Engineering Psychology

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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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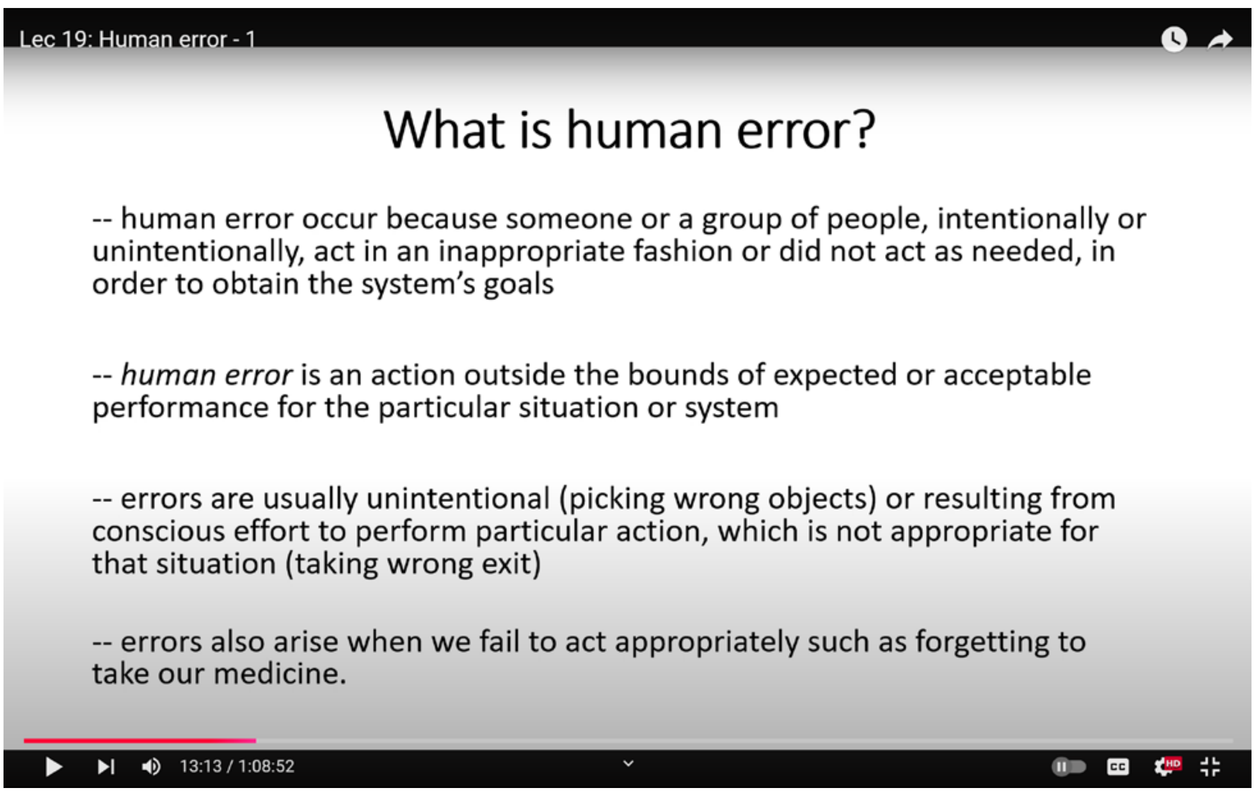

Many machines can identify and resolve their own problems, thus fostering a more effective relationship between the operator and the machine. However, it is important to remember that machines are dependent on human operators for their functionality. Human beings are constrained by their knowledge and 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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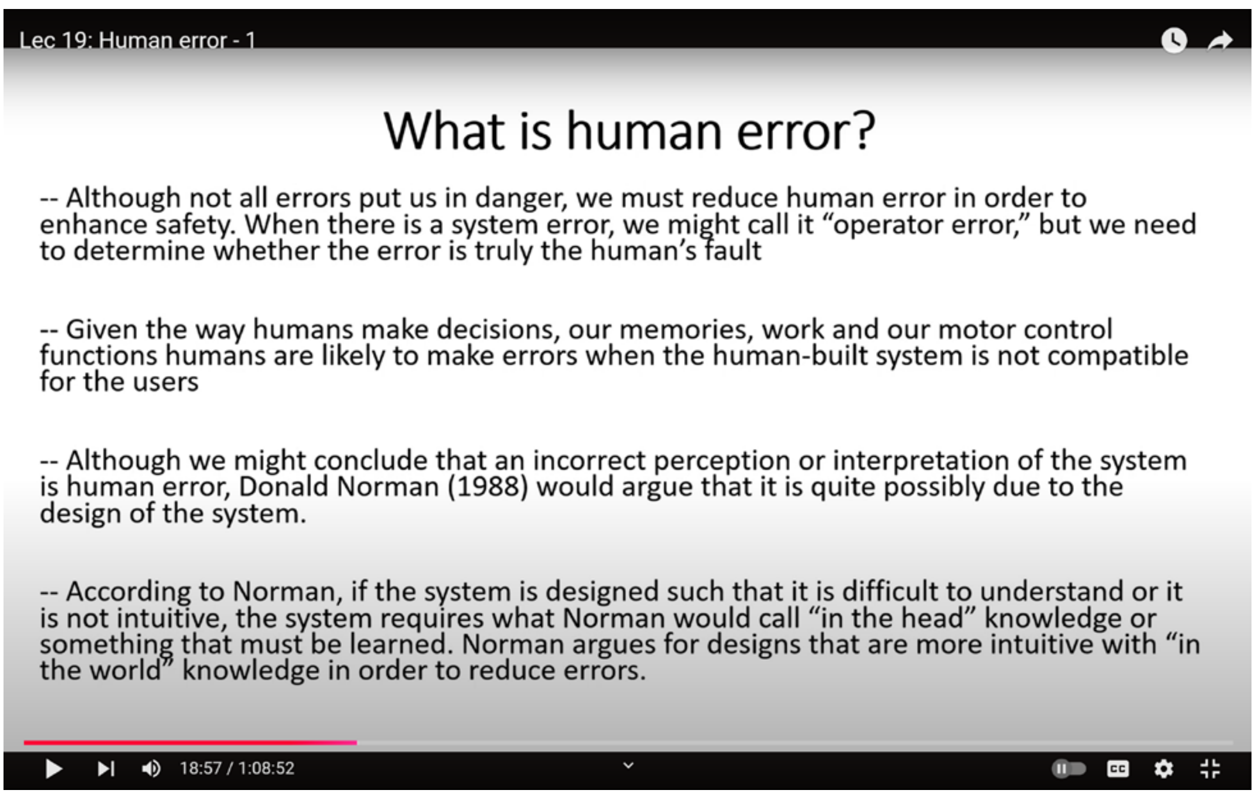

For example, consider two objects on a table: a glass of water and a mobile phone. While talking to a friend, I reach for the mobile phone but unintentionally grab the glass of water instead. Upon realizing my mistake, I set the glass down, causing some water to spill and wetting the desk. This constitutes 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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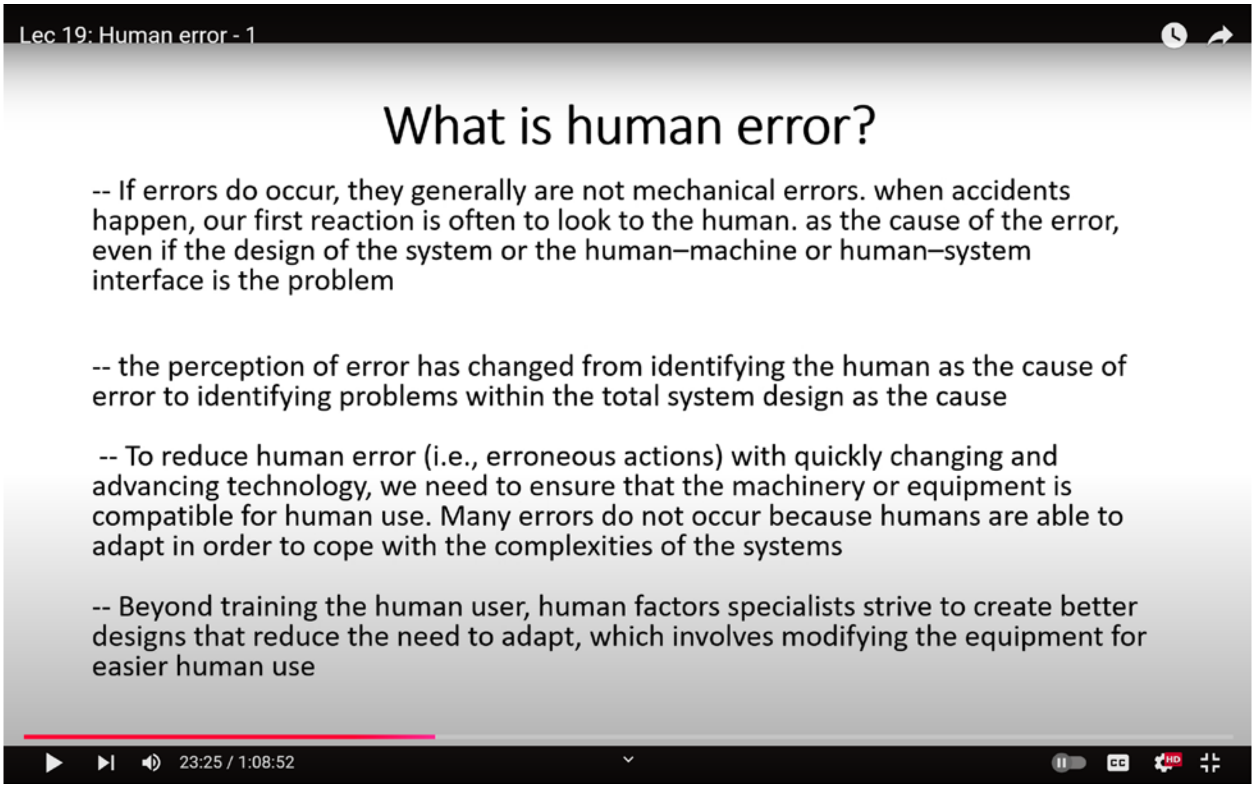

According to Donald Norman, if a system is designed in such a way that it is difficult to understand or lacks intuitiveness, it requires what he terms "in-the-head knowledge," which must be learned. Norman asserts that designers should aim for "in-the-world knowledge," which allows for reduced errors. 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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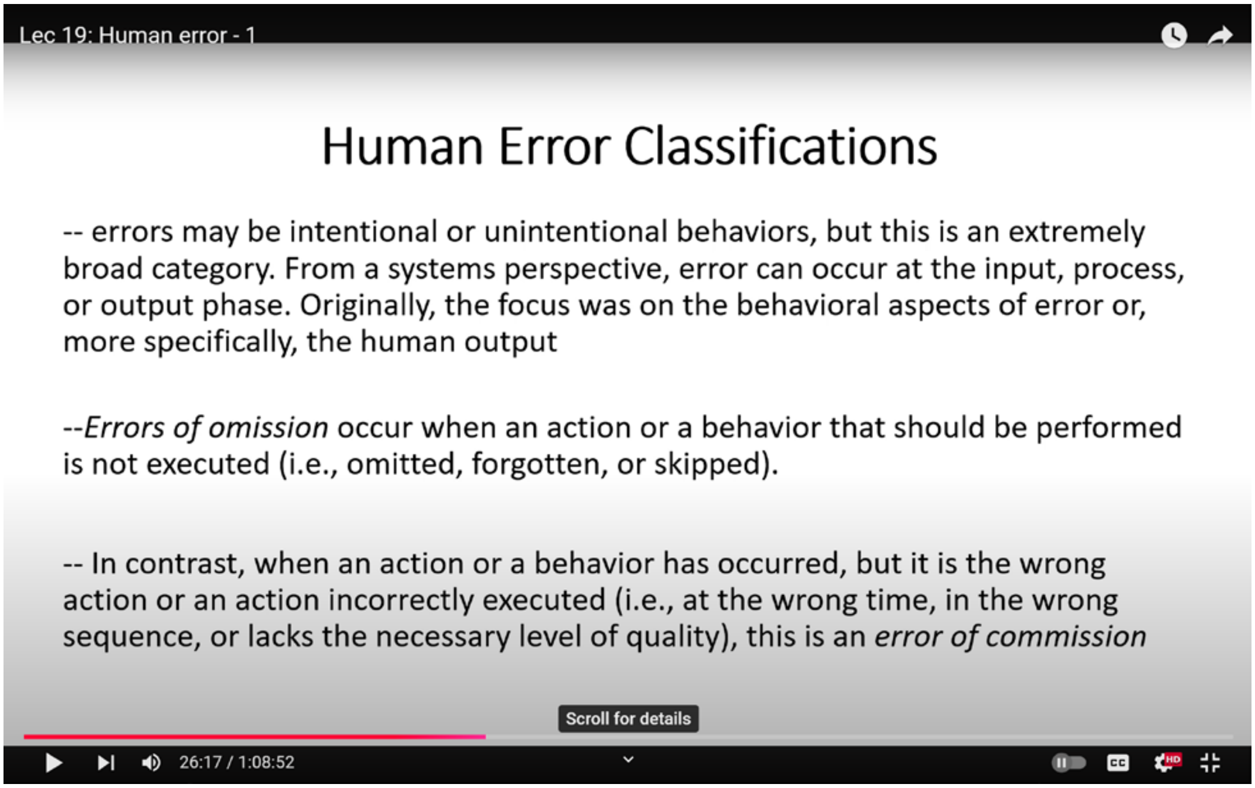

Let us explore some classification systems for human errors. Errors can be classified as either intentional or unintentional behaviors, although this is a broad category. From a systems perspective, errors can manifest during the input, process, or output phases. Recall that in the first section of this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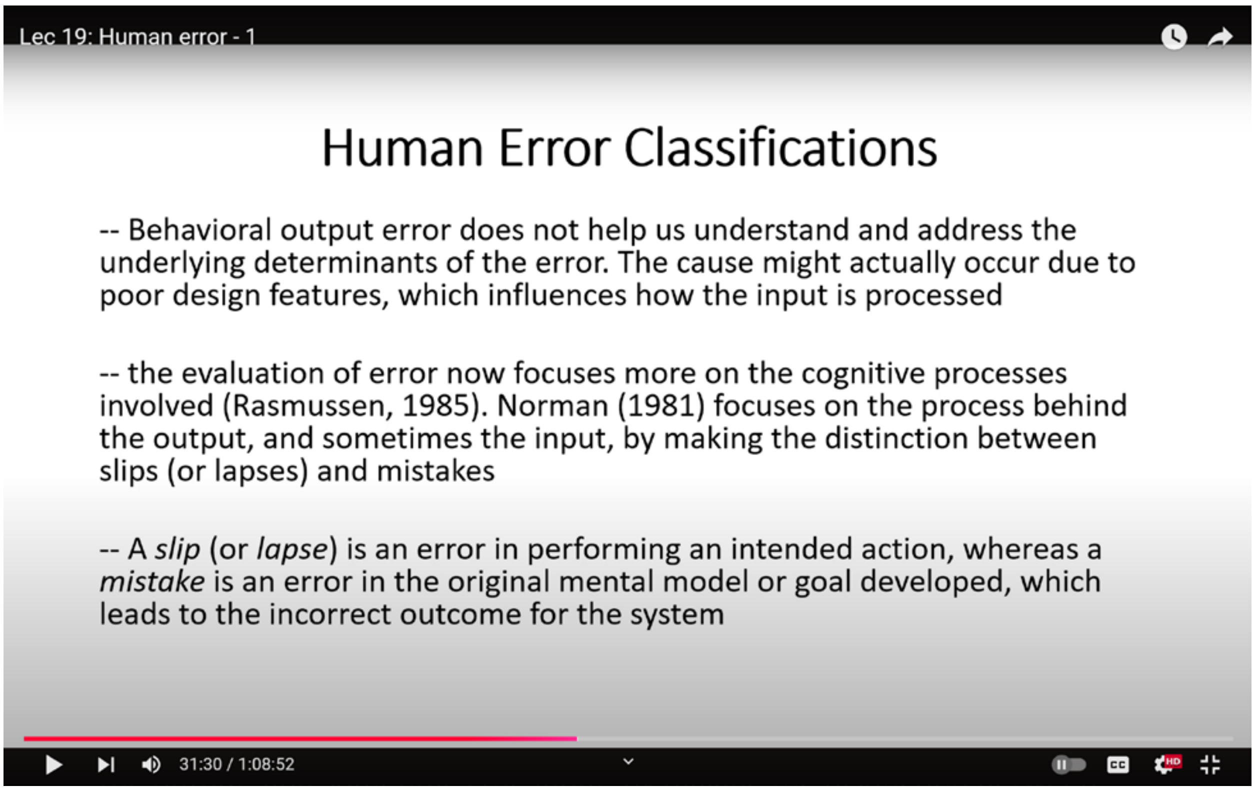

According to this cognitive classification, errors are categorized as slips and mistakes. A slip or lapse is defined as an error in performing an intended action, while a mistake arises from an error in the original mental model or goal, leading to an incorrect outcome. Recall the example I began this 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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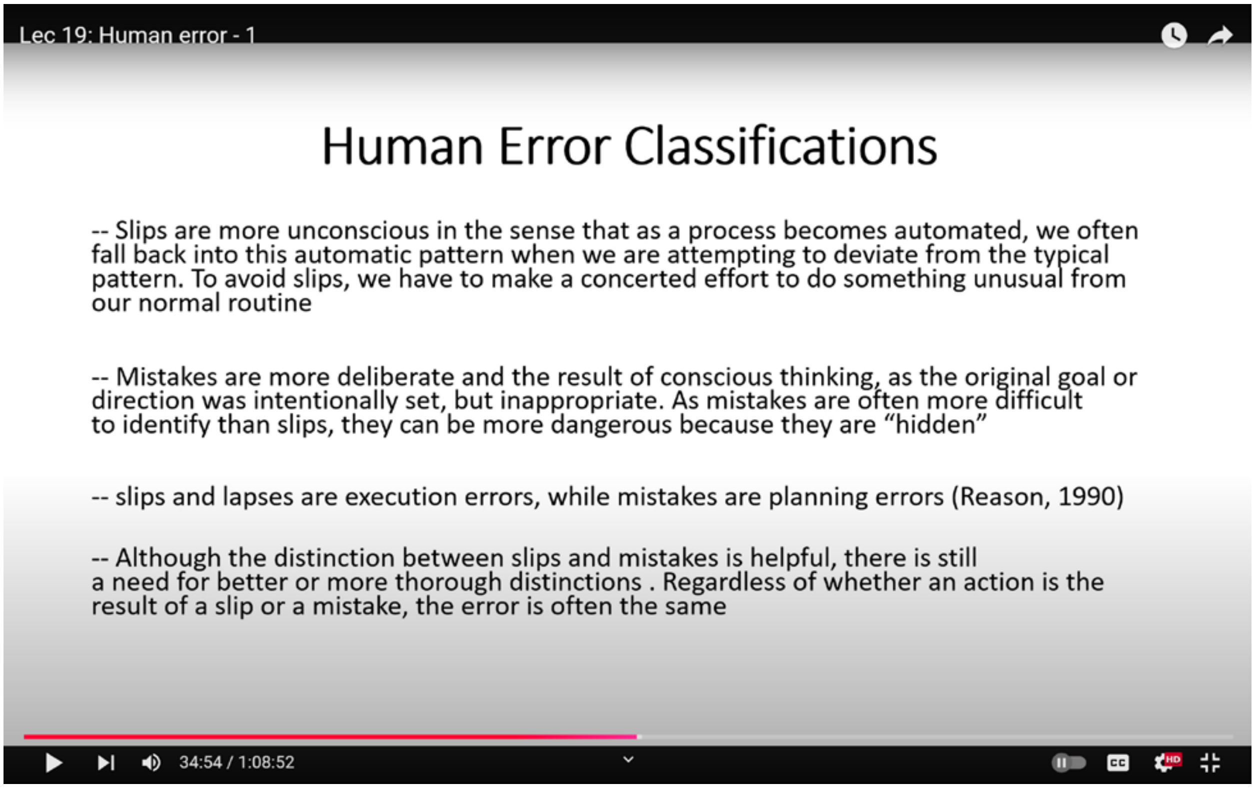

One tray is designated for vegetarian food, and the other for non-vegetarian food. Stickers or some form of indication should be placed on the trays to clearly identify the vegetarian and non-vegetarian options. By applying this conscious effort, Ganesh can resolve the issue of providing the wrong food 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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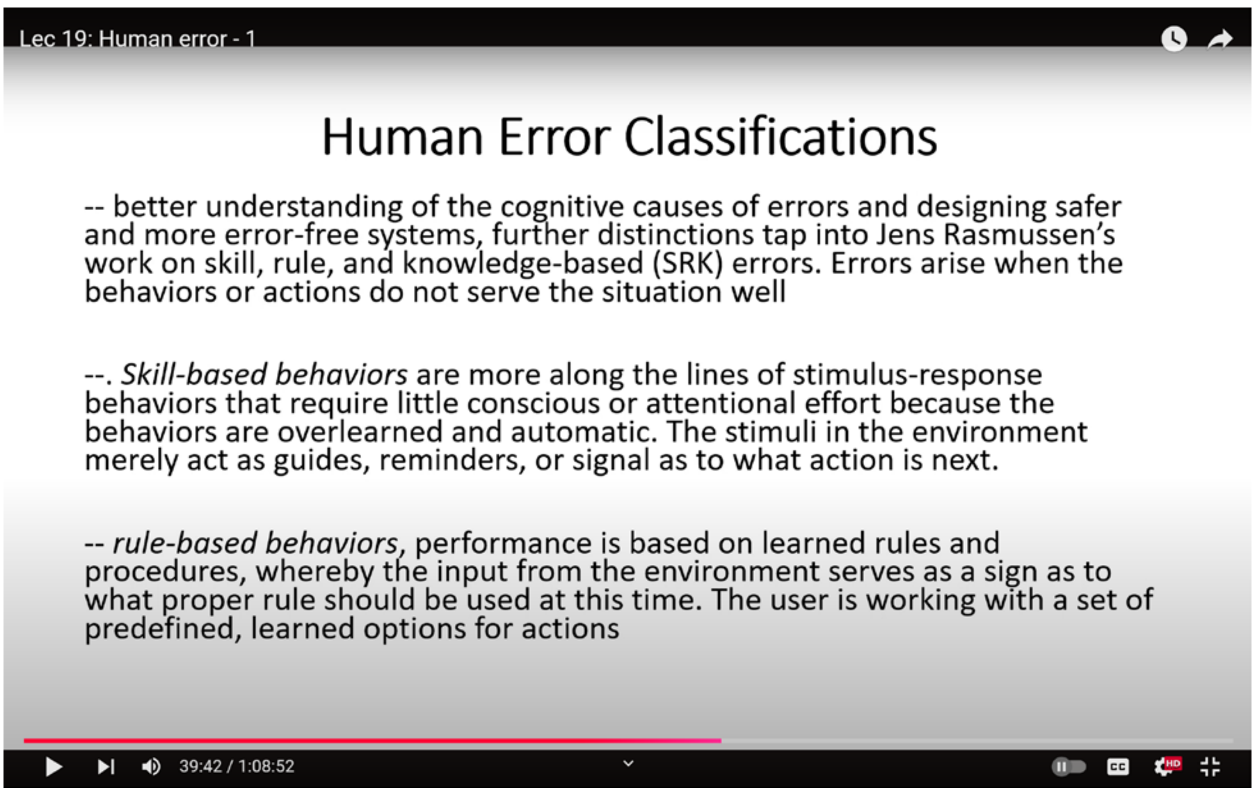

Although distinguishing between slips and mistakes is useful, there is a need for a more comprehensive classification. Regardless of whether an action stems from a slip or a mistake, the resulting error is often the same. While the distinction among errors in terms of slips, lapses, or mistakes is beneficial,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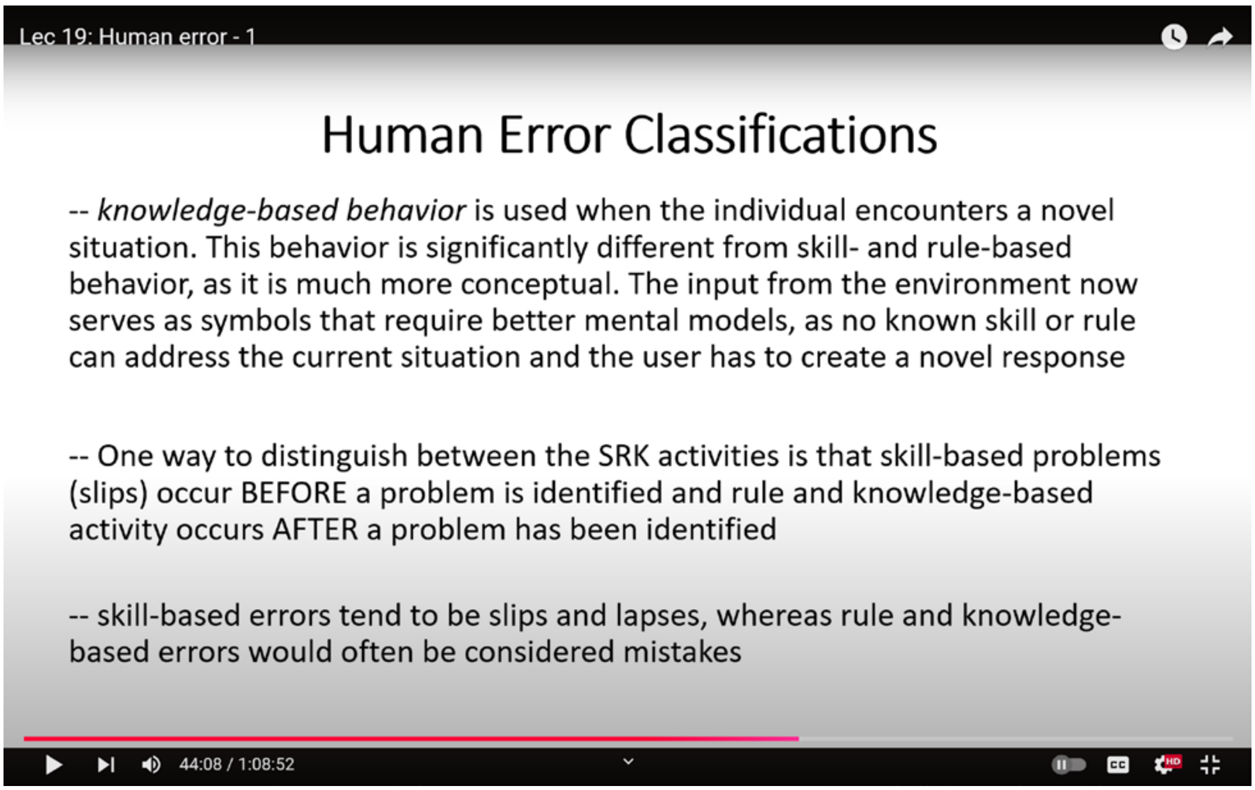

According to Rasmussen, human actions can be categorized into three distinct types: skill-based behavior, rule-based behavior, and knowledge-based behavior. Skill-based behavior is automated, while rule-based behavior involves applying known rules and actions to specific situations. In contrast, knowledge-based 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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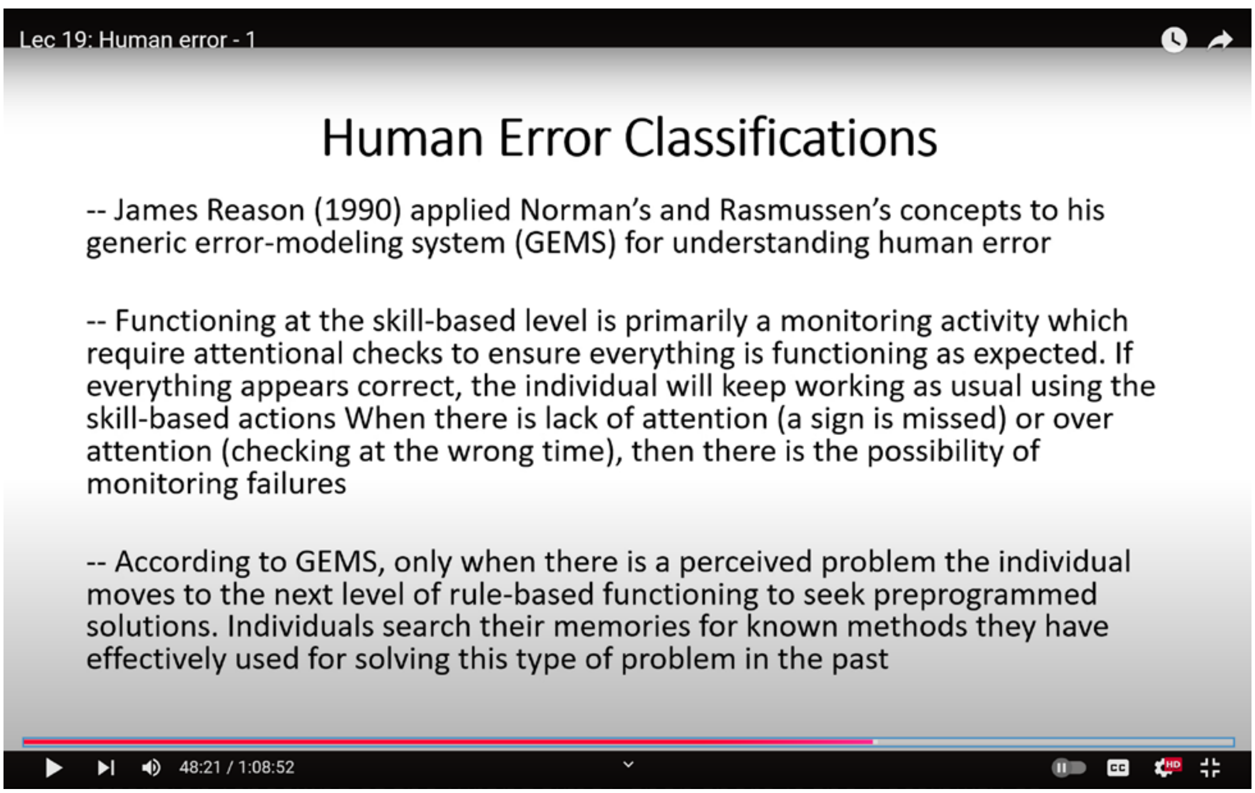

This creates a distinction based on timing, whereby skill-based errors are categorized as slips and lapses, whereas rule-based and knowledge-based errors are identified as mistakes. James Reason integrated the concepts of Norman and Rasmussen into his generic error modeling system, known as GEMS, to 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.

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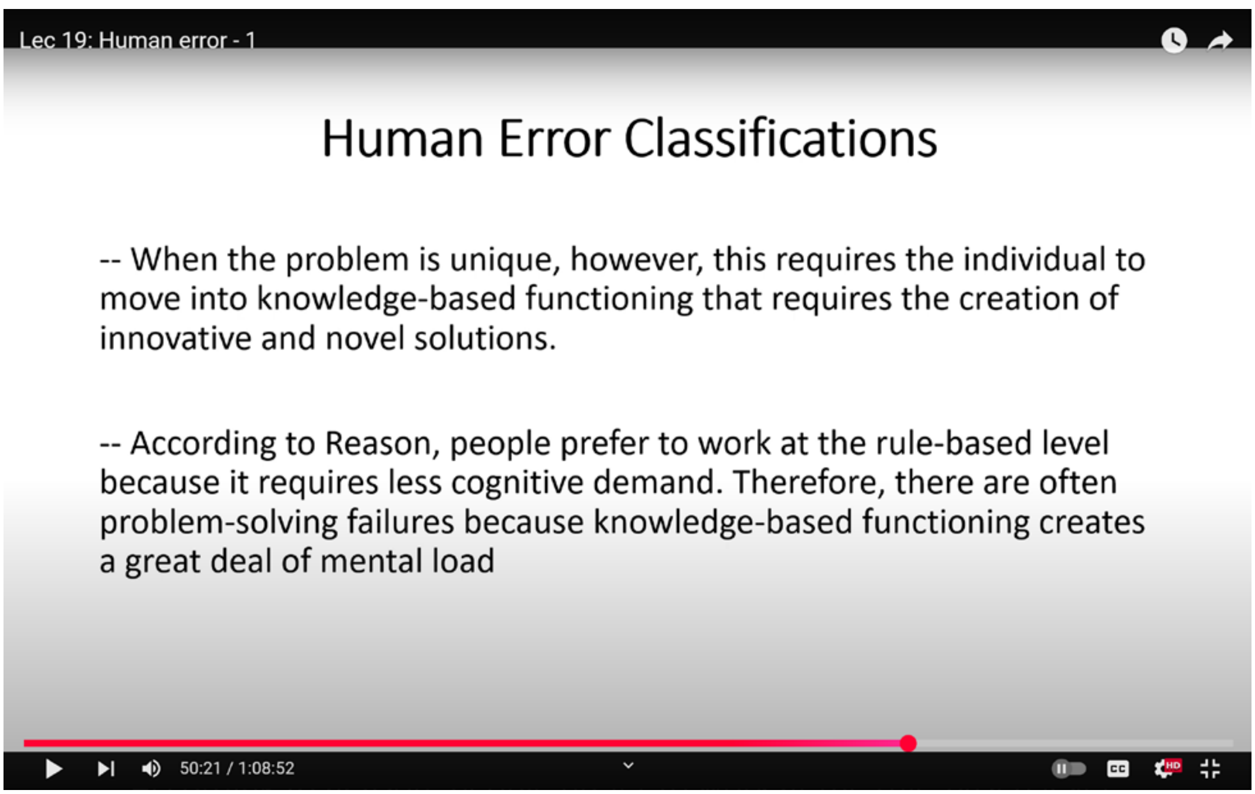

According to GEMS, an individual will transition to rule-based functioning only when they perceive a problem. When an operator recognizes an issue in the system and determines that it is not a lapse (an unintentional problem), they will rely on previously established rules to address it. In this case, 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.

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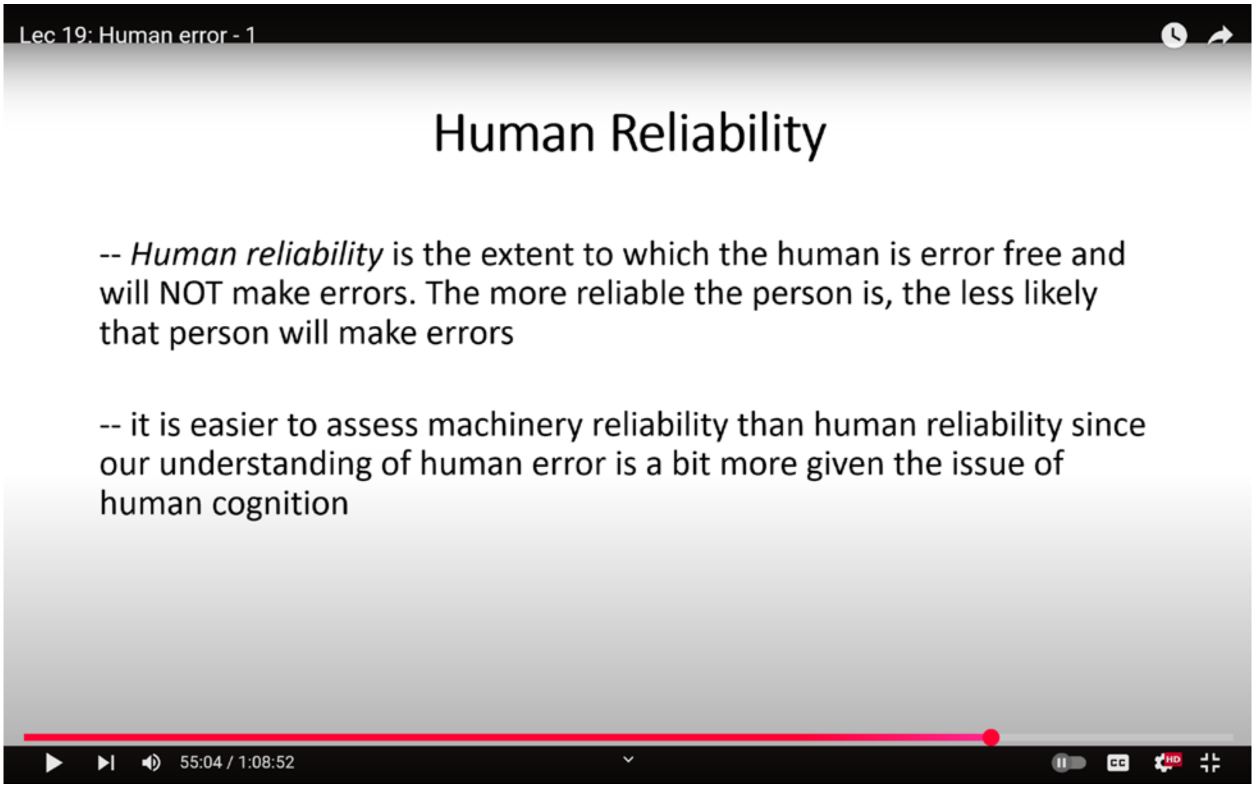

To summarize, we have established the definition of an error and classified the different types of errors. Next, we turn to human reliability, which assesses how trustworthy and error-free individuals can be. The more reliable a person is, the less likely they are to commit errors. However, individuals 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.

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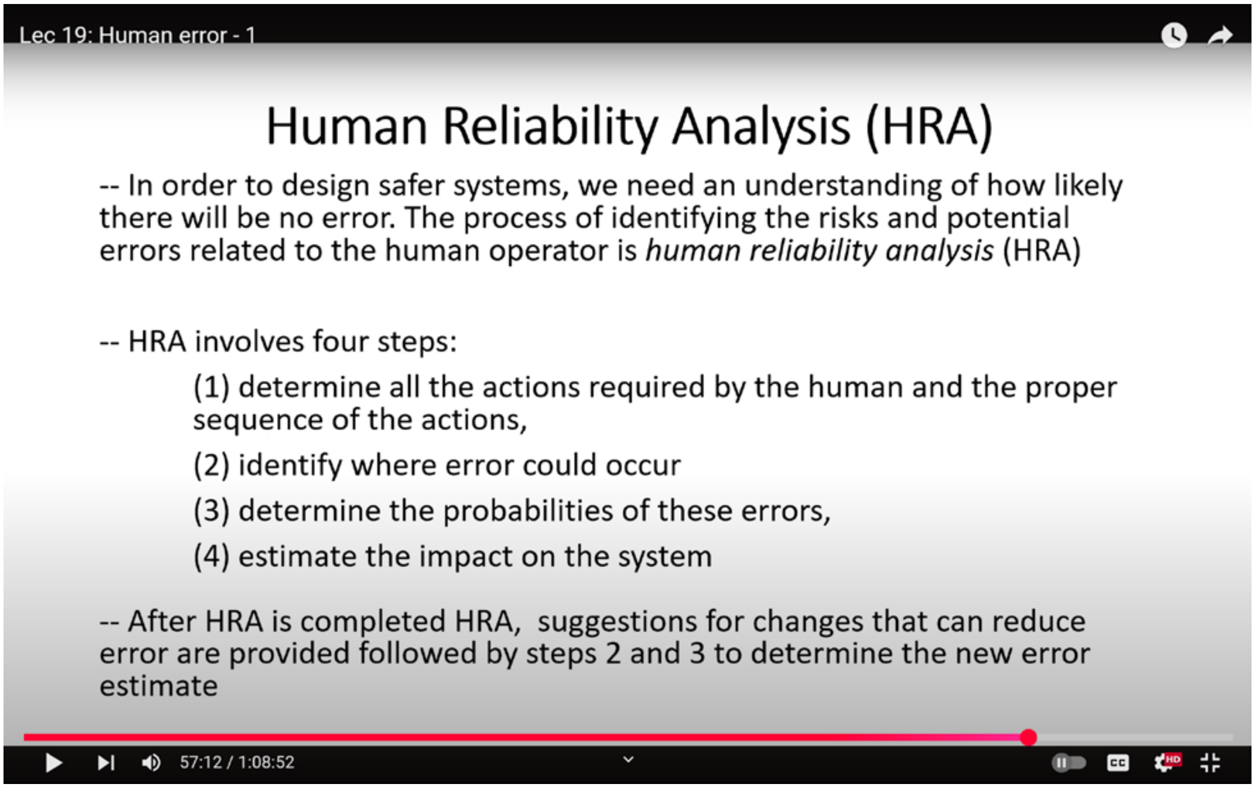

Human cognition operates in unpredictable and probabilistic ways, making it challenging to forecast human behavior, and thus, human reliability cannot be fully trusted. Given this complexity, how should we study human reliability? To design safer systems, we need to understand how likely a human is to 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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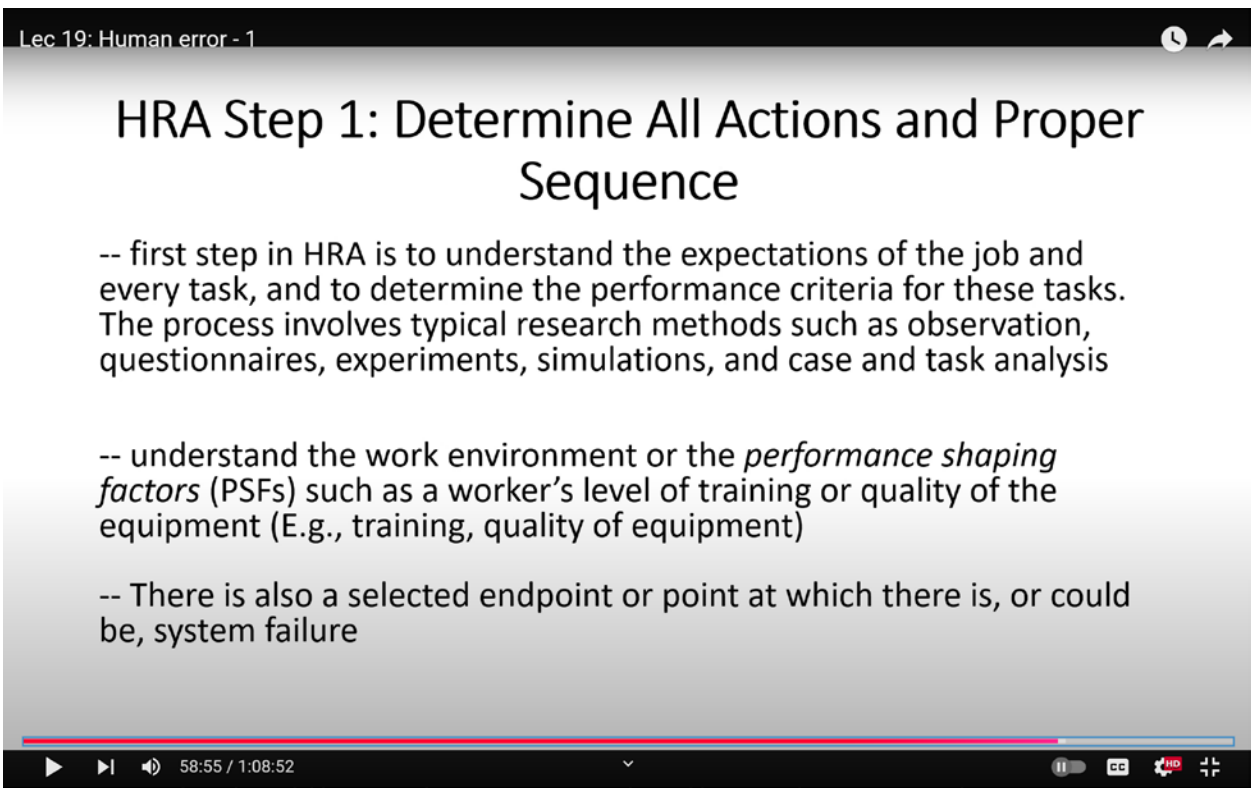

Let us now examine these four steps in detail. The first step involves determining all actions and their proper sequences. In human reliability analysis (HRA), this step entails understanding job expectations for each task and establishing performance criteria for those tasks. Each task has specific 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.

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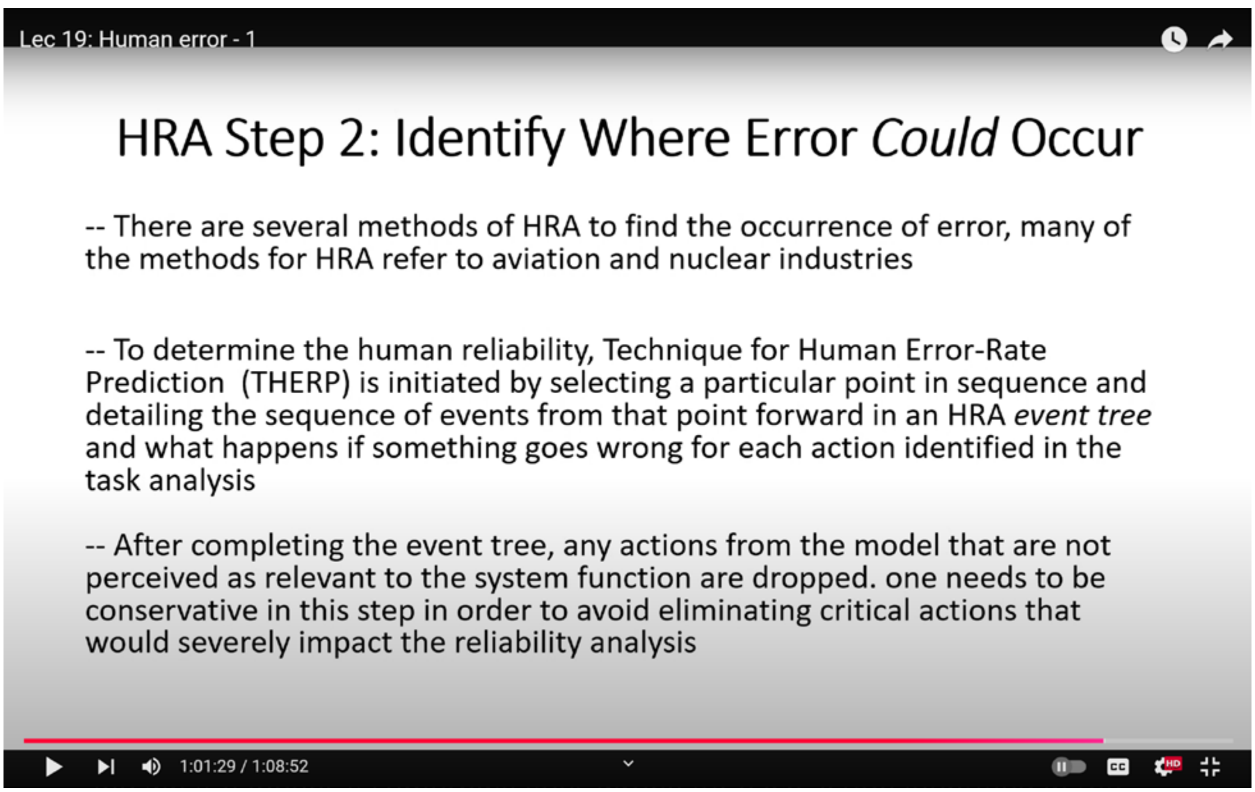

It is important to consider not only the actions of individuals but also performance-shaping factors, including training levels, motivation, equipment usage, and proficiency with the tools required for the job. These factors, along with the work environment, can significantly influence performance and 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.

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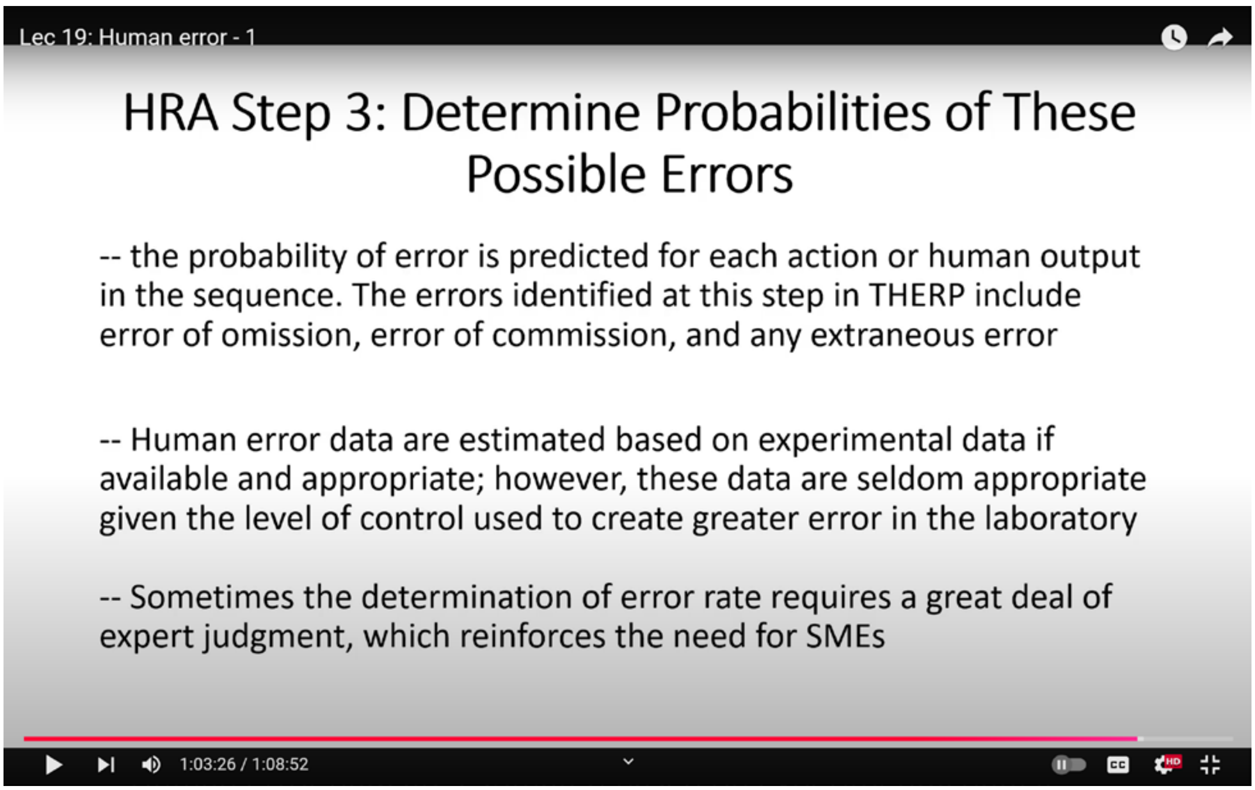

To predict human error rates, the technique known as THERP (Technique for Human Error Rate Prediction) is initiated by selecting a specific point in the sequence and detailing the sequence of events from that point forward in an HRA event tree. This method seeks to determine what might happen if something 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.

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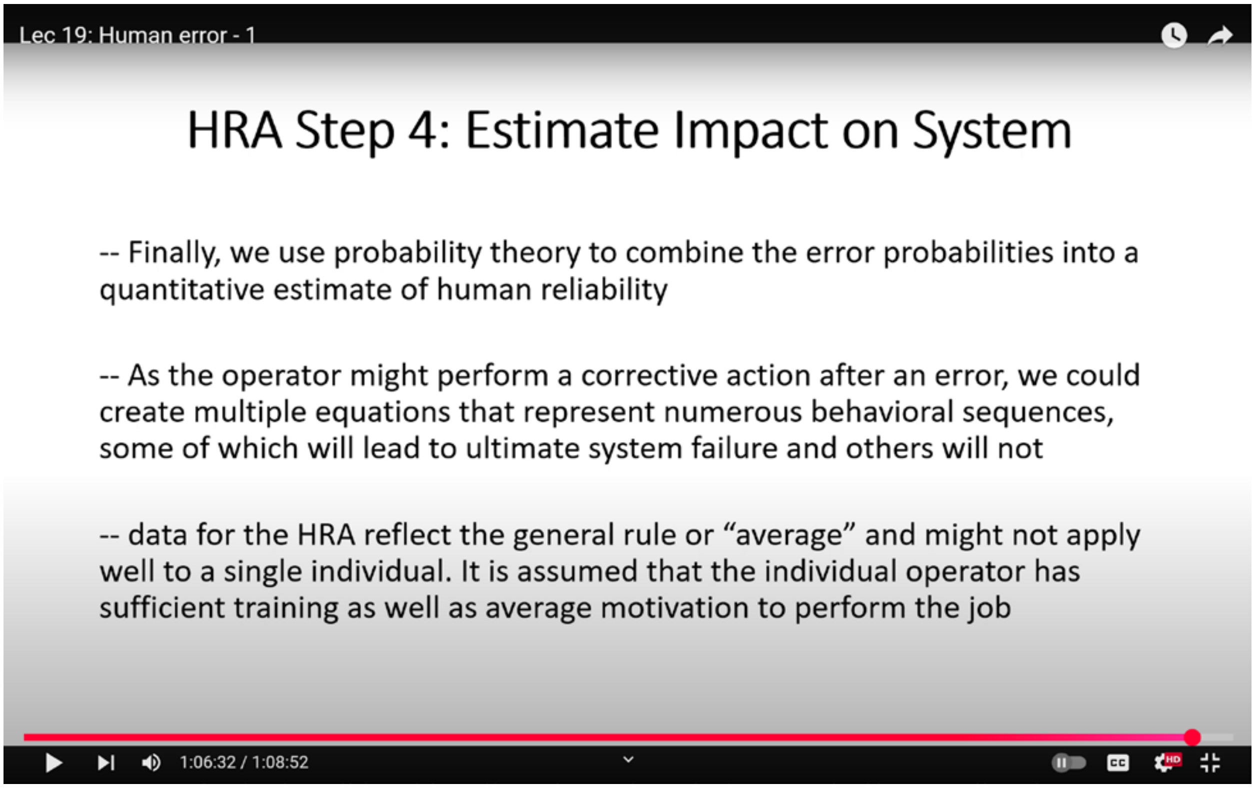

This analysis is informed by task analysis, which also indicates the points at which the probability of executing an alternate or unintentional action may arise. After constructing the event tree, any action deemed irrelevant to the system's functioning is removed from consideration. Throughout this 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.

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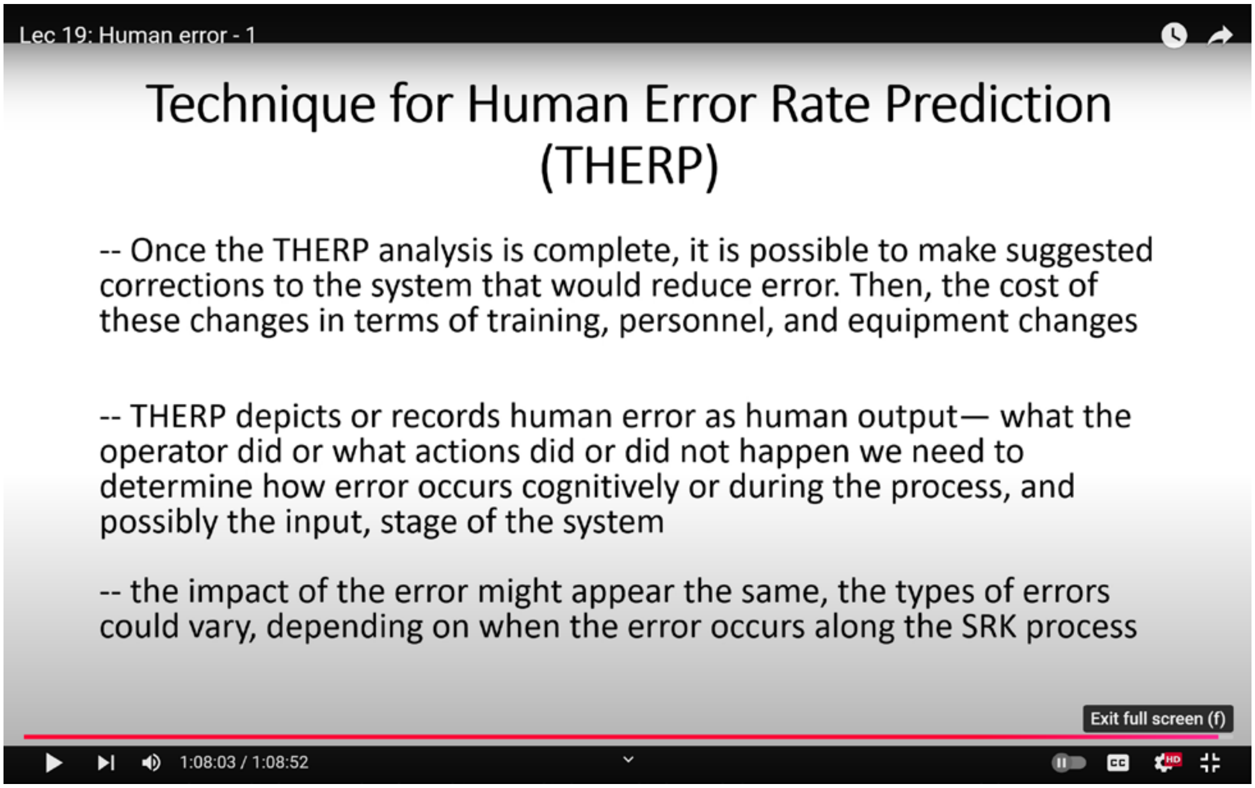

Occasionally, human error databases may be referenced, but most analyses necessitate the collection of unique data specific to each study, as the findings are often context-dependent.

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.