LEARNING HOW TO LEARN
A COURSERA MOOC

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Introduction to the Focused and Diffuse Modes

What do you do when you just can't figure something out? For zombies, it's pretty simple. They can just keep bashing their brains against the wall. But living brains are a lot more complex. It turns out, though, that if you understand just a little bit of some of the basics about how your brain works, you can learn more easily and be less frustrated.

Researchers have found that we have two fundamentally different modes of thinking. Here, I'll call them the *Focused* and the *Diffuse* modes. We're familiar with focusing. It's when you concentrate intently on something you're trying to learn or to understand. But we're not so familiar with diffuse thinking. Turns out that this more relaxed thinking style is related to a set of neural resting states. We're going to use an analogy of the game of pinball to help us understand these two thinking modes. Incidentally, both metaphor and analogy are really helpful when you're trying to learn something new.

If you remember, a pinball game works by, you pull back on the plunger, release it, and a ball goes boinking out, bouncing around on the rubber bumpers, and that's how you get points. So, here's your brain, with the ears right here, and the eyes looking upwards. And we can lay that pinball machine right down inside it. So, there you go. There's the analogy for the focused mode. The blue bumper bumpers here are placed very close to one another. See this orange pattern here towards the top? It represents a familiar thought pattern. Maybe involving something simple like adding some numbers, or more advanced ideas like literary criticism or calculating electromagnetic flows. You think a thought, boom, it takes off, moves smoothly along. And then, as it's bouncing around on the bumpers, you're able to figure out the problem you're trying to solve, or the concept you're trying to understand that's related to something you're rather familiar with. So look at how that thought moves smoothly around on the fuzzy underlying orange neural pathway. In some sense it's as if it's traveling along a familiar, nicely paved road.

But what if the problem you're working on needs new ideas or approaches? Concepts you haven't thought of before. That's symbolized here by this neural pattern towards the bottom of the pinball machine area. But if you haven't thought that thought before, you don't even know how that pattern feels or where it is. So how are you going to develop that new thought in the first place? Not only do you not know where the pattern is or what the pattern looks like, but see all the rubber bumpers that are blocking your access whatever direction you do decide to move in? To get to this new thought pattern, you need a different way of thinking. And that's represented here, by the diffuse mode.

Look at how widely spaced the rubber bumpers are. Thought takes off, look at how it moves widely, bounces around. It could travel a long way before being interrupted by hitting a bumper. In this diffuse mode of thinking, you can look at things broadly from a very different, big picture perspective. You can make new neural connections traveling along new pathways. You can't focus in as tightly as you often need to, to finalize any kind of problem solving. Or understand the finest aspects of a concept. But you can at least get to the initial place you need to be in to home in on a solution.

Now as far as neuroscientists know right now, you're either in the focused mode or the diffuse mode of thinking. It seems you can't be in both thinking modes at the same time. It's kind of like a coin. We can see either one side, or the other side of the coin. But not both sides at the same time. Being in one mode seems to limit your access to the other mode's way of thinking. In our next video we're going to see how some extraordinary people access their diffuse ways of thinking to do great things.

Thanks for learning about learning. I'm Barbara Oakley. [BLANK_AUDIO]

Terrence Sejnowski & Barbara Oakley - Introduction to the Course Structure

Dr. Sejnowski: Welcome to Learning How to Learn. Your brain has amazing abilities, but it didn't come with an instruction manual. Perhaps the greatest gif that our brains give us is the ability to learn new things every day. On my way here, I thought about the journey that will take us to the last day of the course and how much we will learn along the way. Our goal is to give you a better understanding of how we learn, so that your brain becomes a better learner. These insights are based on solid research from neuroscience, from cognitive psychology, and also from dozens of leading instructors and practitioners in difficult-to-learn subjects. Whether you're a novice or an expert, you will find great new ways to improve your skills and techniques for learning, especially related to math and science.

Dr. Oakley: This course is meant to help you reframe how you think about learning, to help reduce your frustration and increase your understanding. We approach things a little differently. You're not expected to have an in-depth background in any particular subject. Instead, you're expected to take these ideas and apply them to whatever subject you're trying to learn or improve in, to help you learn more deeply, effectively, and with less frustration. You'll hear experts from a variety of different disciplines talking about their best tips for learning more effectively. You can benefit from these ideas whether you are struggling in high school or soaring through math and science at graduate levels at a university.

Dr. Sejnowski: I'm a co-director of a science and learning center that is sponsored by the National Science Foundation, based here in La Jolla. In recent years, we've made great strides from research, in discovering how to learn most effectively. Finding a way to simply and effectively share these ideas with you, has been a big undertaking, but we feel it's well worth doing. You'll see that many of these ideas, although simple, are incredibly powerful. And along the way, we'll also learn a lot in the process of teaching you.

Dr. Oakley: You'll see how you can fool yourself about whether you actually know the material. You'll discover new ways to hold your focus and embed the material more deeply and powerfully in your mind. And you'll learn to condense key ideas you're learning about, so you can grasp them more easily, master the simple, practical approaches outlined here, including simple tips to help prevent procrastination. And you'll be able to learn more effectively and with less frustration. This course is meant to enrich both your learning and your life. You'll able to get what you want from this material. So, welcome to the course, and happy learning!

Using the Focused & Diffuse Modes – or, a little Dali will do

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So let's take a look at some famous people from history who used their different thinking modes to help them with their problem solving. If you look at that guy right there, he was Salvador Dali, a very well-known surrealist painter of the 20th century. He was the very definition of a wild and crazy guy. You can see him here with his pet ocelot, Babou.

Dali used to have an interesting technique to help him come up with his fantastically creative surrealist paintings. He'd relax in a chair and let his mind go free, often still vaguely thinking about what he had been previously focusing on. He'd have a key in his hand, dangling it just above the floor. And as he would slip into his dreams, falling asleep, the key would fall from his hand [SOUND] and the clatter would wake him up, just in time so he could gather up those diffuse mode connections and ideas in his mind. And off he'd go back into the focused mode bringing with him the new connections he'd made while in the diffuse mode. Now you might think, well, you know, that's okay for an artist, but what is it have to do with more scientific or mathematical kinds of thinking?

Well, if you look down here, this guy was Thomas Edison, one of the most brilliant inventors ever. According to legend, what Edison used to do was he'd sit and relax in his chair, holding ball bearings in his hand. He'd relax away letting his mind run free, although it would often noodle back in a much more relaxed way to what he'd been focusing on previously. When Edison would fall asleep, the ball bearings would drop [NOISE] and clatter to the ground just as with Dali, and it would wake Edison up and off he'd go with his ideas from the diffuse mode, ready to take them into the focused mode and build on them.

So the bottom line is, when you're learning something new, especially something that's a little more difficult, your mind needs to be able to go back and forth between the two different learning modes. That's what helps you learn effectively. You might think of it as a bit analogous to building your strength by lifting weights. You would never plan to compete in a weight lifting competition by waiting until the very day before a meet and then spending that entire day working out like a fiend. I mean, it just doesn't happen that way. To gain muscular structure, you need to do a little work every day, gradually allowing your muscles to grow. Similarly, to build neuro-structure, you need to do a little work every day, gradually allowing yourself to grow a neuro-scaffold to hang your thinking on, a little bit every day and that's the trick.

In summary then:

- We learned that analogies provide powerful techniques for learning.
- We learned about how the brain's two different thinking modes, focused and diffuse, each helps us learn, but in very different ways.
- And finally, we learned that learning something difficult can take time. Your brain needs to alternate its ways of learning as it grapples with and assimilates the new material.

Thanks for learning about learning. I'm Barbara Oakley.

What is Learning?

Welcome to learning how to learn. My name is Terry Sejnowski. Let me introduce you to your brain!

First, some brain surgery. We take off the skull and take out the brain. This brain weighs three pounds, but it consumes ten times more energy by weight than the rest of the body, a very expensive organ. It is the most complex device in the known universe. All of your thoughts, your hopes, your fears are in the neurons in this brain. We prize our abilities to do chess and math, but it takes years of practice to acquire these skills. And digital computers are much better at it than we are. It came as a surprise to discover that what we do so well and take for granted, like seeing, hearing, reaching, running, are all much more complex problems than we thought and way beyond the capability of the world's fastest digital computers. What this illustrates is that we are not consciously aware of how our brains work.

Brains evolved to help us navigate complex environments, and most of the heavy lifting is done below our level of consciousness. And we don't need to know how it's done in order to survive. Psychologists who study the unconscious mind have found that influences include thought processes, memory, emotions and motivation. We are only aware of a very small fraction of all of the activity in the brain, so we need to rely on brain imaging techniques to guide us.

Here is the activity map of someone's brain who was asked to lie still, at rest, in a brain imaging scanner. On the left is the side view of the brain and on the right is the view from the midline. The colors indicate brain areas whose activities were highly correlated, as shown by the time courses below, color-coded to the brain areas. The blue areas are highly active when the subject interacts with the world, but turn off in a resting state. The red-orange areas are most active in the resting state and are called the default mode network. Other brain areas are also more active when you are resting, and these areas can be further divided into groups of areas that have common patterns of activity. This is a new and intense area of research, and it will take time to sort out all the resting states and their functions.

There are a million billion synapses in your brain where memories are stored. The old view of the brain is that once it matures, the strengths of synapses can be adjusted by learning, but the pattern of connectivity does not change much unless there is brain damage. But now we know that brain connectivity is dynamic and remains so even after it matures. With new optical techniques for imaging single connections between neurons called synapses, we can see constant turnover, with new synapses being formed and others disappearing. This raises a puzzle. In the face of so much turnover, how do memories stay stable over so many years?

This is a picture of one dendritic branch on a neuron which receives inputs from other neurons. The synapses are on the spiny knobs coming off the dendrite. On the top, the dendrite was imaged before learning. The same dendrite is shown below after learning and after sleep. Multiple synapses that are newly formed together on the same branch are indicated by the white arrowheads. You are looking down into the brain of a live animal. This is really a fantastic new technique. Synapses are less than a micron in diameter. In comparison, a human hair is around 20 microns in diameter. This new technique allows us to see how learning changes the structure of the brain with a resolution that is near the limit of light microscopy.

This illustrates that, intriguingly, that you are not the same person you were after a night's sleep or even a nap. It is if you went to bed with one brain and woke up with an upgrade. This is a better deal than you can get from Microsoft. Shakespeare, the great English poet, already knew this. Here is Macbeth lamenting his insomnia: "Sleep that knits up the raveled sleeve of care, the death of each day's life, sore labor's bath, balm of hurt minds, great nature's second course, chief nourisher in life's feast." Here, Shakespeare is making an analogy between knitted clothes and sleep that knits up the loose threads of experience and concerns during the day and weaves them into the tapestry of your life story.

You will learn in this first week how to take advantage of your unconscious mind, and also sleep, to make it easier to learn new things and solve problems. During the lectures you may ask yourself, how does the brain do this? A good place to find out more about your brain is the website brainfacts.org, brainfacts, one word, .org (http://www.brainfacts.org/). You will find a wealth of interesting things about brains and behavior, and in particular about learning and memory.

I am Terry Sejnowski. Happy learning until we meet again.

A Procrastination Preview

Everybody has some issues with procrastination. Because if you're working on something, it means you're not working, on a lot of other things. But some people have more issues with procrastination than others. In this video, we're going to give you a little insight into procrastination. Why it arises, and a powerful little tool to help you address it.

When you look at something that you really rather not do, it seems that you activate the areas of your brain associated with pain. Your brain, naturally enough, looks for a way to stop that negative stimulation by switching your attention to something else. But here's the trick. Researchers discovered that not long after people might start actually working out what they didn't like, that neuro-discomfort disappeared. So it seems what happens when you procrastinate, is something like this; first, you observe, and get a cue about something that causes a tiny bit of unease. You don't like it, so to make the sensation go away you turn your attention from whatever caused that unease. You turn toward something more pleasant. The result, you feel happier, temporarily.

We're going to talk more about procrastination later on. But in the mean, time I'm going to let you in on a handy little mental tool. This tool is called, the *Pomodoro*. It was invented by Francesco Cirillo, in the early 1980's. Pomodoro is Italian for tomato. The timer you use often looks like a tomato and really, a timer is all there is to this elegant little technique. All you need to do, is set a timer to 25 minutes, turn off all interruptions, and then focus. That's it! Most anybody can focus for 25 minutes. The only last important thing is to give yourself a little reward when you're done. A few minutes of web surfing, a cup of coffee, or a bite of chocolate, even just stretching or chatting mindlessly, allowing your brain to enjoyably change its focus for a while. You'll find that using the Pomodoro technique is very effective. It's a little like doing an intense 25 minute workout at a mental gym. Followed by some mental relaxation. Give it a try.

Next, we're going to see how one very shy ten year old, changed her brain.

Practice Makes Permanent

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Yep, that's me when I was 10. I loved animals, handicrafts, and dreaming. Back then, I was the belligerent queen of anti-math. I neglected, ignored, flunked, and downright hated math and science all through grade school, middle school, and high school. It's strange to realize I'm now a professor of Engineering. I enlisted in the army right out of high school to study language at the Defense Language Institute. That's me at 18, looking very nervous and very focused while throwing a hand grenade.

I only started to study math and science when I was 26 years old, after I got out of the military. At first, it was really hard. There were all these quick thinkers in my classes who seemed to get everything a lot easier and faster than me. Sometimes I'd take a break for a few months, I'd go out and work as a Russian translator on Soviet trawlers. That's me up in the Bering Sea. And I'd come back to school and try and learn some more. As I gained technical know-how, new doors started opening up for me. I ended up working as a radio operator at the South Pole Station in Antarctica. That's where I met my husband. I always say I had to go the end of the Earth to meet that man. Here he is, after only 10 minutes outside at minus 70 degrees Fahrenheit with a 60-mile-an-hour wind. The wind chill takes it off the charts.

Now, I wasn't natural in math and science. Not at all. The way I succeeded was to gradually begin to figure out some tricks. But let's back up a step. In the greater scheme of all the different careers and disciplines that people can pursue, why are those involving math and science, sometimes, a bit more challenging? We think it may be related, at least in part, to the abstract nature of the ideas. I mean, let's take a cow for example, out standing in a field. If you have the word cow, you can point right to a cow to learn what that word means. Even the letters for the word cow, C-O-W, are roughly analogous to sounds that they stand for. But for mathematical ideas, there's often no analogous thing that you can point to. There are no plus signs standing out in a field. No multiplication, division, or other kinds of things that can directly equate to mini mathematical or scientific terms. These terms are more abstract, in other words. Well, you might say, yeah, but what about ones like love, zest, or hope? Those are all abstract. Yes they are, but the thing is, these abstract terms are often related to our emotions. We can feel our emotions, even if we can't see and point to concrete examples, like we could with the cow. This means it's important to practice with ideas and concepts your learning in math and science, just like anything else you're learning to help enhance and strengthen the neural connection you're making during the learning process.

You can see on your left here the symbolic representation of a thought pattern. Neurons become linked together through repeated use. The more abstract something is, the more important it is to practice in order to bring those ideas into reality for you. Even if the ideas you're dealing with are abstract, the neural thought patterns you are creating are real and concrete. At least they are if you build and strengthen them through practice. Here's a way to picture what's going on. When you first begin to understand something, for example, how to solve a problem, the neural pattern from is there, but very weak. Kind of like the faint pattern at the top of our paintball machine analogy here. When you solve the problem again fresh from the start, without looking at the solution, you, you begin deepening that neuron pattern, kind of like the darker pattern you see here in the middle. And

when you have the problem down cold, so you can go over each step completely and concisely in your mind without even looking at the solution, and you've even had practice on related problems, why then, the pattern is like this dark firm pattern you can see towards the bottom of the pinball frame. Practice makes permanent.

When you're learning, what you want to do is study something. Study it hard by focusing intently. Then take a break or at least change your focus to something different for a while. During this time of seeming relaxation, your brain's diffuse mode has a chance to work away in the background and help you out with your conceptual understanding. Your, your neural mortar in some sense has a chance to dry. If you don't do this, if instead you learn by cramming, your knowledge base will look more like this, all in a jumble with everything confused, a poor foundation. If you have problems with procrastination, that's when you want to use the Pomodoro, that brief timer. This helps you get going, using brief periods each day of focused attention that will help you start building the neural patterns you need to be more successful in learning more challenging materials. Next stop, we'll be talking about chunking, the vital essence of how you grasp and master key ideas.

I'm Barbara Oakley. [BLANK_AUDIO]

Introduction to Memory

When I look back on my childhood or I remember some words from Spanish or from Russian, Здравствуйте, or I bring to mind one of Maxwell's equations, I'm drawing on portions of my brain involved in long term memory. But what I'm trying to hold a few ideas in mind to connect them together so I can understand a concept or solve a problem, I'm using my working memory. Obviously, sometimes I'll bring something from my long term memory into my working memory, so I can think about it. So the two types of memory are related. There are lots of different ways to slice our understanding a memory, but for this course on learning, we're going to talk about only these two major memory systems, *working memory* and *long term memory*.

Working memory is the part of memory that has to do with what you're immediately and consciously processing in your mind. Your working memory is centered out of the prefrontal cortex, although as we'll see later, there are also connections to other parts of your brain, so you can access long term memories. Researchers used to think that our working memory could hold around seven items or chunks, but now it's widely believed that the working memory is holds only *about four chunks* of information. We tend to automatically group memory items in to chunks so it seems our working memory is bigger than it actually is. Although your working memory is like a blackboard, it's not a very good blackboard. You often need to keep repeating what you are trying to work with so it's stays in your working memory. For example, you'll sometimes repeat a phone number to yourself until you have a chance to write it down. Repetition is needed so that your metabolic vampires, that is, natural dissipating processes, don't suck those memories away. You may find yourself shutting yours eyes to keep any other items from intruding into the limited slots of your working memory as you concentrate.

So we know that short term memory is something like an inefficient mental blackboard. The other form of memory, long term memory, is like a storage warehouse. And just like a warehouse, it's distributed over a big area. Different kinds of long term memories are stored in different regions of the brain. Research has shown when you first try to put a short term memory in long term memory, you need to revisit it at least a few times to increase the chances that you'll be able to find later when you might need it. The long term memory storage warehouse is immense. It's got room for billions of items. In fact, there can be so many items they can bury each other, so it can be difficult for you to find the information you need unless you practice and repeat at least a few times.

Long term memory is important because it's where you store fundamental concepts and techniques that are often involved in whatever you're learning about. When you encounter something new, you often use your working memory to handle it. If you want to move that information into your long term memory, it often takes time and practice. To help with this process, use a technique called *spaced repetition*. This technique involves repeating what you're trying to retain, but what you want to do is space this repetition out. Repeating a new vocabulary word or a problem solving technique, for example, over a number of days. Extending your practice over several days does make a difference.

Research has shown that if you try to glue things into your memory by repeating something 20 times in one evening, for example, it won't stick nearly as well as if you practice it the same number of times over several days. This is like building the brick wall we saw earlier. If you don't leave time for

the mortar to dry, that is, time for the synoptic connections to form and strengthen, you won't have a very good structure. And talk about lasting structure, look at this part of the Acropolis here.

Thanks for learning about learning. I'm Barbara Oakley. [BLANK_AUDIO]

The Importance of Sleep in Learning

You might be surprised to learn that just plain being awake creates toxic products in your brain. How does the brain get rid of these poisons? Turns out that when you sleep, your brain cells shrink. This causes an increase in the space between your brain cells. It's like unblocking a stream. Fluid can flow past these cells and wash the toxins out. So sleep, which can sometimes seem like such a waste of time, is actually your brain's way of keeping itself clean and healthy.

So, let's get right to a critical idea. Taking a test without getting enough sleep means you're operating with a brain that's got little metabolic toxins floating around in it. Poisons that make it so you can't think very clearly. It's kind of like trying to drive a car that's got sugar in its gas tank. Doesn't work too well. In fact, getting too little sleep doesn't just make you do worse on tests, too little sleep, over too long of a time, can also be associated with all sorts of nasty Conditions, including headaches, depression, heart disease, diabetes, and just plain dying earlier.

But sleep does more than just allow your brain to wash away toxins. It's actually important part of the memory and learning process. It's seems that during sleep your brain tidies up ideas and concepts your thinking about and learning. It erases the less important parts of memories and simultaneously strengthens areas that you need or want to remember. During sleep your brain also rehearses some of the tougher parts of whatever you're trying to learn, going over and over neural patterns to deepen and strengthen them. Sleep has also been shown to make a remarkable difference in your ability to figure out difficult problems and to understand what you're trying to learn. It's as if the complete deactivation of the conscious you in the pre-frontal cortex at the forefront of your brain helps other areas of your brain start talking more easily to one another, allowing them to put together the neural solution to your learning task while you're sleeping.

Of course, you must also plant the seed for your diffuse mode by first doing focused mode work. If you're going over what you're learning right before you take a nap or going to sleep for the evening you have an increased chance of dreaming about it. If you go even further and set it in mind that you want to dream about the material, it seems to improve your chances of dreaming about it still further. Dreaming about what you're studying can substantially enhance your ability to understand. It somehow consolidates your memories into easier to grasp chunks.

And now time for a little sleep 😴

Summary Video for Module 1

Although living brains are pretty complex, this week we've used metaphor and analogy and zombies to help simplify matters. In essence, people have two fundamentally different modes of thinking that, for the purpose of this course, we've labeled *focused* and *diffuse*. We used a simple pinball analogy to help us understand the differences between the modes.

The focused mode has tight spacing for the rubber bumpers which seems to, in some sense, help keep your thoughts concentrated. The diffuse mode, on the other hand, has more widely spaced bumpers that allow for more broad ranging ways of thinking. The focused mode is centered more in the prefrontal cortex, and it often seems to involve thinking about things you're somewhat familiar with. For example, if you're familiar with multiplication and you're trying to solve a multiplication problem or you're trying to find a word that rhymes with another word. You're probably stepping along the somewhat familiar pathways of the focused mode. But if you're trying to solve or figure out something new, it often cries out for the more broad-ranging perspectives of the diffuse mode. This mode, as it turns out, is representative of the brain's many neural resting states.

Creative thinkers throughout history, whatever their discipline, have found ways to access the diffuse mode, often more directly and quickly. But we all access this mode quite naturally when we do things like go for a walk or take a shower or even just drift off to sleep. When we find ourselves stuck on a problem, or even if we're unsure of a situation in the course of living our daily life, it's often a good idea, once you've focused directly on the situation, to let things settle back, and take a bit more time. That way, more neural processing can take place, often below conscious awareness in the diffuse mode.

The thing is, it often takes time for neural processing to take place, and time as well to build the new neural structures that allow us to learn something new. This is why tackling procrastination is so very important. The easiest way to tackle procrastination is to use the Pomodoro technique; that brief 25 minute stretch of focused concentration, followed by a bit of mental relaxation. It's through practice and repetition that we can help enhance and strengthen the neural structures we're building as we're learning something new. Practice and repetition is particularly important for more abstract topics.

Memory, of course, is an important aspect of learning. There are *four slots in our working memory*. Things can fall out of those slots unless we keep repeating them to hold them in mind. In that sense, working memory is like a not very good blackboard. Long term memory, on the other hand, is like a storage warehouse. If you practiced and repeated something well enough to get it into long term memory, you can usually call it up later if you need it, although you may need an occasional bit of repetition to freshen the memory up. It's never a good idea to cram your learning by repeating things many times all in one day. Because that's like trying to build muscle by lifting weights all in one day. There's no time for solid structures to grow.

We've also learned of the importance of sleep in washing away the toxins that develop during our day's activities. You want to avoid taking tests or doing anything difficult with little sleep the night before, because it's like trying to think with poison on the brain. And just as importantly, exercise is surprisingly valuable in helping improve both our memory and our ability to learn.

We've had a lot of fun while learning this week, I'll bet you'll find next week's material to be even more exciting.

I'm Barbara Oakley. Thanks for learning how to learn.

Excitement About What's Next! Mary Anne Nestor Gives Special Hints

Hi, I'm Mary Anne, one of the TA's for the Learning How to Learn Course. The first module is almost over and I would like to take a minute to encourage you.

I can tell you from my own experience this course has changed how I study and learn. Before this course I would study hard, but no matter how much I studied I couldn't retain what I learned. Honestly, I thought there was something wrong with me. Then I took this course and I found out it was the way I was learning, or thought I was learning, that was the problem. All these years of schooling, including an undergraduate degree, and a master's degree and I never had one instructor show me what the instructors in this course share with us.

Using the techniques I learned in this course, I now know how to retain the information I want to learn. Participants in other courses sometimes drop the first week. But don't do that in this course. You will lose out on an opportunity of a lifetime. Knowing how we can learn effectively is a life skill everyone needs, no matter where we are in life. It's never too late. If you see me in the discussion forum, say hello. I'd love to hear your thoughts and how we can help each other learn, how to learn.

Introduction to Chunking

[SOUND].

This week, we're going to be talking about chunks, compact packages of information that your mind can easily access. We'll talk about how you can form chunks, how you can use them to improve your understanding of, and creativity with the material, and how chunks can help you do better on tests. We'll also talk about illusions of competence in learning. This was when you're using ineffective study methods that fool your mind into thinking you're learning something when you're mostly just wasting your time. We'll cover what those less effective study methods are and tell you what methods research has shown will work better to help you in your studies. Finally we'll talk about something called *overlearning*, which can solidly ingrain information in your mind, but also can be a little like digging deeper ruts as you might spin your wheels ineffectively in learning. You can make your study time more valuable by interleaving, providing intelligent variety in your studies.

I'm Barbara Oakley. Thanks for learning how to learn.

What is a Chunk?

[SOUND]

In this video, we're going to answer the question. What is a chunk?

When you first look at a brand new concept it sometimes doesn't make much sense, as shown by the jumbled puzzle pieces here. Chunking is the mental leap that helps you unite bits of information together through meaning. The new logical whole makes the chunk easier to remember, and also makes it easier to fit the chunk into the larger picture of what you're learning. Just memorizing a fact without understanding or context doesn't help you understand what's really going on or how the concept fits together with other concepts you're learning. Notice there are no interlocking puzzle edges on the puzzle piece to help you fit it to other pieces.

We talked earlier about working memory and how those four slots of working memory appear to hang out in the part of your brain right behind your forehead known as the prefrontal cortex. When you're focusing your attention on something it's almost as if you have an octopus. The octopus of attention that slips its tentacles through those four slots of working memory when necessary to help you make connections to information that you might have in various parts of your brain. Remember, this is different from the random connections of the diffuse mode. Focusing your attention to connect parts of the brain to tie together ideas is an important part of the focused mode of learning. It is also often what helps get you started in creating a chunk. Interestingly when you're stressed your attentional octopus begins to lose the ability to make some of those connections. This is why your brain doesn't seem to work right when you're angry, stressed, or afraid.

Chunks are pieces of information, neuroscientifically speaking, through bound together through meaning or use. You can take the letters P-O and P and bind them together into one conceptual easy to remember chunk, the word pop. [SOUND]. It's like converting a, a cumbersome computer file into a ZIP file. Underneath that single pop chunk is a symphony of neurons that have learned to sing in tune with one another. The complex neural activity that ties together our simplifying abstract chunks of thought. Whether those thoughts pertain to acronyms, ideas, or concepts are the basis of much of the science, literature, and art.

Let's say you want to learn how to speak Spanish. If you're a child hanging around a Spanish speaking household, learning Spanish is as natural as breathing. Your mother says, mama. And you say, mama, right back to her. Your neurons fire and wire together in a shimmering mental loop cementing the relationship in your mind between the sound mama and your mother's smiling face. That scintillating neural loop is one memory trace, which is connected, of course, to many other related memory traces. The best programs for learning language, such as those of the Defense Language Institute where I learned Russian, incorporate structured practice that includes repetition and rote focus mode learning of the language along with more diffuse-like free speech with native speakers. The goal is to embed the basic words and patterns so you can speak as freely and creatively in your new language as you do in your native language.

As it turns out one of the first steps towards gaining expertise in academic topics is to create conceptual chunks, mental leaps that unite scattered bits of information through meaning. The

concept of neural chunks also applies to sports, music, dance, really just about anything that humans can get good at. Basically, a chunk means a network of neurons that are used to firing together so you can think a thought or perform an action smoothly and effectively. Focused practice and repetition, the creation of strong memory traces, helps you to create chunks. The path to expertise is built little by little, small chunks can become larger, and all of the expertise serves to underpin more creative interpretations as you gradually become a master of the material. In other words, as you'll see later, practice and repetition in building chunks aren't all you need to become a truly creative master of the material you're learning. Chunking helps your brain run more efficiently. Once you chunk an idea, a concept, or an action, you don't know need to remember all the little underlying details. You've got the main idea, the chunk, and that's enough. It's like getting dressed in the morning. You just think one simple thought like, I'll get dressed, but it's amazing when you realize the complex swirl of underlying activities that take place with that one, simple chunk of thought. Next, we'll talk about how you can form a chunk.

I'm Barbara Oakley. Thanks for learning how to learn. [BLANK_AUDIO]

How to form a Chunk – Part 1

In this video, we're going to give you a little background about how to make a chunk.
If you're learning to play a difficult song on the guitar, the neural representation of the song in your mind can be considered as a rather large chunk. You would first listen to the song. Maybe you'd even watch someone else playing the song especially if you were just a beginner who was learning things like, how to hold the guitar.

Getting an initial sense of the pattern you want to master for yourself is similar for most subjects or skills. You often have to grasp little bits of songs that become neuro mini-chunks, which will later join together into larger chunks. For example, over several days, you might learn how to smoothly place the musical passages on a guitar, and when you've grasped those passages, you could join them together with other passages that you've learned, gradually putting everything together so you can play the song. In learning a sport, say basketball, soccer, golf. You grasp and master various bits and pieces of the skills you need. You're creating little neural mini-chunks that you can then gradually knit together into larger neural chunks. Later you can hit those larger chunks into still larger and more complex chunks that you can draw up in an instant, in reaction to say to a slight, shift and twist in a soccer ball that's coming your way.

The best chunks are the ones that are so well ingrained, that you don't even have to consciously think about connecting the neural pattern together. That, actually, is the point of making complex ideas, movements or reactions into a single chunk. You can see this in language learning. In the beginning often just saying a single word with the proper nuance, tone and accent involves a lot of practice. Stringing extemporaneous sentences together involves the ability to creatively mix together various complex mini-chunks and chunks in the new language.

To see what I mean, try repeating the following tongue-twister in the Indian language of Kannada.
>> Hi, I am Shilpa Konkani. I am native speaker of Kannada which is one of the oldest language spoken in India. Today, I'm going share with you a tongue-twister in Kannada. So let's get started. Terikere yri male muru kari kurimari meyuthiddavu. >> Not easy, is it? Unless you are a native speaker of Kannada, but the language was learned bit by bit.

Learning in math and science involves the same approach. When you're learning new math and science material, you're often given sample problems with worked out solutions. This is because, when you're first trying to understand how to work a problem, you have a heavy cognitive load. So it helps to start out with a work through example. It's like first listening to a song before trying to play the song yourself. Most of the details of the work out solution are right there, and your job is simply to figure out why the steps are taken the way they are. They can help you see the key features, and underline principles of a problem.

One concern about using worked out examples in math and science to help you in starting to form chunks, is that it can be all too easy to focus too much on why an individual step works and not on the connection between steps. That is, on why this particular step is the next thing you should do. So keep in mind that I'm not just talking about a cookie-cutter, just-do-as-you're told, mindless approach when following a worked-out solution. It's more like using a road map to help you when traveling to a new place. Pay attention to what's going on around you when you're using the map,

and soon you'll find yourself able to get there on your own. You'll even be able to figure out new ways of getting there.

Next, we'll walk you through the actual steps of chunk formation. I'm Barbara Oakley. Thanks for learning how to learn.

[MUSIC] #Hey little girl sometimes the times get hard but soon #the storm will pass and you'll be playing in the yard. #Hey little girl sometimes you might feel sad but some #day you'll realize it really ain't that bad. Just part of growing up.# [MUSIC]

How to Form a Chunk – Part 2

[SOUND]

In this video I'm going to walk you through the basic steps behind how to make a chunk. Every discipline is a little different. Chunking in the subject of history, for example, is quite different from chunking in chemistry or in karate. In my explanations here, I'm going to lean a little more towards explaining chunking of mental ideas rather than physical body motions. But you'll see that the two approaches are closely related. So, whether you're learning something mental or something physical, you'll find some helpful ideas here.

The first step on chunking is simply to *focus your undivided attention* on the information you want to chunk. If you had the television going on in the background, or you're looking up every few minutes to check or answer your phone or computer messages, it means you're going to have more difficulty in making a chunk, because your brain is not really focusing on chunking the new material. When you first begin to learn something, you're making new neural patterns and connecting them with pre-existing patterns that are spread through many areas of the brain. Your octopus tentacles, so to speak, can't reach very well if some of them are off on other thoughts using up some of the limited slots in your working memory.

The second step in chunking is to *understand the basic idea* you're trying to chunk, whether it's understanding a concept such as continental drift, seeing the connection between the basic elements of the plot for a story, grasping the economic principle of supply and demand, or comprehending the essence of a particular type of math problem. Students can often synthesize the gist; that is figure out the main idea or ideas, pretty naturally. Or at least they can grasp those ideas if they allow the focused and diffuse modes of thinking to take turns in helping them figure out what's going on. Understanding is like a superglue that helps hold the underlying memory traces together. It creates broad encompassing traces that can link to other memory traces. Can you create a chunk if you don't understand? Yes, but it's often a useless chunk that won't fit in with, or relate to other material of your learning. That said, it's important to realize that just understanding how a problem was solved, for example, does not necessarily create a chunk that you can easily call to mind later. Don't confuse the "Aha!" of a breakthrough in understanding, with solid expertise. That's part of why you can grasp an idea when a teacher presents it in class, but if you don't review it fairly soon after you first learned it, it can seem incomprehensible when it comes time to prepare for a test. In math and science related subjects, closing the book and testing yourself on whether you, yourself, can solve the problem you think you understand, will speed up your learning at this stage. You often realize the first time you actually understand something is when you can actually do it yourself. It's the same in many disciplines, just looking at someone else's painting doesn't mean you could actually create that painting yourself, and just hearing a song won't give you the expertise you need to sing it in the same resonant fashion. >> [MUSIC] >> Just because you see it or even that you understand it, it doesn't mean that you can actually do it. Only doing it yourself helps create the neural patterns that underlie true mastery.

The third step to chunking is *gaining context*, so you can see not just how, but also when to use this chunk. Context means going beyond the initial problem and seeing more broadly, repeating and practicing with both related and unrelated problems, so that you can see not only when to use the

chunk, but when not to use it. This helps you see how your newly formed chunk fits into the bigger picture. In other words, you may have a tool in your strategy or problem solving tool box, but if you don't know when to use that tool, it's not going to do you a lot of good. Ultimately, practice helps you broaden the networks of neurons that are connected to your chunk, ensuring it's not only firm, but also accessible from many different paths. As you can see from this top down, bottom up illustration, learning takes place in two ways. There's a bottom up chunking process, where practice and repetition can help you both build and strengthen each chunk, so you can easily access it whenever you need to. And there's also a, a sort of a top down big picture process that allows you to see what you're learning and where it fits in. Both processes are vital in gaining mastery over the material. Context is where bottom up and top down learning meet. To clarify here, chunking may involve your learning how to use a certain problem-solving technique. Context means learning when to use that technique instead of some other technique. Doing a rapid two-minute picture walk through a chapter in a book before you begin studying it, glancing at pictures and section headings, can allow you to gain a sense of the big picture. So can listening to a very well organized lecture. These kinds of activities can help you know where to put the chunks you're constructing, how the chunks relate to one another, just as you see here, with the image of the man in the car. Learn the major concepts or points first. These are often the key parts of a good instructor or book chapter's outline, flow charts, tables, or concept maps. Once you have this done, fill in the details. Even if a few of the puzzle pieces are missing at the end of your studies, you can still see the big picture. So there you go!

Summing it up, chunks are best built with focused attention, understanding of the basic idea, and practice to help you gain mastery and a sense of the big picture context. Those are the essential steps in making a chunk and fitting that chunk into a greater conceptual overview of what you're learning. But there's more.

I'm Barbara Oakley. Thanks for learning how to learn. [BLANK_AUDIO]

Illusions of Competence

[SOUND]. In this video, we're going to talk about some essential ideas in getting your learning on track. The importance of recall, illusions of competence in learning. Mini-testing and the value of making mistakes.

One of the most common approaches for trying to learn material from a book or from notes is simply to reread it. But psychologist, Jeffrey Karpicke, has shown that this approach is actually much less productive than another, very simple, technique. *Recall*. After you've read the material, simply look away, and see what you can recall from the material you've just read. Karpicke's research, published in the Journal Science, provided solid evidence along these lines. Students studied a scientific text and then practiced it, by recalling as much of the information as they could. Then they re-studied the text and recalled it again. That is, they tried to remember the key ideas, once more. The results, in the same amount of time, by simply practicing and recalling the material students learned far more and at a much deeper level than they did using any other approach. Including simply rereading the text a number of times. Or drawing concept maps that supposedly enrich the relationships in the materials under study.

This improved learning comes whether students take a formal test, or just informally test themselves. This gives an important reminder. When we retrieve knowledge, we're not just being mindless robots. The retrieval process itself enhances deep learning, and helps us to begin forming chunks. It's almost as if the recall process helps build in little neural hooks, that we can hang our thinking on. Even more of a surprise to researchers, was that the students themselves predicted that simply reading and recalling the materials, wasn't the best way to learn. They thought, concept mapping, drawing diagrams that show the relationship between the concepts would be the best. But if you're trying to build connections between chunks, before the basic chunks are embedded in the brain, it doesn't work as well. It's like trying to learn advanced strategy in chess, before you even understand the basic concepts of how the pieces move. Using recall, mental retrieval of the key ideas, rather than passive rereading, will make your study time more focused and effective. The only time rereading text seems to be effective, is if you let time pass between the rereading, so that it becomes more of an exercise in spaced repetition.

One way to think about this type of learning and recall, is shown right here. As we mentioned earlier, there are four or so slots, in working memory. When you're first learning how to understand a concept, or technique to solve a problem, your entire working memory is involved in the process. As shown by this sort of, mad tangle of connections between the four slots of working memory. As you begin to chunk the concept, you will feel it connecting more easily and smoothly in your mind. Once the concept is chunked, it takes up only one slot in working memory. It simultaneously becomes one smooth strand that's easy to follow, and to use to make new connections. The rest of your working memory is left clear. That dangling strand of chunked material has, in some sense, increased the amount of information available to your working memory. It's as if the slot in working memory is a hyperlink that's been connected to a great big web page.

Now you understand why it is key that you are the one doing the problem solving or mastering the concept. Not whoever wrote the solution manual, or book, on whatever subject you're studying. If you just look at the solution, for example, then tell yourself. Oh yeah, I see why they did that. Then

the solution is not really yours. You've done almost nothing to knit those concepts into your own underlying neural circuitry. Merely glancing at a solution and thinking you truly know it yourself is one of the most common illusions of competence in learning. You must have the information persisting in your memory if you're to master the material well enough to do well on tests and to think creatively with it. In a related thing, you may be surprised to learn that highlighting and underlining must be done very carefully. Otherwise it can not only be ineffective, but also misleading. It's as if, making lots of motions with your hand can fool you into thinking you've placed the concept in your brain. If you do mark up the text, try to look for main ideas before making any marks. And try to keep your underlining or highlighting to a minimum. One sentence or less per paragraph.

On the other hand, words or notes in a margin that synthesize key concepts are a very good idea. Jeff Karpicke, the same researcher who's done such important work related to recall, has also done research on a related topic. *Illusions of competence in learning*. The reason students like to keep rereading their notes or a textbook, is that when they have the book or Google open right in front of them, it provides the illusion that the material is also in their brains. But it's not, because it can be easier to look at the book instead of recalling, students persist in their illusions studying in a way that just isn't very effective. This is a reminder that just wanting to learn the material, and spending a lot of time with it, doesn't guarantee you'll actually learn it. A super helpful way to make sure you're learning and not fooling yourself with illusions of competence, is to test yourself on whatever you're learning. In some sense, that's what recall is actually doing. Allowing you to see whether or not you really grasp an idea. If you make a mistake in what you are doing, it's actually a very good thing. You want to try not to repeat you mistakes, of course, but mistakes are very valuable to make in your little self-tests before high stakes real tests. Because they allow you to make repairs and you're thinking flaws bit by bit mistakes help correct your thinking, so that you can learn better and do better.

As you know now recall is a powerful tool. But here's another tip, recalling material when you are outside your usual place of study can also help you strengthen your grasp of the material. You don't realize it, but when you are learning something new you can often take in subliminal cues for the room and the space around you at the time you were originally learning the material. This can throw you off when you take tests because you often take tests in a room that's different from the room you were learning in. By recalling and thinking about the material when you are in various physical environment, you become independent of the cues from any one given location. That helps you avoid the problem of the test room being different from where you originally learned the material.

I'm Barbara Oakley, thanks for learning about learning.

What Motivates You?

Welcome back! It is hard to learn when you're not into it. But if it's something you're really interested in, learning is easy. Why is that?

Most of the neurons in your cortex carry information about what is happening around you and what you're doing. Your brain also has a set of diffusely projecting systems of neuromodulators, that carry information not about the content of an experience but its importance and value to your future, neuromodulators are chemicals that influence how a neurons responds to other neurons. And today we will discuss three of them. *Acetylcholine, Dopamine and Serotonin*.

Acetylcholine neurons form neuromodulatory connections to the cortex that are particularly important for focused learning, when you are paying close attention. These acetylcholine neurons project widely and activate circuits that control synaptic plasticity. Leading to new long term memory. Neuromodulators also have a profound impact on your unconscious mind.

One of the great brain discoveries in my life time, has been that our motivation is controlled by a particular chemical substance called *Dopamine*. Which is found in a small set of neurons in our brain stem shown here in orange. These dopamine neurons are part of a large brain system that controls reward learning and in particular in the basal ganglia, which is located in the green region above the dopamine neurons and below the cortex at the top of the brain. Dopamine is released from these neurons, when we receive an unexpected reward. Dopamine signals project widely and have a very powerful effect on learning. And this is something that also affects decision-making. And even the value of sensory inputs.

Dopamine is in the business of predicting future rewards and not just the immediate reward. This can motivate you to do something that may not be rewarding right now but will lead to a much better reward in the future. Addictive drugs artificially increase dopamine activity and fool your brain into thinking that something wonderful has just happened. In fact just the opposite has just happened. This leads to craving and dependence, which can hijack your free will and can motivate actions that are harmful to you. Loss of Dopamine neurons leads to a lack of motivation; and something called anhedonia, which is a loss of interest in things that once gave you pleasure. Severe loss of Dopamine neurons causes resting tremor, slowness, rigidity, this is called Parkinson's disease. Ultimately it leads to catatonia, a complete lack of any movement. Dopamine neurons are part of the unconscious part of your brain that you learned about in the first week. When you promise to treat yourself something after a study section you are tapping into your dopamine system.

Serotonin is a third diffuse neuromodulatory system that strongly affects your social life. In monkey troops the alpha male has the highest level of serotonin activity and the lowest ranking male has the lowest levels. Prozac, which is prescribed for clinical depression, raises the level of Serotonin activity. The level of Serotonin is also closely linked to risk taking behavior. With higher risk in lower Serotonin monkeys. Inmates in jail for violent crimes have some of the lowest levels of serotonin activity in society.

Finally your emotions strongly affect learning as you are well aware. Emotions were once thought to be separate from cognition but recent research has shown that emotions are intertwined with

perception and attention and interact with learning and memory. The amygdala an almond shaped structure shown here, nestled down at the base of the brain is one of the major centers where cognition and emotion are effectively integrated. The amygdala is part of the limbic system which together with hippocampus is involved in processing memory and decision making as well as regulating emotional reactions. You will want to keep your amygdala happy to be an effective learner. The emotions and your neuromodulatory systems are slower than perception and action but are no less important for successful learning.

If you want to learn more about Acetylcholine, Dopamine, and Serotonin, look them on www.brainfacts.org, a website that is filled with valuable facts about your brain.

I'm Terry Sejnowski. Happy learning, until we meet again.

The Value of a Library of Chunks

[SOUND]

The ability to combine chunks in new and original ways underlies a lot of historical innovation. Bill Gates and other industry leaders set aside extended week-long reading periods so that they can hold many and varied ideas in mind during one time. This helps generate their own innovative thinking by allowing fresh in mind not yet forgotten ideas to network amongst themselves.
Basically what people do to enhance their knowledge and gain expertise is to gradually build the number of chunks in their mind. Valuable bits of information, they can piece together in new and creative ways. Chess masters, for example, can easily access thousands of different chess patterns. Musicians, linguists and scientists can each access similar chunks of knowledge in their own disciplines. The bigger and more well practiced your chunked mental library, whatever the subject you're learning, the more easily you'll be able to solve problems and figure out solutions. As we'll discover soon, chunking isn't all you'll need to develop creative flexibility in your learning. But it's an important component.

Chunks can also help you understand new concepts. This is because when you grasp one chunk, you'll find that that chunk can be related in surprising ways to similar chunks, not only in that field, but also in very different fields. This idea is called *transfer*. For example, concepts and problems solving methods you learned for physics can be very similar to chunked concepts in business. I've found some aspects of language learning were very helpful for me when I later began to learn Computer Programming.

A chunk is a way of compressing information much more compactly. As you gain more experience in chunking in particular subject, you'll see that the chunks you're able to create are bigger. In some sense, that the ribbons are longer. Not only are those ribbons longer but the neural patterns are in some sense darker. They're more solid and firmly ingrained. If you have a library of concepts and solutions internalized as chunked patterns, you can think of it as a collection or a library of neural patterns. When you're trying to figure something out, if you have a good library of these chunks, you can more easily skip to the right solution by metaphorically speaking, listening to whispers from your diffuse mode. Your diffuse mode can help you connect two or more chunks together in new ways to solve novel problems. Another way to think of it is this. As you build each chunk, it is filling in a part of your larger knowledge picture. But if you don't practice with your growing chunks, they can remain faint, and it's harder to put together the big picture of what you're trying to learn.

In building a chunked library, you're training your brain to recognize not only a specific concept, but different types and classes of concepts so that you can automatically know how to solve quickly or handle whatever you encounter. You'll start to see patterns that simplify problem solving for you and will soon find that different solution techniques are lurking at the edge of your memory. Before midterms or finals it can be easy to brush up and have these solutions at the mental ready.

There are two ways to figure something out or to solve problems. First there's sequential step by step reasoning, and second through a more holistic intuition. Sequential thinking, where each small step leads deliberately towards a solution, involves the focused mode. Intuition on the other hand often seems to require this creative diffuse mode linking of several seemingly different focused

mode thoughts. Most difficult problems and concepts are grasped through intuition, because these new ideas make a leap away from what you're familiar with. Keep in mind that the diffuse mode's semi-random way of making connections means that the solutions they provide should be very carefully verified using the focused mode. Intuitive insights aren't always correct. You may think there are so many problems and concepts, just in a single section or chapter of whatever you're studying, there's just no way to learn them all. This is where the law of serendipity comes into play. Lady luck favors the one who tries. Just focus on whatever section you're studying. You'll find that once you put that first problem or concept in your mental library, whatever it is, then the second concept will go in a little more easily. And the third more easily still. Not that all of this is a snap, but it does get easier.

I am Barbara Oakley. Thanks for learning about learning. [BLANK_AUDIO]

Overlearning, Chocking, Einstellung, and Interleaving

When you're learning a new idea, for example a new vocabulary word or a new concept or a new problem solving approach, you sometimes tend to practice it over and over again during the same study session. A little of this is useful and necessary, but continuing to study or practice after you've mastered what you can in the session is called *overlearning*.

Overlearning can have its place. It can produce an automaticity that can be important when you're executing a serve in tennis or a perfect piano concerto. If you choke on tests or public speaking, overlearning can be especially valuable. You know that even expert public speakers practice on the order of 70 hours for a typical 20-minute TED Talk? Automaticity can indeed be helpful in times of nervousness, but be wary of repetitive overlearning during a single session. Research has shown it can be a waste of valuable learning time. The reality is, once you've got the basic idea down during a session, continuing to hammer away at it during the same session doesn't strengthen the kinds of long term memory connections you want to have strengthened. Worse yet, focusing on one technique is a little like learning carpentry by only practicing with a hammer. After a while you think you can fix anything by just bashing at it.

Using a subsequent study session to repeat what you're trying to learn is just fine and often valuable. It can strengthen and deepen your chunked neuron patterns. But be wary; repeating something you already know perfectly well, is, face it, easy. It can also bring the illusion of competence that you've mastered the full range of material, when you've actually only mastered the easy stuff. Instead, you want to balance your studies by deliberately focusing on what you find more difficult. This focusing on the more difficult material is called *deliberate practice*. It's often what makes the difference between a good student and a great student.

All this is also related to a concept known as *Einstellung*. In this phenomenon, your initial simple thought, an idea you already have in mind or a neural pattern you've already developed and strengthened, may prevent a better idea or solution from being found. We saw this in the focus pinball picture, where your initial pinball of thought went to the upper part of the brain, but the solution thought pattern was in the lower part. The crowded bumpers of the focus mode and the previous patterns you built can create a sort of rut that prevents you from springing to a new place where the solution might be found.

Incidentally, the German word Einstellung means mindset. Basically you can remember einstellung as installing a roadblock because of the way you were initially looking at something. This kind of wrong approach is especially easy to do in sports and science, not to mention other disciplines, because sometimes your initial intuition about what's happening or what you need to be doing is misleading. You have to unlearn your erroneous older ideas or approaches even while you're learning new ones.

One significant mistake students sometimes make in learning is jumping into the water before they learn to swim. In other words, they blindly start working on homework without reading the textbook, attending lectures, viewing online lessons, or even speaking with someone knowledgeable. This is a recipe for sinking. It's like randomly allowing a thought to, kind of pop off in the focus mode pinball

machine, without paying any real attention to where the solution truly lies. Understanding how to obtain real solutions is important in learning and in life.

Mastering a new subject means learning not only the basic chunks, but also learning how to select and use different chunks. The best way to learn that is by practicing jumping back and forth between problems or situations that require different techniques or strategies. This is called *interleaving*. Once you have the basic idea of the technique down during your study session, sort of like learning to ride a bike with training wheels, start interleaving your practice with problems of different types or different types of approaches, concepts, procedures. Sometimes this can be a little tough to do. A given section in a book, for example, is often devoted to a specific technique, so when you flip to that section you already know which technique you're going to be using. Still, do what you can to mix up your learning.

In science and math in particular it can help to look ahead at the more varied problem sets that are sometimes found at the end of chapters. Or you can deliberately try to make yourself occasionally pick out why some problems call for one technique as opposed to another. You want your brain to become used to the idea that just knowing how to use a particular concept, approach, or problem-solving technique isn't enough. You also need to know when to use it. Interleaving your studies, making it a point to review for a test, for example, by skipping around through problems in the different chapters and materials can sometimes seem to make your learning a little more difficult, but in reality, it helps you learn more deeply.

Interleaving is extraordinarily important. Although practice and repetition is important in helping build solid neural patterns to draw on, it's interleaving that starts building flexibility and creativity. It's where you leave the world of practice and repetition, and begin thinking more independently. When you interleave within one subject or one discipline, you begin to develop your creative power within that discipline. When you interleave between several subjects or disciplines, you can more easily make interesting new connections between chunks in the different fields, which can enhance your creativity even further. Of course it takes time to develop solid chunks of knowledge in different fields, so sometimes there's a tradeoff. Developing expertise in several fields means you can bring very new ideas from one field to the other, but it can also mean that your expertise in one field or the other isn't quite as deep as that of the person who specializes in only one discipline. On the other hand, if you develop expertise in only one discipline, you may know it very deeply but you may become more deeply entrenched in your familiar way of thinking and not be able to handle new ideas.

Philosopher of science Thomas Kuhn discovered that most paradigm shifts in science are brought about either young people or people who were originally trained in a different discipline. They're not so easily trapped by einstellung, blocked thoughts due to their preceding training. And of course there's the old saying that science progresses one funeral at a time as people entrenched in the old ways of looking at things die off.

Finally, don't make the mistake of thinking that learning only occurs in the kinds of subjects you acquire from teachers or books. When you teach a child how to deal effectively with a bully, or you fix a leaky faucet, or you quickly pack a small suitcase for a business trip to Hong Kong, all of these illustrate the outcomes of important aspects of learning. Physicist Richard Feynman was inspired in

his Nobel Prize-winning work by watching someone throw a dinner plate into the air in a cafeteria. Mike Rowe of the television shows Dirty Jobs and Somebody's Gotta Do It shows how important and exciting learning can be in a variety of different, non-academic disciplines.

I'm Barbara Oakley. Thanks for learning about learning.

Summary Week 2

[SOUND]

In this video, I'm going to synthesize some of the main ideas of this week's videos. In other words, we'll chunk our week on chunking. Here we go:

- Chunks are pieces of information, neuroscientifically speaking, that are bound together through use and often through meaning. You can think of a chunk as a scintillating network of neurons that compactly synthesizes key ideas or actions.

- Chunks can get bigger and more complex. But at the same time, they're a single easy to access item that you can fit like a ribbon into the slot on your working memory.

- Chunks are best built with focused, undivided attention, understanding of the basic idea, and practice to help deepen your patterns and to help you gain big picture context.

- Simple recall, trying to remember the key points without looking at the page, is one of the best ways to help the chunking process along. It seems to help build neural hooks. They help you better understand the material. Also try recalling material in places that are different from where you originally learned the material, so it becomes more deeply ingrained and accessible, regardless of what room you're in. This can be very helpful for tests.

- Transfer is the idea that a chunk you've mastered in one area can often help you much more easily learn chunks of information in different areas that can share surprising commonalities.

- Interleave your learning by practicing your choice of different concepts, approach, and techniques all in one session. Chunks are very important, but they don't necessarily build flexibility, which is also important in becoming an expert with the material you're learning.

- Illusions of competence in learning – learn to recognize when you're fooling yourself about whether you're actually learning the material. Test yourself frequently. Using little mini-tests to see whether you're actually learning the material, or whether you've been fooling yourself, thinking you're learning when you're actually not. Recall is actually a form of mini-testing. Try to avoid depending too much on highlighting, which can fool you into thinking that the material is going into your brain when it actually isn't.

- Mistakes are a good thing to make when you're learning. They allow you to catch illusions of competence. Avoid practicing only the easy stuff, which can bring the illusion that you've mastered the material.

- Deliberately practice what you find more difficult to gain full mastery of the material.

- Einstellung is when your initial thought, an idea you've already had in mind, or a neural pattern you've already developed well and strengthened, prevents a better idea or solution

from being found. Or keeps you from being flexible enough to accept new, better, or more appropriate solutions. The Law of Serendipity is helpful – Lady Luck favors the one who tries. Just pick one tiny thing out to learn, then another. Just keep trying and you'll be pleasantly surprised at the results.

I'm Barbara Oakley. Thanks for learning about learning. [BLANK_AUDIO]

Introduction to Procrastination and Memory

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This week we're going to be talking about two seemingly different ideas. *Procrastination* and *memory*. But the two topics are intimately related. Why? Because building solid chunks of long term memory, chunks that are easily accessible by your short term memory, takes time. It's not the kind of thing you want to be putting off until the last minute. You already have one good tool for procrastination. The pomodoro. That powerful 25 minute concentrated period of energized focus. This week we're going to fill you in with more information about how procrastination happens and simple ways to tackle it. And this is key. Ways that don't take much will power, then we'll move on to talking about some of the best ways to access your brain's most powerful long-term memory systems.

I'm Barbara Oakley. Thanks for learning how to learn.

Tackling Procrastination: It's easier and more valuable than you think

Arsenic is incredibly toxic. For centuries until modern methods of detection were discovered, murderers found it to be a very popular substance. So you can imagine the shock at the 48th meeting of the German Association of Arts and Sciences in 1875 when two men sat in the front of the audience and downed more than double a deadly dose of arsenic. The next day the men were back at the conference smiling and healthy. How is it possible to take something so bad for you and stay alive, and even look healthy, despite the damage being done at a microscopic level to your body? The answer has an uncanny relationship to procrastination that's what we're going to be talking about in the next few videos.

You've already learned one handy tool to help you with procrastination, the Pomodoro, that 25 minute period of uninterrupted focus followed by a bit of relaxation. This week we're going to learn more. Understanding a little about the cognitive psychology of procrastination, just like understanding the chemistry of poison, can help us develop healthy preventatives. In these videos, I'm going to teach you the lazy person's approach to tackling procrastination. This means you'll be learning about your inner zombies – the routine, habitual responses your brain falls into as a result of specific cues. These zombie responses are often focused on making the here and now better. As you'll see you can trick some of these zombies into helping you fend off procrastination when you need to.

Not all procrastination is bad. Even if you're pretty good already in handling procrastination you'll learn some helpful insights here that can allow you to better prioritize your learning. The reason that learning to avoid procrastination is so important is that good learning is a bit by bit activity. You want to avoid cramming which doesn't build solid neural structures. By putting the same amount of time into your learning but spacing that learning out by starting earlier you'll learn better. First things first.

Unlike procrastination which is easy to fall into, willpower is hard to come by. It uses a lot of neural resources. You shouldn't waste willpower on fending off procrastination except when absolutely necessary. Best of all as you'll see you don't need to. If you'll remember we procrastinate about things that make us a little bit uncomfortable. You think about something you don't particularly like and the pain centers of your brain light up so you shift and narrow your focus of attention to something more enjoyable. This causes you to feel better. At least temporarily but sadly the long term effects of habitual avoidance can be nasty. When you put off your studies it can become even more painful to think about studying it. You can choke on tests because you haven't laid the firm neural foundations you need to feel comfortable with the material.

Procrastination can be a single monumentally important keystone bad habit, a habit in other words that influences many important areas of your life. If you improve your abilities in this area many other positive changes will gradually begin to unfold. Procrastination shares features with addiction. It offers temporary excitement and relief from sometimes boring reality. It's easy to fool yourself for example into thinking that the best use of any given moment is. Surfing the web for information instead of actually reading the textbook or doing the assigned problems. You start to tell yourself stories. For example you might tell yourself that organic chemistry requires special reasoning, your weakness, so of course you're doing very poorly at it. You devise irrational excuses that sound

superficially reasonable like if I study too far ahead of the test I'll forget the material. If you're troubled by procrastination you may even start telling yourself that procrastination is an innate unchangeable characteristic. After all if procrastination were easily fixable wouldn't you have fixed it by now?

The higher you go in your studies however the more important it is to take control of procrastination. Habits that worked in earlier years can turn around and bite you. What I'll show you in these next few videos is how you can become the master of your habit. You should be making the decisions, not your well-meaning but unthinking zombies, your habits. As you'll see, the strategies for dealing with procrastination are simple. It's just that sometimes they aren't intuitively obvious.

So let's return to that story that began this video. The arsenic eaters started with tiny doses of arsenic. In tiny doses, arsenic doesn't seem harmful. You can even build up an immunity to its effects. This can allow you to take larger doses and look healthy, even as the poison is slowly increasing your risk of cancer and ravaging your organs. In a similar way procrastinators put off just that one little thing. They do it again and again gradually growing used to it. They can even look healthy but the long term effects? Not so good.

I'm Barbara Oakley. Thanks for learning how to learn.

Zombies Everywhere

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Just imagine backing out of a driveway for the first time ever in your life. For some of you, that might seem like a pretty exciting proposition. The first time you might do this you would be in hyper alert. The deluge of information coming at you would make the job seem almost impossibly difficult. But, once you've chunked how to back up down your driveway, all you have to do is think, let's go. And, off you go. Your brain goes into this sort of zombie mode, where it is only semi aware of a few key factors, instead of being overwhelmed by all the data. It's the same idea with riding a bicycle. At first, it's really hard, later it's easy.

Neuro-scientifically speaking, chunking is related to habit. Habit is an energy saver for us. It allows us to free our mind for other types of activities. You go into this habitual zombie mode far more often than you might think. That's the point of habit, you don't have to think in a focused manner about what you're doing while you're performing the habit. It saves energy. Habits can be good and bad. They can be brief, like absently brushing back your hair. Or they can be long, for example when you take a walk, or watch television for a few hours after you get home from work.

You can think of habits as having four parts. The first is the *cue*. This is the trigger that launches you into zombie mode. The cue may be something as simple as seeing the first item in your to do list. Time to start next week's homework. Or seeing a text message from a friend. Time to stop work. A cue by itself is, neither helpful nor harmful; it's the routine. What we do in reaction to that cue, that's what matters.

Number two – the *routine*. This is your zombie mode. The routine habitual response your brain is used to falling into when it receives the cue. Zombie responses can be useful, harmless, or sometimes harmful.

Number three, the *reward*. Every habit develops and continues because it rewards us. It gives us an immediate little feeling of pleasure. Procrastination's an easy habit to develop because the reward, moving your mind's focus to something more pleasant, happens so quickly and easily. But good habits can also be rewarded. Finding ways to reward good study habits is important for escaping procrastination.

Number four – the *belief*. Habits have power because of your belief in them. For example, you might feel you'll never be able to change your habits of putting off your studies until late in the day. To change a habit, you'll need to change your underlying belief.

I'm Barbara Oakley, thanks for learning how to learn.

Surf's Up: Process versus Product

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One of the best ways of being effective in your learning is to use mental tools and tricks to inspire and motivate yourself. First, when it comes to learning in general, you should realize that it's perfectly normal to start with a few negative feelings about beginning a learning session. Even when it's a subject you ordinary like, it's how you handle those feelings that matters. Researchers have found that non-procrastinators put their negative thinking aside saying things to themselves like: quit wasting time and just get on with it, once you get going, you'll feel better about it. If you find yourself avoiding certain tasks because they make you feel uncomfortable, you should know there's another helpful way to re-frame things. And that's to learn to focus on process not product.

Process means, the flow of time and the habits and actions associated with that flow of time. As in, I'm going to spend 20 minutes working. *Product* is an outcome, for example, a homework assignment that you need to finish. To prevent procrastination you want to avoid concentrating on product. Instead, your attention should be on building processes. Processes relate to simple habits, habits that coincidentally allow you to do the unpleasant tasks that need to be done. For example, let's say you don't like doing homework in a particular class. So you put off working on the homework. It's only five questions you think. How hard could that be? Deep down, you realize that answering these five questions could be a very lengthy job. It's easier to live in a fantasy world where the five questions, or the ten page report or whatever, can be done at the last minute. Your challenge is to avoid focusing on the product, the answers to the questions. The product is what triggers the pain that causes you to procrastinate. Instead, you need to focus on the process or processes – the small chunks of time you need over days or even weeks to answer the questions or prepare for tests. Who cares whether you finish the homework or grasp the key concepts in any one session. The whole point instead, is that you calmly put forth your best effort for a short period.

Now process. Notice how in this picture physicist and surfer Garret Lacy is focused on the moment. Not on the accomplishment of having surfed that wave. For you, one of the easiest ways to focus on process is to focus on doing a Pomodoro, a 25 minute timed work session, not on completing a task. The essential idea here is that the zombie habitual part of your brain likes processes because it can march mindlessly along. It's far easier to enlist the friendly zombie habit to help with a process, than to help with a product. By focusing on process rather than product, you allow yourself to back away from judging yourself, am I getting closer to finishing? And instead you allow yourself to relax into the flow of the work. The key is when a distraction arises, which it inevitably will, you want to train yourself to just let it flow by. Of course, setting yourself up so that distractions are minimal is also a very good idea. Many students find that either a quiet space or noise canceling headphones if, if you can afford them, can be helpful when they're really trying to concentrate.

I'm Barbara Oakley. Thanks for learning above learning. [BLANK_AUDIO]

Harnessing Your Zombies to Help You

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In this video, we're going to get into the specifics of harnessing your zombie powers of habit to help you avoid procrastination while minimizing your use of willpower. You don't want to do a full scale change of old habits. You just want to override parts of them and develop a few new ones. The trick to overriding a habit is to look to change *your reaction to a cue*. The only place you need to apply willpower is to change your reaction to the cue. To understand that, it helps to go back through the four components of habit and re-analyze them from the perspective of procrastination.

The first one is *the cue*. Recognize what launches you into your zombie procrastination mode. Cues usually fall into one of the four following categories:

1. Location
2. Time
3. How you feel, and
4. Reactions either to other people or to something that just happened

Do you look something up on the web and then find yourself web surfing? Does a text message disturb your studying taking you 10 minutes to get back into the flow of things even when you try to keep yourself on task? The issue with procrastination is that because it's an automatic habit, you're often unaware that you've begun to procrastinate. You can prevent the most damaging cues by shutting off your cell phone or keeping yourself away from the internet and other distractions for brief periods of time, as when you're doing a pomodoro.

Number two, *the routine*. Let's say then instead of doing your studies you often divert your attention to something less painful. Your brain wants to automatically go into this routine when you've gotten your cue. So this, is the reaction clue where you must actively focus on re-wiring your old habit. The key to re-wiring is to have a plan. Developing a new ritual can be helpful. Some students make it a habit to leave their phone in their car when they head in for class which removes a potent distraction. Many students discovered the value of settling into a quiet spot in the library or closer to home, the productive effects of simply sitting in a favorite chair at the proper time with all Internet access disconnected. Your plan may not work perfectly at first, but just keep at it. Adjust the plan if necessary, and savor those victories when your plan works. Don't try to change everything at once. The Pomodoro technique can be especially helpful in shifting your reaction to the cues.

Number three is *the reward*. This can sometimes require a little bit of investigation. Why are you procrastinating? Can you substitute an emotional payoff, maybe a feeling of pride for accomplishing something, even if it's small, a sense of satisfaction? Can you win a small internal bet or a contest about something you've turned into a personal game or allow yourself to indulge in a latte or read a favorite web site, provide yourself, maybe, with an evening of mindless television or web surfing without guilt, and will you give yourself a bigger reward for a bigger achievement? Maybe movie tickets or a sweater or an utterly frivolous purchase. Remember that habits are powerful because they create neurological cravings. It helps to add a new reward if you want to overcome your previous cravings. Only once your brain starts expecting that reward will the important rewiring take place that will allow you to create new habits. Many people find that setting a reward at a specific

time, for example, breaking for lunch with a friend at the deli at noon or stopping the main task at 5 p.m., gives a solid, mini deadline that can help spur work. Don't feel bad if you find you have trouble getting into a flow state at first. I sometimes find it takes a few days of drudgery, through a few cycles of the Pomodoro technique before flow begins to unfold. And I find myself starting to enjoy work on a new topic. Also remember that the better you get at something, the more enjoyable it can become.

Number four is *the belief*. The most important part of changing your procrastination habit is the belief that you can do it. You may find that when the going gets stressful. You long to fall back into old, more comfortable habits. Belief that your new system works is what can get you through. Part of what can underpin is to develop a new community. Hang out with classmates, or virtually hang out with MOOC-mates, who may have that can-do philosophy that you too want to develop. Developing and encouraging culture with like-minded friends can help us remember the values that in moments of weakness we tend to forget.

I'm Barbara Oakley, thanks for learning how to learn. [BLANK_AUDIO]

Juggling Life and Learning

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Learning for most people involves a complex balancing of many different tasks. A good way for you to keep perspective about what you're trying to learn and accomplish, is to once a week write a brief weekly list of key tasks in a planner journal. Then each day on another page of your planner journal, write a list of the tasks that you can reasonably work on or accomplish. Try to write this daily task list the evening before. Why the evening before? Research has shown that this helps your subconscious to grapple with the tasks on the list so you can figure out how to accomplish them. Writing the list before you go to sleep, enlists your zombies, to help you accomplish the items on the list the next day. If you don't write your tasks down on a list, they lurk at the edge of the four or so slots of your working memory, taking up valuable mental real estate. But once you make a task list, it frees working memory for problem solving. So let's look at one of my daily task lists.

As you can see here, there are only six items. Some are process oriented. For example, I have a paper due to a journal in several months. So, I spend a little focus time on most days working towards completing it. A few items are product oriented. But that is only because they are doable within a limited period of time. Note my reminders. I wanted to keep my focus on each item when I'm working on it. And I want to have fun. I did catch myself getting side tracked, because I forgot to shut down my email. To get myself back into gear, I set a 22 minute Pomodoro challenge, using a timer on my computer desktop. Why 22 minutes? Well, why not? I, I don't have to do the same thing each time. And notice, too, that by moving to Pomodoro mode, I've switched to a process orientation. None of the items on my list is too big, because I've got other things going on in my day. Meetings to go to, a lecture to give. Sometimes I sprinkle a few tasks that involve physical motion on my list, even if it's just cleaning something. Which, I'll admit, isn't ordinarily one of my favorite things to do. Somehow because I'm using them as diffuse mode breaks, I often look forward to them.

Mixing other tasks up with your learning seems to make everything more enjoyable and keeps you from prolonged and unhealthy bouts of sitting. Over time, as I've gained more experience, I've gotten much better at gauging how long it takes to do any given task. You'll find yourself improving quickly as you become more realistic about what you can reasonably do in any given time. Make notes in your planner journal about what works and what doesn't. Notice my goal finish time for the day, 5 p.m. doesn't seem quite right, does it? But it is right, and it's one of the most important components of your daily planner journal. Planning your quitting time is as important as planning your working time. Generally, I aim to quit at 5 p.m., although when I'm learning something new, it can sometimes be a pleasure to look at it again after I've taken an evening break, just before I go to sleep, and occasionally, there's a major project that I'm wrapping up, like say, this MOOC that has me running into a bit of overtime. You might think, well, yeah, you know, but you're a professor who's shall we say, past your youthful study days. Of course an early quitting time is fine for you. However, one of my most admired study experts, Cal Newport, used the 5 p.m., quitting time through most of his student career. He ended up getting his PhD from MIT. In other words, this method, implausible though it may seem for some, can work for undergraduate and graduate students in rigorous academic programs.

Time after time, those who are committed to maintaining healthy leisure time along with their hard work, outperform those who doggedly pursue an endless treadmill. Of course, your life may not lend itself to such a schedule with breaks and leisure time. You may be running on fumes with two jobs and too many classes. But however your life is going, try to squeeze a little break time in. One more thing – as writing coach Daphne Graygrant recommends to her writing clients, eat your frogs first in the morning. Try to work on a most important and most disliked task first. At least just one Pomodoro, as soon as you wake up. This is incredibly effective. Do you need to sometimes make changes in your plans because of unforeseen events? Of course, but remember the law of serendipity; Lady Luck favors the one who tries. Planning well is part of trying. Keep your eye on your learning goal, and try not to get too unsettled by occasional roadblocks.

I'm Barbara Oakley. Thanks for learning how to learn. [BLANK_AUDIO]

Summing Up Procrastination

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Learning well often involves bit by bit, day by day building of solid neural scaffolds. Rather like a weight lifter builds muscle with day to day exercise. This is why tackling procrastination is so incredibly important. You want to keep up with your learning and avoid last minute cramming. So with that, here's an overview of the key aspects of tackling procrastination.

- Keep a planner journal so you can easily track when you reach your goals and observe what does and doesn't work.
- Commit yourself to certain routines and tasks each day.
- Write your planned tasks out the night before so your brain has time to dwell on your goals and help ensure success.
- Arrange your work into a series of small challenges.
- Always make sure you, and your zombies, get lots of rewards.
- Take a few minutes to savor the feelings of happiness and triumph, which also gives your brain a chance to temporarily change modes.
- Deliberately delay rewards until you've finished a task.
- Watch for procrastination cues. Try putting yourself in new surroundings with few procrastination cues, such as the quiet section of a library.
- Gain trust in your new system. You want to work hard during times of focused concentration and also to trust your system enough so that when it comes time to relax, you actually relax without feelings of guilt or worry.
- Have back up plans for when you still procrastinate. No one’s perfect after all.
- Eat your frogs first every day. Happy experimenting.

I'm Barbara Oakley. Thanks for learning, how to learn.

Diving Deeper into Memory

In this video and the next, we're going to deepen our understanding of memory. As you're probably beginning to understand, memory is only part of learning and developing expertise but it's often an important part. It may surprise you to learn that we have outstanding visual and spatial memory systems that can help form part of our long-term memory. Here's what I mean.

If you were asked to look around a house you never visited before, you'd soon have a sense of the general furniture layout and where the rooms were, color scheme, the pharmaceuticals in the bathroom cupboard. In just a few minutes, your mind would acquire and retain thousands of new pieces of information. Even weeks later, you'd still hold far more in your mind than if you'd spent the same amount of time staring at a blank wall. Your mind is built to retain this kind of general information about a place. You can greatly enhance your ability to remember if you tap into these naturally super-sized, visual, spatial memorization abilities. Our ancestors never needed a vast memory for names or numbers but they did need a memory for how to get back home from the three day deer hunt, or for the location of those plump blueberries on the rocky slopes to the South of the camp. These evolutionary needs helped lock in a superior "where things are" and "how they look" memory system.

To begin tapping into your visual memory system try making a very memorable visual image representing one key item you want to remember. For example, here's an image you could use to remember Newton's second law, $f = ma$. This is a fundamental relationship relating force to mass and acceleration (force = mass x acceleration). And it only took humans, oh, a couple of hundred thousand years to figure out. The letter *f* in the formula could stand for flying, *m* could stand for mule, and *a*, well that's up to you.

Part of the reason an image is so important to memory is that images connect directly to your right brain's visual spatial centers. The image helps you encapsulate a seemingly humdrum and hard to remember concept by tapping into visual areas with enhanced memory abilities. The more neural hooks you can build by evoking the senses, the easier it will be for you to recall the concept and what it means. Beyond merely seeing the mule, you can smell the mule, you can feel the same windy pressure the mule is feeling. [SOUND]. You can even, hear the wind whistling past. The funnier and more evocative the images, the better. Focusing your attention brings something into your temporary working memory, but for that something to move from working memory to long term memory two things should happen: the idea should be memorable; there's a gigantic flying mule braying $f = ma$ on my couch, and it must be repeated. Otherwise remember your tiny metabolic vampires, they can suck away the neural pattern related to that memory before it can strengthen and solidify.

Repetition is important. Even when you make something memorable, repetition helps get that memorable item firmly lodged into long-term memory. Remember to repeat not a bunch of times in one day but sporadically over several days. Index cards can often be helpful. Writing and saying what you're trying to learn seems to enhance retention. For example, if you're trying to learn concepts in physics you might take an index card and write the greek letter *rho* (ρ). That's a common abbreviation for density. You'd write it on one side and you'd write the remaining information on the other. Handwriting helps you to more deeply encode, that is convert into neural memory structures

what you are trying to learn. While you're writing out the kilograms per cubic meter (kilogram/m^3) you might imagine a shadowy kilogram just feel that mass lurking in an oversize piece of baggage that happens to be one meter on each side. The more you can turn what you're trying to remember into something memorable, the easier it will be to recall.

You'll want to say the word and its meaning aloud to start setting auditory hooks to the material. Next, just look at the side of the card with the Greek letter *rho (ρ)* on it, and see whether you can remember what's on the other side of the card. If you can't, flip it over and remind yourself what you're supposed to know. If you can remember, put the card away. Now, do something else. Perhaps prepare another card and test yourself on it. Once you have several cards together, try running through them all and even mixing them around to see if you can remember them. This helps interleave your learning. Don't be surprised if you struggle a bit. Once you've given your cards a good try, put them away. Wait and take them out again, maybe before you go to sleep. Remember that sleep is when your mind repeats patterns and pieces together solutions. Briefly repeat what you want to remember over several days. Perhaps for a few minutes each morning or each evening. Gradually extend the time between the repetitions as the material firms itself into your mind.

By increasing your spacing as you become more certain of mastery, you'll lock the material more firmly into place. Great flash card systems like Anki have built in algorithms that repeat in scale ranging from days to months. Interestingly, one of the best ways to remember people's names, is to simply try to retrieve the people's names from memory at increasing time intervals, after first learning the name.

I'm Barbara Oakley. Thanks for learning, about learning. [BLANK_AUDIO]

What is Long Term Memory?

Welcome back to Learning How to Learn. What would it be like if you couldn't learn new things, you would not be able to remember new people you met, or remember what you were told? This actually happened to a famous patient in the annals of memory research whose initials were HM.

At the age of 27, HM had an operation for epilepsy that took out his hippocampus on both sides of his brain. The hippocampus has a shape of a seahorse and is named from the Greek hippos, meaning horse and kampos, meaning sea monster. The operation was a success. The epilepsy was cured but the price was steep. HM could no longer remember new things. He had become profoundly amnesic. Curiously, you could have a normal conversation with HM, but if you left the room for a few minutes, he could not remember you or what you had discussed.

In the film Memento, the character played by Guy Pearce had this form of amnesia from a concussion. Note that he tattooed his body with messages, so that he would not forget what he had to do. HM could learn other things, like a new motor skill, but he could not remember having learned it. There are multiple memory systems for different types of learning. From the studying HM and animals with similar operations, we have learned that the hippocampus is important part of a brain system for learning and memory of facts and events. Without the hippocampus and its inputs, it is not possible to store new memories in the cortex, a process called *memory consolidation* that can take many years. HM could remember things from his childhood but he had trouble remembering things that had occurred in the years just before his operation, things that had not yet become fully consolidated. Something similar happens when you have a bad concussion but this usually resolves, unlike HM who never improved.

Memories are not fixed but living, breathing parts of your brain that are changing all of the time. Whenever you recall a memory, it changes, a process called, *reconsolidation*. It is even possible to implant false memories, which are indistinguishable from real ones by simply suggesting and imagining, especially in children who have vivid imaginations.

Here is a summary:

The green process of consolidation takes the brain state in active memory and stores it in long term memory by modifying synapses on the dendrites of neurons. These long term memories can remain dormant for a long time until the memory is retrieved and reinstated, by the red process, in short term working memory. The reinstated memory is in a new context, which can itself be transferred to long term memory, thereby, altering the old memory through reconsolidation.

Our memories are intertwined with each other. As we learn new things, our old memories also change. Like consolidation, reconsolidation also occurs during sleep. This is why it is more effective to space learning over time, rather than mass learning all at once. If you want to study something for an hour, you will retain it longer if you spend 10 minutes each month over a semester than an hour on one day. In contrast, if you wait until the day before an exam to cram the material, you may be able to retrieve for the next day on the exam but it will quickly fade from memory.

In addition to neurons, brains have several types of supporting cells called *glial cells*. The *astrocyte* is the most abundant glial cell in the human brain. Astrocytes provide nutrients to neurons, maintain extra cellular ion balance, and are involved with repair following injury. In this photo of the cortex, the astrocytes are staying green and the neurons are blue. The intricate arms of the astrocytes wrap around the neurons, each embracing thousands of synapses. A recent experiment suggest that these astrocytes may also have an important role in learning. When human astrocytes were put into mouse brains, the humanized mice learned faster. Interestingly, when Einstein's brain was examined to find out what made him so awesomely creative, the only difference that could be found was that he had many more astrocytes than the average human. Could astrocytes be the key to understanding human intelligence? Well, the more we learn about the brain, the more may we have to rethink learning.

I'm Terry Sejnowski. Happy learning, until we meet again.

Creating Meaningful Groups and the Memory Palace Technique

In this video, we're going to delve deeper into memory. Another key to memorization is to create meaningful groups that simplify the material. Let's say you wanted to remember four plants that help ward off vampires. Garlic, rose, hawthorn and mustard. The first letters abbreviate to GRHM, so all you need to do to remember is use the image of a graham cracker.

It's much easier to remember numbers by associating them with memorable events. The year 1965 might be when one of your relatives was born for example. Or you can associate numbers with a numerical system you're familiar with. For example, 11.0 seconds is a good running time for the 100 meter dash. Or 75 might be the number of stitches on a knitting needle for the ski hats you like to make. Personally, I like to associate numbers with the feelings of, when was I was or will be at a given age. The number 18 is an easy one. That's the age when I went out into the world. By age 104 I hope to be an old, but happy great grandma.

Many disciplines use memorable sentences to help students memorize concepts. The first letter of each word in the sentence is also the first letter of each word in a list that needs to be memorized. Medicine, for example, is laden with memorable mnemonics. Among the cleaner of which are: "Some Lovers Try Positions That They Can't Handle", to memorize the names of the carpal bones of the hand. And "Old People from Texas Eat Spiders", for the cranial bones. Time after time, these kinds of memory tricks prove helpful. If you're memorizing something commonly used, see whether someone has come up with a particularly memorable memory trick by searching it out online. Otherwise, try coming up with your own.

The memory palace technique is a particularly powerful way of grouping things you want to remember. It involves calling to mind a familiar place. Like the layout of your house, and using it as a sort of a visual notepad where you can deposit the concept images that you want to remember. All you have to do is call to mind the place you're familiar with. Your home, your route to school, or your favorite restaurant and voila in the blink of an imaginative eye this becomes the memory palace that you'll use as your notepad.

The memory palace technique is useful for remembering unrelated items, such as a grocery list. Milk, bread, eggs. To use the technique, you might imagine a gigantic bottle of milk just inside your front door. The bread plopped on the couch and a cracked egg dribbling off the edge of the coffee table. In other words, you'd imagine yourself walking through a place you know well, coupled with shockingly memorable images of what you want to remember. If you're studying Finance, Sociology, Chemistry or what have you, and you have lists to remember, you could use this same approach. The first time you do this, it will be slow. It takes a bit of time to conjure up a solid mental image. But the more you do it, the quicker it becomes.

One study showed that a person using the Memory Palace technique could remember more than 95% of a 40 to 50 item list after only one or two practice mental walks, where the items were placed on the grounds of the local university. In using the mind this way, memorization can become an outstanding exercise in creativity that simultaneously build neural hooks for even more creativity. Purists might sniff that using oddball memorization gimmicks isn't really learning. But researchers show that students who use this kind of tricks outperform those who don't. In addition, imaging

research on how people become experts, shows that such memory tools speed up the acquisition of both chunks and big picture templates. Helping transform novices to semi experts much more quickly, even in a matter of weeks.

Memory tricks allow people to expand their working memory with easy access to long term memory. What's more, the memory process itself becomes an exercise in creativity. The more you memorize using these innovative techniques, the more creative you become. This is because you're building these wild, unexpected possibilities for future connections early on. Even as you're first internalizing the ideas, the more you practice this type of memory muscle so to speak, the more easily you'll be able to remember. Where at first it may take 15 minutes to build an evocative image for an equation and embed it say, in the kitchen sink of your memory palace, it can later take only minutes or seconds to perform a similar task. You'll also realize that as you begin to internalize key aspects of the material, taking a little time to commit the most important points to memory, you come to understand it much more deeply. The formulas will mean far more to you, than they would if you simply looked them up in a book. And you'll be able to sling those formulas around much more proficiently on tests and in real world applications. You may say, well, you're just not that creative, an equation or theory could hardly have its own grandiose motivations or persnickeity emotional needs to help you understand and remember it. But always remember, your childlike creativity is still there inside you. You just need to reach out to it.

I'm Barbara Oakley. Thanks for learning how to learn. [BLANK_AUDIO]

Summing Up Memory

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Learning to use your memory in a more disciplined yet creative manner helps you learn to focus your attention, even as you create wild diffuse connections that build stronger memories. Here are the key ideas about memory we've covered:

- In this course, we discussed two main memory systems involved in your ability to chunk concepts. The first is *long term memory*, which is like a storage warehouse. You need to practice and repeat in order to help store items in long term memory so you can retrieve them more easily. Practicing and repeating, all in one day, is a bad idea. You want to extend your practice to several days. This is why tackling procrastination is important. It helps you build better memories because you start earlier.

- The second, is *working memory*, which is like a poor blackboard that quickly fades. You can only hold about *four items* in your working memory. When you master a technique or concept in some sense, it compacts the ideas so they can occupy less space in your working memory when you do bring them to mind. This frees your mental thinking space so that it can more easily grapple with other ideas.

- We have outstanding visual and spatial memory systems. If you tap into those systems, it will help improve your memory. To begin tapping into your visual memory system, try making a very memorable visual image representing one key item you want to remember. Beyond merely seeing, try to feel, to hear and even to smell something you're trying to remember. The funnier and more evocative the image is, the better. As always, repetition over several days is really helpful.

- Another key to memorization is to create meaningful groups that simplify the material. Try associating numbers with years or with systems you're familiar with like running times. Many disciplines use memorable sentences. The *memory palace technique*, placing memorable images in a scene that's familiar to you, allows you to dip into the strength of your visual memory system, providing a particularly powerful way of grouping things you want to remember. By making meaningful groups and abbreviations, you can simplify and chunk what you're trying to learn so you can more easily store it in memory. And by memorizing material you understand, you can internalize the material in a profound way. You're reinforcing the mental library you need to become a genuine master of the material. Happy memories!

I'm Barbara Oakley. Thanks for learning how to learn.

How to Become a Better Learner

Welcome back to Learning How to Learn. Today we're going to talk about how to become a better learner. As we learn more about the brain we can become better learners, and here are two tips for how to learn better.

Tip number one – the best gift that you can give your brain is Physical Exercise. We once thought that all of the neurons in your brain were already present at birth, but we now know that in a few places, new neurons are born every day. One of these places is in your Hippocampus, a brain area that is very important for learning new things that we already discussed earlier in the course. In this experiment, a rat is shown, learning how to distinguish a picture of a flower from a picture of an airplane. In the background is a photo of neurons in the hippocampus, with the old neurons shown in blue and newly generated neurons in red. As the rat learns the task, these new neurons are recruited to help perform better pattern separation between the two pictures. These new neurons help you learn new things but they will die if you don't use them. New experiences will rescue them.

Exercise, interestingly, also helps new neurons survive. Exercise is by far, more effective than any drug on the market today to help you learn better. It benefits all of your vital organisms, not just your brain. It is unfortunate that schools are dropping gym and recess to make room for more instruction. Gym and recess are by far the most important parts of the curriculum.

Here's another tip – and this has to do with practice making perfect, but only when your brain is prepared. There are certain critical periods in the development of your brain. When sudden improvements occur in specific abilities, expect them to happen and prepare your brain for them. The critical period for first language acquisition extends up to puberty. One of the best studied critical periods in the brain is when binocular depth perception or stereopsis matures during the first two years of life.

Stereopsis is the magic behind Magic Eye pictures like the one shown here. If you stare at this image and slightly cross your eyes, you will see staircases pop out of the page. There is a slight shift between the images in the two eyes and your brain interprets this slight shift as difference in depth. Not everyone, however, can see this. Over 5% of the population is stereo blind. If the two eyes are not properly aligned during the first two years of development, the neurons in your visual cortex will fail to properly strengthen the inputs from the two eyes and depth perception is permanently impaired. Well, that's the dogma. Sue Barry, a friend of mine from graduate school at Princeton, was able to recover stereo vision through eye exercises, and wrote a book about it, entitled *Fixing My Gaze, a Scientist's Journey Into Seeing in Three Dimensions*.

Practice can repair, as well as train the brain. But this takes much longer, past the critical period. This brings us to zombies. Zombies can't learn. It is also clear from their behavior that they have brain damage. Especially in the front of their cortex, which is the part that makes plans, as well as in their language areas. Learning, planning, language, these are the skills that make us human. The prefrontal cortex is also involved in complex analysis in social behaviors, as well as decision making and planning. It is the last part of the cortex to mature, so until this happens, there may be a little bit of zombie in you.

Another patient, EVR, suffered a stroke in the social parts of his prefrontal cortex. EVR had a high IQ and seemed normal, but he was ruined by making bad financial decisions and bad social interactions. He lost both his home and his family. Good judgment takes a long time, and a lot of experience to acquire. Learning is too important to be left behind in the classroom. Learning to learn is a skill you can master, and you can use it to improve every part of your life. You'll be learning even more learning tips this week, and can follow up on them at http://www.brainfacts.org/.

I'm Terry Sejnowski, happy learning to you until we meet again.

Introduction to Renaissance Learning and Unlocking Your Potential

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This week we are going to wrap up a slew of important ideas, and techniques that will help round out and enhance your ability to learn well, using metaphors and analogies, to work profitable with teammates, and not undercut your own strengths, and finally to perform well on tests.

One important thought though, before we launch into this week's videos, learning doesn't progress logically, so that each day just adds an additional neat package to your knowledge shelf. Sometimes you hit a wall in constructing your understanding. Things that made sense before can suddenly seem confusing. This type of knowledge collapse seems to occur when your mind is restructuring its understanding, building a more solid foundation. In the case of language learners, they experience occasional periods when the foreign language suddenly seems completely incomprehensible. Remember it takes time to assimilate new knowledge. You'll inevitably go through some periods when you seem to take and exasperating step backwards, in your understanding. This is a natural phenomenon, that means that your mind is wrestling deeply with the material. You'll find that when you emerge from these periods of temporary frustration, your knowledge base will take a surprising leap forward.

I'm Barbara Oakley, thanks for learning how to learn.

Create a Lively Visual Metaphor of Analogy

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One of the best things you can do to not only remember, but understand concepts, is to create a metaphor or analogy for them; often the more visual the better. A metaphor is just a way of realizing that one thing is somehow similar to another. Simple ideas like one geography teacher's description of Syria is shaped like a bowl of cereal, and Jordan as a Nike Air Jordan sneaker, can stick with a student for decades. If you're trying to understand electrical current, it can help to visualize it as water. Similarly, electrical voltage can feel like pressure. A push. As you climb to a more sophisticated understanding of whatever topic you're concentrating on, you can revise your metaphors or toss them away and create more meaningful ones.

Metaphors and visualization, being able to see something in your mind's eye, have been especially helpful not only in art and literature, but also in allowing the scientific and engineering world to make progress. In the 1800s for example, when chemists began to imagine and visualize the miniature world of molecules, dramatic progress began to be made. Here's a fun illustration of monkeys in a benzene ring from an insider spoof of German Academic Chemical Life printed in 1886. Note the single bonds, or the monkeys' hands, and the double bonds with their tiny little tails.

It's often helpful to pretend that you are the concept you're trying to understand. Put yourself in an electron's warm and fuzzy slippers as it burrows through a slab of copper. Or sneak inside the X of an algebraic equation and feel what it's like to poke your head out of the rabbit hole. But just don't let it get exploded by an inadvertent divide by zero. In chemistry, compare a Cation with a cat that has paws and is therefore pawsitive. And an Anion with an onion that's negative, because it makes you cry. Metaphors are never perfect, but then in science, all models are just metaphors which means they break down at some point. But never mind that.

Metaphors and models are often vitally important in giving a physical understanding of the central idea behind the process or concept you are trying to understand. Interestingly, metaphors and analogies are useful for getting people out of Einstellung, that is, being blocked by thinking about a problem in the wrong way. For example, telling a simple story of soldiers attacking a fortress from many different directions at once can open creative paths for students to see how many low-intensity rays can be effectively used to destroy a cancerous tumor. Stories, even if they're just used as silly memory tricks, can also allow you to more easily retain what you're trying to learn. Metaphors also help glue an idea into your mind because they make a connection to neural structures that are already there. It's like being able to trace a pattern with tracing paper. Metaphors at least help you get a sense of what's going on.

I'm Barbara Oakley. Thanks for learning how to learn. [BLANK_AUDIO]

No Need for Genius Envy

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This is a good place for us to step back and look again at chunking from another perspective. Notice what we're doing here. We're interleaving our learning by jumping back to revisit and deepen our understanding of a topic we've already covered.

There's an interesting connection between learning math and science and learning a sport. In baseball, for example, you don't learn how to hit in one day. Instead, your body perfects your swing from lots and lots of repetition over a period of years. Smooth repetition creates muscle memory, so your body knows what to do from a single thought, one chunk, instead of having to recall all the complex steps involved in hitting a ball. In the same way, once you understand why you do something in math and science, you don't have to keep re-explaining the how to yourself every time you do it. It's not necessary to go around with a hundred beans in your pocket and to lay out ten rows of ten beans again and again so you get that ten times ten is equal to 100. At some point you just know it from memory.

For example you memorize the idea that you simply add exponents, those little superscript numbers, when you are multiplying numbers that have the same base. Ten to the fourth times ten to the fifth is equal to ten to the ninth. If you use the procedure a lot, by doing many different types of problems you'll find that you understand both the *why* and the *how* behind the procedure far better than you do after getting a conventional explanation from a teacher or a book. The greater understanding results from the fact that your mind constructed the patterns of meaning, rather than simply accepting what someone else has told you. Remember, people learn by trying to make sense out of the information they perceive. They rarely learn anything complex simply by having someone else tell it to them.

Chess masters, emergency room physicians, fighter pilots, and many other experts often have to make complex decisions rapidly. They shut down their conscious system and instead rely on their well-trained intuition, drawing on their deeply ingrained repertoire of chunks. At some point self-consciously understanding why you do what you do, just slows you down and interrupts the flow resulting in worse decisions. But wait, are chess masters and people who can multiply six digit numbers in their heads exceptionally gifted? Not necessarily. I'm going to tell it to you straight. Sure intelligence matters. Being smarter often equates to having a larger working memory. Your hot rod of a memory may be able to hold nine things in mind instead of four and you can latch on to those things like a bulldog, which makes it easier to learn. But guess what, it also makes it more difficult for you to be creative. How's that? It's our old friend and enemy Einstellung.

The idea you are already holding in mind can block you from fresh thoughts. A superb working memory can hold its thoughts so tightly that new thoughts can't easily peek through. Such tightly controlled attention could use an occasional whiff of ADHD-like fresh air, the ability, in other words, to have your attention shift even if you don't want it to shift. If you're one of those people who can't hold a lot in mind at once, you lose focus and start daydreaming in lectures and have to get to some place quiet to focus so you can use your working memory to its maximum, well welcome to the clan of the creative. Having a somewhat smaller working memory means you can more easily generalize

your learning into new, more creative combinations. Because your working memory, which grows from the focusing abilities of the prefrontal cortex doesn't lock everything up so tightly. You can more easily get input from other parts of your brain. These other areas, which include the sensory cortex, not only are more in tune with what's going on around you in the environment, but are also the source of dreams, not to mention creative ideas. You may have to work harder sometimes or even much of the time to understand what's going on. But once you get something chunked you can take that chunk and turn it outside in and inside round, putting it through creative paces even you didn't think you were capable of.

Here's another point to put into your mental chunker: it is practice, particularly deliberate practice on the toughest aspects of the material that can help lift average brains into the realm of those with more natural gifts. Just as you can practice lifting weights and get bigger muscles over time, you can also practice certain mental patterns that deepen and enlarge in your mind. Whether you're naturally gifted or you have to struggle to get a solid grasp of the fundamentals, you should realize that you're not alone if you think you're an imposter. That it's a fluke when you happen to do well on a test, and then on the next test, for sure they, and your family and friends, are finally going to figure out how incompetent you really are. This feeling is so extraordinarily common that it even has a name – *The Imposter Syndrome*. If you suffer from these kinds of feelings of inadequacy just be aware that many others secretly share them. Everyone has different gifts, as the old saying goes, when one door closes, another opens. Keep your chin up and your eye on the open door.

I'm Barbara Oakley. Thanks for learning how to learn.

Change Your Thoughts Change Your Life

I love reading history and being inspired by the biographies of extraordinary people. One of the most unusual people I've ever read about, is inspiring not only because he was so extraordinary, but also, because he was so ordinary.

Santiago Ramón y Cajal was a born troublemaker. In rural Spain of the 1860s, there weren't many options for oddball juvenile delinquents. So that's how at 11 years old, Cajal found himself in jail. Cajal was stubborn and rebellious. Who knew that Santiago Ramón y Cajal would one day not only earn the Nobel Prize, but eventually become known as the Father of Modern Neuroscience?

Cajal was already in his early 20s when he began climbing from bad boy delinquency into the traditional study of medicine. There's evidence that *myelin sheaths*, the fatty insulation that helps signals move more quickly along a neuron, don't finish developing in some people until they're in their twenties. This may explain why teenagers often have trouble controlling their impulsive behavior. The wiring between the intention and the control areas of the brain isn't completely formed. When you use neural circuits however, it seems you help build the *myelin sheath* over them; not to mention making many other microscopic changes.

Practice appears to strengthen and reinforce connections between different brain regions, creating highways between the brain's control centers and the centers that store knowledge. In Cajal's case, it seems his natural maturation processes coupled with his own efforts to develop his thinking, helped him to take control of his overall behavior. It seems people can enhance the development of their neuronal circuits by practicing thoughts that use those neurons. We're still in the infancy of understanding neural development. One thing is becoming clear, we can make significant changes in our brain by changing how we think.

Cajal met and worked with many brilliant scientists through his lifetime. People who were often far smarter than he. In Cajal's autobiography however, he pointed out that although brilliant people can do exceptional work, just like anyone else they can also be careless and biased. Cajal felt the key to his own success was his perseverance. What he called the *virtue of the less brilliant*, coupled with his flexible ability to change his mind and admit errors. Anyone, Cajal noted, even people with average intelligence, can change their own brains so that even the least gifted can produce an abundant harvest.

People like Charles Darwin, whose theory of evolution has made him one of the most influential figures in human history, are often thought of as these, sort of, natural geniuses. You may be surprised to learn that much like Cajal, Darwin was a poor student in school. He washed out of medical school and ended up, to his father's horror, heading out on a round the world voyage as the ship's naturalist. Out on his own, Darwin was able to look with fresh eyes at the data he was collecting. Approaching material with a goal of learning it on your own, can give you a unique path to mastery. Often no matter how good your teacher and textbook are, it's only when you sneak off and look at other books or videos that you begin to see what you learn through a single teacher, or book, is a partial version of the full three dimensional reality of the subject, which has links to still other fascinating topics that are of your choosing. Taking responsibility for your own learning is one of the most important things you can do.

Santiago Ramón y Cajal had a deep understanding, not only of how to conduct science but also of how people just interact with one another. He warned fellow learners that there will always be those who criticize or attempt to undermine any effort or achievement you make. This happens to everybody; not just Nobel Prize winners. If you do well in your studies, the people around you can feel threatened. The greater your achievement, the more other people will sometimes attack and demean your efforts. On the other hand, if you flunk a test, you also may encounter critics who throw more barbs, saying you don't have what it takes.

We're often told that empathy is universally beneficial. But it's not. It's important to learn to switch on an occasional cool dispassion that helps you to not only focus on what you're trying to learn, but also to tune people out if you discover that their interests lie in undercutting you. Such undercutting is all too common, as people are often just as competitive as they are cooperative. When you're a young person, mastering such dispassion can be difficult. We're naturally excited about what we're working on, and we like to believe that everyone can be reasoned with and then, almost everyone is naturally good hearted towards us. Like Santiago Ramón y Cajal, you can take pride in aiming for success. Because of the very things that make other people say you can't do it. Take pride in who you are. Especially, in the qualities that make you different, and use them as a secret talisman for success. Use your natural contrariness to defy the always present prejudices from others about what you can accomplish.

I'm Barbara Oakley. Thanks for learning about learning.

The Value of Team Work

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This is a CT scan. If you look carefully, the shadowed region right here reveals the damage caused by right hemisphere *ischemic stroke*. Such a stroke can cause an unusual condition known as *broad-perspective perceptual disorder* of the right hemisphere. People with this disorder can still function, but only partially. They can retain their intelligence, even a formidable way for solving complex math problems, if that was a skill they'd had before. But an interesting anomaly, however, is if they make a mistake in their calculations, concluding something nonsensical, such as that a hot dog stand had a, a profit and loss statement with a loss of nearly a billion dollars. It doesn't bother them. There's no big picture; click, that says, wait a minute; that answer does not make sense.

Although we need to be careful about faulty and superficial left brain, right brain assumptions. We also don't want to throw the baby out with the bath water, and ignore worthwhile research that gives intriguing hints about differences between the two hemispheres of the brain. There's a great deal of evidence from research that the right hemisphere helps us step back and put our work into big picture perspective. People with damage to the right hemisphere are often unable to gain ah-ha, insights. The right hemisphere, as it turns out, is vitally important in getting into the right track and doing reality checks. People with strokes can remind us of the dangers of not using our full cognitive abilities, which involve many areas of our brain.

Even subtle avoidance of some of our capabilities can have a surprisingly negative impact on our work. In some sense, when you whiz through a homework or test question and don't go back to check your work, you're acting a little like a person who's refusing to use parts of your brain. You're not stopping to take a mental breath. And then revisit what you've done with the bigger picture in mind to see whether it makes sense. As leading neuroscientist Vilayanur S. Ramachandran has noted, the right hemisphere serves as a sort of devil's advocate to question the status quo and look for global inconsistencies. While the left hemisphere instead tries to cling tenaciously to the way things were. This echoes the pioneering work of psychologist Michael Gazzaniga who posited that the left hemisphere interprets the world for us and will go to great lengths to keep those interpretations unchanging.

When you work in the focus mode, it's easy to make minor mistakes in your assumptions or calculations. If you go off track early on, it doesn't matter if the rest of your work is correct. Your answer is still wrong. Sometimes, it's even laughably wrong. The equivalent of calculating a circumference of the earth that's only two and a half feet around. But these non-sensical results just don't matter to you because the more left centered focus mode has associated with it a desire to cling to what you've done. That's the problem with the focus, sometimes a bit left hemisphere leaning mode of analysis. It provides for an analytical and upbeat approach, but abundant research evidence suggests there's a potential for rigidity, dogmatism, and egocentricity. When you're absolutely certain that what you've done on a homework or test is fine, thank you very much, be aware that this feeling may be based on overly confident perspectives arising in part from the left hemisphere. When you step back and recheck, you're allowing for more interaction between the hemispheres, taking advantage of the special perspectives and abilities of each. Nobel Prize winning

physicist Richard Feynman perhaps said it best when he pointed out, the first principle is that you must not fool yourself. And you are the easiest person to fool.

One of the best ways to catch your blind spots and errors is to brainstorm and work with others who are also smartly focused on the topic. It's sometimes just not enough to use more of your own neural horsepower. Both modes and hemispheres to analyze your work. After all, everyone has blind spots. You're naively upbeat focused mode can still skip right over errors, especially if you're the one who committed the original errors. Worse yet, sometimes you can blindly believe you've got everything nailed down intellectually, but you haven't. This is the kind of thing that can leave you in shock when you discover you've flunked the test you thought you aced. By making it a point to do some of your studying with friends, you can more easily catch where your thinking has gone astray. Friends and teammates can serve as sort of ever questioning larger scale diffuse mode outside your brain that can catch what you missed, or what you just can't see. And of course, explaining to friends helps build your own understanding.

The importance of working with others doesn't just relate to learning. It's also important in career building. A single small tip from a teammate to take a course from the outstanding Professor Passionate, or to check out a new job opening, can make an extraordinary difference in how your life unfolds. A word of warning, however; study groups can be powerfully effective for learning, but if study sessions turn into socializing occasions, all bets are off. Keep small talk to a minimum, get your group on track. And finish your work. If you find that your group meetings start five to 15 minutes late, members haven't read the material, and the conversation consistently veers off topic, you're best off to find another group.

I'm Barbra Oakley. Thanks for learning how to learn.

A Test Checklist

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We've mentioned it earlier, but it's worth repeating. Testing is itself an extraordinarily powerful learning experience. This means that the effort you put into test-taking, including the preliminary mini test of your recall and your ability to problem solve during your preparation is of fundamental importance. If you compare how much you learn by spending one hour studying, versus one hour taking a test on that same material, you'll retain and learn far more as a result of the hour you spent taking a test. Testing, it seems, has a wonderful way of concentrating the mind. Virtually everything we've talked about in this course has been designed to help make the testing process seem straightforward and natural, simply an extension of the normal procedures you use to learn the material. So it's time now to cut directly to one of the final features of this course: a checklist you can use to see whether your preparation for test taking is on target. This checklist was developed by legendary educator Richard Felder. Although, it was originally developed for engineers, it's actually suitable for many disciplines. As Doctor Felder says the answer to the question, "how should I prepare for the test?" is do whatever it takes to be able to answer, yes. Meaning, usually to most of the questions on this list:

- Did you make a serious effort to understand the text? Just hunting for relevant worked-out examples doesn't count.
- Did you work with classmates on homework problems or at least check your solutions with others?
- Did you attempt to outline every homework problem solution before working with classmates?
- Did you participate actively in homework group discussions contributing ideas and asking questions?
- Did you consult with the instructor or teaching assistants when you were having trouble with something?
- Did you understand all your homework problem solutions when they were handed in?
- Did you ask in class for explanations of homework problem solutions that weren't clear to you?
- If you had a study guide, did you carefully go through it before the test and convince yourself you could do everything on it?
- Did you attempt to outline lots of problem solutions quickly without spending time on the Algebra in calculations?
- Did you go over the study guide and problems with class mates and quiz one another?

- If there was a review session before the test, did you attended and asked questions about anything you weren't sure about?

- And lastly, did you get a reasonable night's sleep before the test? If your answer is no, your answers to all the preceding questions may not matter.

Taking a test is serious business. Just as fighter pilots and doctors go through checklists before takeoff and surgery, going through your own test preparation checklist can vastly improve your chances of success. The answer to the question "How should I prepare for the test?" becomes clear once you've filled our Doctor Felder's checklist.

I'm Barbara Oakley. Thanks for learning How to Learn.

Hard Start Jump to Easy

Now that you've gotten some insight into how your brain works, we can give you some final useful tricks that can empower your test taking. The classic way students are taught to approach tests is to tackle the easiest problems first. This is based on the idea that by the time you finish the relatively simple problems, you'll be confident in handling the more difficult. This approach works for some people, mostly because, well, anything works for some people. Unfortunately, however, for many people it's counterproductive. Tough problems often need lots of time, meaning you'd want to start on them first thing on the test. Difficult problems can also scream for the creative powers of the diffuse mode. But to access the diffuse mode, you need to not be focusing on what you so badly want to solve. What to do? Easy problems first, or hard?

The answer is to start with the hard problems but quickly jump to the easy ones. Here's what I mean. When the test is first handed out to you, first take a quick look to get a sense of what it involves. You should do this in any case. Then, when you start working the problems, start first with what appears to be the hardest problem. But steel yourself to pull away within the first minute or two, if you get stuck or you get a sense that you might not be on the right track. This does something exceptionally helpful. Starting hard loads the first most difficult problem in mind and then switches attention away from it. Both these activities are what allow the diffuse mode to begin its work. If your initial work on the first hard problem has unsettled you, turn next to an easy problem, and complete or do as much as you can. Then move, next, to another difficult looking problem and try to make a bit of progress. Again, change to something easier as soon as you feel yourself getting bogged down or stuck.

When you return to the more difficult problems, you'll often be pleased that the next step or steps in the problem will seem to be more obvious to you. You may not be able to get all the way to the end immediately, but at least you can get further before you switch to something else of which you can make progress. In some sense, with this approach to test taking, you're being a little like an efficient chef. While you're waiting for a steak to fry, you can swiftly slice the tomato garnish and turn to season the soup and then stir the sizzling onions. The hard start jump to easy technique may make more efficient use of your brain by allowing different parts of the brain to work simultaneously on different thoughts.

Using the hard start jump to easy technique on tests guarantees that you will have at least a little work done on every problem. It's also a valuable technique for helping you avoid Einstellung, getting stuck on the wrong approach - because you have a chance to look at the problem from differing perspectives. All of this is particularly important if your instructor gives you partial credit. The only trick with this approach is that you must have the self-discipline to pull yourself off a problem once you find yourself stuck for a minute or two. For most students it's easy, for others it takes discipline and willpower. This may be why test takers sometimes find that the solution pops to mind right as they walk out the door; when they give up, their attention switched, allowing the diffuse mode the tiny bit of traction it needed to go to work and return the solution. Too late of course.

Sometimes, people are concerned that starting a problem and then pulling away from it might cause confusion on an examination. This doesn't seem to be a problem for most people. After all, chefs learn to bring various facets of a dinner together. But if you still have worries about whether this

strategy might work for you, try it first on homework problems. Also keep in mind that if you haven't prepared well for a test, then all bets are off. Just take what simple points you can.

I'm Barbara Oakley. Thanks for learning how to learn. [BLANK_AUDIO]

Final Helpful Hints for Tests

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If you're a stressed out test taker, keep in mind that the body puts out chemicals such as *cortisol* when it's under stress. This can cause sweaty palms, a racing heart, a knot on the pit of your stomach. But interestingly, research finds, it's how you interpret these symptoms. The story you tell yourself about why you're stressed makes all the difference. If you shift your thinking from, this test has made me afraid, to this test has got me excited to do my best. It can really improve your performance.

Another good tip for panicky test takers is to momentarily turn your attention to your breathing. Relax your stomach, place your hand on it, and slowly draw a deep breath. Your hand should move out, even as your whole chest is expanding outward like a barrel. By doing this type of deep breathing, you're counteracting the fight or flight response that fuels anxiety. This calms you down. But don't just start this breathing on the day of the test. If you practice this breathing technique in the weeks before, just a minute or two here or there is all it takes. You'll slide more easily into the breathing pattern during the test. Remember, practice makes permanent. It's especially helpful deliberately moving to a deep breathing pattern in those final anxious moments before a test is handed out.

I've gotten great tips on test taking from top professors from around the world. And here are some of the best. Susan Sajna-Hebert, a professor of psychology at Lakehead University, advises her students to cover up the answers to multiple choice questions and to try to recall the information. So they can answer the question on their own first. If her students might complain that the practice test was way easier than the real one, she asks, what makes the two situations different? When you took the practice test, were you at home relaxing with toons on? Taking it with a fellow student? No time limit? Did you have the answer key and class materials at hand? These circumstances are not exactly like a crowded classroom with a clock ticking away and no way to access the answers.

Tracy Magrann, a professor of biological sciences at Saddleback College, tells her students to face your fears. Often, your worst fear is not to get the grade you need for your chosen career. How can you handle this? Simple. Have a Plan B for the alternative career. Once you have a plan for the worst possible contingency, you'll be surprised that the fear will begin to subside. Professor Magrann notes, study hard up until the day of the test and then let it go. Tell yourself, oh well, let me just see how many questions I can get right. I can always pursue my other career choice. That helps release stress, so you can actually do better and get closer to your first career choice. And Bob Bradshaw, a professor of math at Ohlone College, tells his students about good worry and bad worry. Good worry helps provide motivation and focus, while bad worry simply wastes energy.

Here are a few final thoughts. The day before a test, or tests, have a quick, final look over the materials to brush up on them. You'll need both your focus mode and diffuse mode muscles, so to speak, the next day. So you don't want to push your brain too hard. You wouldn't run a ten mile race the day before running a marathon. Don't feel guilty if you can't seem to get yourself to work too hard the day before a big examination. If you prepared properly, this seems to be a natural reaction, almost as if you're subconsciously pulling back to conserve mental energy. While taking a test, you

should also remember how your mind can trick you into thinking that what you've done is correct, even if it isn't. This means whenever possible, you should blink, shift your attention, and then double check your answers using a, a big picture prospective asking yourself, does this really makes sense.

There's often more than one way to answer a question and checking your answers from different perspectives provides a golden opportunity for verifying what you've done. If there's no other way to check, except to step back through your logic, keep in mind that simple issues have tripped up even the most advanced students. Just do your best. In science classes, having your units of measurement match on each side of the equation can provide an important clue about whether what you've done is correct. The order in which you work tests is also important. Students generally work tests from front to back. When you're checking your work if you start more towards the back and work towards the front, it sometimes seems to give your brain a fresher perspective that can allow you to more easily catch errors. Nothing's ever certain. Occasionally you can study hard and the test gods simply don't cooperate, but if you prepare well by practicing and building a strong mental library, and you approach test taking wisely, you'll find that luck will increasingly be on your side.

I'm Barbara Oakley. Thanks for learning how to learn.

Summary Week 4

This week, we've done a wide sweep through some of the deepest aspects of learning.

- Metaphors and analogies aren't just for art and literature. One of the best things you can do to not only remember, but more easily understand concepts in many different fields, is to create a metaphor or analogy for them. Often, the more visual, the better.

- We've learned from Nobel Prize winner Santiago Ramón y Cajal that if you change your thoughts, you can really, truly change your life. It seems people can enhance the development of their neuronal circuits by practicing thoughts that use those neurons. Like Santiago Ramón y Cajal, you can take pride in aiming for success because of the very things that make other people say you can't do it.

- Keep in mind that when you whiz through a homework or test question and you don't go back to check your work, you're acting a little like a person who is refusing to use parts of your brain. You're not stopping to take a mental breath and then revisit what you've done with the bigger picture in mind, to see whether it makes sense.

- Overconfidence in your results can result from using only one mode of thinking. By making it a point to do some of your studying with friends, you can more easily catch where your thinking has gone astray.

- Taking a test is serious business, just as fighter pilots and doctors go through checklists before takeoff and surgery, going through your own test preparation checklist can vastly improve your chances of success.

- Counterintuitive strategies such as the hard start jump to easy technique, can give your brain a chance to reflect on harder challenges even as you're focusing on other more straightforward problems.

Here are some last test taking pointers:

- The body puts out chemicals when it's under stress. How you interpret your body's reaction to those chemicals makes all the difference. If you shift your thinking from, this test has made me afraid, to this test has got me excited to do my best, it helps improve your performance.

- If you're panicked on a test, momentarily turn your attention to your breathing. Relax your stomach, place your hand on it, and slowly draw a deep breath. Your hand should move outward and your whole chest should expand like a barrel.

- Your mind can trick you into thinking that what you've done is correct even if it isn't. This means that whenever possible you should blink, shift your attention, and then double check your answers using a big picture perspective, asking yourself, does this really make sense?

- And finally, remember that not getting enough sleep the night before a test can negate any other preparation you've done.

I'm Barbara Oakley. Thanks for learning about learning.

Wrap Up to the Course by Terrence Sejnowski and Barbara Oakley

Dr. Sejnowski: Welcome to the last video of Learning How to Learn. If you're still listening to us, then you've come all the way through the course. And may remember at the beginning, I said that brains do not come with an instruction manual. So we have to write one ourselves. And that was one of our goals. In this final video, we want to tell you how much we've enjoyed teaching and learning. We've learned from you as we hoped you've learned from us. The truth is you've always been in the driver's seat when it comes to your own learning. But now that you have a better feeling for what's under your neural hood, you can use this to help you learn new things all during your lifetime.

Dr. Oakley: What we're hoping is that as the days and months will pass you'll continue to bring to mind some of the key ideas you've learned in the course. Approaches such as switching your mode of thinking from focused to diffuse can help reduce your frustration and allow for more creative problem solving. Strengthening your chunking can give you a firmer grasp of the material. Even seemingly tiny changes in your daily approach to your work. Using the pomodoro technique, for example, can make a dramatic long-term difference in your learning and in your ultimate success.

Dr. Sejnowski: Learning is so vitally important to our future that most of us spend 12 to 16 of our earliest years of our lives in school, culminating in high school or college. But the focus in formal education is on the product of learning, not the process of learning. In this course, we've tried to give you a better sense of the learning process. Although this is our last video, we hope it's not our last chance to influence you. You have not truly learned something unless you can teach it to others. Teach those ideas to others and you will find that they will continue to resonate and deepen in your own mind.

Dr. Oakley: We hope you'll also have discovered how powerful these ideas can be at helping you broaden your interest, passion, and expertise. Many people believe that what they're initially, sort of, naturally good at is what they're supposed to be doing in life. But I myself am living proof that passions can broaden, change, and grow. The world is evolving and a broad tool kit that allows you to learn effectively in many different subject areas is one of the most powerful assets you can have.

Dr. Sejnowski: Best of luck in your life of learning.

Dr. Oakley: Ditto that.