Engineering Psychology

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Week-02

Lecture-03

Research Methods -1

Namaskar, viewers. Welcome to the second section of this course on engineering psychology. In the first section, we discussed the history and nature of engineering psychology, as well as the various subject methods used in this field. The first section was designed to provide an introduction to engineering psychology, laying the foundation for subsequent sections, and helping you to understand how the different areas of study are interconnected.

In today's session, section two, I will introduce you to the research methods used in engineering psychology. These research methods are not exclusively used in engineering psychology but are commonly applied across various behavioral science experiments. Let’s begin this section on research methods and how they help us understand engineering psychology and its subject matter.

I’ll start today's lecture with a scenario. One of the basic premises in cognitive psychology is that attention is limited. Cognitive resources, which the brain utilizes to focus attention, are strategically managed by the brain. Additionally, attention is highly variable, with the brain typically allocating more attention to important tasks, while tasks that are habitual or repetitive receive less cognitive focus. This process of reducing attention or diverting fewer cognitive resources is referred to as "optimization of attention."

One common scenario that we are all familiar with is driving while using a cell phone. As we've already established, attention is limited and should be reserved for tasks of higher importance. Now, if you are driving and simultaneously using a cell phone, this becomes a distraction. Imagine a situation where you are driving and receive a phone call. If you take the call or respond via text message, your attention shifts away from the road and towards handling the phone, leading to a potential accident. You may have seen cautionary statements on driving licenses, advising against using a cell phone while driving. Despite these warnings, most people continue to use their cell phones while driving, whether the call is urgent or routine.

So, how does this become an engineering psychology problem? Consider this: no matter how many warnings or regulations are put in place, people will still engage with their cell phones while driving. Strict rules alone will not prevent this behavior. Therefore, as an automotive company or software designer for an automotive system, what can be done to minimize cell phone use while driving?

As I mentioned earlier, caution alone won't help because human behavior is hard to control, and people will continue using their phones. To address this, some form of modification in the design of the vehicle or its software system should be made to prevent accidents or at least provide critical warnings to the driver. This is a classic engineering psychology problem that can be approached from various angles.

Now, if you give this problem to designers who do not use the scientific method and rely solely on intuition, they might come up with solutions such as adding a warning system or creating a loud audio alert to prevent collisions. But think about it, this is merely an intuitive solution. If you're driving and paying attention to your phone, a loud auditory warning could actually increase interference, leading to faster accidents rather than preventing them. This example highlights a solution that is based on intuition and not on scientific testing.

So, what approach should be taken, and what could be the solution to this problem? To find the most scientific solution, we need to apply research methods or principles of research to test this problem across various conditions and user types. This involves using a user-centered design, collecting data, proposing hypotheses, and arriving at results that are then tested against modified designs to provide accurate solutions. Today's topic will briefly introduce the research methods and explain how these methods can be applied to problems in ergonomics and human engineering. Let's get started.

As discussed earlier, there are two ways to approach a problem: the common-sense approach, based on intuition or personal ideas, and the scientific approach. The common-sense approach often relies on intuitive solutions, but if these solutions are not tested against empirical data, there is little consensus on what the final solution should be. Here, I am proposing the scientific method, which uses research principles to solve problems.

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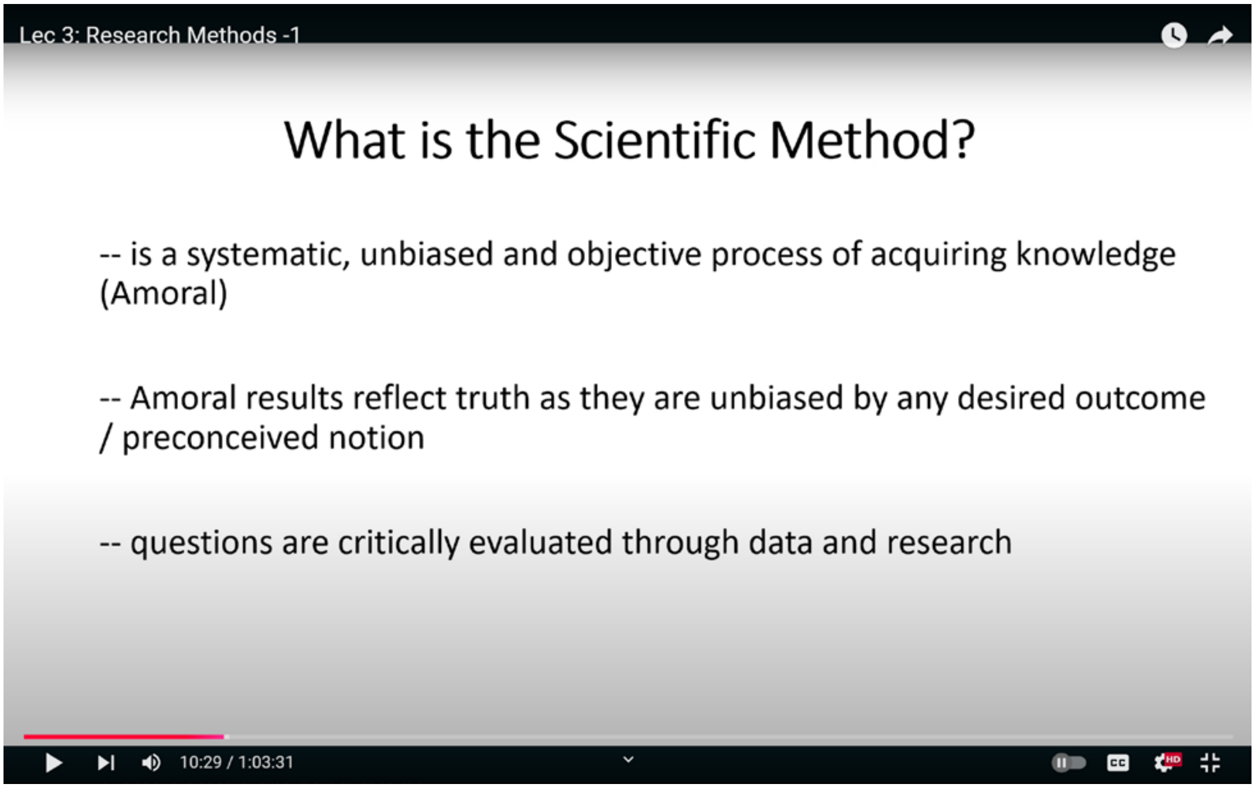

Let’s first discuss what a scientific method is. The scientific method is a systematic, unbiased, and objective process of acquiring knowledge, often referred to as a "moral process." A systematic process requires experiments to be conducted in a logical sequence, such as starting with a hypothesis. Before proposing a hypothesis, it's important to review existing research literature and identify theories that might apply to the problem. From there, tentative solutions are proposed, and designs are developed to test these solutions. The process involves engaging participants, collecting data, testing against control variables, and analyzing the results. Based on this analysis, modifications can be made, and the solutions are tested again. This entire research process is what makes it systematic.

Now, what is an unbiased system? An unbiased research process means that the experimenter’s personal intuitions or expectations do not influence the results. The researcher must avoid bias and collect objective data that can be measured using defined parameters. For example, to measure a driver's performance, you could assess the number of errors made or the time taken to complete a task, both of which are quantifiable and objective. A subjective approach, on the other hand, would involve gathering opinions from participants. Therefore, scientific methods prioritize systematic, unbiased, and objective processes.

What is meant by "amoral processes"? Amoral results reflect the truth as they are free from preconceived notions or desired outcomes. We touched on this earlier when we discussed the risk of experimenter bias. Certain research designs, such as double-blind experiments, can help eliminate this bias. In a double-blind design, the person conducting the experiment and the one collecting the data are two different individuals. This separation ensures that the experimenter's expectations do not influence the data collection process, leading to more reliable results. This is what defines an amoral process in scientific research.

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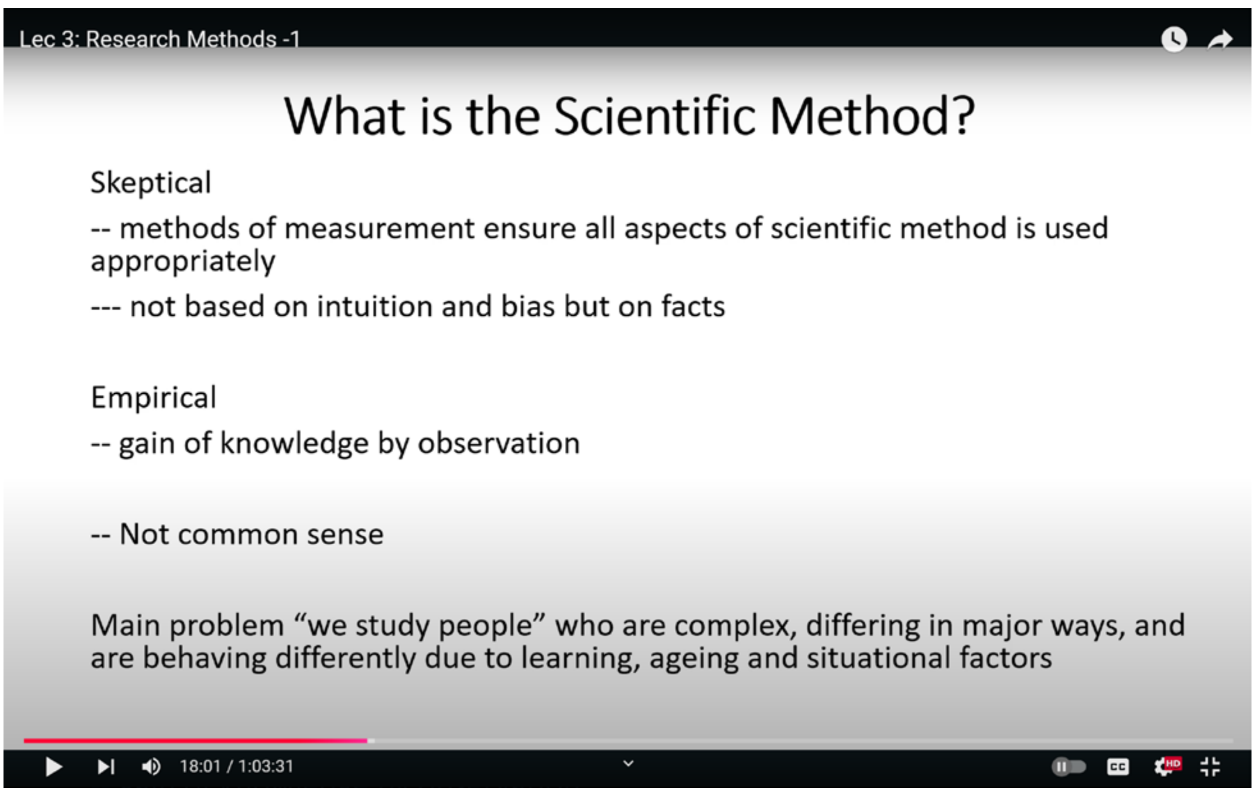

In the scientific method, questions are critically evaluated using data and research. This means that the problems and hypotheses we explore are rigorously tested, often under skeptical scrutiny.

When research findings are subjected to criticism and opposing results, it helps refine the accuracy of the conclusions. Instead of focusing solely on reaching a goal or confirming prior findings, a key part of scientific research involves identifying what not to do. Learning from failures is just as important, if not more so, than identifying what works. Eliminating incorrect approaches brings us closer to finding the right solution.

Lastly, scientific methods are inherently skeptical. Being skeptical in research means questioning the methods and ensuring that all aspects of the scientific process are properly applied. This includes operationalizing variables, defining them in measurable terms, which we will discuss later in this section. It also involves using measurement methods that are feasible and accurate.

Being skeptical also means that you are not influenced by your own intuition or biases. The results you propose should be based on facts and not clouded by the researcher's personal expectations or beliefs. Instead, they should be grounded in hard empirical data. The scientific method must be empirical, meaning the knowledge and understanding we gain about a problem is based on real-time observation. We observe phenomena, collect data, test it against control data, and then derive results or solutions to the problem. This approach is not about creating imaginary or hypothetical solutions without evidence.

Empiricism, the foundation of the scientific method, involves observing and gathering data to generate knowledge. Unlike common sense, which is often viewed as the obvious solution to a problem, the scientific method tests these assumptions. What is common sense? And if it is so common, why can it be wrong? For instance, many believe that when people drive while looking at their phones, an audio alert could effectively warn them of an accident-prone situation. However, consider this: when attention is divided, 80% on the phone and only 20% on driving, the driving process becomes automatic. An audio alert would shift all attention to the alert, disrupting this automatic driving process.

When I say something is automatic or habitual, it means that a sequence of motor actions is so well-coordinated that they occur without much conscious awareness. If attention is pulled away from this task, the sequence breaks, leading to uncoordinated actions. For example, in motorbike accidents, instead of slowing down, people sometimes increase their speed because of habit. The natural movement of the hand is clockwise, which increases speed. Slowing down requires an anticlockwise motion, which goes against the natural sequence. So, the common-sense belief that audio alerts would help is incorrect. When tested scientifically, we find that audio alerts often cause more accidents.

This example illustrates how common sense can sometimes create more problems and should be avoided in scientific research. Solutions should be based on data collection and analysis. However, a significant challenge in studying human behavior is that people are complex, differing in major ways due to factors such as learning, aging, and situational influences. These differences can be summed up as "individual differences," meaning people vary in their habits, expectations, and experiences, even if they share the same genetic makeup. Therefore, common sense or intuition-based solutions are not always reliable. In engineering psychology, the focus should be on using the scientific approach.

Now, let’s consider the problem of what modifications should be made to a car's software system to help drivers briefly glance at their phones without compromising safety. A step-by-step, scientific approach should be applied. First, we need to review the relevant literature. Before jumping into existing solutions, we should propose tentative solutions to the problem. The problem is clear: what kind of modification should be made to the car’s software so it assists drivers when their attention is momentarily diverted? It is crucial that these diversions are not prolonged, but momentary shifts in attention.

One potential solution is the Advanced Driver Assistance System (ADAS), which helps prevent accidents through automation. But how did this system come into existence? To address our problem, we need to explore possible solutions. Proposing these initial solutions is what we call forming a hypothesis.

The implementation of the scientific method involves hypothesis testing. First, we propose potential solutions, then test them against control groups who do not have access to these solutions. In the language of hypothesis testing, we formulate a null hypothesis and an alternate hypothesis. The null hypothesis asserts that there is no difference between the newer design and the older one, while the alternate hypothesis suggests that using the newer design improves performance. Performance must be measured in objective terms, such as the number of errors or the time taken to complete a task. This is how the scientific method operates.

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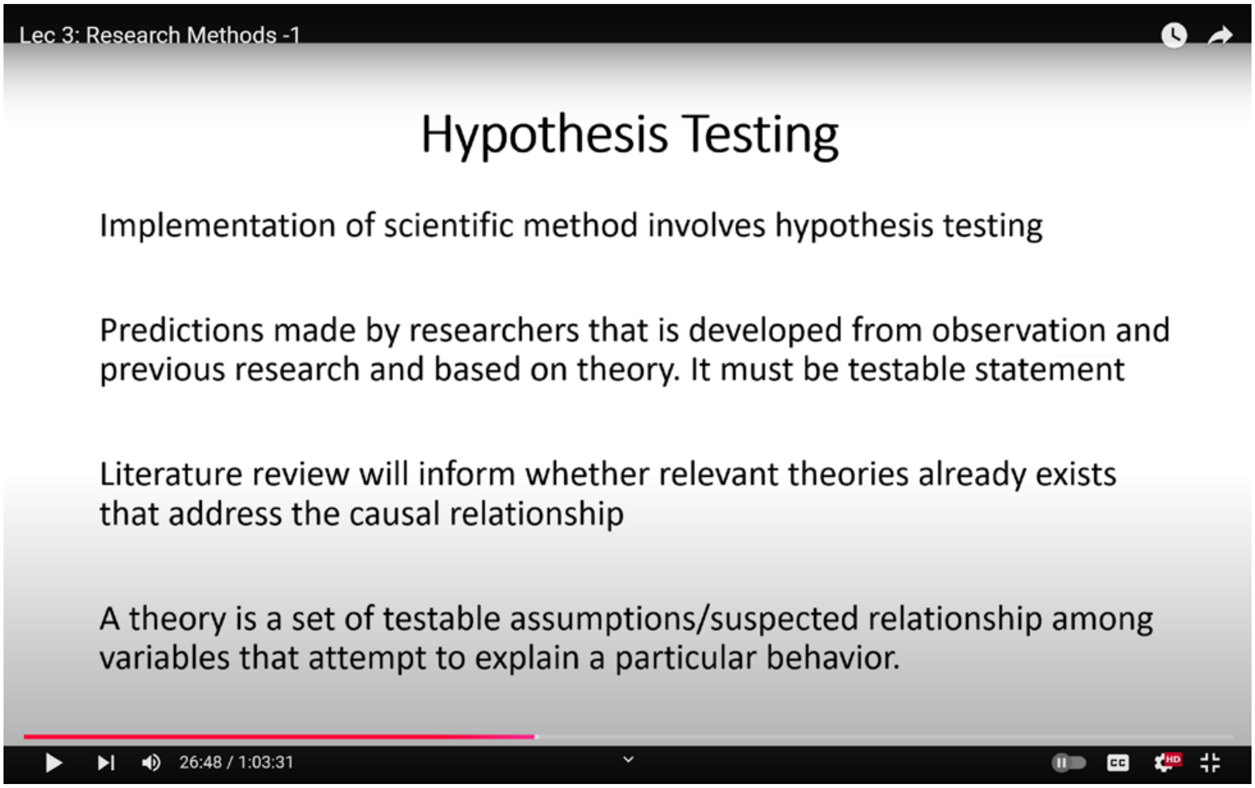

The scientific method begins with hypothesis testing. In our case, we aim to determine what modifications should be made to software systems to assist drivers in situations involving momentary lapses in attention. Predictions made by researchers are based on observations and previous research, grounded in a theory that must be testable. Solutions proposed by researchers are similarly based on theory, which requires a foundation in basic research to ensure that the solutions are indeed testable. For example, one possible solution to momentary lapses in attention while driving could involve tactile feedback from the car’s steering wheel. This feedback would alert the driver, signaling that their attention has wandered. The intensity of the vibration from the steering wheel would indicate the severity of the situation.

The theory behind this solution stems from cognitive science, which posits that the brain can process inputs from multiple channels. When attention is divided between the phone and driving, both the auditory and visual sensory organs are engaged. Introducing an audio alert into this situation could lead to a psychological refractory period, during which either the second stimulus (the audio alert) is degraded or completely ignored, or, if the alert is too strong, it may trigger unnecessary motor responses. The solution, then, is to engage a third input system, the tactile channel. This is the underlying theory, and the proposed solution of using tactile feedback is based on it. This demonstrates how theory informs the development of solutions.

Now that we understand the problem, which involves determining what modifications should be made to the system, we can propose a hypothetical solution: using the tactile system to provide feedback to the driver. The theory supports the notion that utilizing an unengaged sensory channel is more effective than overloading a channel that is already occupied. This is how hypotheses, or tentative solutions, are proposed. A literature review will reveal whether relevant theories exist that address the causal relationship. Arriving at a solution like this involves reviewing literature related to attention and the competition between signals from different sensory systems in the brain.

What is a theory? A theory is a set of testable assumptions or proposed relationships among variables that aim to explain a particular behavior. Theories are based on previous literature or research findings and can be used to formulate hypotheses. Once a hypothesis is established, the appropriate method and means of analysis are determined, data is collected, and the results are analyzed. After the solution is developed, we need to determine a method for conducting the research.

We could, for example, create two groups: one group would have access to tactile feedback, while the other would rely on the more common solution of audio alerts. We would then place them in different driving situations and collect measurable data, such as the number of errors or the time taken. Once the data is collected, we would compare the outcomes to determine which method is more effective. Statistical analysis will be essential for collecting and analyzing the data from these experiments. Remember, we discussed hypotheses as tentative solutions.

There are two types of tentative solutions. In one experiment, you may get positive results from your design, but if the experiment is not replicated in different contexts, the design may not be effective in real-life scenarios. We are dealing with real people in real driving situations. Results from laboratory experiments may not always apply directly to real-world conditions. Testing solutions on a limited number of people a few times may not yield comprehensive results.

So, how do we arrive at a more robust conclusion? The answer is to test the hypothesis against a null hypothesis. What is a null hypothesis? A null hypothesis posits that no relationship exists between the variables of interest. In our case, it would suggest that improving the design by using tactile feedback does not lead to better driving performance, in terms of fewer errors or accidents. The alternate hypothesis would suggest that providing tactile feedback results in fewer accidents and faster reactions in avoiding them, compared to situations where no tactile feedback is given.

The null hypothesis states that there is no relationship between the variables, and our goal is to test this hypothesis and reject it if the data supports the alternate hypothesis. This means we need to collect enough data to demonstrate that the null hypothesis is not valid. In contrast, the alternate hypothesis, which states that tactile feedback improves driving performance and reduces accidents, is supported by the data.

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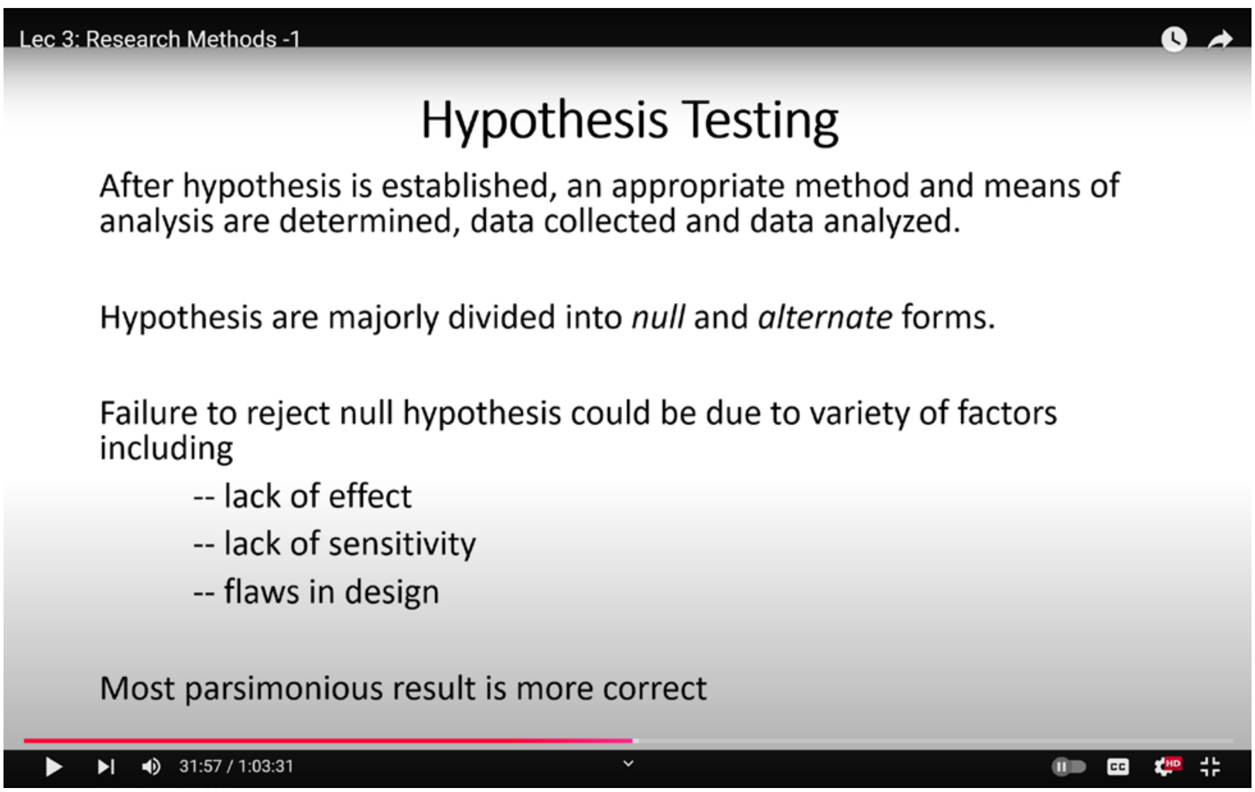

These are the two different forms of hypotheses. There are times when we cannot reject the null hypothesis. For instance, I might have introduced tactile feedback, which worked effectively in a controlled lab setting, but when applied in real-world conditions, it did not yield significant results. This means that the number of accidents in the group without tactile feedback and the group with tactile feedback remains the same. In such a case, the null hypothesis is equal to the alternate hypothesis, implying that the alternate hypothesis does not provide better outcomes. Therefore, we cannot reject the null hypothesis in this instance.

However, non-rejection of the null hypothesis does not necessarily mean that the alternate hypothesis is ineffective. The inability to achieve clear results could be due to several factors, and failure to reject the null hypothesis does not imply that the new design is flawed. There could be many reasons behind such outcomes. For instance, the feedback system might not have been expected by the driver, and therefore, they did not interpret the tactile feedback correctly. In such cases, the driver should be first introduced to the concept of feedback, so they understand that the tactile feedback serves as a warning system.

Another reason could be the lack of sensitivity to the feedback. The tactile feedback might not have been strong enough to be detected by the driver. Some individuals are less sensitive to vibrations, so they may not have noticed the feedback. Design flaws may also be at play, such as the timing of when the feedback is delivered, whether it occurs before the accident, after the accident, or simultaneously. If the feedback is provided at the same time as the accident, it becomes ineffective. Ideally, the feedback system should function as a prediction system, alerting the driver before the accident occurs, giving them enough time to process and respond to the warning. These issues highlight potential design flaws.

Rejection of the null hypothesis suggests that there is a flaw in the system, but this does not necessarily mean that no relationship exists between the variables. It is similar to a legal situation where an individual is presumed innocent until proven guilty. Sufficient evidence is required to prove guilt, and until that evidence is presented, the individual remains innocent. A similar approach applies here: we believe the design works, but we must identify the reason it is not functioning as expected. The reason could lie in how the design is implemented or tested.

The proposed designs are based on established literature and theory, which have been thoroughly researched by earlier scholars. Therefore, it is unlikely that the design itself is fundamentally flawed. Researchers should take this approach when proposing a hypothesis. Additionally, it is important to remember that in hypothesis testing, the simplest and most parsimonious results are often the most accurate. When complex propositions are involved, there are more chances of failure due to the involvement of multiple processes. Simpler results tend to be more reliable and accurate.

The process begins with identifying a problem, followed by proposing a tentative solution or hypothesis. In engineering psychology and behavioral sciences, research can be categorized into two types. First, we have basic research, which focuses on acquiring knowledge and developing theory by controlling real-world factors to answer scientific questions. Basic research addresses fundamental problems, often system-based, which, when studied, provide theoretical knowledge. This theoretical knowledge can subsequently lead to the development of applied solutions.

For example, consider how the eye perceives things. Basic research would involve studying the retina, the part of the eye responsible for forming the final image. The retina contains specialized cells that detect changes in contrast, allowing us to distinguish between background and foreground objects or identify edges. It also has cells that measure the orientation of objects in the visual field, helping us locate and navigate them. Additionally, the retina contains cells that detect motion, enabling us to perceive when something is moving toward or away from us.

How is this possible? By studying the retina. The knowledge we obtain from such research is referred to as theoretical knowledge because, by itself, it does not offer a direct solution; instead, it enhances our understanding of the visual system. Examples of theoretical knowledge or basic research include studying visual systems, developing cognitive maps, and exploring problem-solving in humans. These are all basic research-related problems. For example, how do humans solve problems?

There are two primary ways to solve a problem: the algorithmic approach and the heuristic approach. The algorithmic approach involves several steps, and by following these steps one by one, you will always arrive at a solution if one exists. For example, if you create an algorithm to make tea, no matter how rudimentary it may be, following those steps will result in successfully making tea. The process starts by selecting a vessel for boiling water, identifying a heating system, turning on the heating system, placing the vessel on the heat source, adding water, waiting for it to boil, and so on, until the tea is made. However, solving problems this way requires significant time and effort, which is why humans typically prefer a heuristic or shortcut approach.

What is a shortcut approach? In the context of making tea, it would involve putting all the ingredients into the water and then placing it on a heating source. While this method can still produce tea, you might forget a crucial step, such as igniting the heating source. As a result, despite having all the ingredients, you will not get the tea you desire because one essential step was overlooked. Although this example seems simple, the algorithmic approach ensures that if you follow the step-by-step process, you will always arrive at a solution.

This is the essence of theoretical knowledge. Theoretical knowledge clarifies which steps are necessary and which are not. It is the foundation of basic research, which focuses on such problem-solving abilities. Understanding which approach, algorithmic or heuristic, is preferred and most beneficial in a given situation can be determined through this theoretical knowledge.

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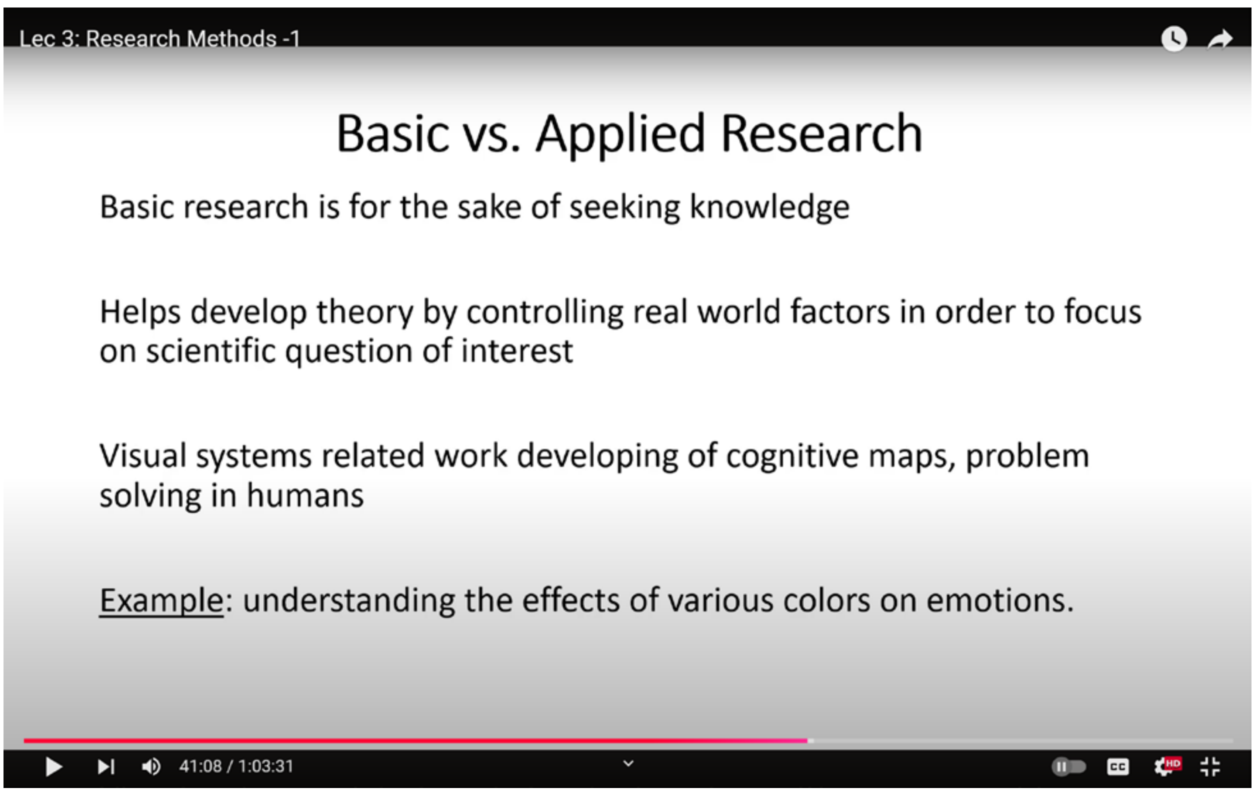

One example of basic research is exploring how different colors affect emotions. Do colors influence emotions? The underlying theory is that colors are variations of wavelengths, and different wavelengths of light stimulate the cone cells in the retina. From there, the signal passes through the fovea, where specialized retinal cells respond to color. The excitation of these cells triggers several processes, which ultimately affect the brain's emotion processing area. The specific wavelength of light and the number of cone cells activated in the retina determine the level of excitation. This excitation then travels to the visual perception area and eventually to the brain's emotion-processing region. While we will not delve into the details of this theory here, this is the basic idea behind how color affects emotion. This represents basic research.

In contrast, applied research focuses on addressing real-world problems. Basic research is theoretical, while applied research solves practical problems. For example, the problem we are currently investigating is whether a system can be designed to assist drivers in diverting their attention momentarily to other tasks, such as checking their phone for emergencies, while still driving safely. This is an example of applied research. Applied research also explores questions like which colors lead to increased happiness or higher customer traffic in a store, which can ultimately result in more purchases.

Applied research also examines the effects of store atmosphere, how the environment can encourage people to visit and make purchases. We previously discussed the impact of color and mood, landmark effects on navigation, and the influence of cell phones on driving, all examples of real-world problems that fall under applied research. Human factors researchers address these types of problems by finding ways to reduce errors in work and everyday life.

Human factors researchers provide solutions to problems that arise in daily life. Their goal is to design systems that minimize errors and enhance performance. Unlike basic research, which expands theoretical knowledge, applied research takes theories from basic research, modifies them, applies them to practical designs or solutions, and then addresses everyday problems. This results in less stress, fewer errors, and increased performance in day-to-day functioning.

Now, let us explore some fundamental concepts in research.

We have understood so far what a hypothesis is, how hypotheses are designed, what types of research exist, and the basics of the scientific method. Now, we are ready to examine what kinds of solutions exist and how these solutions can be implemented to solve problems. Let us revisit the original problem we posed: can designs be modified in such a way that they help users momentarily divert their attention to cell phones or other activities in emergencies? And can software designers or car designers develop feedback mechanisms to alert users, thereby preventing accidents in such situations? Essentially, can the temporary diversion of attention work in a driving scenario?

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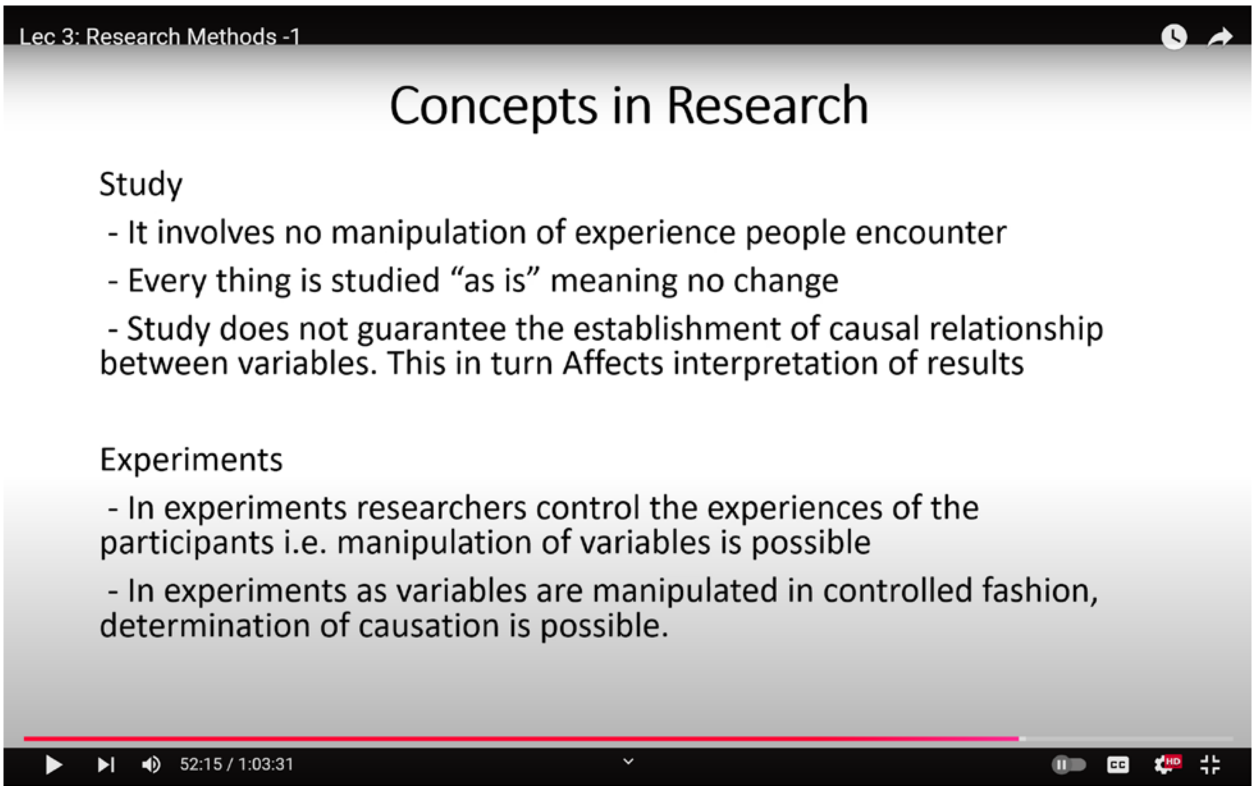

If we have proposed potential solutions, such as providing tactile feedback, how do we test these solutions?

Testing these solutions requires conducting either a study or an experiment, collecting data from them, and then analyzing the results. To begin with, let us distinguish between a study and an experiment. In everyday language, "study" and "experiment" are often used interchangeably, but there are key differences between the two. What are they?

A study involves no manipulation of the experiences people encounter. In a study, we merely observe without altering any variables. For example, if we want to understand how consumers purchase products in a showroom versus a mall, we can observe people in real time as they make purchases. In this case, we are not changing anything about the consumers; we are simply watching how they shop. This is a study.

In a study, everything is observed as it naturally occurs. For instance, when we examine how people shop, we do not alter their shopping behavior or instruct them on how to shop. Instead, we enter the environment where they are shopping and observe the necessary steps they take, how they make decisions, the choices they make, the movements they make, and their shopping patterns. So, nothing is changed here. We are observing their shopping behavior in real time, exactly as it would naturally happen.

However, a study does not guarantee the establishment of a causal relationship between variables, which in turn affects how we interpret the results. For instance, in a study, there is no guarantee that a causal relationship can be drawn between the variables of interest. If we want to determine whether a certain redesign of a mall leads to better purchasing experiences, we cannot definitively establish such a causal link. At best, we can compare how much people buy under two different designs.

But consider this: suppose Person A purchases more in a well-designed mall than in a poorly designed one. While we are observing them shop, it could be that Person A is more interested in the product, enjoys the shopping experience, or simply has a greater need for certain products on that particular day. Therefore, attributing their increased purchases solely to the mall design can only be speculated upon. We cannot conclude a direct cause-and-effect relationship between the mall's design and the person's buying behavior because many other factors, unknown to us, could also be influencing the outcome.

Thus, interpreting results from a study where variables are not controlled is inherently uncertain.

On the other hand, experiments allow for a more controlled environment. In experiments, researchers control the participants' experiences, making it possible to manipulate variables. For example, in the same experiment, we could create a hypothetical mall and deliberately place people in two different virtual malls. Since this is a controlled, hypothetical scenario, all extraneous factors like motivations, needs, and habits can be accounted for.

In this controlled setup, participants are asked to virtually shop, and any external influences that could affect their purchasing behavior are eliminated. After testing these individuals in two different virtual mall designs, we can assess whether the design of interest leads to increased purchases. If the results show that people buy more due to the new design, we can confidently state that the design change is responsible for the increased purchases.

In this case, we are testing only one variable (the mall design) while eliminating all others, and we are manipulating this variable to observe the effect. In a study, however, we cannot modify the design of the mall. We can only observe people in two different malls with two different designs. Moreover, we cannot have the same person shop in both malls. Therefore, studies require us to work with different groups of people, whereas in experiments, we can create these design variations in a controlled environment to test their impact.

In virtual malls, we can study the same group of people under two different conditions. Here, we control for both the mall design and the participants, thereby increasing the level of control. Since variables are manipulated in a controlled manner in experiments, determining causation becomes possible. As mentioned earlier, we can control the mall design, the participants entering the mall, and even what and how they are purchasing, providing a more controlled environment. In this scenario, if the newer mall design leads to more hypothetical purchases, we can confidently state that the design modifications are responsible for the increased purchases.

What is the difference between a study and an experiment? In research, these terms are often used interchangeably, as we previously discussed. Studies and experiments are generally considered substitutes for each other in a broad sense. Both are empirical methods, meaning they involve observation and data collection rather than hypothesizing or generating hypothetical data. However, experiments tend to be more widely used because they are more effective at explaining relationships, as they allow for the manipulation of variables and control of external factors.

Experiments are considered more powerful because they provide the opportunity to control specific variables, which may lead to either alternative outcomes or the desired results. In our mall example, experiments can specifically control one design factor while regulating other influences, such as a person's interest in certain products or their shopping experience. The motivation to shop can be controlled since the mall is hypothetical, and the effects of design on purchases can be studied in a more focused manner.

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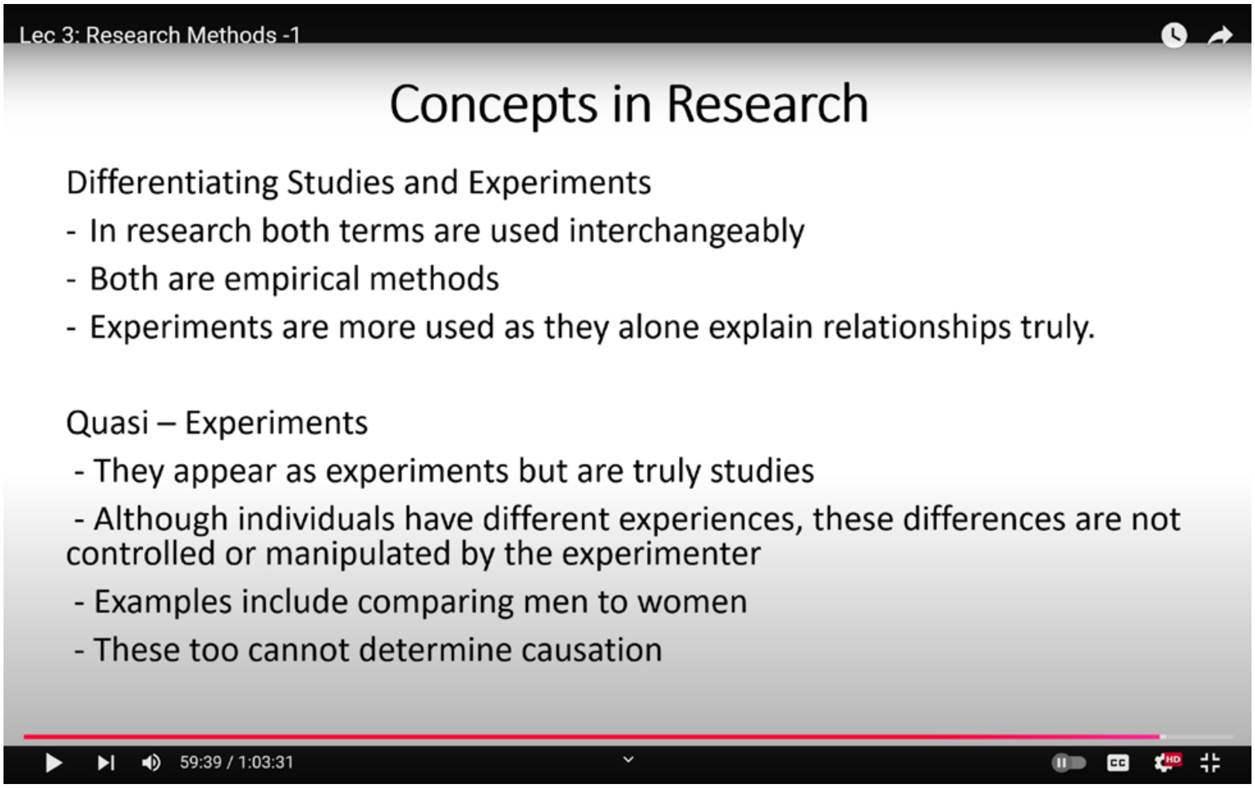

There is a third type of experiment, known as a quasi-experiment. These resemble experiments but are essentially studies. Though they appear experimental, quasi-experiments do not involve the true manipulation of variables. For instance, in a quasi-experiment, we might compare two different groups, but there is no actual manipulation within those groups, meaning it functions more like a study. Participants experience different conditions, but the experimenter does not control or manipulate these differences.

Returning to the mall example, suppose we want to explore whether males and females behave differently with respect to mall designs. We could create separate groups of males and females and observe any differences. However, the limitation here is that we cannot change males into females, nor can we control how males and females process information or make purchasing decisions. At most, we can study the shopping behavior of these two groups. This is a quasi-experiment, where we analyze gender effects on purchasing but cannot control individual characteristics or ensure equivalence between groups.

Equivalence refers to having identical counterparts between groups, but in practice, we cannot create an exact equivalent. For example, we can compare men and women, but we cannot create perfect male-female equivalents across the groups. Moreover, causation remains difficult to establish, as personal factors may influence the results. The outcomes may be due to individual differences rather than the experimental variable itself.

In today’s lecture, we explored some fundamental concepts in research methodology, particularly as they apply to engineering psychology. We covered the scientific method, discussed experiments and studies, and examined the differences between applied and basic research, as well as the concept of hypothesis testing. In the next session, we will continue from here and dive deeper into more concepts in research. Until then, thank you, namaskar, and goodbye from the MOOC studio.