Engineering Psychology Course Pack

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For use in PSYCH 444, The Pennsylvania State University.

Information processing- what is it?

Information processing is a construct that describes attending to information in our environment and then doing something with it. That something may be an action (open up our homework assignment and turn it in) or it may be a decision (I have to call the dentist and move my cleaning appointment) or it may be something we want to remember (I'll never forget where I was when I got that phone call). Information processing can be complicated, and a lot can go wrong as information travels from our senses to its destination.

First, let's talk about the types of information that is processed. There is information specific to our person, such as internal sensory input (my foot hurts) and internal environmental information (I am tired from not getting enough sleep). This is internal information. Internal information contains conditions that are specific to us and conditions experienced only by our person no one else.

Then, there is information specific to our external environment which is shared. This could be external sensory input (I heard my phone beep) and external environmental information (The heat in this room is making it difficult for everyone to concentrate). It can also be shared communication or relationships between humans or between humans and systems.

Let's think about how these types of information are processed in general. First, the senses take in information. Then, this information is stored briefly in memory. There is memory for auditory information called echoic memory. There is memory for visual information called iconic memory. At this point in time, we believe that echoic and auditory memory is not selective, but the memory store is very brief, only a few seconds.

Attention guides the selectivity of what is to be understood from echoic and auditory memory. Attention guides perception of the sensory story. The other things that the person is attending to or thinking about influences processing of the sensory information. Occasionally, this gives rise to controversy as different people perceive the same sensory information in different ways. The black and blue dress controversy is one example < https://en.wikipedia.org/wiki/The_dress>.

After the information is selected and processed through sensory memory, it goes into working memory. Echoic and auditory memories that are not used are discarded/forgotten. In working memory, it is parsed and then stored in short term memory ready to be combined with other information. Luke Mastin (2009) has a nice reference page on memory < http://www.human-memory.net/types_short.html> where he points out that many people refer to short term and working memory interchangeably.

Once all the information is in short term memory, a part of working memory called the central executive collates the information and decides what to do next with it. Alan Baddeley and colleagues called these components the visuo-spatial sketchpad (visual/spatial information) and the phonological loop (auditory information). Scholarpedia is a version of Wikipedia edited and maintained by scholars rather than the general public. Here is their page on Baddeley's work < http://www.scholarpedia.org/article/Working_memory>

The central executive in working memory is thought to be constrained in the same way that attention is constrained. In other words, every person has a limited ability to process items based on their internal

environment and their specific capabilities. There are people who have vast capacities in working memory and can manipulate a wide variety of items. Then, there are others whose working memory is less. Here is an example of working memory at work.
https://opl.apa.org/src/index.html#/Demonstrations

After the information has been organized in working memory, then it may be acted upon or stored in long term memory for later retrieval. For example, let's say that you have a test in history class coming up in two weeks. You would attend the lectures each week and your working memory would compile the information and store it in your long-term memory. When the test is given in two weeks, then your working memory would locate that information using the cues in the test questions. Hopefully, if everything goes correctly, the right information will be retrieved, and you do well on the test.
http://www.scholarpedia.org/article/Memory

Each time that you put something in working memory, it must be related to something else for it to be stored properly. If you have something that is completely unrelatable, connecting it to an order or repetition will also store it. Working or Short term memory is thought to be very limited and lasts for about 20 minutes. The number of items that can be stored at any one time in short term memory are thought to be about 7 items according to George Miller’s famous article (1956). Other researchers since then have disputed his article and found that the true number that most people can juggle in working memory is closer to 3 or 4 (Cowan, 2012). You can read more about this at
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4486516/

To expand this capacity, people may do things such as Chunking. This refers to combining the seven items into a single item that is easier to remember. Let's say that you need to remember the code BMIP for a test. You remember that your father worked at the IBM Poughkeepsie office. You switch the order of BMIP to IBM-P. Then, it is easier to remember based on your personal history. The test day happens, and you freeze. You are unable suddenly to remember the new code IBM-P. You remember that it had something to do with your father and something to do with where he worked but the information is lost after that.

Two things may have happened. You might have retrieved something similar and it interfered (Cisco SF is where your father worked after IBM-P). If you cannot remember the information at all and fail to retrieve it, it is called a retrieval error.

Why do retrieval errors happen?

There could be failure at encoding when the information wasn’t practiced enough. There could be failure at retrieval (the two places where your father worked could easily be confused). Or there could be a consolidation error in which the right information was remembered incorrectly (he actually was at INTEL). All of these types of errors have implications for system designs in which the system relies on the human to rescue a process or as a part of the process.

Why is this important?

There are many times that systems are not fully automated. The system relies on the human to input information or give feedback. Sometimes the system fails and needs a human to restart it or repair a certain part. This is when the system designers need to understand human memory and human information processing.

One of the most common instances in which a human needs to input information is when the system verifies that the human is an authorized user. Many systems currently use password authentication to verify use. Knowing that a human can only remember about 4-7 items in short term memory, the system designers have made many password authentications to accommodate this human limitation. However, the problem becomes when the human needs to authenticate the system infrequently. Or, the system keeps the password in memory for thirty days and the human needs to remember the password after the thirty days have passed.

This is a difficult task for the human as infrequent practice has failed to establish the password in long term memory. Therefore, password managers are necessary for many people who must remember 5-20 unique passwords per day. This site: https://techxplore.com/news/2018-12-passwords-ready.html estimates that the average user has 200 accounts in 2019. This would mean that people must remember 200 unique passwords.

Typically, users will create a single password or suite of passwords and reuse them over multiple accounts pushing the responsibility for the security of the account back to the organization providing the service. Users have an incomplete understanding of how a system works which contributes to an increase in risk taking at the service of convenience. When a breach happens because of insecure passwords, in the users' mind, the organization providing the account is liable not the user. This can take a financial toll on both. To remedy this dilemma, many organizations are using biometric log ins as in face recognition, fingerprint recognition or iris recognition. These approaches do not rely on the human information processing system.

What are the implications of problems in information processing or memory?

If the person is unable to rescue or restart the system, the consequences vary. In most consumer applications, the person is left without the use of the application or device. In commercial applications, the consequences could become critical. In addition to memory errors, other things may impact a person's ability to rescue a system. These may be due to the person's internal environment overloading the cognitive system.

What is cognitive workload.

Imagine that you are a new pilot and it is the first time that you are flying solo. You have your instructor in the air traffic control tower to guide you. At the last minute, your mother or father wants to be in the plane with you. You are terrified. The addition of your parent joining you on the flight will compromise your working memory's ability to attend to the system's pertinent information by taking up attentional resources. If that parent talks to you during the flight, you will need to attend to the conversation in addition to processing the information during flight to fly the plane. The addition of the internal emotional turmoil will overload your cognitive system and you may find it difficult to concentrate. The impairment increases the likelihood of error and a crash.

In another example, imagine that you have a critical exam in an important class. The class is very difficult for you with a lot of new information to memorize. You need to get a C in the class, or you will have to change majors. You have already taken the class twice and failed it both times. During the exam, your ex-boyfriend/girlfriend comes in and sits next to you. The presence of this person will compromise your ability to concentrate and do well on the exam. You may find that you are unable to retrieve information that you knew before she/he arrived. You will be unable to process both the emotions that you are feeling and the information for the test. Both examples are times when a person's cognitive workload had increased dramatically and impaired their information processing ability.

What is cognitive fatigue.

Cognitive fatigue is when your brain is tired. Maybe you have had several difficult exams in a single day, maybe there was an argument between friends, or maybe you watched too many episodes of Letterkenny on Hulu the day before. Or maybe you haven't had enough sleep for several days and you feel foggy. Your brain doesn't want to process information and it's difficult to attend to anything for more than a few minutes.

In both cognitive overload and fatigue, the human information processing machine is overtaxed. If this happens during a critical system failure, there should be supports in place for the human to act regardless of their temporary impairment. If the failure is time sensitive, then immediate supports are needed for memory and processing. These could be in the form of reminder or decision cards or a second human backup. If the failure is not time sensitive, allowing the human to resume after rest is used.

Information processing decline.

Sometimes rest does not fix the human information processing problem. There are several instances where information processing from the human is unavailable to the system. In cases of dementia, brain injury, or aging the human may not respond. The first two items cannot be remediated. The third item, aging, can be compensated for in many circumstances. As people age, their working memory speed declines but other memory systems will compensate. Their knowledge stores increase as they have vast amounts of information from their years of experience. While they may not be able to process information quickly, they know from experience what needs to be done.

Another item, lack of practice, will also contribute to a declining information processing speed. A person who hasn't driven a manual transmission car in many years may need extra time to get used to the pedals and controls again. In certain professions, decisions are made based on content knowledge that changes over time. For example, a computer scientist educated in 1970 would have to work to maintain her level of expertise in 2020 as the content knowledge of the domain area of computers and computer programming has changed. This affects her ability to quickly process information as she must select the most recent information from her vast experience and apply it while suppressing what she had learned initially in the 1970s. As the frequency of accessing the most recent information increases, so will the efficiency.

Decision Making is associated with information processing.

Hick-Hyman law or Hick's law.

The time it takes for a person to choose is related to the number of items she must choose from, the complexity of the decision and the consequences of a poor choice. In other words, a choice between two items is rather simple and should be rapid. A choice between four items, a bit longer. A person deciding between two laptop computers for the next school year would typically take longer than the same person deciding what type of coffee to buy.

Expertise

Expertise in a particular domain, let's say Clash of Clans, builds over time. Some researchers claim that ten years or 10,000 hours is the minimum time needed (Ericsson, Charness, Feltovich, & Hoffman, 2018). However, the exact number or length of time is controversial. Most researchers agree that deliberate practice is what builds expertise. Deliberate practice means that the novice has a coach or other expert critiquing his/her performance and giving tips on better performance. The novice incorporates the feedback and the performance improves.

The concept of mentorship or expert critique continues to be what drives the accumulation of expertise in most domains. For research purposes, an expert is also called a subject matter expert or SME. Since the 1980's efforts have been made to quantify and capture the knowledge of SMEs. Organizations wish to capture the institutional knowledge of their most senior executives. Military and educational institutions wish to model the knowledge of their most valuable personnel so that the knowledge continues to contribute beyond the human's life. Expertise is most valuable when it comes to decision making within a domain. When Sully Sullenberger landed the plane on the Hudson river, that decision came from years of investigating plane crashes and years of piloting < https://en.wikipedia.org/wiki/Chesley_Sullenberger>.

Cognitive Engineering

Cognitive engineering is a new branch of Human Factors concerned with how people think and make decisions in real situations. It is popular in professions where the 3Ds (Dirty, Dangerous, and Dull) and time constraints are a factor in human performance. Cognitive engineers combine what is known about cognitive psychology along with some of the investigative methods developed in engineering psychology to produce insights on how to improve problem solving and decision making. The military, first responders, and healthcare settings are ideal for cognitive engineering approaches.

Cognitive Task/Work Analysis

One of the methods used in cognitive engineering is a Cognitive Work Analysis. In this method, the analyst observes or transcribes interactions within a socio technical system. The analysis describes the actors within the system, the nature of their interaction, work domains, activities, strategies, social analysis, and competencies analysis (Stanton, Salmon, Rafferty, Walker, Baber, & Jenkins, 2013). The CWA is done with the aim of developing a model of the system, system design improvements, system tools or training, team design, or interface design. It describes the constraints within a system along with dependencies and contingencies.

Critical Decision Method

The critical decision method (CDM) is an interview method that was an outgrowth the Critical Incident Technique (Flanagan, 1954). Since that time, it has been used to investigate decision making in time stressed situations where specific types of expertise are needed. Examples of these situations are Firefighting, Law Enforcement, Health Care and Air Traffic Control. The CDM requires the analyst to learn about the domain so that she/he can ask the right questions at the right times. From these questions, the analyst can derive key decision points. These are times when the SME had choices on what to do next. The analyst will ask for additional information that informed the choice, the possible outcomes, and possible weights. This helps the analyst understand the nature of the decision task and the nature of the domain. The output of a CDM can be constructed as a flow chart that describes networks of knowledge for expert systems, training, or evaluation.

Conclusion

Information processing is a complex cognitive process that uses sensory, short term, and long-term memory. Attending to information is only the first step in this process. Along the way, information can experience interference or other errors. Attention and emotion can impact our ability to remember information by increasing cognitive load. Hick's law refers to the relationship between the number of items a person has to choose from and the time it takes to make a choice. Expertise is built over time with deliberate practice from a coach or mentor giving critical feedback on the person's performance. Cognitive engineering is a new area of Human Factors that investigates decision making and the cognitive aspect of humans in a socio technical system. There are several methods based in observation and interviewing that reveal how humans process knowledge and make decisions in socio technical systems. These methods yield artifacts that can be used for training, creating expert systems, or optimizing the system.

References

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