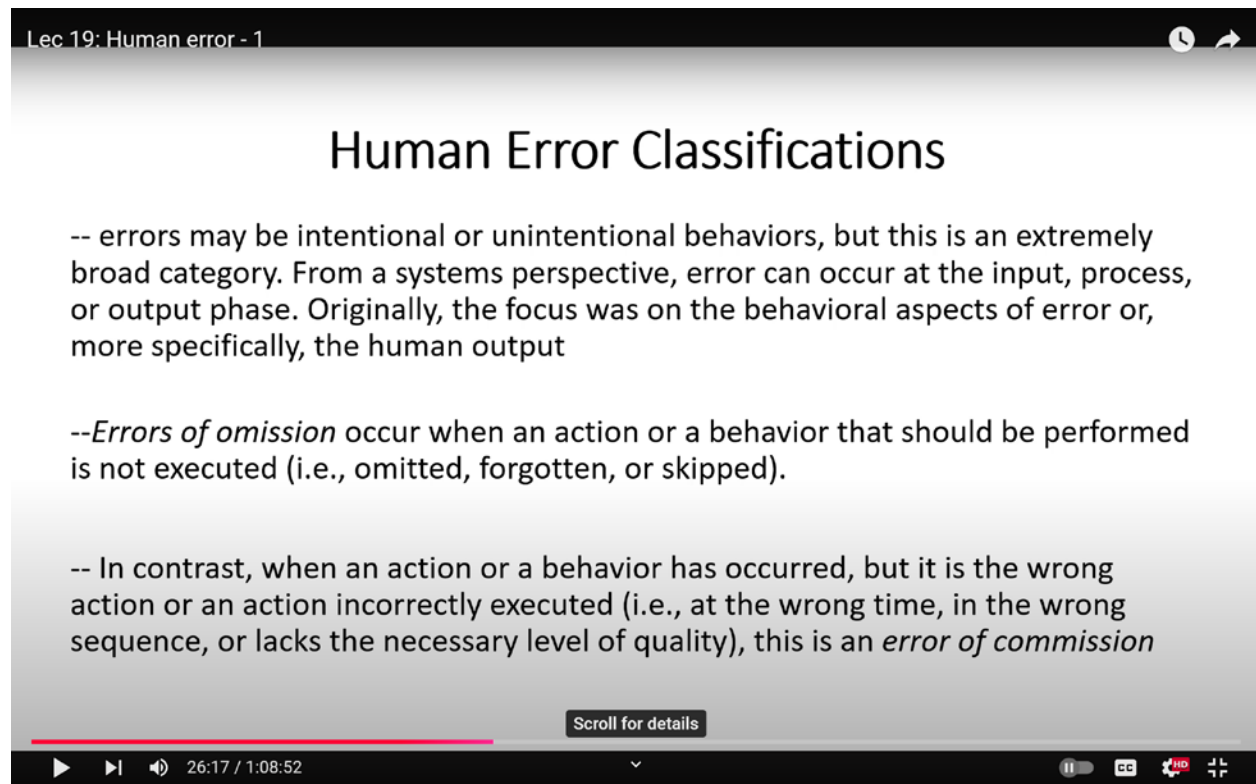
The most effective way to manage errors is to design systems that communicate in a language that humans can easily understand. These systems should be so intuitive that individuals can solve problems without relying heavily on their knowledge or conscious effort. Rather than solely focusing on training human users, specialists in human factors aim to create improved designs that minimize the need for adaptation, which involves modifying equipment to enhance usability. Therefore, training and better design are potential strategies for reducing errors.

Through training, human behavior in relation to specific systems can become automatic, as certain actions will require less conscious processing. This improvement can lead to better interactions between humans and machines, resulting in enhanced performance. Conversely, redesigning

machines to accommodate human adaptation can foster more functional and fruitful human-machine interactions. We have now established an understanding of what errors are and acknowledged that humans are not usually the primary cause of these errors. Next, we will examine how we classify errors.

There are multiple classification systems for human errors, which predominantly focus on how outputs are processed by humans. Additionally, the way inputs from machines are processed can also lead to errors. Essentially, we analyze human behavior and actions to categorize errors. However, incorrect perceptions of certain outputs from the system may lead humans to employ ineffective problem-solving methods, which can result in errors. Thus, errors can occur at both the output and input stages.

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The screenshot shows a video player interface. At the top, a black bar contains the text 'Lec 19: Human error - 1' on the left and a clock icon on the right. Below this is a large white area with the title 'Human Error Classifications' in bold black text. Under the title, there are three bullet points, each preceded by '--'. The first bullet point discusses intentional vs. unintentional behaviors and the systems perspective. The second bullet point defines 'Errors of omission'. The third bullet point defines 'error of commission'. At the bottom of the white area is a black button that says 'Scroll for details'. Below the white area is a video player control bar with a red progress bar, play/pause buttons, a volume icon, and a timestamp '26:17 / 1:08:52'. On the right side of the control bar are icons for full screen, a red 'HD' logo, and a share icon.

Lec 19: Human error - 1

Human Error Classifications

- errors may be intentional or unintentional behaviors, but this is an extremely broad category. From a systems perspective, error can occur at the input, process, or output phase. Originally, the focus was on the behavioral aspects of error or, more specifically, the human output
- Errors of omission* occur when an action or a behavior that should be performed is not executed (i.e., omitted, forgotten, or skipped).
- In contrast, when an action or a behavior has occurred, but it is the wrong action or an action incorrectly executed (i.e., at the wrong time, in the wrong sequence, or lacks the necessary level of quality), this is an *error of commission*

Scroll for details

26:17 / 1:08:52

Let us explore some classification systems for human errors. Errors can be classified as either intentional or unintentional behaviors, although this is a broad category. From a systems perspective, errors can manifest during the input, process, or output phases. Recall that in the first

section of this course, I discussed how a system can be divided into input, process, and output components. Borrowing this framework, errors can occur at any point in the integration of these three processes.

An error can arise during either the input phase or the output phase. Traditionally, the focus has been on the behavioral aspect of errors, specifically human output. As a result, most error classification systems have centered on human output, examining it as a manifestation of human error. However, as previously noted, it can also be the case that poor design or inadequate information provided by the system to users can result in errors. For now, let us consider the classical approach to studying errors, which emphasizes human output errors.

Errors can be categorized based on how human behavior leads to them, resulting in two primary classifications: errors of omission and errors of commission. Errors of omission occur when an action or behavior that should have been performed is not executed. For instance, if you are required to press a button to open a door but forget to do so, resulting in the door not opening, this situation exemplifies an error of omission. Omitting, forgetting, or skipping actions are all classified as errors of omission.

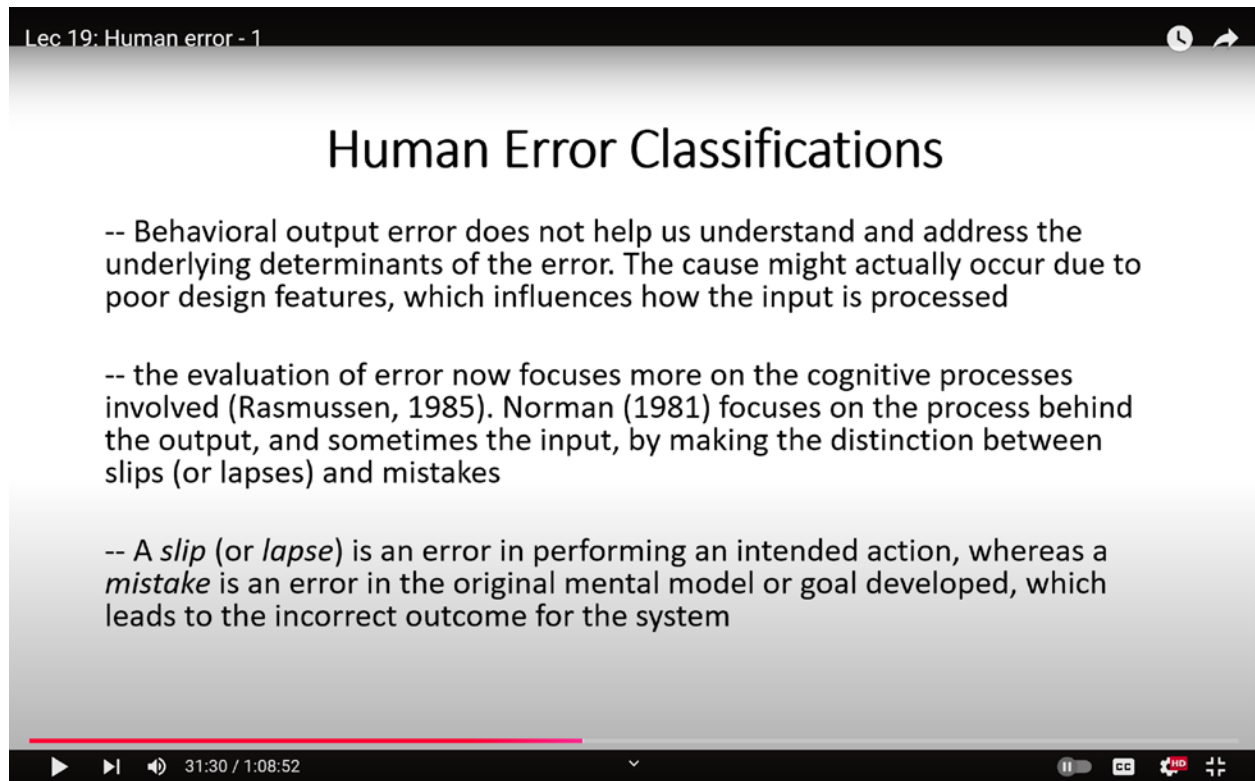
On the other hand, errors of commission occur when an action or behavior is performed incorrectly, such as executing the wrong action, acting at an inappropriate time, or lacking the necessary quality. For example, if you are supposed to take medication at 6 p.m. but, after forgetting whether you have taken it, inadvertently take a double dose 30 minutes later, this is classified as an error of commission, as you mistakenly believe an action has not been performed.

Behavioral output errors, however, do not help us understand or address the underlying determinants of errors. While errors of commission and omission indicate that an error has occurred, the main cognitive factors that caused the error remain obscured. The root cause may stem from poor design features that influence how inputs are processed. At times, incorrect perceptions of inputs can lead to errors classified as commission or omission. Therefore, cognitive factors that contribute to errors cannot be adequately analyzed using the classification of errors as omission and commission.

A new form of error classification has been proposed, emphasizing the cognitive processes

involved. Rasmussen developed a classification system focusing on cognitive processes. In 1981, Norman distinguished between slips or lapses and mistakes, concentrating on the processes behind outputs and sometimes inputs. Donald Norman's classification suggests that errors can occur at both output and input levels.

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The image is a screenshot of a video player showing a lecture slide. The slide title is 'Human Error Classifications'. It contains three bullet points discussing behavioral output errors, cognitive processes, and the distinction between slips/lapses and mistakes. The video player interface at the bottom shows the current time as 31:30 out of 1:08:52.

Lec 19: Human error - 1

Human Error Classifications

- Behavioral output error does not help us understand and address the underlying determinants of the error. The cause might actually occur due to poor design features, which influences how the input is processed
- the evaluation of error now focuses more on the cognitive processes involved (Rasmussen, 1985). Norman (1981) focuses on the process behind the output, and sometimes the input, by making the distinction between slips (or lapses) and mistakes
- A *slip* (or *lapse*) is an error in performing an intended action, whereas a *mistake* is an error in the original mental model or goal developed, which leads to the incorrect outcome for the system

31:30 / 1:08:52

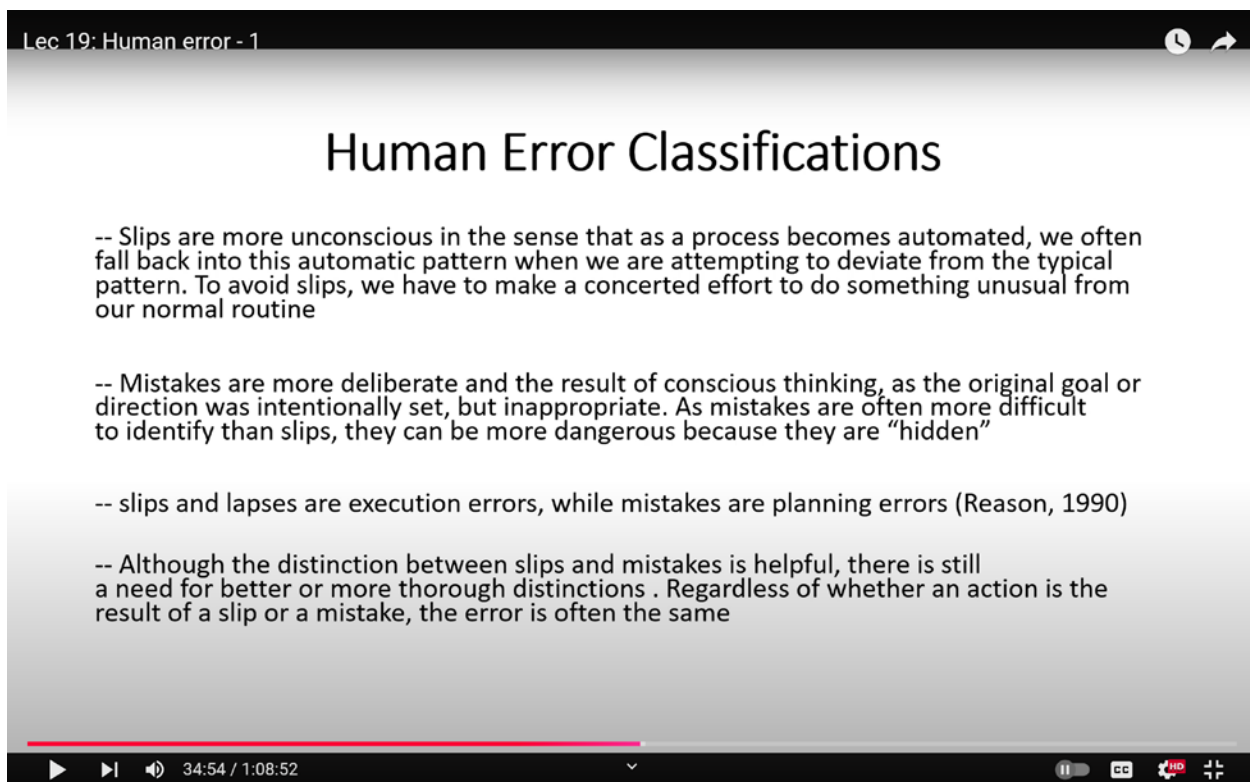
According to this cognitive classification, errors are categorized as slips and mistakes. A slip or lapse is defined as an error in performing an intended action, while a mistake arises from an error in the original mental model or goal, leading to an incorrect outcome. Recall the example I began this lecture with: the incident in which food was incorrectly given to the wrong person was a slip. This mistake occurred unintentionally, likely due to lapses in attention.

Conversely, Ganesh's misunderstanding of how an electrical distribution box functions, believing it can distribute power to various equipment without recognizing that different devices require different power sources, illustrates a mistake. This faulty mental model led him to connect a high-voltage cooking stove to a low-output outlet, resulting in a breakdown. This example highlights

the distinction between a lapse (slip) and a mistake.

Slips tend to be more unconscious in nature. As a process becomes automated, individuals often revert to automatic patterns when attempting to deviate from their typical behaviors. To avoid slips, one must make a conscious effort to engage in actions that differ from their established routine. Slips typically occur because certain actions become automated; thus, even minor deviations from routine can lead to errors. To mitigate slips, various strategies can be employed. For instance, Ganesh could design his food distribution tray with two sections to minimize confusion.

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The screenshot shows a video player interface. At the top, a black bar contains the text 'Lec 19: Human error - 1' on the left and a clock icon on the right. The main content area is a light gray slide with the title 'Human Error Classifications' in a large, bold, black font. Below the title, there are four bullet points, each preceded by '--'. The first bullet point discusses slips as unconscious errors. The second discusses mistakes as deliberate errors. The third states that slips and lapses are execution errors, while mistakes are planning errors, citing Reason (1990). The fourth states that although the distinction is helpful, there is still a need for better distinctions. At the bottom of the slide, there is a red progress bar. Below the slide, the video player controls are visible, including a play button, a progress bar with the time '34:54 / 1:08:52', and various icons for volume, subtitles, and full screen.

Lec 19: Human error - 1

Human Error Classifications

- Slips are more unconscious in the sense that as a process becomes automated, we often fall back into this automatic pattern when we are attempting to deviate from the typical pattern. To avoid slips, we have to make a concerted effort to do something unusual from our normal routine
- Mistakes are more deliberate and the result of conscious thinking, as the original goal or direction was intentionally set, but inappropriate. As mistakes are often more difficult to identify than slips, they can be more dangerous because they are "hidden"
- slips and lapses are execution errors, while mistakes are planning errors (Reason, 1990)
- Although the distinction between slips and mistakes is helpful, there is still a need for better or more thorough distinctions . Regardless of whether an action is the result of a slip or a mistake, the error is often the same

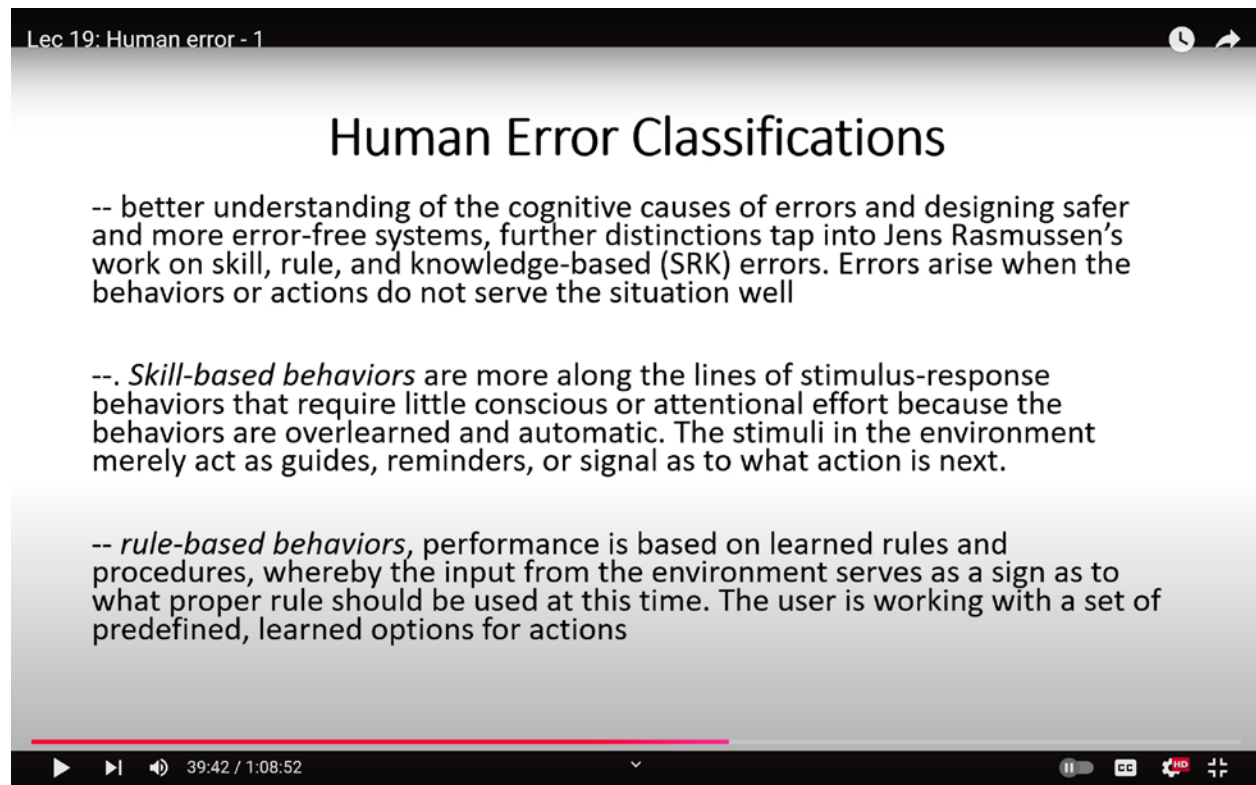
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One tray is designated for vegetarian food, and the other for non-vegetarian food. Stickers or some form of indication should be placed on the trays to clearly identify the vegetarian and non-vegetarian options. By applying this conscious effort, Ganesh can resolve the issue of providing the wrong food to the wrong person. In contrast, mistakes are more deliberate and arise from conscious thought, where the original goal or intended direction is intentionally established but

executed inappropriately. For instance, intentionally plugging high-power equipment into an outlet is a deliberate action, but it is inappropriate.

Mistakes are often more challenging to identify than slips, making them potentially more dangerous because they can be hidden. The mental model that Ganesh possesses regarding how a distribution box or electrical outlet functions may lead him to plug equipment with the wrong wattage into an incorrect outlet, resulting in a mistake. Slips and lapses are classified as execution errors, whereas mistakes are categorized as planning errors. Slips or lapses can occur due to inattention during the execution of a task. In contrast, mistakes involve erroneous actions that highlight errors in the planning of an action.

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Lec 19: Human error - 1

Human Error Classifications

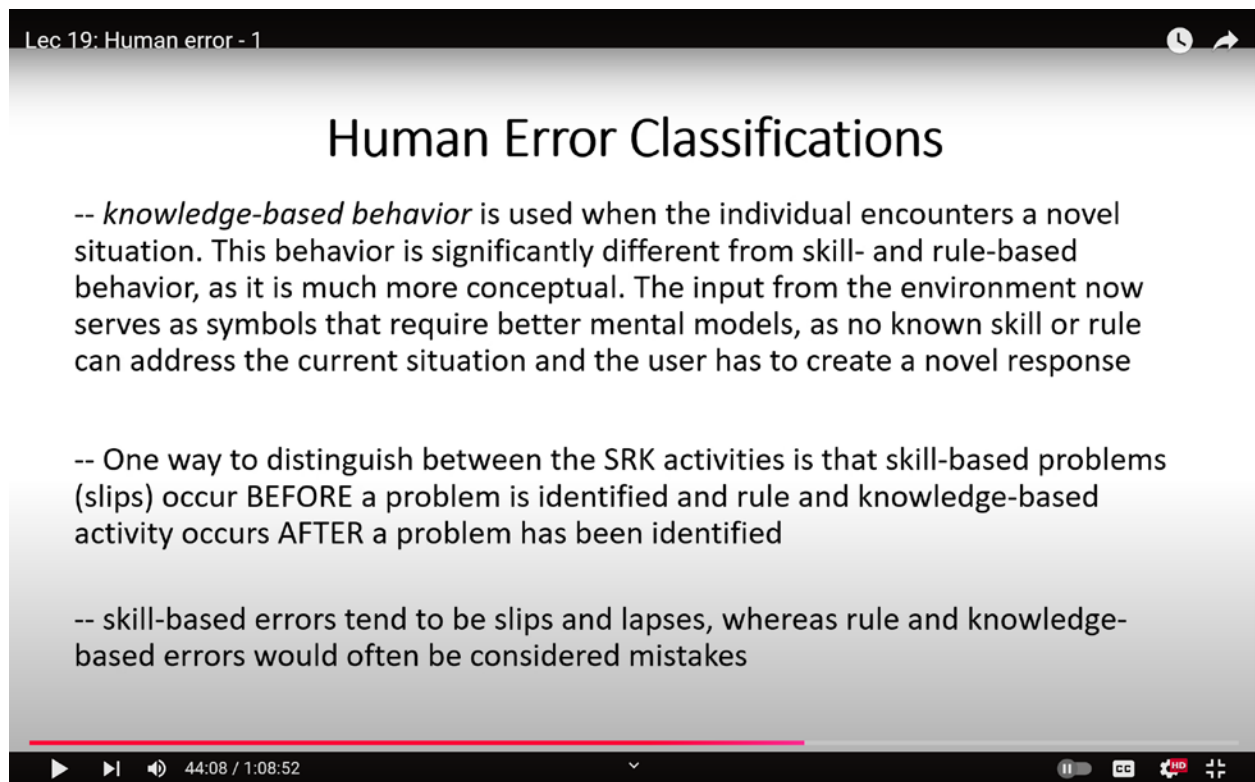
- better understanding of the cognitive causes of errors and designing safer and more error-free systems, further distinctions tap into Jens Rasmussen's work on skill, rule, and knowledge-based (SRK) errors. Errors arise when the behaviors or actions do not serve the situation well
- *Skill-based behaviors* are more along the lines of stimulus-response behaviors that require little conscious or attentional effort because the behaviors are overlearned and automatic. The stimuli in the environment merely act as guides, reminders, or signal as to what action is next.
- *rule-based behaviors*, performance is based on learned rules and procedures, whereby the input from the environment serves as a sign as to what proper rule should be used at this time. The user is working with a set of predefined, learned options for actions

39:42 / 1:08:52

Although distinguishing between slips and mistakes is useful, there is a need for a more comprehensive classification. Regardless of whether an action stems from a slip or a mistake, the resulting error is often the same. While the distinction among errors in terms of slips, lapses, or mistakes is beneficial, it has its limitations. One issue is that whether a behavior results from a slip

or a mistake, the error can sometimes manifest similarly. Thus, understanding the cognitive factors behind an error may not always provide the necessary insights. A more effective distinction is required, which is encapsulated in the SRK model of error classification. This model enhances the understanding of cognitive causes of errors and aids in designing safer, error-free systems, drawing from Jan Rasmussen's work on skill-based, rule-based, and knowledge-based errors.

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The image is a screenshot of a video player showing a lecture slide. The slide title is 'Human Error Classifications'. It contains three bullet points explaining the SRK model. The video player interface at the bottom shows a progress bar at 44:08 / 1:08:52 and various control icons.

Lec 19: Human error - 1

Human Error Classifications

- *knowledge-based behavior* is used when the individual encounters a novel situation. This behavior is significantly different from skill- and rule-based behavior, as it is much more conceptual. The input from the environment now serves as symbols that require better mental models, as no known skill or rule can address the current situation and the user has to create a novel response
- One way to distinguish between the SRK activities is that skill-based problems (slips) occur BEFORE a problem is identified and rule and knowledge-based activity occurs AFTER a problem has been identified
- skill-based errors tend to be slips and lapses, whereas rule and knowledge-based errors would often be considered mistakes

44:08 / 1:08:52

According to Rasmussen, human actions can be categorized into three distinct types: skill-based behavior, rule-based behavior, and knowledge-based behavior. Skill-based behavior is automated, while rule-based behavior involves applying known rules and actions to specific situations. In contrast, knowledge-based behaviors necessitate the use of an individual's cognitive resources to address novel problems that have not been previously encountered. Consequently, the potential for error is considerably higher in this category.

This distinction provides a comprehensive understanding of how errors occur. Error classification becomes relevant when behaviors or actions fail to align appropriately with the situation. Skill-

based behaviors resemble stimulus-response actions that require minimal conscious and attentional effort, as these behaviors are overlearned and automatic. Such behaviors require a low level of consciousness and attentional engagement.

Referring back to the example that initiated this lecture, providing the correct food to the right person exemplifies a skill-based action. Ganesh's task involves simply moving his hand, observing the texture of the food, and listening to the individual's request to match and deliver the appropriate meal. This process is automated and requires a minimal level of consciousness and attention. These behaviors are so well learned and practiced that they become automatic. Hence, the first type of error can be classified as a skill-based error.

In skill-based behaviors, environmental stimuli act as guides, reminders, or signals indicating the next action to take. For instance, the texture of the food will inform Ganesh whether to serve it to a non-vegetarian or vegetarian. This is an example of skill-based behavior.

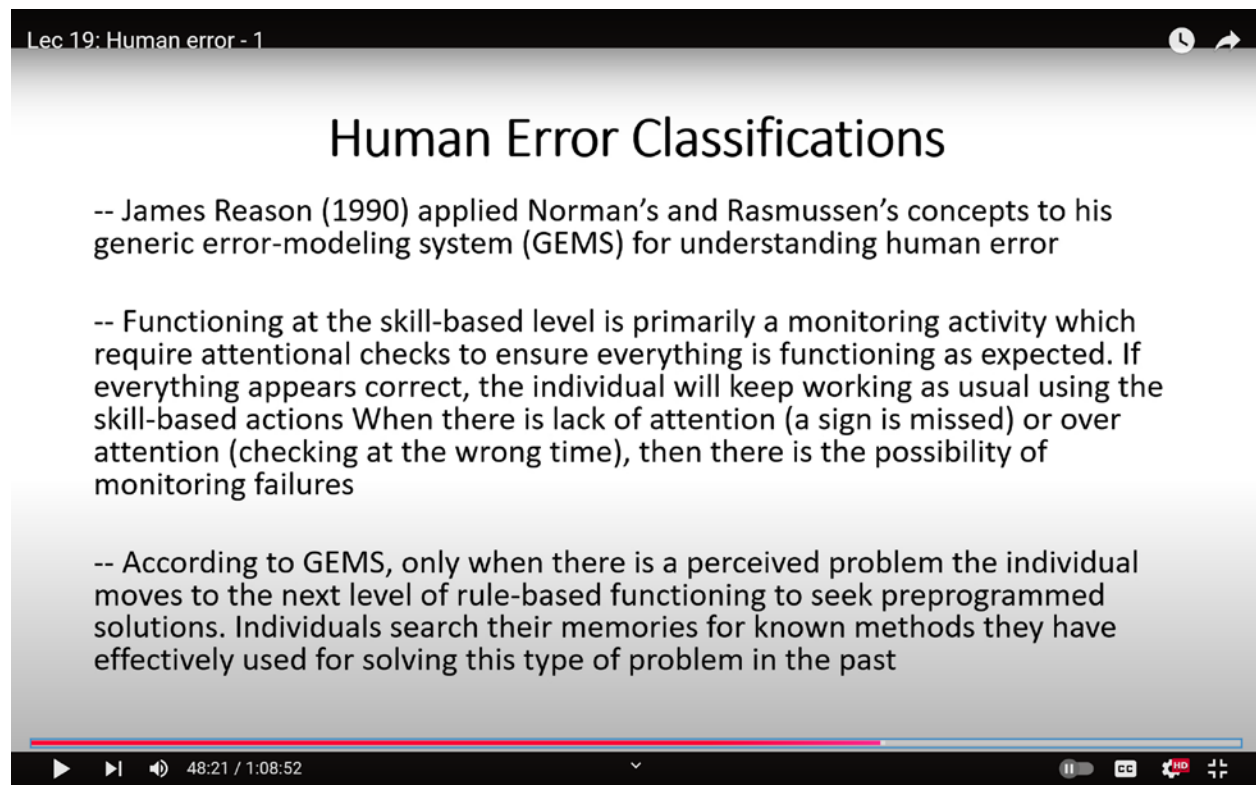
On the other hand, rule-based behaviors depend on learned rules and procedures, wherein environmental inputs serve as indicators of which appropriate rule to apply in a given situation. In the case of rule-based behavior, individuals rely on their understanding of the environment to determine the appropriate response. For example, if Ganesh observes a spark, his prior knowledge indicates that he should disconnect the electrical equipment. Failing to do so could lead to accidents, as his understanding of how electrical equipment operates suggests that sparking at the connection point could cause an electrical fault. If he had acted promptly by removing or disconnecting the electrical equipment, the accident could have been averted.

In rule-based behavior, individuals utilize a predefined set of learned options for their actions. Additionally, Rasmussen's classification system introduces a third category: knowledge-based behavior, which applies when individuals encounter novel situations. This type of behavior is fundamentally different from both skill-based and rule-based behaviors, as it relies heavily on conceptual understanding. In knowledge-based behaviors, the input from the environment serves as a symbol that necessitates the development of more complex mental models. As there are no established skills or rules applicable to the current situation, individuals must generate a novel response based on their experiences and the symbols presented by the environment.

Based on this understanding, Ganesh must take action to minimize errors. For instance, he may soon realize that the low voltage or the sparking issue could indicate a potential problem with the electrical outlet. In response, he should quickly lower the miniature circuit breaker to prevent further losses. This action exemplifies knowledge-based behavior, as it is not something he performs frequently and requires him to comprehend the situation and adjust his understanding to avert accidents. Therefore, this type of behavior is categorized as knowledge-based behavior.

One way to differentiate between skill, rule, and knowledge-based activities is to note that skill-based problems typically occur before a problem is identified, while rule-based and knowledge-based activities happen after the problem has been recognized. Slips, lapses, or skill-based issues arise before an incident occurs, whereas knowledge-based actions take place after the problem has manifested. Thus, skill-based problems may lead to issues, but once a problem arises, individuals must resort to either predefined rules or their own experiences and expertise to resolve it.

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The screenshot shows a video player interface. At the top, a black bar contains the text 'Lec 19: Human error - 1' on the left and a clock icon on the right. Below this is a white slide with the title 'Human Error Classifications' in a large, bold, black font. The slide contains three bullet points, each preceded by a double dash '--'. The first bullet point discusses James Reason's (1990) application of Norman's and Rasmussen's concepts to the GEMS system. The second bullet point describes skill-based functioning as a monitoring activity requiring attentional checks. The third bullet point explains that according to GEMS, individuals move to rule-based functioning when a problem is perceived. At the bottom of the slide, a red progress bar is visible. Below the slide, a black video player control bar shows a play button, a progress bar with the time '48:21 / 1:08:52', and various icons for volume, full screen, and other controls.

Lec 19: Human error - 1

Human Error Classifications

- James Reason (1990) applied Norman's and Rasmussen's concepts to his generic error-modeling system (GEMS) for understanding human error
- Functioning at the skill-based level is primarily a monitoring activity which require attentional checks to ensure everything is functioning as expected. If everything appears correct, the individual will keep working as usual using the skill-based actions When there is lack of attention (a sign is missed) or over attention (checking at the wrong time), then there is the possibility of monitoring failures
- According to GEMS, only when there is a perceived problem the individual moves to the next level of rule-based functioning to seek preprogrammed solutions. Individuals search their memories for known methods they have effectively used for solving this type of problem in the past

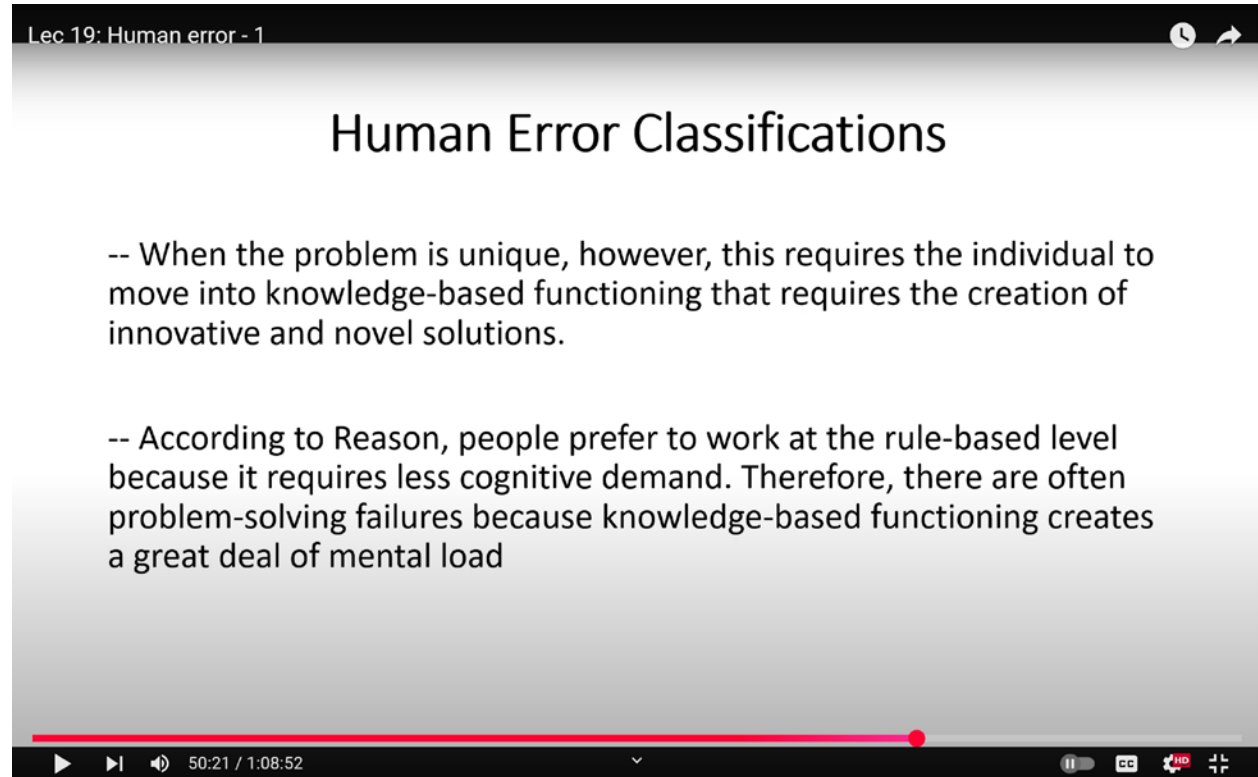
48:21 / 1:08:52

This creates a distinction based on timing, whereby skill-based errors are categorized as slips and

lapses, whereas rule-based and knowledge-based errors are identified as mistakes. James Reason integrated the concepts of Norman and Rasmussen into his generic error modeling system, known as GEMS, to better understand human error. This system operates on the premise that functioning at the skill-based level primarily involves monitoring activities that require attentional checks to ensure everything is operating as expected.

When an individual functions at a skill-based level, they constantly monitor their actions with minimal attention. They may occasionally redirect their attention to confirm that everything is proceeding correctly. If no mistakes are detected, they will continue their skill-based actions. However, if there is a lack of attention, either through missing necessary checks or performing them at inappropriate times, this can lead to monitoring failures. For instance, failing to conduct attentional checks could result in overlooking a potential error indication in the system, or checking at the wrong moment could lead to further complications that can only be addressed through rule-based or knowledge-based behavior.

(Refer Slide Time: 50:21)



The screenshot shows a video player interface. At the top, a black bar contains the text 'Lec 19: Human error - 1' on the left and a circular icon with a right-pointing arrow on the right. Below this is a large white rectangular area with the title 'Human Error Classifications' in a bold, black, sans-serif font. Under the title, there are two bullet points, each preceded by two dashes '--'. The first bullet point reads: '-- When the problem is unique, however, this requires the individual to move into knowledge-based functioning that requires the creation of innovative and novel solutions.' The second bullet point reads: '-- According to Reason, people prefer to work at the rule-based level because it requires less cognitive demand. Therefore, there are often problem-solving failures because knowledge-based functioning creates a great deal of mental load'. At the bottom of the slide is a red progress bar. Below the slide area is a black video player control bar. It contains a play button icon, a next button icon, a volume icon, the text '50:21 / 1:08:52', a downward arrow icon, a closed captions icon, a red 'HD' logo, and a full-screen icon.

Lec 19: Human error - 1

Human Error Classifications

- When the problem is unique, however, this requires the individual to move into knowledge-based functioning that requires the creation of innovative and novel solutions.
- According to Reason, people prefer to work at the rule-based level because it requires less cognitive demand. Therefore, there are often problem-solving failures because knowledge-based functioning creates a great deal of mental load

50:21 / 1:08:52

According to GEMS, an individual will transition to rule-based functioning only when they perceive a problem. When an operator recognizes an issue in the system and determines that it is not a lapse (an unintentional problem), they will rely on previously established rules to address it. In this case, the operator will draw upon their memory to recall effective methods used to resolve similar problems in the past. Therefore, if a lapse is not the cause of a system error, operators will search for pre-programmed solutions that have worked previously and apply these to mitigate the error state.

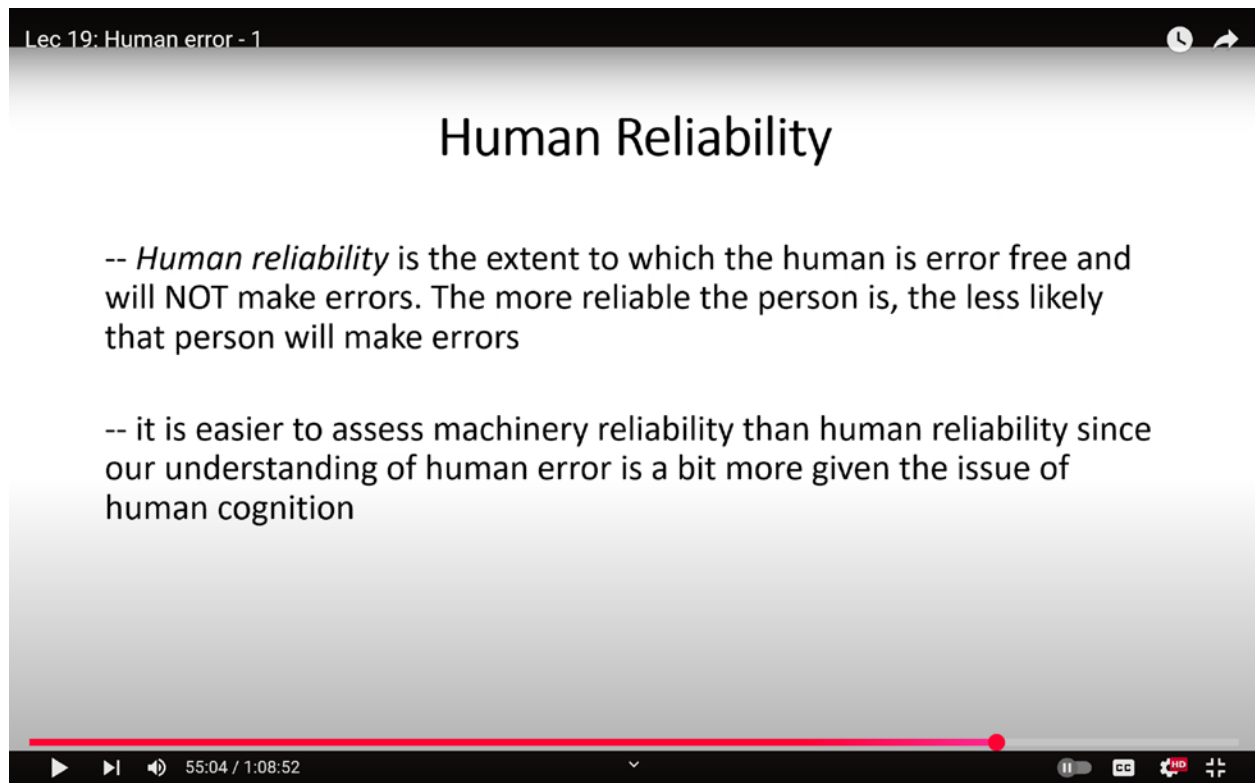
However, when a problem is unique and does not have an available solution, the operator must engage in knowledge-based functioning, requiring them to devise innovative and novel solutions. This scenario arises when no pre-existing solutions or programmed responses can address the current issue. In such cases, the operator must utilize their understanding of the system and personal experiences to synthesize various approaches to problem-solving. This process is referred to as knowledge-based problem-solving. When employing a knowledge-based approach, individuals often generate creative solutions to tackle novel situations. They leverage their knowledge and expertise to explore various combinations until a viable solution emerges, which they then attempt to implement.

If successful, they will have developed a new solution. Knowledge-based problem-solving can be likened to Kekulé's discovery of the benzene ring's structure. Kekulé frequently worked with organic structures resembling the benzene ring, and through his understanding of atomic structures and experience, he deduced how these rings behave, exhibiting characteristics of both single and double bonds.

According to Reason, individuals prefer to operate at the rule-based level because it demands less cognitive effort. Consequently, failures in problem-solving often occur when engaging in knowledge-based functioning, which imposes a significant mental load. Most operators prefer to work within a rule-based framework, as it does not require extensive use of their mental resources. Since rule-based problems are generally variations of known issues, all they need to do is identify the correct rule to apply for resolution. For example, if a pilot makes a minor error during a checklist and discovers an existing solution, they can swiftly implement that solution to rectify the plane's position.

In contrast, had they relied on their knowledge-based system, the solution might have been formulated too late, with no opportunity for the pilot or the aircraft to benefit from it. Therefore, knowledge-based systems can be time-consuming and demand substantial mental effort.

(Refer Slide Time: 55:04)



Lec 19: Human error - 1

Human Reliability

- *Human reliability* is the extent to which the human is error free and will NOT make errors. The more reliable the person is, the less likely that person will make errors
- it is easier to assess machinery reliability than human reliability since our understanding of human error is a bit more given the issue of human cognition

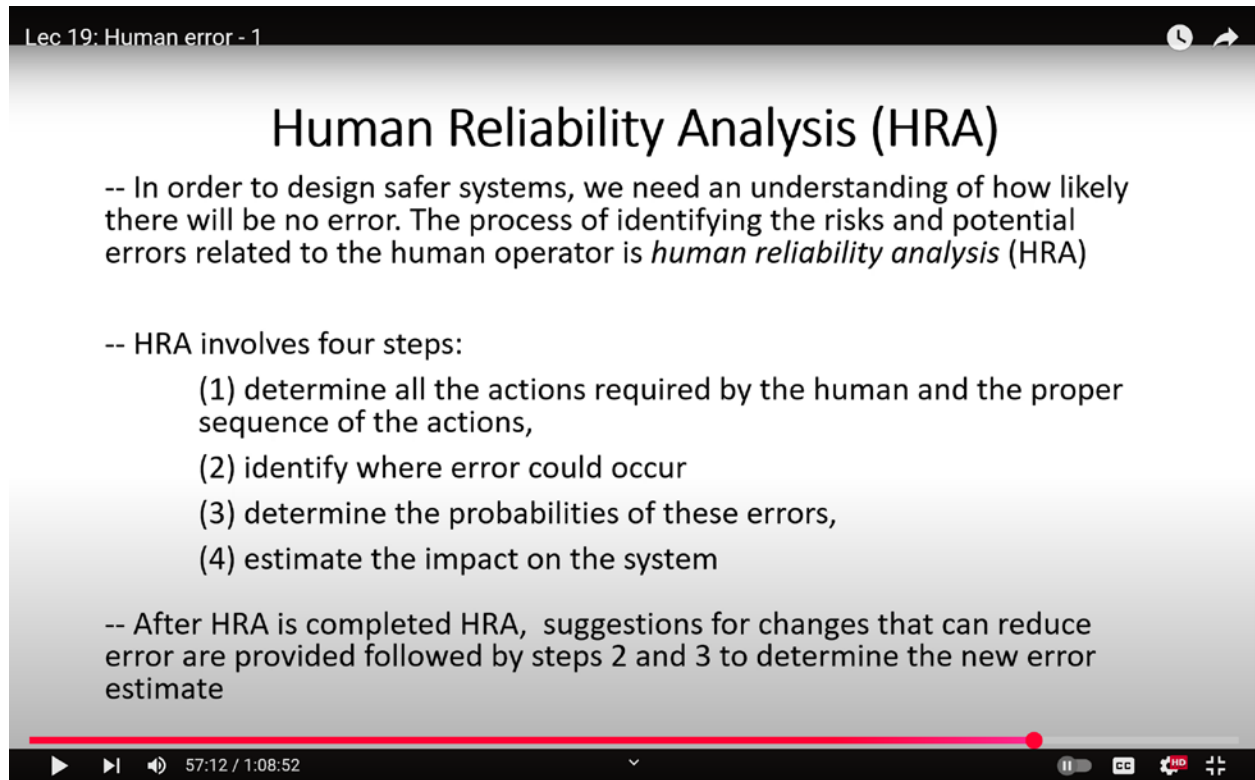
55:04 / 1:08:52

To summarize, we have established the definition of an error and classified the different types of errors. Next, we turn to human reliability, which assesses how trustworthy and error-free individuals can be. The more reliable a person is, the less likely they are to commit errors. However, individuals cannot be expected to be entirely reliable, as they are inherently prone to mistakes. There are variations in reliability among individuals; some commit more errors than others, and the frequency of errors can be specific to particular tasks, situations, and contexts.

In examining human reliability, it is essential to note that assessing machine reliability is generally more straightforward than evaluating human reliability. This is due to our more developed understanding of human error compared to human cognition. Machines consist of known components and functions and typically operate within defined parameters, remaining consistent

with their designed purpose. In contrast, humans possess dynamic minds, which can introduce unpredictability and complications.

(Refer Slide Time: 57:12)

The image is a screenshot of a video player interface. At the top, a black bar contains the text 'Lec 19: Human error - 1' on the left and a clock icon on the right. The main content area has a light gray background. The title 'Human Reliability Analysis (HRA)' is centered in a large, bold, black font. Below the title, there are two bullet points, each preceded by '--'. The first bullet point discusses the need for understanding human error in system design. The second bullet point lists four steps of HRA: (1) determine all the actions required by the human and the proper sequence of the actions, (2) identify where error could occur, (3) determine the probabilities of these errors, and (4) estimate the impact on the system. Below the steps, another bullet point explains that after HRA is completed, suggestions for changes to reduce error are provided, followed by steps 2 and 3 to determine a new error estimate. At the bottom of the video player, a red progress bar is visible, with a play button, a volume icon, and a timestamp '57:12 / 1:08:52' on the left, and a full screen icon on the right.

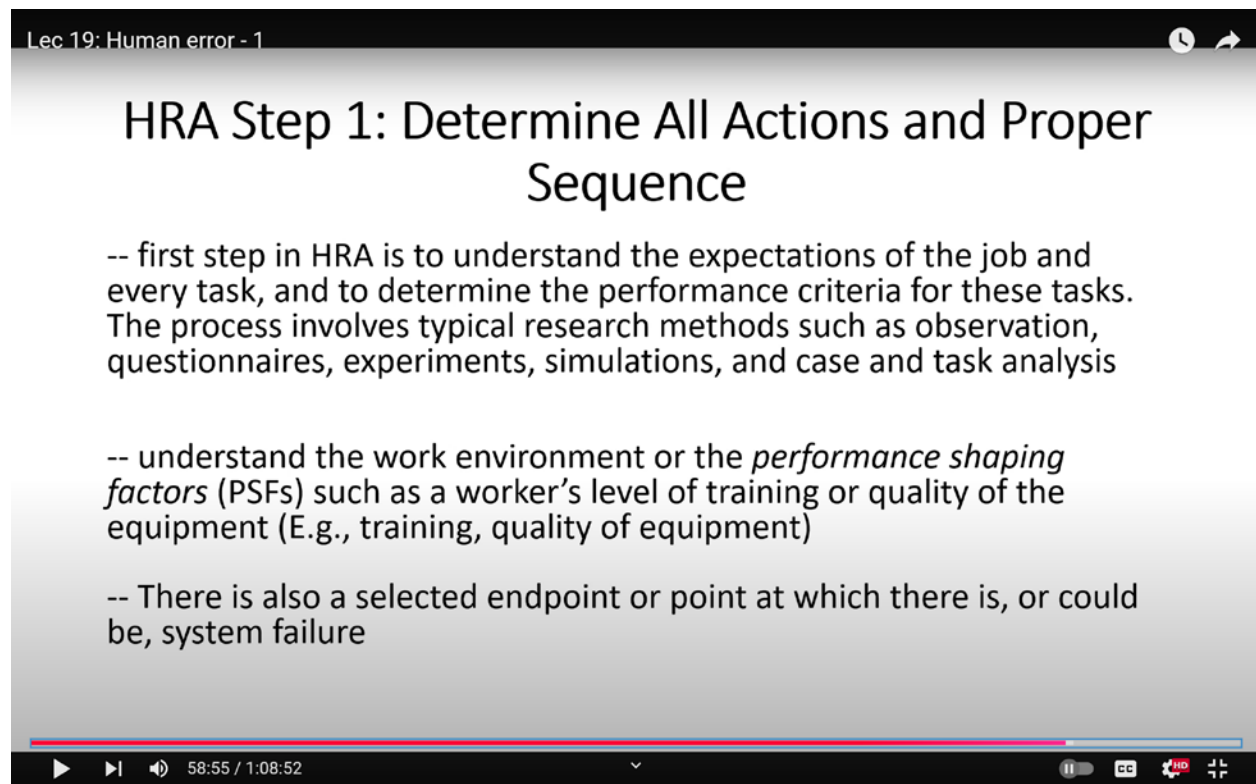
Human cognition operates in unpredictable and probabilistic ways, making it challenging to forecast human behavior, and thus, human reliability cannot be fully trusted. Given this complexity, how should we study human reliability? To design safer systems, we need to understand how likely a human is to make errors. The process of identifying risks and potential errors associated with human operators is referred to as human reliability analysis. This analysis involves investigating what types of errors occur and at which points during operation those errors manifest.

Human reliability analysis consists of four steps. The first step involves determining all actions required by humans in the correct sequence. It is crucial to understand what actions need to be taken and in what order they should occur, including which behaviors should follow one another and which behaviors are being studied. The second step is to identify where errors can exist within

this sequence of actions and behaviors. The third step entails determining the probabilities of these errors, assessing the likelihood of their occurrence. Finally, the fourth step focuses on estimating the impact of the error on the system. This involves analyzing the consequences that an error could have once it has occurred.

Upon completing these four steps, we can ascertain the necessary actions to be performed in the correct sequence, identify potential error points within this sequence, evaluate the probabilities of those errors, and finalize the impact of these errors on the overall system. Based on this analysis, suggestions can be made for changes aimed at reducing errors. After proposing such changes, Steps 2 and 3, identifying errors and calculating their probabilities, must be re-evaluated to determine whether new errors have emerged and to assess how the system has improved based on updated error estimates.

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Lec 19: Human error - 1

HRA Step 1: Determine All Actions and Proper Sequence

- first step in HRA is to understand the expectations of the job and every task, and to determine the performance criteria for these tasks. The process involves typical research methods such as observation, questionnaires, experiments, simulations, and case and task analysis
- understand the work environment or the *performance shaping factors* (PSFs) such as a worker's level of training or quality of the equipment (E.g., training, quality of equipment)
- There is also a selected endpoint or point at which there is, or could be, system failure

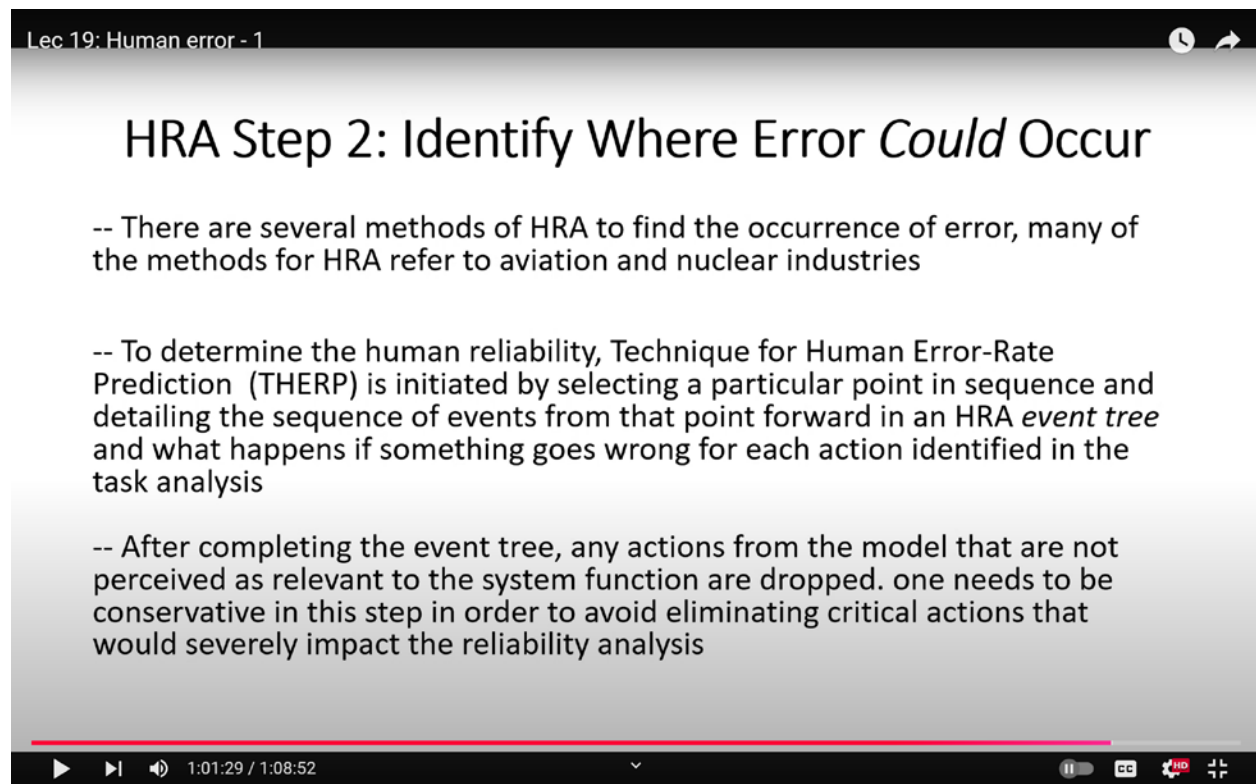
58:55 / 1:08:52

Let us now examine these four steps in detail. The first step involves determining all actions and their proper sequences. In human reliability analysis (HRA), this step entails understanding job

expectations for each task and establishing performance criteria for those tasks. Each task has specific expectations, a sequence of performance, and criteria for success. Therefore, the initial focus of HRA is to comprehend these aspects.

The process includes typical research methods such as observation, questionnaires, experimental simulations, and task analysis. By employing observations, experimental settings, in-person discussions, and task analysis, HRA experts identify the necessary actions to be performed and the correct sequence for executing those actions. For instance, in the example of Ganesh introduced at the beginning of this lecture, a human reliability analysis expert could engage in conversations with Ganesh to determine all the steps he follows during his daily work. Task analysis is integral to this process, alongside understanding the work environment and performance-shaping factors, such as the workers' level of training and the quality of equipment used.

(Refer Slide Time: 1:01:29)

The image is a screenshot of a video player showing a lecture slide. The slide title is 'HRA Step 2: Identify Where Error Could Occur'. It contains three bullet points: 1. '-- There are several methods of HRA to find the occurrence of error, many of the methods for HRA refer to aviation and nuclear industries'. 2. '-- To determine the human reliability, Technique for Human Error-Rate Prediction (THERP) is initiated by selecting a particular point in sequence and detailing the sequence of events from that point forward in an HRA event tree and what happens if something goes wrong for each action identified in the task analysis'. 3. '-- After completing the event tree, any actions from the model that are not perceived as relevant to the system function are dropped. one needs to be conservative in this step in order to avoid eliminating critical actions that would severely impact the reliability analysis'. The video player interface at the bottom shows a progress bar at 1:01:29 / 1:08:52 and various control icons.

Lec 19: Human error - 1

HRA Step 2: Identify Where Error *Could* Occur

- There are several methods of HRA to find the occurrence of error, many of the methods for HRA refer to aviation and nuclear industries
- To determine the human reliability, Technique for Human Error-Rate Prediction (THERP) is initiated by selecting a particular point in sequence and detailing the sequence of events from that point forward in an HRA *event tree* and what happens if something goes wrong for each action identified in the task analysis
- After completing the event tree, any actions from the model that are not perceived as relevant to the system function are dropped. one needs to be conservative in this step in order to avoid eliminating critical actions that would severely impact the reliability analysis

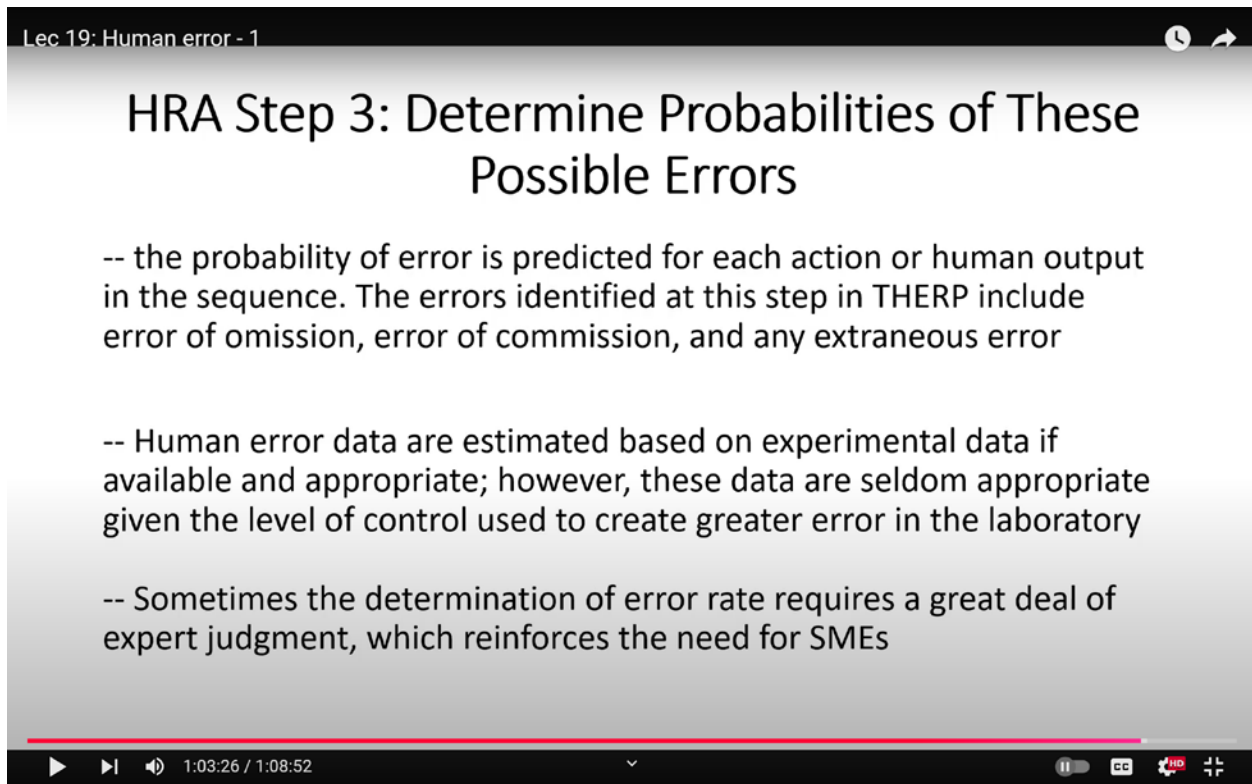
1:01:29 / 1:08:52

It is important to consider not only the actions of individuals but also performance-shaping factors, including training levels, motivation, equipment usage, and proficiency with the tools required for

the job. These factors, along with the work environment, can significantly influence performance and error rates. Additionally, a selected endpoint should be identified, representing a potential point of system failure.

In the second step, HRA experts focus on identifying where errors could occur. Once the sequence of actions is established, the next task is to pinpoint possible error occurrences. Various methods exist within HRA to assess error occurrence, with many of these techniques originating from the aviation and nuclear industries, where HRA is predominantly applied.

(Refer Slide Time: 1:03:26)



The screenshot shows a video player interface. At the top, a black bar contains the text 'Lec 19: Human error - 1' on the left and a clock icon on the right. Below this, the main title 'HRA Step 3: Determine Probabilities of These Possible Errors' is centered in a large, bold, black font. Underneath the title, there are three bullet points, each preceded by two dashes '--'. The first bullet point discusses the prediction of error probability for each action in a sequence, mentioning THERP and types of errors like omission and commission. The second bullet point states that human error data are estimated from experimental data but may not be appropriate for all levels of control. The third bullet point notes that determining error rates often requires expert judgment, specifically mentioning SMEs. At the bottom of the slide, a red progress bar is visible, along with standard video controls (play, pause, volume, etc.) and a timestamp '1:03:26 / 1:08:52'.

Lec 19: Human error - 1

HRA Step 3: Determine Probabilities of These Possible Errors

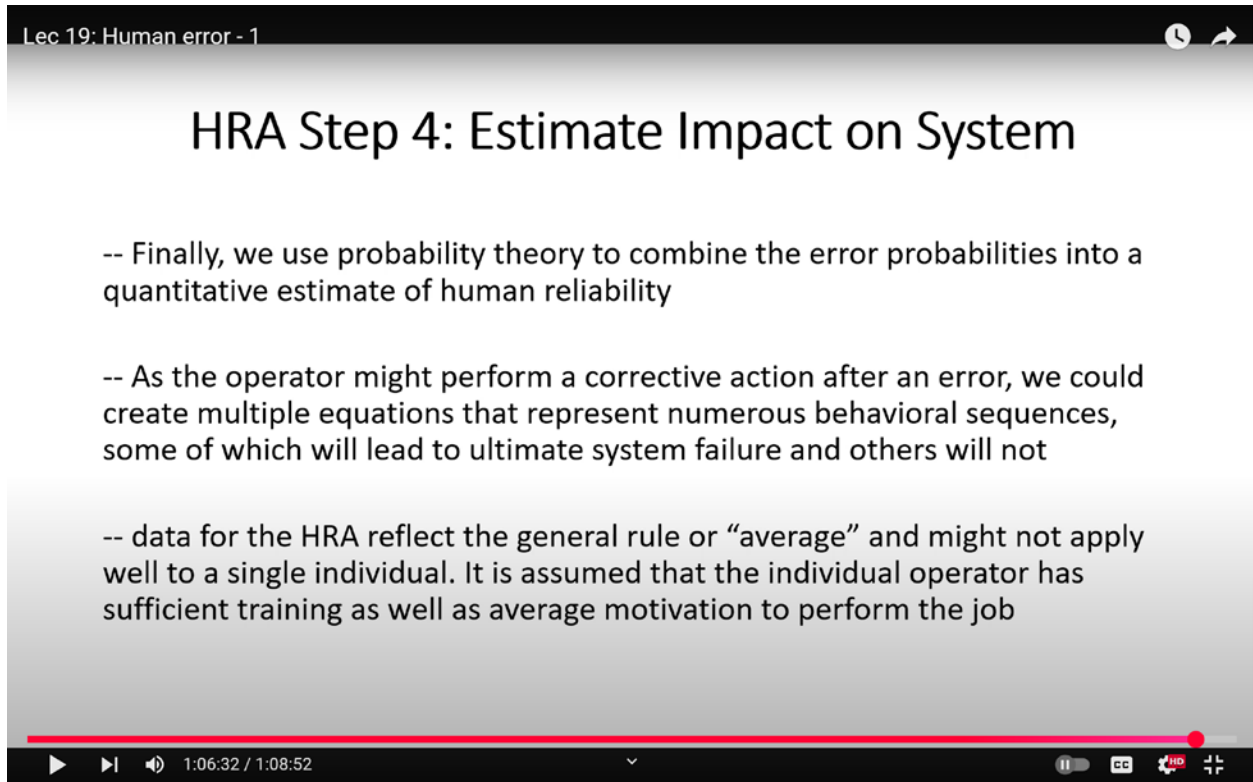
- the probability of error is predicted for each action or human output in the sequence. The errors identified at this step in THERP include error of omission, error of commission, and any extraneous error
- Human error data are estimated based on experimental data if available and appropriate; however, these data are seldom appropriate given the level of control used to create greater error in the laboratory
- Sometimes the determination of error rate requires a great deal of expert judgment, which reinforces the need for SMEs

1:03:26 / 1:08:52

To predict human error rates, the technique known as THERP (Technique for Human Error Rate Prediction) is initiated by selecting a specific point in the sequence and detailing the sequence of events from that point forward in an HRA event tree. This method seeks to determine what might happen if something goes wrong at each identified action in the task analysis. An event tree is created to enumerate all possible events associated with a particular action. The analysis begins from the point at which an error occurs or a decision is made, and all subsequent actions are studied

to identify the likelihood of error.

(Refer Slide Time: 1:06:32)



Lec 19: Human error - 1

HRA Step 4: Estimate Impact on System

- Finally, we use probability theory to combine the error probabilities into a quantitative estimate of human reliability
- As the operator might perform a corrective action after an error, we could create multiple equations that represent numerous behavioral sequences, some of which will lead to ultimate system failure and others will not
- data for the HRA reflect the general rule or “average” and might not apply well to a single individual. It is assumed that the individual operator has sufficient training as well as average motivation to perform the job

1:06:32 / 1:08:52

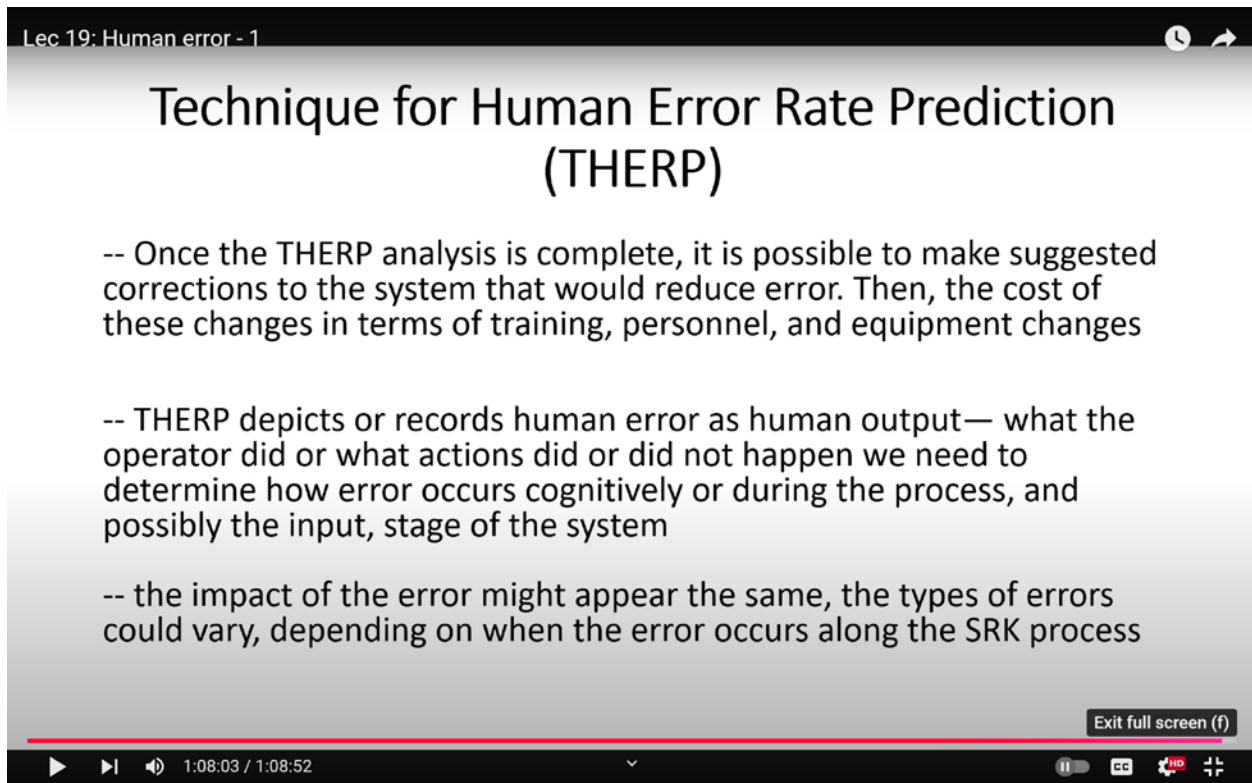
This analysis is informed by task analysis, which also indicates the points at which the probability of executing an alternate or unintentional action may arise. After constructing the event tree, any action deemed irrelevant to the system's functioning is removed from consideration. Throughout this process, it is essential to exercise caution to avoid eliminating critical actions that could significantly impact the reliability analysis.

The human reliability expert should apply stringent criteria and involve individuals with expertise in the system to ensure that no critical steps in job performance are overlooked. The third step in human reliability analysis involves determining the probabilities of these potential errors. Here, the likelihood of error is predicted for each human action within the sequence. Each action taken to complete a task is assigned a specific probability of error.

Errors identified in this step of THERP may include errors of omission, errors of commission, and extraneous errors. For each action performed during task completion, the probabilities of potential

errors at each step are calculated, focusing on likely errors such as commissions, omissions, or system-related and extraneous errors. Human error data are estimated based on available experimental data, although such data are often limited due to the controlled conditions under which error rates are typically assessed in laboratory settings.

(Refer Slide Time: 1:08:03)



The screenshot shows a video player interface. At the top, a black bar contains the text 'Lec 19: Human error - 1' on the left and a clock icon on the right. Below this is a slide with a light gray background. The slide title is 'Technique for Human Error Rate Prediction (THERP)' in a large, bold, black font. Below the title are three bullet points, each preceded by '--'. The first bullet point discusses making suggested corrections to the system to reduce error and the associated costs. The second bullet point describes how THERP depicts human error as human output and the need to determine how error occurs. The third bullet point discusses how the impact of errors could vary depending on when they occur along the SRK process. At the bottom of the slide, there is a red progress bar and a small button that says 'Exit full screen (f)'. Below the slide, the video player controls are visible, including a play button, a progress bar showing '1:08:03 / 1:08:52', and various icons for volume, settings, and full screen.

Lec 19: Human error - 1

Technique for Human Error Rate Prediction (THERP)

- Once the THERP analysis is complete, it is possible to make suggested corrections to the system that would reduce error. Then, the cost of these changes in terms of training, personnel, and equipment changes
- THERP depicts or records human error as human output— what the operator did or what actions did or did not happen we need to determine how error occurs cognitively or during the process, and possibly the input, stage of the system
- the impact of the error might appear the same, the types of errors could vary, depending on when the error occurs along the SRK process

Exit full screen (f)

1:08:03 / 1:08:52

Occasionally, human error databases may be referenced, but most analyses necessitate the collection of unique data specific to each study, as the findings are often context-dependent.

Determining the error rate often necessitates considerable expert judgment, highlighting the importance of subject matter experts (SMEs). Calculating the probability of an error for any step performed by an operator requires substantial judgment. Consequently, experts are consulted to provide their insights regarding whether the assigned probability for a specific action that has led to an error is accurate. If the assessment is incorrect, the experts recommend appropriate corrective measures. Additionally, the potential impact of these errors on the system must be evaluated.

To synthesize these findings, we apply probability theory to combine the error probabilities into a

qualitative estimate of human reliability. By utilizing probability theory and integrating error probabilities from various assessments, we arrive at an estimate of human reliability. When operators perform corrective actions following an error, it becomes possible to develop multiple equations that represent various behavioral sequences; some of these sequences may lead to ultimate failures, while others may not. By obtaining the probabilities of all actions and types of errors, we can create a probability chart or action chart. This chart will outline error probability sequences, allowing us to identify which actions are likely to result in ultimate failure and which actions are not.

It is important to note that the data used in human reliability analysis (HRA) reflect general rules or averages. The HRA data represent typical users, providing average values or fault analyses that may not apply well to individual cases. Each person is unique; as previously explained, individuals possess different ways of understanding and approaching tasks. Therefore, the rules or steps outlined by an HRA may not hold true for every individual.

It is assumed that individual operators possess sufficient training and an average level of motivation to perform their jobs effectively. Consequently, factors such as training and motivation are not accounted for when conducting an HRA. Once the THERP (Technique for Human Error Rate Prediction) analysis is completed, it becomes possible to propose corrective actions aimed at reducing errors. The costs associated with these changes, including training and personal equipment adjustments, can also be calculated.

After conducting a THERP analysis and identifying potential errors, error probabilities, and possible corrective measures, these suggestions can be evaluated in terms of their cost implications. A cost analysis can then be prepared for training personnel and system design changes that are intended to minimize errors. THERP documents or records human error as a function of human output, focusing on the actions performed by the operator. However, it is essential to examine how errors occur cognitively or during the input stage of the system, as THERP is primarily an output-based system. It emphasizes the actions that humans perform but does not explicitly address the cognitive factors that contribute to error.

While the impact of errors may appear consistent, the nature of the errors can vary depending on when they occur within the Skill, Rule, Knowledge (SRK) framework. The type of error, whether

it occurs during skill-based, rule-based, or knowledge-based behavior, will influence the error's nature and aid in understanding both the errors themselves and the probability of their occurrence. Furthermore, identifying the specific point at which an error occurs in the SRK analysis can facilitate better design adaptations for a diverse range of users and operators working with the same machinery or setup.

This concludes my presentation for today. Namaskar, and thank you.