10a | Introduction to Thinking, Problem Solving, and Reasoning

In this section of the course, we're going to be talking about thinking, problem solving, and reasoning. In this module, we're just going to really talk about what thinking really is – how we can go about defining it. In later modules in this section, we're going to cover more specific problem solving techniques, then move on to some blocks in problem solving, so, what sorts of cognitive processes might stop you or halt you from solving a specific problem, and then move on to reasoning.

So, what is thinking? Well, here are a couple examples. Imagine your favourite restaurant. What is its name? Where is it? What are its best dishes? What makes it your favourite? Those all examples, however simple they may seem, are examples of thinking. Here's another example. So, look at the following figure. Create unusual, but appropriate titles for the drawings. For example, for the one on the left, A, you might come up with "Giant Egg on a Baseball Diamond," or, simply, "Xs and Os." Those two examples we just talked about are very different, and they highlight the broad range of tasks that might be subsumed under the title "thinking." They also show how it's difficult to come up with a precise definition of "thinking." It's something we all know something about, and we all can provide our own sort of definitions for it. Here are a couple definitions that we've come up with by scouring through the literature. So Bruner, 1957, defined thinking as "going beyond the information given." Bartlett, 1958, defined thinking as "complex and high-level skill; fills up gaps in the evidence." Newell and Simon, 1972, define thinking as "the process of searching through a problem-space." And finally, Baron, 1994, defined thinking as "what we do when we are in doubt about how to act, what to believe, or what to desire."

As you can see by these definitions, "thinking" is used to refer to more than one specific activity, and what this also suggests is that since we have such a vast array of tasks that can be subsumed under the title "thinking," there are likely several different types of thinking. And indeed, most researchers do believe that there are different types of thinking. One distinction that we'll talk about a little bit in this module is that between focussed and unfocussed thinking. So, here, focussed thinking, pretty much as the name suggests, involves thinking that has a clear starting point and has a specific goal. An example of that would be trying to figure out a way, how to get to the Air Canada Centre in Toronto to go see a concert. You have a definite goal in mind – that is, getting to the concert – and there are a clear number of steps along the way that you could help solve that goal. The key think here with focussed thinking is that your mind is definitely focussed on the task at hand, and you're deliberately working through the problem. Unfocussed thinking, on the other hand, has the characteristic of being not on task. So, for example, daydreaming, unintentional thinking, and even some forms of creative thinking might involve more unfocussed thinking processes. We're going to be primarily spending our attention talking about focussed thinking in this task. Indeed, the vast majority of research in thinking, and problem solving, and reasoning, is done looking at more focussed thinking processes.

This is also a good time of the course to think again about how it is that we can go about measuring cognitive activities. So, one thing that we've looked at throughout the course, and what we've used throughout the course have been responses, accuracy, reaction times, and looking at what goes on in the brain when people are doing specific tasks. When it comes to reasoning, problem solving, and decision making, researchers have also relied quite a bit on what is termed "introspection." Introspection is the detailed, concurrent, and non-judgemental observation of the contents of your own consciousness as you work on a problem. You might be able to do this online, thinking aloud while you're doing a task, or be asked to judge or respond to what you think you were doing retrospectively after you do the task. Of course, there are a lot of problems with this technique, for example, how can you actually externally validate this process – again, we don't have privileged access into the minds of others – nonetheless, it has been shown to be a very powerful tool. This would probably be a good time to take a look at box 10.1 in your textbook. It goes through some of the specific instructions for introspecting. To maximize what you can get out of this section of the course, you might want to work through some of the problems in the textbook that we provide, and use the technique of introspection while you're solving the problem. That will give you some good first-hand experience in trying to understand and uncover some of the thinking processes that are involved in completing some of these tasks.

There are two more key definitions that we need to talk about before we can move on in this section of the course. That has to do with the types of problems that we are trying to solve. There are at least two different classes of problems. There are well-defined problems, and these are problems that have a clear goal. They have a beginning and an end, and you can use rules of guidelines to solve the problem. A good example of a well-defined problem might be games or puzzles. Take, for example, the Rubik's cube. There is a clear end state to that game, or that puzzle, where you have to have each side having its own colour. And there are a number of steps that you can complete where you have to follow specific rules to get to that end state. As another example, consider chess, highlighted by this picture of Bobby Fisher. There is a clear beginning state, a clear goal, and a number of rules that you need to follow in order to achieve that goal.

In contrast to well-defined problems, there are ill-defined problems, and the definition of an ill-defined problem is basically the opposite of a well-defined problem. There may be no clear goal, very little starting information, and they don't have many rules or steps clearly laid out for you. An example of an ill-defined problem might be if you had to write a difficult, sensitive letter to somebody. You might find yourself sitting, staring blankly at a computer screen, not knowing quite sure how to start the message, or, how to finish it, for that matter. And there are no clear rules at your disposal on how to get from the starting point to the end point.

As we talked about moments ago, cognitive psychologists have mainly spent their time researching focussed thinking, and, perhaps not surprisingly, cognitive psychologists have also focussed most of their research attention on well-defined problems. Now, there are several reasons for this. First-off, they're just simply easier to present. That is, it's easier to come up with and present a series of well-defined problems than it is to come up with and generate a bunch of ill-defined problems. And, plus, we know that well-defined problems can be solved relatively shortly, whereas, the ill-defined problem, some participants may never solve it. Scoring is another issue. Scoring an algebra problem, or a simple problem solving task like the Rubik's cube, for instance, is relatively straight-forward: they either solve it or they don't. An ill-defined problem, on the other hand, is very difficult to score, and that is largely due to the fact that for many ill-defined problems, there really is no clear goal state, so there might be not a clear right or wrong answer to the problem. And finally, well-defined problems are easy to modify and change – that is, you can change some aspect of the problem, some small aspect of the problem, while leaving the remainder of the problem intact. So, unfortunately, because of the preponderance of research on well-defined problems, there is very little work that has been done on ill-defined problems to date. As such, for the remaining modules of this section, we're going to be focussing our attention on focussed thinking with well-defined problems. It is assumed by researchers that problem solving for ill-defined problems works in very similar ways to problem solving for well-defined problems.

10b | Problem Solving Techniques

In the previous section, we provided some definitions about what we really mean by problem solving and thinking. In this section, what we're going to be doing now is talk about some general problem solving techniques. What we mean by general problem solving techniques is techniques that could work for a variety of different classes of problems. This can be contrasted with domain-specific problem solving techniques – those that might only work with specific types of problems. In this module, we're going to talk about four different domain-general problem solving techniques: the generate and test technique, means-ends analysis, working backwards, and reasoning by analogy.

First, we'll talk about the generate and test technique. As the name suggests, the generate and test technique involves we generate a number of potential solutions and then test to see if those solutions fit. For example, consider the task of generating as many foods as you can that begin with the letter C. In the following figure, there's a couple examples here, for example, cream, cheese, candy, cookies, celery, carrots, cantaloupe, cheese, cocoa, cereal, and so on and so on. In this example, you may have generated a number of words that actually didn't start with the letter c, for example, ketchup. In addition, you might have generated some words that start with the letter c, but that might not be food, for example, commute. So, in the second step, when you were verifying which of the words actually truly fit, you would have eliminated those examples. As you can probably see by this example, it's a pretty simple strategy, but it's only really useful if there is a limited number of possibilities. If there are a large number of possibilities, this strategy would not be a very useful problem solving technique. This can also be problematic due to, again, the limited cognitive capacity that we have. This point has come up over and over again in this course, in that we have a finite processing capacity, and when you look at working memory capacity, again, we can only hold so much information in our mind. As this technique requires us to hold in mind the number of alternatives, this can again easily surpass that limited capacity that we have,

The next technique we're going to talk about is called means-ends analysis. Now, this is a very popular technique, and very powerful as well. So, first, in order to think about means-ends analysis, let's think of an example. So, let's just suppose that what your goal in life, your ultimate goal in life, is to become a cognitive psychologist. Well, how would you go about doing that? Well, first off, you might think to yourself "Well, I should think about taking Psych207 and I should try to do very well in that class. Then, maybe after 207, I might move on to a third year class, and take an advanced lab class in cognitive psychology. And, if I'm still passionate about cognitive psychology at that point, I might do an honours thesis, and then send off all my applications to graduate school. Once I get all my acceptance letters, and I pick a good graduate school, and I'm well on my way to becoming a cognitive psychologist. After a few years, I'll have my PhD in hand." Now, I just made that sound very simple, didn't I? Well, it's a little bit more work than that, I skipped a couple steps, but at least I gave you a good idea of how means-ends analysis works. You look, you have an initial state, and that is the conditions at the beginning of a problem, you'll have a goal state, those the conditions at the end of the problem, and again here, it's getting that PhD in cognitive psychology and becoming a cognitive psychologist, thee are intermediate states, those are conditions that exist along the way, pathways between the initial and the goal state, that is, all those courses that I might want to take along the way to becoming a PhD in cognitive psychology, and then there are operators: permissible moves, that would basically be some of the rules that you have to follow along the way. This would be a good point in the module to take a close look at the tower of Hanoi problem. There are numerous fun examples of this problem online that you can try for yourself, or, you might be lucky enough to have a manual, physical version of this at home. In this task you need to determine a sequence of moves to transfer the discs from the first to the third peg, moving only one disc at a time and never placing a bigger disc on tip of a smaller one. So, try this task a few times, and see how efficient you can get at it – and efficiency, here, is determined by how few moves you can complete the task in. This task, the tower of Hanoi, could also be solved by working backwards. Here, this involves creating a series of sub-goals and reducing the differences between the current state and the goal state, like means-ends analysis, however, the sub-goals are created by working backwards from the goal state. So, considering the tower of Hanoi problem, you can create, in your mind, what the goal state looks like – those three discs sitting on the third peg – and generate sub-goals from that goal state until you arrive at your initial state.

So, think back, now, how you went about solving the tower of Hanoi task. Did you solve it using means-ends analysis, by working forward from the initial state to the goal state, or, did you find it more efficient to work backwards, trying to generate sub-goals from the end state, the goal state, to the initial state? Another good example of working backwards, and one that might be relevant to a student taking a class in cognitive psychology, is how you might improve your grade on a test. So, let's just consider the case where you didn't do quite as well on the last test as you would liked to have. Well, so your problem, your goal state, is "How can I get an A on the next test?" Your first sub-goal might be, "well, before I do better, I need to have a better understanding of the material. In order to have a better understanding of the material, I need to have more efficient study strategies." Then, you might look through your cognitive psychology notes and see if you can find any sort of hints about how better to encode information so that you will be able to retrieve it better at the time of testing.

The final problem-solving technique that we're going to talk about in this module is reasoning by analogy, and what we're going to do in this section is we're going to actually work through a problem ourselves, because I think that's one of the better ways to really, truly understand how powerful this technique is. So, take a look at box 10.3 in your textbook: the story of the general. A small country was ruled from a strong fortress by a dictator. The fortress was situated in the middle of a country, surrounded by farms and villages. Many roads led to the fortress through the countryside. A rebel general vowed to capture the fortress. The general knew that an attack by his entire army would capture the fortress. He gathered his army at the head of one of the roads, ready to launch a full-scale direct attack. However, the general then learned the dictator had planted mines on each of the roads. The mines were set so that the small bodies of men could pass over them safely, since the ditator needed to move his troops and workers to and from the fortress. However, any large force would detonate the mines. Not only would this blow up the road, but it would also destroy many neighbouring villages. It therefore seemed impossible to capture the fortress. However, the general devised a simple plan. He divided his army into small groups and dispatched each group to the head of a different road. When all was ready, he gave the signal, and each group marched down a different road. Each group continued down its road to the fortress so that the entire army arrived together at the fortress at the same time. In this way, the general captured the fortress and overthrew the dictator.

Alright, now let's move past that, admittedly, very dramatic, story, to another problem: the tumour problem. Given a human being with an inoperable stomach tumour, and rays that destroy organic tissue at sufficient intensity, by what procedure can one free him of the tumour by these rays, and, at the same time, avoid destroying the healthy tissue that surrounds it? You might want to pause here and think about this problem for a moment. Once you generate a solution to this tumour problem that you think will work, then we'll continue.

Now that you're back, I'm going to give you a hint. What if I told you that the general problem can be used to help you solve the tumour problem? So, think back to the general problem, now, and look through it, and think if there is any information in there that might help you solve this new problem. You might want to pause the program here, again, just so you can have some time to think through this.

Okay, now it's time for the solution. The solution to the tumour problem is to send weak rays of radiation from several angles, such that all rays converge at the site of the tumour. So, although the radiation from any one ray would not be strong enough to destroy the tumour, or the healthy tissue in its path, the convergence of the rays will be strong enough. As you can see here, now, the tumour problem and the problem of the general, although they differ in what is called "surface features," share a common underlying, or analogical, structure. The components of one correspond, at least roughly, with the components of the other. So, the army is analogous to the rays, the capturing of enemy forces is analogous to the destruction of the tumour, the convergence of soldiers at the fortress is analogous to the convergence of rays at the site of the tumour. So, in order to solve the new problem by using the analogous problem, you need to be able to automatically abstract that abstract relationship between those two different domains. Now, don't feel bad if you weren't able to abstract that analogical relationship between those two different domains. In a study by Dick and Holyoak in 1980, they found that only 30% of individuals in their experiments not told about the analogy noticed the analogy, and even when given an explicit hint that the general story could be used to solve the tumour problem, then, 75% of individuals were able to extract the analogy between the two different domains. So, as you can see, this isn't an easy problem. Analogies can be a very powerful problem solving tool. In fact, if you look to the history of science, you'll find that a number of discoveries that have been made have been linked to the effective use of analogies. For example, William Harvey likening the circulatory system to a water pump. Or, more close to our own hearts here in cognitive psychology, thinking about attention as a spotlight.

Perhaps the most famous analogy of them all is that of the relationship between the structure of the hydrogen atom and the solar system. In this analogy, the sun and the planets of the solar system domain are analogous to the nucleus and electron in the atom domain. This example highlights another important role for analogy: that in education and teaching. Many of us may have learned the structure of the atom by comparing it to our solar system. By doing so, it makes it easier to understand and more concrete, by taking something we already know something about, and comparing it to something that we do not.

10c | Blocks to Problem Solving

In the previous section, we covered a number of different problem solving strategies. These strategies are useful because many problems that we have to solve can't be solved in a single step. In addition, many problems have barriers that hinder us from successfully solving a problem. What we're going to talk about now are some of the classic blocks, some of the classic things that hinder us from successfully solving a problem. Before we do this, I'm going to present to you a couple problems that highlight this phenomenon. When I present you with the problem, what I want you to do is press pause on the module, so that you can work on it a little bit before you move on to see the actual solution. The first two problems I want you to try are called the nine dot and the six matches problem. So, first, take a look at the nine dot problem. So, what you see here are a series of dots, and what the task is, is to draw four straight lines that pass through each of the nine dots, without removing your pencil from the paper. The six matches problem is a similar type of task, and what this task requires you to do is to arrange the six matches so that they form four triangles will all sides equal to the length of one match. So, press pause now, and try to work on this problem for a couple of minutes, and then resume play so that you can see what the solutions are.

Welcome back. Now, take a look at the solution to those two problems. First, take a look at the nine-dot problem on the left. As you can see, the problem is easily solvable, as long as you draw the lines outside of the box. Most people aren't able to solve this problem, because they make the faulty assumption that the four lines must stay within the borders of the dots. So, literally, in this example, you have to think outside the box in order to solve the problem. Now, look at the matchstick problem. As you can see, the solution to this problem requires that you think in three dimensions, and create a three-dimensional object. Most people, however, constrain themselves to creating the four triangles in a two-dimensional plane, and thus, cannot solve this problem. Both of these problems illustrate how people typically go into a problem – or often go into a problem, anyways – with faulty assumptions, and these faulty assumptions, of faulty rules about the problem, hinder successful problem solving. There are a couple other examples in the textbook: the string problem, and the candle problem, which I'd also recommend you try out. These blocks to problem solving highlight what is called "mental set." Now, mental set is the tendency to adopt a certain framework, strategy, or procedure, or, more generally, to see things in a certain way instead of in another, equally plausible way. It can be induced by short amounts of practice, and it causes people to make certain unwarranted assumptions, without being aware of making them. So, for example, when you look at the matchstick problem, by looking at that original picture, where all the matches are sitting in a two-dimensional space, people typically make the unwarranted assumption that the final object, or the final image that they create, must also be in two dimensions. However, this is not stated at all anywhere in the rule. Mental set can also be induced by what is called functional fixedness. Now, here, this is an adoption of a rigid mental set towards an object. If you looked at the string problem in the textbook, what you'd find is a perfect example of functional fixedness. To solve that problem, what you'd need to do is to attach the screwdriver to one of the strings to swing it like a pendulum. People typically don't discover that solution because the fail to think that a screwdriver can have other functions besides screwing in screws.

So far, we've talked about mental set as a block to problem solving. Well, there's other blocks as well. One is the lack of problem-specific knowledge or expertise. So, most of the problems studied by cognitive psychologists are about equally unfamiliar to everyone, and people go about solving them in basically the same way. Other kinds of problems, for example, those in chess, or other skilled games, textbook problems in physics, geometry, and electronics, computer programming, and problems in diagnosis, for example, medical diagnosis, seem to be different in kind from the puzzles we have been talking about so far. Perhaps, not surprisingly, experts and novices have been found to approach most such problems differently. Here, the familiarity within a domain of knowledge seems to change the way one solves problems within that frame of reference. There have been numerous studies done comparing experts and novices in a number of domains. For example, Chase and Simon compared novice and expert chess players, and they found that expert chess players were able to extract much more information from a brief exposure to a chess board than novices. In addition, they found that experts could recall more items from a brief exposure than novices. However, these expert-novice differences were only evident when the pieces of the chessboard were configured to depict a possible chess game. When the chess pieces were random, no differences were evident. Presumably, these differences occurred because when experts were presented with a meaningfully configuration, they were able to draw on their extensive memories of past plays, and past games. Now, since novices don't have that extensive long-term memory base of past pays and past moves, they are forced to simply try to maintain the information in their working memory.

Another area where researchers have found extensive differences in the way that experts and novices solve problems is in physics. Here, Chi and colleagues, 1981, found that experts, when given a series of problems to categorize, tended to organize the problems in terms of principles, so, underlying structures of the problem – for example, Newton's first law of motion – whereas novices, on the other hand, focussed on the superficial features of the problems, so, for example, was there an incline plane present, or, was there a frictionless surface? To reiterate, here, experts focussed on underlying principles, underlying deep structures of the problems, whereas novices were cued into the superficial features of the problem, and did not see the underlying structure. What you can see here is that there is a commonality between the expert-novice differences in chess and in physics. For example, in both cases, experts see and represent the problem in their domain at a deeper and more principled level than do novices, who tend to represent information more superficially. An important point to remember about these studies, however, is that experts excel in their own domain of expertise, that is, their knowledge is domain-specific. For example, you take the expert chess player and you ask him to partake in the experiment on physics, then chances are, unless, of course, he's an expert in physics as well, he will behave like the novices, and represent and code the information superficially in that domain, whereas he will still encode and represent the information in a deeper domain within chess. So, to reiterate, expertise, and the degree to which someone will encode, store, and retrieve information at a deeper, structural level, or at a more shallow, superficial level, depends entirely if it is within the individual's domain of expertise. For example, take the professional chess player. Although he will reveal very deep, structured processing in the chess environment, unless he's also an expert in physics, when tested in the physics environment, he will behave like a novice – that is, he will reveal superficial problem solving strategies that is focussed on the surface features of the problem, and not the deeper, structural features.

10d | Reasoning

In the last section of this module, we're going to be talking about reasoning, and you might wonder, well, how is reasoning different than thinking? Well, the term "reason" is often used interchangeably with the term "thinking," so therefore, you're going to notice a great deal of overlap between the types of processes that we talk about within reasoning, and those within thinking. However, researchers that consider themselves working on problems of reasoning typically have specific areas in mind. So, when reasoning, we typically have one or more particular goal in mind. That is, our thinking is very focussed. Reasoning also includes inferences or conclusions drawn form other information. Now, there are two main forms of reasoning that we're going to be talking about. These are deductive reasoning and inductive reasoning.

First, consider deductive reasoning. Now, in deductive reasoning, the information goes from the general to the specific. So, consider the following example: All college students like pizza. Kerri is a college student; therefore, Kerri likes pizza. The final conclusion necessarily follows from the initial premises. Inductive reasoning, on the other hand, goes from the specific to the general, that is, it takes specific information and allows one to make inferences that are more generalized. For example, consider the following syllogism: Brian is a university student. Brian lives in a dormitory; therefore, all university students live in dormitories.

We're going to focus our attention now on deductive reasoning. Now, there are a number of different types of deductive reasoning processes that researchers have focussed on. The two that we're going to talk about are conditional reasoning and categorical reasoning. One of the most well-researched tasks within conditional reasoning is called the Wason selection task. So, let's work through this problem – this is in your textbook as well. So, consider this: you have been hired as a clerk. Your job is to make sure that a set of documents is marked correctly according to the following rule: if the document has an A on one side, then it must have a 4 on the other. You've been told that there are some errors in the coding of the documents, and that you need to find the errors. Each document has a letter written on one side, and a numerical code on the other. Here are the four documents: which documents do you need to turn over to check for errors? You might want to pause, now, for a little bit, and try this problem on your own, and then press play again and then we'll work through it together. So, how about the A card? Well, most people correctly assume that you need to turn over the A card, because, again, you need to check to see if there if there is a 4 on the other. The D card is completely irrelevant on this one, because the rule says nothing about cards that have a D on one side. How about the 4 card? A lot of people mistakenly select the 4 card, thinking that the statement "If the document has an A on one side, then it must have a four on the other" means that if a document has a 4 on one side, it must have an A on the other. Importantly, however, the conditional statement "If the document has an A on one side, then it must have a 4 on the other," says nothing about whether a 4 card must have an A. This is a common error that people often make when reasoning conditionally, in that they assume that a conditional statement is bi-conditional. And, finally, how about the 7 card? The 7 card also needs to be turned over, but most people neglect to do this. The 7 card is required to check to see if the rule is violated. If you turn over the 7 card, and there is an A on the other side, then the conditional statement "If the document has an A on one side, then it must have a 4 on the other," would be violated. If you didn't select the A and the 7 card, don't feel bad. Only a small percentage of people actually do select those cards correctly. Although I'm not going to specifically go through them in this module, it would be a good idea to look through the examples of inferences, rules, and fallacies in the textbook. For example, the modus ponens, the modus tollens, denying the antecedent, and affirming the consequent, to see if they map onto these selections in the Wason selection task.

Now, let's consider that same problem, however, this time, we're going to put meaningful content to it. So, consider this problem: You've been hired as a bouncer in a bar, and you must enforce the following rule: if a person is drinking beer, then he must be over 19 years old. The cards above have information about four people in the bar. One side of each card lists a person's age, and the other side shows what he or she is drinking. Which card, or cards, do you need to turn over, to be sure that no-one is breaking the law? Here, the task feels very transparent, and is very easy. You need to turn over the beer card, to make sure the person is of age, and you need to turn over the card of the 16 year old, to see what they're drinking. Both of these cards are necessary to check to see if the rule has been followed. You probably got a sense from this task that this is much, much easier than the preceding problem. In fact, researchers have found that the majority of university students can correctly solve this problem. However, the previous one I showed you is very difficult , and very, very few people actually solve it correctly. This is what is called a content effect, where the content of a problem can facilitate the logical reasoning process. Griggs and Cox in 1982 were the original researchers to look at this problem, and they came up with what is called the memory cueing explanation. And what they argued was that certain contents of the problem cue, or call to mind, personal experiences that are relevant to the rule. The authors argued that university students did very well on this task because of their own personal experience with drinking age laws, and, perhaps, with violations of those laws. The same participants would have had no relevant experience reasoning about vowels and numbers, and so, performance on that task could not be facilitated by personal experience.

The preceding problems that we just talked about dealt with conditional statements. A second class of problems that researchers have focussed on have been to do with categorical statements. These are often called syllogisms or categorical syllogisms, and in these problems, people are presented with premises that deal with classes of entities. Quantifiers provide information about how many members of a class are under consideration, whether that be all, none, or some. Take a look at the examples provided in the textbook. So, for example, syllogisms like "all red books are astronomy books, all astronomy books are large, therefore, all red books are large," are relatively easy. However, syllogisms that contain "somes" or negatives are much more difficult, and people are typically much slower at responding to them and make many more errors. Just like conditional syllogisms, there are content effects as well, too, in categorical syllogisms – that is, the content of the syllogism can significantly impact logical processing. One content effect that has probably received more research attention than any other in deductive reasoning is the believability effect. Here, people are much more likely to accept a conclusion as valid if the conclusion is believable, irrespective of if it logically follows from the premises.

We're now going to move from deductive reasoning to inductive reasoning. Inductive reasoning is reasoning about conclusions that are likely, but not guaranteed to be true. It's an inferential process that expands knowledge in the face of uncertainty, and it often involves categorization and formation of rules or hypotheses. A famous task designed to look at inductive reasoning is the Wason 2-4-6 task. In this task, participants are given the following triplet: 2, 4, 6, and they are told that the triplet conforms to a particular rule, and the task is to determine what the rule is. But, you may not ask direct questions about the rule, you have to offer examples of triplets, and for each one you give, you'll be told by the experimenter whether it follows the rule or not. And, you should not try to guess the rule, you should only announce the rule when you are confident you know what it is. You might want to pause here and give this a try. What triplets did you come up with? Was it, 4, 6, 8? 10, 12, 14? I, 3,5? All of those triplets would conform to the rule, and most people, when given this task, generate those sorts of triplets. What if I told you that what the rule was , was any three numbers in ascending order? Would you have guessed that? Well, of the 29 original participants in this study, only six discovered the correct rule, without first making any incorrect guesses. Thirteen others made one wrong guess, nine reached two or more incorrect conclusions, and one reached no conclusion at all. What typically happens here is that people come up with an original hypothesis, like, for example, any two numbers increasing by two, and then construct examples that follow that rule. What they fail to do is to test that rule by constructing a counter-example – a triplet that, if the rule is correct, won't receive a "yes" answer from the experimenter. That is, if the participant believes that the rule is "any two numbers increased by two" they will continue to generate triplets that conform to that rule, and they won't try a simpler triplet, like any two numbers that increase by one, or, try to test to see if any numbers that decrease will violate the rule. This is an example of what is termed a "confirmation bias," that is, participants seem to be trying to confirm that the rule is true, rather than trying to test the rule.

We've just spent some time talking about a number of different reasoning tasks. As with the other areas of cognitive psychology that we've talked about, researchers typically try to come up with a broad theoretical framework that explains the cognitive performance. We're going to briefly talk about two major theoretical approaches to the study of reasoning. These are the rules-based approaches, and the mental models approach. The rules-based approach basically argues that people rely on special-purpose mental rules which we have implicit access to – that means we can't consciously think about them – to draw conclusions. They can be sensitive to context, and they can be domain-specific. That is, they could be adapted to solve specific problems that we might encounter. An alternative to the rule-based approach is the mental models approach. Proponents of this approach deny that reasoning consists of using special-purpose rules of inference. Rather, they argue that reasoning consists of constructing mental models to depict the premises. A mental model might be a quasi-pictoral representation of the relationship between the information in the premises and the conclusion. Effective reasoning is thought to occur when the reasoner checks to be sure that his or her first idea of the conclusion might be is assessed by an attempt to construct alternative models consistent with the premises but inconsistent with the hypothesized conclusion. So, which theoretical approach is correct, and which better captures reasoning performance? Well, the jury is still out on that, and, actually, recent neuroimaging research by Goel and colleagues at York University have found evidence for both rule-based and mental models-based approaches, depending on the problem. They found evidence for reliance on more rule-based mechanisms when reasoning with content-laden material, that is, like the drinking age problem we talked about before, and more visual-spatial mental model bases mechanisms when reasoning with abstract material, that is, material that you can't rely on your past experience and knowledge.

10e | Summary of Thinking, Problem Solving, and Reasoning

In summary, in this module, we talked about thinking, problem solving, and reasoning, and the general definition we gave of thinking is really just any sort of cognitive process or mental process that goes beyond the information given. We covered several different distinctions among types of problems, these could be well-defined or ill-defined ones, and among types of thinking, for example, could be focussed thinking versus unfocussed thinking. Cognitive psychologists typically focus on focussed thinking with well-defined problems. We then discussed four different domain-general problem solving strategies, and when I say domain-general, I mean problem solving strategies that can be used across a wide variety of problems. Here, we talked about the generate and test technique, means-ends analysis, working backwards, and reasoning by analogies. And people can use these, again, in a wide variety of situations, independent of the context. We then moved on to talk about several different blocks to problem solving. These can be though of as barriers and constraints that prevent, or at least seriously interfere with, finding a successful solution to a problem. Here, we talked about mental set and lack of problem-specific expertise. We then finished off by talking about two types of reasoning: deductive, going from general to specific, and inductive, going from specific to general. Within deductive reasoning, we talked about categorical and conditional reasoning. We completed our discussion on deductive reasoning by covering two main theoretical approaches, that is, the rule-based approach, and the mental models approach.

11a – Introduction to Decision Making

In this section we're going to be talking about making decisions. We're going to begin by introducing the topic to you by talking about some of the main pieces of information that people use when making decisions. We're then going to move on to a very big area in the area of decision making, called heuristics. Heuristics can be thought of as mental shortcuts that help you arrive at a decision faster. Often, however, these mental shortcuts could cause the reasoner to arrive at an erroneous conclusion. We're then going to briefly talk about some of the main models of decision making, and then finish by talking about some recent work looking at decision making in the brain.

Let's begin by talking about some of the main sources of difficulty in making a decision. Oftentimes many decisions involve conflict and uncertainty. So first off, when we talk about conflict what we is, is that a decision maker must make trade-offs across different dimensions. So, for example, consider the case of shopping for a car. Well, you might look at the trade-off between a car's power versus its gas mileage, or, its options versus its price. In addition to conflict, there is often uncertainty, that is, the outcome of a decision often depends on uncertain variables. I think a good example of uncertainty in decision making in the real world is investing in the stock market. One can't be certain whether the stock that you've just invested in will grow dramatically, will fall dramatically, or will perform somewhere in the middle. This second source of difficulty, that of uncertainty, highlights one of the main aspects of decision making, that is, that many decisions involve uncertain events with unknown probabilities. This being the case, often researchers have focussed on probabilistic reasoning when looking at decision making, and we will as well, when we talk about some studies throughout this section of the course. Specifically, we'll be talking about how it is that we estimate probabilities, what strategies do we use, what information influences us, and the big question out of all of this is are we rational decision makers? Here, we define rationality in terms of following some sort of objective rule in judging probabilities – that is, not letting our beliefs or our expectations get in the way.

Interestingly, decision making is one of the areas in cognitive psychology where there is a large amount of research done in the applied world. For example, people have been studying how people make decisions in business, in medicine, in law, in countless areas. One example that's highlighted in the textbook is the research that's being conducted at the DRDC in Toronto. There are a number of applied researchers at that centre who are interested in issues of decision making. For example, they are examining how fatigue due to sleep loss affects decision making performance under a wide variety of conditions.

11b – Heuristics in Decision Making

One of the most popular areas in the field of decision making has to do with the examination of heuristics and biases, that is, ways that people go about solving problems and making decisions that can lead to systematic errors. You can think about these biases in decision making in much the same way as we thought about biases in perception, that is, these are errors of cognition that come about for understandable reasons, and that they provide us with information relevant to understanding normal functioning. So, the systematic biases that people have in decision making tell us a bit about how people go about making decisions in general.

We're going to briefly talk about six different heuristics in decision making: availability, representativeness, anchoring, illusory correlation, confirmation bias, and overconfidence. Let's start with the availability heuristic. Consider the following problem: in of four pages in a novel, how many words would you expect to find having the following form, that is, ending in "–ing," or having "n" as the second-last letter in the word. Think about this for a second, and then arrive at your answer. When given this problem, most people choose the first option, that is, words ending in "–ing." However, this is incorrect. Words ending in "–ing" cannot be more prevalent than words having the letter "n" as the second to last letter in the word, that is because words ending in "–ing" also have the letter "n" as the second-to-last letter in the word, so there will be at least as many words with the letter "n" as the second to last letter in the word as there are words ending in "–ing," and again, likely much more. However, people judge words ending in "–ing" as being more prevalent because they are easier to come to mind, and people use this ease of coming to mind, that is, they can think of words relatively easily ending in "–ing," as a measure of how probable that word is.

Let's now move on to a second heuristic, called the representativeness heuristic. So, consider the following problem: of all families having exactly six children, in what percentage do you think the exact birth order of boys and girls would be? Would it be a) boy, boy, boy, girl, girl, girl, or b) girl, boy, boy, girl, boy, girl. Most people given this problem intuitively select option b, and they do so because option b looks like it has less of a pattern, like it's more random. In fact however, both of these options, a and b, are equally likely to occur. The problem here is that most people general expect the random process, that is, whether you're going to have a boy or a girl, will always produce results that are relatively random looking. This is also related to what's known as the gambler's fallacy. Here, people mistakenly believe that each roll of a dice or each flip of a coin is dependent on the other. However, each one of these events is completely independent of the previous one. So, if you flip a coin five times and it comes up heads five times, the sixth coin still has an equal chance of coming up heads or tails.

The next heuristic that we're going to talk about is called anchoring. So, imagine an experiment where you're in a classroom of people, and you ask everyone with the last name to solve the following equation, 8x7x6x5x4x3x2x1, in less than five seconds. Conversely, those with last names ending from N-Z solve the problem 1x2x3x4x5x6x7x8, again, in less than five seconds. Now, even though these two problems would result in the identical answer, that is, 40 320, those given the first equation that started with 8 would have a larger estimation, in general, than those given the second equation that started with 1. What happens here is the first part of the problem serves as an anchor, and determines, to some degree, what the final answer will look like. Tversky and Kahneman, in 2000, explain these results in this way: They argue that people tend to perform the first few steps of multiplication and then extrapolate. So, those who started with 1x2x3 would begin with a smaller value than those who began with 8x7x6. So this first group would more severely underestimate the final result than the latter group.

Another prevalent heuristic is that of illusory correlation. That is where people see a relationship that one expects to see, even when no relationship exists. Take a look at the following table that can be found in your textbook. This table notes the frequency of those that were found to twist their hair with their fingers, versus not twist their hair with their fingers, and those that were deemed to be under stress, and those deemed to be not under stress. Now, looking at this table, try to determine what you think the relationship is between the likelihood that someone is going to twist their hair and be under stress. More often than not, people will look at this table and judge that there is a moderate relationship between the two. However, when you do the math, you basically would find out that people were just as likely to be a hair-twister or not a hair-twister when they were under stress or not under stress, that is, a quarter of those under stress and a quarter of those not under stress were hair-twisters. The point is that you might expect those who are under stress to be more likely to twist their hair than those that are not under stress, so people would typically see that relationship in those data, even though it does not exist. Put more generally, the associations that we bring to a situation often colour our judgement to such an extent that we see them even if they are not really there.

Another example of a heuristic is the confirmation bias, and I'm not going to go into depth, here, on this, because we talked about this previously when we talked about inductive reasoning in the previous section. I just want to highlight again, here, that the confirmation bias is the tendency to search only for information that will confirm one's own initial hunch or hypothesis, and to overlook or ignore other information. So, in the 2-4-6 task, when people generate triplets, what they typically do is they generate triplets that confirm their original rule that they have in mind, rather than trying to generate triplets that disconfirm their rule.

The final heuristic I want to talk about is that of overconfidence. Take a look at the following trivia questions. For each one choose one answer and rate your confidence in your answer on a scale from 0.5, which would be just guessing, to 1, completely certain. You might want to pause here a bit, just to work through these problems. The following figure is a typical example of how people's confidence is related to their performance or accuracy in that task. The diagonal dotted line depicts what the data would look like if people were perfectly calibrated, that is, if their confidence accurately measured or accurately tracked with their accuracy in the task. The degree to which the confidence-accuracy calibration deviates below this diagonal line indicates the degree of overconfidence that participants have. Here, confidence ratings are higher than actual accuracy. What these data highlight is that people's impressions of their own accuracy on a task are typically inflated.

I just finished introducing to you six different heuristics and biases. This is a very incomplete list, as there are many more heuristics and biases that have been found in literature. These heuristics and biases are an important area of research as understanding how and why the cognitive system goes wrong sometimes can help us understand how the mind works.

11c – Utility Models of Decision Making

In the preceding sections, we talked about how decision making often involves making decisions where pieces of information are in conflict – it typically involves information about probabilities, and also we talked about a number of heuristics and biases that show how decision making often goes awry. As in many areas of cognitive psychology, researchers have developed models that try to capture what it is that people do in these tasks. We're going to talk about expected utility theory, image theory, and recognition primed decision making.

Expected utility theory is a normative model of decision making. What that means is that it defines ideal performance under ideal circumstances. Because of this, it's mathematical in nature. It is often expressed or compared to a gamble. That is, making a decision, such a choosing a major in high school or university, can be compared to a gamble. For example, in most gambles you win or lose particular amounts of money depending on certain outcomes, and probability theory tells us – assuming fair coins, decks of cards, and the like – what the odds are of any outcome. The dollar amount won, or lost, tells us the monetary worth of each outcome, or, put another way, the expected value of that outcome. To derive the expected value, all you need to do is you multiply the probability of each outcome by the amount of money won or lost for that outcome, and summing these values over all possible outcomes. We can do this for all possible alternative gambles. Presumably, then, if offered a choice between two gambles, one would choose the better one by calculating the expected value of each one and choosing the gamble with the higher expected value. That would be the rational thing to do. Researchers in decision making have adopted the term expected utility, rather than expected value, because we often care about other aspects of life, rather than money, so utility can be a more general term that captures ideas like happiness, pleasure, and the satisfaction that comes from achieving one or more personal goals. You can apply this simple equation, where expected utility equals the sum of the probability of an event, multiplied by the utility of an event, over all events.

Let's work through some examples, here. So, take a look at the following table: here is an example of expected utility calculations for the decision of selecting a major in selective subjects. What you see in the first column is a list of a bunch of different majors: art, Asian studies, biology, chemistry, economics, and so on. The column next to that, you see probability of success. Here you have to use your imagination a little bit, and try to predict the probability of success in each of these majors. And, let's just say, for example, in this hypothetical situation, you determine that the probability of success for you, as an art major, would be quite high at 0.75, similarly, for sociology, quite high at 0.8, however, your success for mathematics would be quite low at 0.05, and physics, 0.01. And again, the other majors sit somewhere in between those extremes. You then multiply the probability of your success in these majors by the utility that each of these professions or each of these majors would afford you, that is, how much you would value this profession or this major. Then, to arrive at the expected utility of each major, you multiply the probability of success of each major by the utility for success, and then you add to that the probability of failure of that major to the utility of failure for that major.

Let's just work though a couple of examples here, just to make sure this is clear. Let's calculate the expected utility for art. So, the probability of success for art, as an art major, is 0.75. The utility for success is 10, and the utility for failure is 0. So, what we do, is to determine the value for the probability for success and utility for success, we take the 0.75 multiplied by 10. Now, that gives us a value of 7.5. And then what we do is we add to that the probability of failure with the utility of failure. And to do that we say okay, if the probability of success if 0.75, well then that means by definition the probability of failure is 0.25. So, we take the 0.25, multiplied by 0, which is going to be 0. So then we take the 7.5, plus 0, which gives us an expected utility value of 7.5. Let's just work through one more of these. So, let's look at biology, now. So, the probability of success for biology is 0.3. The utility for success is 25, and the utility for failure is 5, which means utility still, so this participant judged that even if they failed in biology, they still wouldn't feel that bad about it. Alrighty, so then what we would do, is we take the probably of success, which is 0.3, multiplied by the utility for success, which is 25, that gives us a value of 7.5. Then what we do is we multiply the probability of failure by the utility for failure. Now, here again, since the probability of success is 0.3, the probability for failure should be 0.7. So, we take 0.7, multiplied by the utility for failure, which is 5, which gives us a value of 3.5. Then we simply sum those two values, we sum the 7.5 with the 3.5, and that gives us an expected utility of 11. Now, once we've calculated expected utility for all of the majors, we can simply look down the column and find out which one has the largest value. And here, what it looks like, it is chemistry, and if we are purely rational decision makers we would declare chemistry as our major. The idea being is that chemistry should offer us the largest utility or the biggest utility, and thus we should be happiest with that choice.

As you can probably imagine, expected utility theory has been critiques on a number of grounds, the main issue being, is that although it's a normative account – that is, an idealized way in which people should make decisions, or could make decisions, to optimize utility – people rarely go through such a process. In contrast to expected utility theory, other theories have arisen that seem to be a little bit more realistic in terms of how people actually go about making decisions. One such theory is image theory, and the basic idea behind this view is that people typically whittle down their choices to a small few before they do any active consideration. And this again related back to the recurring theme throughout this course, is that we have a very limited amount of cognitive capacity, and that we can only handle a certain, small amount of information at any given time. Proponents of this view argue that most of the decision making work is done during pre-choice screen of options. This pre-screening allows people to make more deliberate and conscious decisions on a small number of alternatives, rather than trying to weigh the utilities of all options. They do this by asking themselves whether a new goal, plan, or alternative is compatible with three images: the value image, that's containing the decision maker's values, morals, and principles, the trajectory image, that contains the decision maker's goals and aspirations for the future, and the strategic image, that is the way in which the decision maker plans to attain his or her goals. According to image theory, options that are judged incompatible with any three of these images are automatically dropped from further consideration. Ideally what happens then is that the reasoner is left with only one or two options to give careful consideration.

The final decision making theory that I'm going to talk about is recognition primed decision making. This area of research has borrowed much from the area of expertise. Here, when experts are making decisions from within their own domain of expertise, they rely more on intuition, mental simulation, or making metaphors or analogies and recalling or creating stories about previous experiences that they've had in that domain. That is, with a lot of experience in a specific domain, the requirement to use conscious, deliberate, or utility-type strategies diminishes, and this gets replaced with a more intuitive , unconscious-like decision making process. In addition, as a decision maker takes stock of a new situation, they compare it to other situations they've previously encountered in the past and make direct analogies between them. Of course, as we've seen in the previous section, when we talked about heuristics and biases, this can be problematic. Specifically, one's intuitions and expectations may lead to erroneous decision making.

11d – Decision Making, Emotions and the Brain

In this last section, we're going to be talking about decision making, emotions, and the brain, and I just want to highlight the field of neuroeconomics, as this is a field that really focuses in on this. And this is a new field that examines how the brain interacts with the environment to enable us to make complex decisions. What some scientists have argued is that you can't really fully grasp how human beings make decisions in the world without acknowledging the role of emotion. Well, what brain regions are involved with decision making? Well, it probably doesn't surprise you that the frontal lobes play a huge part in decision making. This has been known for a number of years, at least as early as the case of Phineas Gage. Since that time, numerous studies have examined the brain regions that underlie decision making. I'm going to highlight one study here that I think really highlights how cognition and emotion interact when we're making decisions. In this task, Sanfey and colleagues presented participants with a task called the ultimatum game. In this task, you are to imagine that you are working with a partner, and you have the opportunity to split $10 with that partner. You'll receive a one-time offer from your partner, and then you have the opportunity to either accept or reject this offer. If you accept the offer made by your partner, you split the money as determined. If it is rejected, you both go home with nothing. So, if the partner offers you $4, if you accept the $4, you get $4, the partner gets $6. If you reject the $4, you get nothing, and your partner gets nothing. So, think about this for a moment. What would you do if your partner offered you $5? Would you accept that offer and split it, $5 each? How about if the partner offered you $1? Would you take that dollar and let your partner have $9? Well, rationally, if you think about it, one dollar is better than no dollars – if you reject that $1 offer, you will get nothing. What Sanfey found was that many participants actually would reject these unfair offers, that is, they would rather leave with nothing and ensure that their partner had nothing, than leave with $1 when they knew that that was an unfair offer. In addition, these unfair offers were followed by activations in the insula cortex and the dorsolateral prefrontal cortex. The insula has been predominately indicated in response to negative emotional states, such as anger and disgust. So, even though the rational brain, perhaps the prefrontal cortex, should be telling these participants to accept, no matter what the offer is, because any money is better than no money, the insula gets in the way, and in some ways, this emotional response trumps the cognitive response and determines how the decision will be made. Numerous studies have also converged on this idea that complex decision making involving real-world problems often involves this interplay between emotion and those regions of the brain that subserve emotion and cognition. A summary of some of these brain regions can be found in the following figure. In the previous study we discussed the prefrontal cortex and the insula. Other neuroimaging studies of decision making have also found that the anterior cinglulate cortex, that is, a region of the brain found to be involved in error detection and conflict monitoring, as well as the amygdala, which is also known to be involved in processing emotion, work together to help us make decisions in the real world.

11e - Summary

In summary, we began our discussion of decision making by talking about how decisions are often made under conflict and about uncertain variables or events. We then moved on and discussed how there are many heuristics and biases that we use when making decisions. We discussed six of them: the availability heuristic, the representativeness heuristic, anchoring, illusory correlation, confirmation bias and overconfidence. The key thing to remember with these heuristics and biases are that they typically work well for us, and again, they typically serve us well in that they allow us to make decisions efficiently. However, they can lead to erroneous responses. After discussing heuristics and biases, we talked about three utility models of decision making. Specifically, we talked about the expected utility theory, and again, this is the normative model of decision making. We then talked about image theory, and recognition primed decision making – these are more descriptive accounts, in that they describe, more or less, what people actually do when making decisions, not the ideal thing that people should do. We ended our discussion on decision making by talking about the role of emotions, cognition, and the brain. Here, I highlighted how the field of neuroeconomics has recently emerged as a discipline that examines how emotion and cognition jointly contribute to real-life decisions, and we talked about some of the key brain regions that subserve this interplay between cognition and emotion.

12a | Introduction to Individual, Aging, and Gender Differences in Cognition

We've spent an entire term talking about human cognitive processes. You now have a better understanding of the myriad of amazing things your mind does, most of the time without you even thinking about it, or realizing it.

In talking about these fantastic abilities, however, we did so assuming that they are more or less the same for everyone. Other than those instances in which we discussed individual case studies, we talked about cognitive processes that are general to everyone. Even when we talked about case studies, part of our interest was in learning what they said about human cognition, in general. As we noted earlier, the bulk of the experimental work in cognition is based on testing university students, like yourselves, and making generalizations to the larger population. Although there is a lot of merit in this approach, for instance, we do know that cognitive processes unfold pretty similarly for most people, it is also the case that this approach selectively ignores another important area of study.

That is, generalizing to large populations can often ignore the fact that there are, within any group, individual differences. Although cognitive processes may be similar within a group, there are still differences in ability, and in development. There are psychologists who are interested in studying individual differences and the underlying causes.

In this unit, we will discuss three major sources of individual differences in cognitive skills- intelligence, the role of practice and expertise, and bilingualism. These are 3 of the most studied areas associated with individual differences.

We will discuss another factor that leads to differences in cognitive abilities- and this one is associated with changes in cognition within an individual. There are clear effects of aging on cognitive abilities, and researchers are interested in understanding why these arise./

Finally, we will talk about another large source of individual differences in cognition, and this is the role of gender. In examining these differences, we will also try to determine whether the differences are associated with sex- the fact that we are born male or female- or are of gender and our socialization as male or female.

12b | Individual Differences in Cognition

Everyone has some notion of what it means to be intelligent. We can think of individuals that we believe are very intelligent, and those that are less so. That is, we know that there are clear and important differences in intelligence across a population, and that these differences are often associated with differences in achievement. When we speak of intelligence, though, what exactly are we talking about?

Is intelligence one general mental ability that promotes us doing well or less well on all kinds of tasks and processes? Or is intelligence something more complex? Are there multiple intelligences? We'll think about this issue when we discuss differences in intelligence.

Generally speaking, more intelligent people are said to be those that can carry out a basic cognitive process more efficiently. Keating and Bobbitt demonstrated in 1978, as you see in the figure in front of you, that higher-ability children and adults were better able to acquire, store, and manipulate basic information than were same-age, normal-ability peers. That is, our ability to do things like retrieve information from memory improves as we age, but even within an age group there are differences in ability that are associated with intelligence. So, what then is this thing called intelligence?

In their book called the Bell Curve, Hernstein and Murray argued that there is a general cognitive ability, and that this ability is relatively stable over the course of a person's lifetime. More crucially, they argue that this ability is what we are actually talking about when we talk about someone's score on a standardized test of academic aptitude, like an IQ test. They believe that if an IQ test is properly administered, it does not bias against social, economic, ethnic or racial groups and that intelligence is something that is largely inherited from our parents.

In contrast, Gardner takes a view that is very different. His view is that there is not one global concept called intelligence, but that people can express intelligence on at least 6 different dimensions. As you see in the Figure in front of you, these dimensions include linguistic intelligence, logical-mathematical intelligence, musical intelligence, bodily-kinesthetic intelligence, spatial intelligence, interpersonal intelligence, intrapersonal intelligence, naturalist intelligence, and existential intelligence. This makes intuitive sense, as we have all known someone who really seems to excel in one or two of these areas, perhaps they are very strong students in math and very musical, but seem to struggle more in other areas, such as writing or speaking. Gardner claims that these differences are real and measurable, and that we would even do well to tailor our career choices to our individual strengths.

There is still a great deal of debate about what, exactly, intelligence is, and whether standardized tests really tell us anything at all about it.

We've already talked about the role of practice earlier in the course. We all know that practice typically makes us better at something, and in extreme cases, lots of practice can push our performance into the area of expert performance. When we discuss expert performance, do we mean performance that is quantitatively different from normal performance, or is there something special, or qualitiatively different, about expert performance.

Eyal Reingold at the University of Toronto, and his colleagues, have extensively studied expert performance in chess players. Reingold showed that expertise in chess is associated not just with going faster, but with being able to use memory in a way that is very different from how non-experts use memory.

In their experiments, expert chess players and non experts were given very brief views of chess boards, somewhere mid-game, with a considerable number of pieces on them. After a 5-second view, the participants were given a blank chess board, and were asked to reconstruct the board they had just viewed. Experts were able to reconstruct the positions of about 65% of the chess pieces, compared to about 20% for the non-experts. In terms of our unit on memory, it is believed that the experts were able to chunk the chess pieces into meaningful groups, whereas the novices could not. This was further supported by the finding that when chess pieces were scattered in a non-meaningful way, or were randomly placed on the board, experts performed no better than non-experts. In that case, there was no benefit from chunking in memory.

Later research by Reingold in which he actually monitored the eye movements of the experts and novices while they were examining the chess board showed that they actually pay attention to different areas of the board during the 5-second view.

Thus, it appears that experts are better able to recruit their cognitive processes in order to perform a task than are non-experts.

One of the notable things about Canada is that it is officially a bilingual nation, and many of its citizens have experience in two languages. What do we know about how bilingualism affects cognitive abilities?

If you remember back to our unit on attention, you'll remember that part of successful behaviour is not only responding to the information one is supposed to respond to, but also being able to ignore the information that we are not supposed to process. Bilingualism can be considered a massive exercise in just such a thing. That is, a person proficient in multiple languages must always exercise control in responding with the appropriate language. A word spelled in English will not be meaningful if one attempts to read it in French, for instance.

Ellen Bialystok of York University is a leader in the study of bilingualism. She has shown that the ability to attend selectively to relevant information, and to ignore distracting information, develops earlier in bilingual, than in monolingual children. As shown in the Figure of the RAT_MAN in front of you, she has also shown that when appropriate, bilinguals are more successful than monolinguals at seeing multiple possibilities from a common stimulus. That is, bilinguals shown the Rat-man in the far left part of the figure are better able to see it both as a rat (center part of the figure) and as a man (far right part of the figure) than are monolinguals. Bilinguals appear, then, to be more flexible when appropriate.

It is clear, then, that being bilingual confers an advantage in terms of attentional control. From an early age, on, bilinguals are better at directing their behaviour to relevant stimuli, and this advantage continues on until older age (although it is diminished somewhat in the prime of adulthood). But, being bilingual does not come without costs. It has also been shown that bilinguals, when compared to monolinguals on a single language, do not do as well with things like retrieving individual words from memory. This makes sense when one understands that a bilingual, being proficient in multiple languages, likely does not spend as much time on any one language as does a monolingual.

12c | Effects of Aging and Cognition

One of the facts of life is that we all age. We understand that as we age our bodies will change, and we do not expect to run as quickly or to be able to lift as much weight at age 70 as we can at age 20. What about mental abilities? What can we expect as we age?

There are profound changes that can come about with aging such as seen in Alzheimer's disease, but what about normal aging? How will memory be affected by normal aging? There is good news, and bad news. First, our semantic memory generally increases with increasing age. As we live longer, experience more things, learn more things, we are able to store that information away, leading to richer semantic memory later in life. Our ability to access memory in an implicit manner remains relatively stable across life. What can change, however, is our ability to explicitly access a particular episode. As we build up more life experiences, it sometimes gets more difficult to remember exactly which experience was associated with what time.

This decline in remembering which experience was associated with which event is a decline in what we referred to as episodic memory. Episodic memory relies heavily on the frontal lobes, and research has shown that later in life we don't encode information or retrieve it as well as we did when we were younger. Interestingly, we often have a specific difficulty with what we call source memory. That is, we may remember that we heard or saw something, but we may not remember exactly who told us, or where we saw it.

Research has shown that although changes in memory are somewhat inevitable, we can help postpone them or lessen them by keeping ourselves physically and mentally healthy. Proper diet, regular exercise- both mental and physical- and increased reliance on memory strategies can all be helpful.

It is clear that we can document changes in mental abilities, like memory, with advancing age. Why do these occur? There are a number of possibilities that have been advanced by theorists. One general argument is that we just get slower in terms of the speed of our mind. Slower processing can have all kinds of implications. One possibility is that if we are processing something, other information that we might also need might decay in the extra time it takes to process the first bit of information.

A second interesting possibility is that aging is associated with a decline in inhibitory processes. This means that as we get older, it is increasingly difficult to determine what we should pay attention to, and what we should not pay attention to. There have been sad, and informative, reports of elderly individuals overdosing on medication, possibly because they have been confused by seeing take"20 mg 2x per day" and taking 20 pills. In that case, they possibly were not able to inhibit the interpretation that 20 refers to a number of pills, rather than a dosage.

This possible change in inhibitory processes is also associated with a general decline in the availability of attentional resources. It has been shown that not only do we need resources to focus attention on something we want to process, but also to avoid processing, or shut-out, something we do not want to process. If those resources are lacking, we might have more difficulty blocking out the irrelevant stuff and have too little resources to fully activate the things we want to process.

Finally, there has been a specific model, called HAROLD, that associates changes with aging with changes in the frontal lobe of the brain. This model says that the types of executive processes that become impaired as we get older are housed in the frontal lobes. As the frontal lobes deteriorate, so do the processes they are responsible for.

The take home message here, however, is hopeful. We can all benefit from the old adage use it or lose it. Practice and exercise (and overall good health) have been shown to help ameliorate the changes associated with aging. In addition, they make for a happier here and now!

12d | Gender Differences in Cognitive Abilities

The final source of individual differences that we'll discuss is gender. Before we talk about where these differences appear, however, we'll briefly talk about what they might mean. That is, if we say that women generally perform better on some task than do men, we do not necessarily mean that every woman will out-perform every man. There are a number of ways that mean scores can differ, and this needs to be considered as well. Moreover, it is often too simple to say that one gender outperforms another on some task, because those differences can be associated with developmental differences, and once both genders mature, those differences might not be present. So, when discussing gender differences, or any individual differences, it is important to think about what is really being argued.

Having said that, there are some cognitive areas that have revealed pretty consistent individual differences that can be seen between men and women. For instance, men typically outperform women on some visual-spatial tasks, such as mental rotation- we talked about that task in our imagery unit, and spatial relation tasks- but women outperform men on visual tasks requiring observers to determine when the location of an object has changed.

Verbal, or language-based, tasks have also been studied extensively. Generally speaking, language skills develop in females earlier than they do in males, and women typically stay more verbally fluent than males throughout their lifespans. This obviously does not mean that men are linguistically deficient, however. There are many excellent male writers and debaters. One interesting possibility is that the sex based individual differences that we observe are associated with documented differences in brain organization between men and women. Generally speaking, it is known that female brains tend to be less lateralized then are male brains. This means that whereas men's brains are highly specialized in terms of undertaking certain processes in specific areas, this is less the case with women. Because certain tasks tend to be more spread out in women, they often show better recovery than men following brain injury. This is specifically the case with language. Because women's language is less lateralized than men's recovery of language after stroke is often better for women than for men.

12e | Summary of Individual, Aging and Gender Differences in Cognition

We've seen in this unit that despite the fact that there is a lot we can say about general cognitive functioning, we can learn a lot by investigating individual differences in cognition.

Individual differences are seen in intelligence. Whether this indicates a differences in one general ability that affects many tasks and processes, or indicates many different sets of abilities is still of robust debate.

Intelligent, or expert, behaviour in any domain involves better recruitment and use of cognitive skills in the so-called expert behaviour. Some of this might indicate an innate ability- being born with a predisposition towards a particular skill- but hours of practice likely play a very large role, as well.

Bilingualism is also a source of important and documented individual differences. Bilinguals, from an early age, show superior abilities at attentional control tasks than do monolinguals.

We have also discussed individual differences that occur within the individual- the way in which our cognitive skills change as we age. The most profound age-related deficits are associated with tests of episodic memory. As we collect more information, it seems more difficult to be able to sort through it. This change might be associated with overall slowing, with the lost ability to inhibit irrelevant information, with decreased attentional capacity, and has been shown to be associated with brain changes in the frontal lobes.

Finally, we closed the unit thinking about individual differences that are associated with whether we are male or female. There are documented differences in both visuo-spatial and verbal tasks, and it remains to be seen how much of any difference can be accounted for by the fact that we are born male vs. female and how much should be attributed to whether we are raised male or female.

Taken together, our unit on individual differences gives us a more nuanced view on all the material that we've covered throughout the term. We talk about general truths, but can also learn from how we differ from one another.