Prefrontal cortex (PFC): The PFC is the home of working memory. Located in the front of the brain, the PFC coordinates with other areas of the brain through electrical signals and receives information from those regions so your working memory can make use of it. Brain-imaging scans show that when working memory is being used, the PFC glows while it fires thoughts to and works with information from the different brain regions. Working memory is the primary function of the PFC. Though the PFC is the area most often associated with working memory, it is important to note that scientists have also found activation in other areas of the brain, such as the parietal cortex and the anterior cingulate, when people perform a working memory task.

Hippocampus: The hippocampus is where the vast amount of knowledge you have acquired over your lifetime is housed for long-term storage. It is the location of long-term memory (LTM). Your working memory allows you to sift through all the information you have stored in your long-term memory, and pull out the bits most relevant to the task at hand. It gives you the ability to combine that stored knowledge
Test Your Working Memory

To help you get a basic understanding of the strength of your working memory, here are two quick tests. For a more detailed measure of your working memory power, take the full online test at http://testwm.com.

Test 1

Below is a list of three-letter words. Don’t look at it! Ask a friend to quiz you using the list of words. In level 1 of this test, your friend is going to read aloud two words, like *cat* and *bat*. You have to try to remember the two words, reverse them, and repeat them backward. *Tab. Tac.* In level 2, you have to do the same with three words. In level 3, it’s four words. Most people are able to do level 1, but you need a strong working memory to complete levels 2 and 3 correctly.

<table>
<thead>
<tr>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dog</td>
<td>Bun</td>
<td>Dab</td>
</tr>
<tr>
<td>Lid</td>
<td>Car</td>
<td>Tip</td>
</tr>
</tbody>
</table>

Test 1. List of Words
Welcome to the Working Memory Advantage

Test 2

Level 1

1. Look at the pyramid below. Remember the triangle where the letter appears.

2. Now look at this picture. Does it start with the same letter as the letter in the triangle?

3. Here is another pyramid. Remember the triangle where the letter appears.

4. Now look at this picture. Does it start with the same letter as the letter in the triangle?
5. Now draw arrows to the triangles where the letters appeared, in the correct order.
Level 2

Follow the same directions as in Level 1.

1. Remember the triangle where the letter appears.

2. Does the picture start with the same letter as the letter in the triangle?

3. Remember the triangle where the letter appears.

4. Does the picture start with the same letter as the letter in the triangle?
5. Remember the triangle where the letter appears.

6. Does the picture start with the same letter as the letter in the triangle?

7. Now draw arrows to the triangles where the letters appeared, in the correct order.
Level 3

Follow the same directions as in Level 1.

1. Remember the triangle where the letter appears.

2. Does the picture start with the same letter as the letter in the triangle?

3. Remember the triangle where the letter appears.

4. Does the picture start with the same letter as the letter in the triangle?
5. Remember the triangle where the letter appears.

6. Does the picture start with the same letter as the letter in the triangle?

7. Remember the triangle where the letter appears.

8. Does the picture start with the same letter as the letter in the triangle?
9. Now draw arrows to the triangles where the letters appeared, in the correct order.

Scoring

The number of letters you can remember in the correct order gives you an indication of the strength of your working memory. If you are like most adults, you were probably able to complete levels 1 and 2 of this test correctly. Data from thousands of people confirm that the average five-year-old can remember and process two things. Most adults are able to remember four or five items in the correct order.

If you didn't fare so well on these tests, don't get frustrated. You can always make an improvement. If you aced these assessments, don't get too smug. You need to continually challenge your working memory to keep it in tiptop shape. Doing brain training exercises, such as the ones in this book, can help optimize your working memory.
der. Both groups had to perform a working memory task that required them to evaluate the emotional expressions—happy, sad, or neutral—of a series of faces viewed on a computer screen.

As each face appeared on the screen, the participants had to judge whether it had the same or a different emotional expression as a face they had seen previously. The groups performed this task twice. The first trial does not require working memory because the participants only had to determine if the facial expression matched the one they had seen immediately prior (1-back). In the 2-back task, which does engage working memory, they had to determine if the facial expression matched the one they had seen two faces earlier. Here are examples of these tasks:

1-Back Task*

Sad Happy Sad Sad Neutral

2-Back Task

Sad Neutral Sad Happy Neutral Happy Happy

The words that are repeated in the 1-back or 2-back task are in bold.

Levens and Gotlib measured the speed and accuracy of the responses. There was no significant difference between the depressed and nondepressed groups on the 1-back task. The difference emerged when it came to remembering the emotional expressions on the 2-back task, the task that engages working memory. The depressed individuals were faster in matching sad faces, while the non-depressed adults were quicker in matching happy faces. The psychologists suggest that the way we use working memory to process emotions played a role in this difference. They conclude that depressed individuals were more likely to keep sad emotions in their working memory, while the non-depressed people keep happy emotions in their working memory. This suggests

* We have called this the 1-Back Task for ease of explanation.
1. Learn How to Manage Positive and Negative Emotions

An important step to happiness is being able to identify what makes you happy and what makes you sad. We use our working memory to focus on familiar emotional information. This exercise will help train your working memory to evaluate emotional words, so that you can learn to focus the positive, rather than the negative.

1. Below is a list of words. **Don’t look at it!**
2. Ask a friend to read the list of words aloud.
3. Listen for repeating words. When you hear a repeated word that was read out three words before, do this:
   a. Snap your fingers
   b. Tell your friend whether the word is emotionally positive, negative, or neutral.

The answers are in bold on the list.

**Word List**

- leaf
- unfortunate
- ecstatic
- sunny
- syrup
- **ecstatic**
- thankful
- **syrup**
- plank
- downer
- afraid
- friendly
- **downer**
- thankful
2. Have a Few Cups

In 2012, Lars Kuchinke and colleagues from Ruhr University, Germany, discovered that drinking 200 mg of caffeine, or about two to three cups of coffee or four cups of tea, improves how fast and how accurately you can recognize positive words, but not neutral or negative ones. While this study didn't examine if coffee drinkers are less likely to be depressed, one can point out that if coffee makes it easier to recognize the positive, it's a good thing.

3. Filter Out the Negative

When we ruminate, we can focus on negative experiences and emotions. This exercise trains your working memory to filter out negative feelings and focus on the positive ones.

**Level 1: Instructions**

1. Draw a line to connect the positive words and ignore the other ones.
2. Turn the page over and on a separate sheet of paper list all the positive words you’ve just connected.
Level 2: Instructions

1. Draw a line to connect the positive words and ignore the other ones.
2. Turn the page over and on a separate sheet of paper list all the positive words you just connected.

4. Prioritize Your Choices

This exercise helps you to relieve the stress you feel when you are overwhelmed with too many choices by helping you to prioritize what’s most important.
regions of an addict's brain resemble those of people suffering from obsessive-compulsive disorders.

(Out of) Control

The control aspect in this process is located in the PFC, the home of working memory. For nonaddicts, the PFC is an advantage that helps them resist harmful behavior. For example, when you put your hand over the top of the wine glass rather than accepting another glass, your PFC has been activated to make that decision. But in the addict's brain, this behavior is reversed: when a person is engaged in the addictive behavior, the PFC is turned down to low. As you would expect, this diminished activity is associated with less self-monitoring and behavioral control. It's as if the Conductor has left the stage. The salience of how good the addictive substance or activity feels overrides the PFC's ability to rein in the behavior. When an addicted person craves something, as opposed to being engaged in the behavior or using the substance, the PFC increases in activation. While the person is craving, the PFC recruits working memory to bring up the past memories of the salience and reward, as well as to strategize how to satisfy the urge. In the addicted brain, the working memory Conductor, which should be in control, is under the control of the addiction.

The Addiction Process

In the addicted brain, working memory is recruited as a key component of the addictive process, helping to satisfy the addiction rather than inhibiting it. For illustrative purposes, this image shows the addictive process linearly, though the various stages may not always occur in this sequence.
Marion's working memory Conductor helps her break up the compound word. She first works with *along*, which is shuttled to the Broca's and Wernicke's areas. Her working memory discovers that she knows the meaning of that word. Then it does the same with *side*. Next, the Conductor brings both of the definitions back together to get a good sense of the meaning of the word *alongside*. Finally it updates the sentence with the newly discovered meaning, and she understands that the dolphin is near the boat.

**Writing**

While we were writing this book, our older son woke up one morning around 6:00 a.m., before either of us were ready to get up. Ross poured him a bowl of cereal, sat him at the kitchen table, which was strewn with notes for the book, and went back to bed. When Ross woke up, imagine his surprise and gratification when our son proudly presented him with this handwritten text (the image on the left is the text our son was copying; the image on the right is his writing).

At the time, our son was learning to read and found it challenging to decipher words that are more than one syllable, so this was strictly a writing exercise for him. It required his working memory to manipulate both verbal and visual information. The verbal information is the...
This way, students will have a visual cue to help them remember where to find things, which frees up working memory for learning tasks.

—Break It Down—
Understanding instructions is one of the most demanding tasks for a student’s working memory. They have to keep the set of instructions in mind as well as execute each one in the proper sequence. Too many instructions can easily overwhelm a student or a whole class. The more instructions you add, the harder it becomes, and the more likely that a student will give up on an assignment. Solve this common problem by knowing what your class can handle.

### Working Memory Skills by Age

<table>
<thead>
<tr>
<th>Age</th>
<th>Number of Instructions According to Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>5–6</td>
<td>2 instructions</td>
</tr>
<tr>
<td>7–9</td>
<td>3 instructions</td>
</tr>
<tr>
<td>10–12</td>
<td>4 instructions</td>
</tr>
<tr>
<td>13–15</td>
<td>5 instructions</td>
</tr>
<tr>
<td>16 and over</td>
<td>6 instructions</td>
</tr>
</tbody>
</table>

—Go Back to the Basics—
Too often in a classroom, students have yet to master the fundamentals when they are asked to perform a complex task. A good example is reading comprehension. Let’s say a student is asked to explain the meaning of the sentence: “She grabbed the corner of the box and picked it up.” A student who doesn’t yet know that or makes the sound awr will use up his or her working memory trying to figure out the word corner and will not be able to process what it means in the sentence. To fix this, drill the basics of sounds and letters so that they become automatic during reading. This means students will not have to actively work with these sounds and letters, freeing up their working memory to comprehend the sentence.
The key to getting the right balance of working memory engagement (and not interfering with getting in the zone) is in achieving enough mastery of the basic moves of a sport so that we can execute them without having to think about it, which frees up our working memory to be on guard and to activate it when we need it.

To see how working memory can be a disadvantage when playing a sport, think about a time you’ve tried to learn a new sport, or a difficult new technique, such as switching from a one-handed to a two-handed backhand in tennis, or going from skiing to snowboarding. Trying to learn how to execute all of the things an instructor tells you to do can be totally overwhelming. Tracy experienced this when she accompanied Ross, an avid skier, on a trip to the Swiss Alps. She had never skied before and signed up for a lesson. Her instructor spoke perfect English and was a stickler for detail. Before she could move down the slopes, she was given a mental checklist. Hips had to be at a precise angle relative to the back. Arms had to be in an exact position, knees had to be bent to a specified degree, and skis had to be properly edged.

The instructor had told her to remember all of these instructions and say them to herself as she took her first run down the bunny slope. *Hips? Check. Arms? Check. Knees? Check. Skis . . . Plop!* Down she fell after about fifteen seconds. All of the instructions kicked her working memory into high gear, and when this happened, the areas of her brain that coordinate movement and balance froze. To see why this is true, take a look at what we call the working memory motor learning circuit, which is what is engaged when we are being taught a sport. It involves three steps.

**Working Memory Motor Learning Circuit**

![Diagram of the working memory motor learning circuit]

- **Working Memory (PFC)**
- **Cerebellum**
- **Motor Cortex**
1. You hear a set of instructions that your working memory processes using your brain’s cognitive hub, the prefrontal cortex (PFC).

2. Your PFC shuttles those instructions to the cerebellum, the brain’s coordination center, to mentally rehearse the movements.

3. Finally, your cerebellum passes the instructions on to the region of the brain responsible for voluntary movement, the motor cortex, which commands your muscles to move in accordance with the instructions.

Think of these three steps like a “bump-set-spike” sequence in volleyball. Each player has to get to the ball and execute his or her role in the sequence quickly so the teammates can subsequently make their play. If any one of the players makes an error, the whole sequence falls apart, and you lose the point. Or, depending on your sport, you fall on your butt in the snow, strike out, or hook the golf ball into the sand trap. The more information you’re trying to pay attention to, the more likely it is that one of the players is going to slip up.
Choking When the Pressure’s On

Have you ever found yourself with the ball in an intense soccer game and flubbed the shot on goal? Or wanted to make a great golf shot to impress the group you’re playing with and then hit the ball right into the trees? You aren’t alone. Even professional athletes who earn millions of dollars can choke under pressure. Who can forget Bill Buckner missing that easy ground ball to first that would have given the Boston Red Sox the 1986 World Series? Or Rory McIlroy, one of golf’s emerging superstars, wasting a seemingly untouchable four-shot lead going into the final round at the 2011 U.S. Masters in Augusta, only to wind up ten strokes behind the eventual winner? Anyone who’s played a sport knows about choking, but what you may not know is that working memory has a great deal to do with it.

Scientists who study sports and working memory have found that you are more likely to succumb to the pressure of competition if you learn a sport or a new skill by using the working memory motor learning circuit. That’s what Richard Masters, chairman of the Institute of Human Performance at the University of Hong Kong, discovered when he carried out a series of experiments examining the role of working memory in sports performance.

In one study, he assigned participants to two groups to learn how to putt in golf. He gave one group very detailed instructions on how to putt, based on leading coaching techniques. This group had to use the work-
If you’re like the vast majority of Americans, you probably identify with Larry. You envision that once you reach the age of retirement, you’ll hop off that crazy merry-go-round to enjoy the good life and relax, beer in hand and sand between toes. And, hey, can anyone blame you? Even if you enjoy what you do, what is the point of keeping at it if you can afford to stop?

A hundred years ago, Larry would never have been in the position to stop working. Large-scale retirement is a very recent invention. For thousands of years, it didn’t matter how old you were; you kept working until you were unable to do so any more. It is only in the past hundred years or so that large numbers of humans have been retiring. Alicia Munnell, the director of the Center for Retirement Research at Boston College, shows that in the twentieth century retirement has become the common place for the majority of the population aged sixty-five and over. If you were sixty-five or older in the 1800’s (and a man), you would likely have been working. We can’t know the cognitive skills of working older people in centuries previous in terms of either an IQ or a working memory score, but the fact that they were still gainfully employed suggests that they did not have dementia. In fact, work may have been the secret to their long-lived intelligence.

![Graph showing workforce participation rates of men 65 and older from 1880 to 2009.](image)

*Workforce Participation Rates of Men 65 and Older, 1880–2009.*

*With permission from Alicia Munnell and Steven Ruggles.*
Mental rotation task: In the first example, the $F$ images are the same when rotated. In the second example, the letters are not the same when rotated.

In a 2012 trial, older adults were asked to play World of Warcraft, an online game in which players assume the role of a fantasy character and collaborate with other gamers to embark on quests, wage epic battles, and attempt to defeat monsters in a virtual world. The researchers chose this game because it is cognitively demanding: players are required to act within the specific skill set their fantasy character possesses, navigate to new locations within the virtual world using textual descriptions and visual maps, react quickly to constantly changing on-screen indicators, consider the health of their character, and selectively ignore on-screen information that might distract them from accomplishing their goal.

We have to admit that we think having the study participants play World of Warcraft was a somewhat ironic choice given the addictive problems some users experience, which we covered in chapter 4. The training group played for an hour a day for a number of weeks, while the control group did not play the game. Unfortunately, the researchers didn’t test working memory directly, so we can’t draw any conclusions about the effects of the game on it, but it is interesting that the people who played the video game did have better scores in the Stroop test, which is related to working memory skills. In this test, the name of a color, such as the word blue, is printed in a color, such as red, that is different from the one denoted by the name. Participants are asked to say the name of the color—in this case, “red” would be the correct answer—rather than read the word blue. Doing so requires the use of the working memory Conductor to keep instructions in mind and say the color rather than read the word. This suggests that there might also
If you are working on paper, stacking is a good way to calculate because you can write down part of your answer along the way and do single-digit multiplication and addition. However, if you try doing it in your head, you must carry numbers as well as hold all the numbers together at the end in order to add them, a very challenging job for working memory. Gamm’s code-breaker is much easier. You have to keep only three things in mind: the numbers in the problem (490 x 142), your place in the problem (I’ve already multiplied 400 x 100, so now I need to do 400 x 40, and so on), and the overall sum of the preceding steps.

Gamm makes great use of what we call the Working Memory–Long Term Memory (WM-LTM) Loop. The WM-LTM Loop is the process of using your working memory to manipulate information stored in your long-term memory. To build up his long-term memory for math, Gamm practiced and practiced calculations for four hours a day so that he could commit a vast store of solutions in his long-term memory, as well as a number of code breakers that are shortcuts for solving longer problems. It was like memorizing his times tables, but on a far larger scale. Because you know that 6 x 6 is 36, you don’t have to use your working memory to add 6 + 6 + 6 + 6 + 6 + 6 = 36. Similarly, for Gamm, by having a larger set of automatic answers and code breakers, it meant his working memory Conductor had fewer things to manage. When tackling problems, Gamm always sorts through his long-term memory to find answers that he may already know as well as the most efficient code breaker, which allows him to use his working memory to hold the intermediary solutions.

Working Memory–Long Term Memory (WM-LTM) Loop
Many chess players see things differently. Instead of looking for a fork relationship between pieces, they see four separate pieces in different positions on the board. If they try to memorize the exact locations of these pieces in a variety of game situations, they end up creating an unnecessarily large store of chunks. Moreover, if the pieces end up in a way they don’t recognize, they are lost. But by focusing on the fork relationship, Polgar doesn’t have to memorize the exact location of four pieces, she has to remember only the underlying relationship, which allows her to do much more with her chunk than others can when they are remembering locations.

By knowing the relationship, Polgar can apply it in a huge variety of settings, even if the exact positions of the pieces don’t correspond to something she has played previously. Of course, a fork is a relatively simple relationship, and Susan’s winning relationship chunks are more complex, involving numerous pieces and move sequences, but the beauty of her relationship chunking is that what works for a Grandmaster can be scaled down for a novice.

The other distinctive feature of the way Polgar plays that she described to us is that she starts from the outcome she wants, checkmate, and works her way backward to the current state of play on the board. Working backward in this way demands engagement of working memory, but Polgar suggests it gives the working memory Conductor fewer possible moves to consider.
Working Memory Exercises

1. Become a Human Multiplier

Rudiger Gamm’s algorithm or rule for multiplication is to multiply across the numbers, from left to right, adding up the results in between.

<table>
<thead>
<tr>
<th>Example 1: Double-Digit/Single-Digit Multiplication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using Gamm’s technique, 53 x 6 would be solved this way:</td>
</tr>
<tr>
<td>50 x 6 = 300</td>
</tr>
<tr>
<td>3 x 6 = 18</td>
</tr>
<tr>
<td>300 + 18 = 318</td>
</tr>
</tbody>
</table>

When you do this type of calculation in your head, you activate your working memory when keeping your place in the problem and holding the interim answers in your head before adding them together.

Exercise 1

Repeat the same steps above to solve the following problems (answers appear at the end of the chapter):

78 x 4 = ?
33 x 5 = ?
25 x 8 = ?
45 x 3 = ?
Example 2: Double/Double-Digit Multiplication

With two double-digit numbers, the trick is to hold only the running total in mind rather than all the results from the previous multiplication steps. This frees up your working memory Conductor to pay attention to where you are in the problem, which becomes increasingly important when you multiply more numbers.

Using Gamma's technique, $35 \times 56$ would be solved this way:

\[
30 \times 50 = 1,500 \\
30 \times 6 = 180 \\
1,500 + 180 = 1,680 \text{ (keep only 1,680 in mind)} \\
5 \times 50 = 250 \\
1,680 + 250 = 1,930 \text{ (keep only 1,930 in mind)} \\
5 \times 6 = 30 \\
1,930 + 30 = 1,960
\]

Exercise 2

Repeat the same steps above to solve the following problems (answers appear at the end of the chapter):

\[
23 \times 34 = ? \\
12 \times 24 = ? \\
17 \times 55 = ? \\
64 \times 70 = ?
\]
6. Remember Other People’s Names

Before you try these methods to remember people’s names, think about whether it is easier for you to process visual or verbal information. Use whichever is easier for you to bootstrap a contact to your long-term memory. The key is to make an effort processing the information and binding it together with something that you already know.

For visual processors: When you meet someone, focus on what that person is wearing, what she looks like, or how she is wearing her hair. Then take that image and bind it to something you already know. For example, you meet a man named Robert and he's wearing a red tie so you think “red Robert.” Or you meet Maureen and she’s wearing a green necklace and green rhymes with Maureen, so you say to yourself “green Maureen.”

For verbal processors: Pay attention to the conversation and find links with events or memories that happened to you. Here are a few examples of how it works. His name is Phil and he likes to fish, and you have a fish tank in your office. Brian told a joke about a duck, and you just bought a new feather pillow. You meet Jordan, and remember that it’s the same name as one of your high school friends.

Answers to the Math Problems

78 \times 4 = 312 \\
33 \times 5 = 165 \\
25 \times 8 = 200 \\
45 \times 3 = 135 \\
23 \times 34 = 782 \\
12 \times 24 = 288 \\
17 \times 55 = 935 \\
64 \times 70 = 4,480
After all, when you look at the nutrition labels on cartons of milk, the
differences in the amount of saturated fat between whole milk and low-fat milk aren’t all that substantial, especially if you’re drinking only one cup.

<table>
<thead>
<tr>
<th>Type of milk</th>
<th>Saturated fat content per cup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole milk</td>
<td>5 grams</td>
</tr>
<tr>
<td>2 percent milk</td>
<td>3 grams</td>
</tr>
</tbody>
</table>

Going carefully through the data, we realized that the key words in most studies regarding saturated fat and poor cognitive performance are high intake. They don’t say that saturated fat in and of itself is detrimental to mental acuity, but consuming too much of it is. While a small scoop of ice cream could help your working memory, a tub will probably hurt it. So don’t worry so much about higher fat milk products, just make sure that you have them in moderation, like a little cream in your coffee, or a few portions of cheese.

Red Meat

Red meat has gotten a bad rap in recent years, but it has been shown to have benefits for working memory. Red meat contains two working memory-friendly nutrients: carnitine and vitamin B-12. Carnitine helps your body burn fat, and it is also associated with speeding up signals between neurons. The human body naturally produces carnitine in the liver and kidneys, though there is evidence to suggest that the older you get, the more you benefit from consuming it.

In one study with rats, carnitine was found to improve performance on tasks that required the use of their working memory. When doctors looked at the benefits of carnitine for centenarians, they found that it reduced their mental fatigue. Vitamin B-12 is also important because if you don’t get enough of it, your brain will shrink, a symptom associated with diseases like Alzheimer’s that are known to impair working memory.
Meal 1: Venison with Black-Eyed Peas

Venison typically has a slightly gamey flavor. If you're a newbie when it comes to eating venison, opt for roe deer, which has a milder flavor. The trick to cooking wild game is to cook it with things that can be found in the forest that it came from.

Venison

1 venison steak or several medallions from the filet, thawed (total serving size: about the size of the palm of your hand)
2 splashes olive oil
pinch flaked sea salt
pinch ground pepper
6–7 juniper berries, crushed flat with spoon or mortar and pestle
5–6 blueberries or blackberries
1 clove garlic
1 sprig thyme
a dab of whole-grain mustard (Maille has a lovely flavor)
1–2 generous sloshes port wine

1. Splash olive oil on venison and season with salt, pepper, and crushed juniper berries.
2. Set aside to marinate.
3. Preheat a pan (steel, if you have one) on a low temperature setting for 5 minutes or so.
4. Splash olive oil in pan and place marinated venison in pan.
5. Place berries, garlic, thyme, and dab of mustard around venison (not under it).
6. Cook 3 minutes or so until the meat is brown on bottom, then turn over. While cooking, jostle berries and garlic so they don’t burn.
7. Cook 3 more minutes, or until brown.
8. Remove venison and set aside.
9. Pour in port and deglaze the pan, crushing berries, garlic, mustard, and thyme with a wooden spoon. To deglaze, pour liquid in
the pan and use a wooden spoon to remove the residue from the bottom of the pan so it all dissolves. This adds flavor to the sauce.

10. Slice venison thinly. Pour port sauce through a sieve over the top of the venison. Serve.

## Black-Eyed Peas

1 splash olive oil

*Optional: 2–3 small cubes of bacon (adds great flavor, just make sure they are small)*

½ onion

½ red pepper, chopped

small pinch flaked sea salt

small pinch black pepper

½ cup black-eyed peas, soaked overnight and boiled until soft (retain water)

*Optional: 1 slosh of port wine*

1. Splash olive oil in small, preheated pot.
2. Add bacon cubes and cook until brown.
3. Add onion, red pepper, salt, and pepper and cook until onions are translucent.
4. Add black-eyed peas with some of their liquid, and maybe a slosh of port if you desire.
5. Reduce liquor until black-eyed peas are glazed. Serve.

## Dessert

Selection of cheeses, such as mature Gouda, Monterey Jack, and cheddar (one small slice of each)
Meal 2: Salmon and Steamed Kale

Salmon

1 salmon fillet (4–5 oz.)
2 splashes olive oil
small pinch flaked sea salt
small pinch ground black pepper
1 tablespoon dill, chopped
1 dab whole-grain mustard
½ lemon plus ¼ lemon
2 handfuls kale, chopped
1 tablespoon capers

1. Preheat pan on low heat.
2. Splash olive oil on salmon and rub in salt, pepper, dill, and mustard.
3. Place in preheated pan and squeeze ½ lemon on salmon. Cover with a plate or a large lid.
4. Cook for a few minutes on each side.
5. Take the salmon out of pan and squeeze ¼ lemon on it.
6. Let it cool for a few minutes so it will absorb the lemon.
7. While salmon is cooling, steam chopped kale in a pot for a few minutes; dress with olive oil.
8. Top salmon with capers and serve with dressed kale.

Dessert: Berries with Dark Chocolate Sauce

2 heaping tablespoons fresh blackberries
2 heaping tablespoons fresh blueberries
2 heaping tablespoons fresh raspberries
or
4–6 heaping tablespoons of any berries you can get
about 1.5 oz. dark chocolate (Lindt is Ross’s favorite)
2 tablespoons heavy cream

1. Put cream and chocolate bar in a pot over low heat and melt while whisking constantly.
2. Pour sauce over berries and serve.
How Much Sleep Do You Need?

<table>
<thead>
<tr>
<th>Age</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toddlers (1–3)</td>
<td>12–14</td>
</tr>
<tr>
<td>Preschoolers (3–5)</td>
<td>11–13</td>
</tr>
<tr>
<td>Kids (5–12)</td>
<td>10–11</td>
</tr>
<tr>
<td>Teens</td>
<td>8.5–9.25</td>
</tr>
<tr>
<td>Adults</td>
<td>7–9</td>
</tr>
<tr>
<td>Seniors</td>
<td>7–9</td>
</tr>
</tbody>
</table>

**Kids**

Sleep is especially critical for young children, who need their z’s for their developing working memory. It is believed that much of the brain maturation process takes place during sleep. In addition, research shows that when youngsters don’t get the sleep they need, their working memory pays the price and their classroom performance suffers.

**Teens**

Teens are better able than younger kids to compensate for sleep deprivation before it starts affecting their working memory functioning. For example, Mary Carskadon at Brown University found that teenagers were able to perform a working memory task successfully with just four hours of sleep. But when the stakes were increased to tasks that required more effort, their performance suffered, especially if they had stayed up all night.

If you’ve ever been the parent of a teenager, you know how hard it can be to get teens to go to bed early and what a struggle it can be to get them out of bed in the morning. But this doesn’t mean your teen is lazy or purposely disobedient. Studies have found that at the onset of puberty, teenagers develop a delayed sleep pattern known as a two-hour sleep-wake phase. This simply means that due to their body’s changing needs, they need to go to sleep later at night and need more sleep in the
Giving Working Memory the Advantage . . .

The designers of airports, train terminals, and subways would minimize our navigation choices. Simplicity and clarity are the key features here. The fewer bends and corners, branches, terminals, and platforms, the better. Imagine how easy it would be if at any airport, you could just walk in almost a straight line from the parking garage to check-in, to security, to your gate. The straighter the line, the fewer the choices. In Wutopia, airports would be shaped like a flower with elongated terminals that fan out like petals from the top half of a central disk. Connected to it would be a rectangular area in the place of a flower stem, for ticketing and baggage claim, and at the very bottom, like a pot, a parking structure.

In this design, getting from check-in to arrivals requires no more than one or two turns, and hence no more than a single decision as to where to go.
City Planning

Have you ever had your GPS go on the blink and have to figure out on the fly how to get to, say, the intersection of San Marco and Philips? We have. Just the other night, we were meeting some friends for dinner in an area of town we weren’t familiar with. When the GPS battery ran out halfway there, we had no clue how to find the intersection of San Marco and Philips. The problem is that street names in most cities are entirely random, with no discernable logic. Knowing that we were on San Marco, for example, didn’t tell us how close we were to Philips, or even if we were going the right way. Only when the sign for Philips came into view too late and then quickly retreated in the rearview mirror did we realize where it was.

_Giving Working Memory the Advantage . . ._

City planners would name streets using a grid system with numbers or names in alphabetical order. In fact, in the early days of city planning, this practice was fairly common, and grids account for large parts of some of America’s founding cities, such as Manhattan, Chicago, and Washington, D.C.
be beneficial. Our Conductor needs the raw materials in order to put them together in a creative way. For example, learning the alphabet by looking at a letter and then repeating after the teacher, “A, A, A, A,” “B, B, B, B” allows youngsters to build their language foundation. It’s the same with math. Mastering counting and writing the numbers 1 through 100 lays the groundwork for solving math problems.

In Wutopian language classes, preschoolers would memorize their ABCs, and over the course of the year, they would build up to learning common word sounds, both speaking them and writing them. Then they could use their working memory to bring together sounds into words. For example, they would learn the sounds /sk/ /ip/ /in/ /sl/, and with these basics, they would be able to spell the words *skip* or *skin* the first time they were asked to do so. In order to understand the meaning of words, children would learn a list of word roots and use their working memory to help them unlock the meanings from those building blocks.

In math, schools would base their procedure on how the brain solves a math problem. The way this works is that first the problem is held in working memory. Then the long-term memory of numbers is called on to recognize the numbers in the problem. Those numbers are next sent to the intraparietal sulcus, which performs the calculation, and finally the answer is sent back to working memory.

**Simple Addition**

To maximize the ability to perform their procedure, kindergartners would be taught to memorize their numbers first and lock them safely into long-term memory. At some point in the year, they would be able to use their working memory to hold a problem in their head, recognize the numbers (long-term memory), and go up and down the number line in their mind to find the correct answer, hold it in mind (working memory), and write it down. As students got older, they would memo-
Some companies realize the value of physical activity and set up treadmills in an on-site gymnasium or offer on-site yoga classes. We take our play a little more seriously and would love to see companies encourage people to learn a new sport and physically challenge themselves—basically to do the opposite of sitting in front of a screen. This new perspective would be hugely advantageous for creativity as some of the best ideas come when running on a trail or clinging to a climbing wall.
The key to his design is a sliding wall system, which means that at any one time, you are focused on only a single room function. The bed folds into the wall, the kitchen is behind the TV, and the guest bed is above the bathtub.

Efficiency of space is also a principle at work in the new microhome trends, that is, homes for a fraction of the price (and space): small functional kitchens, beds on the roof, small areas to heat. You can’t accumulate there. You have to make choices about what you keep.

The Wutopian home would be designed according to a concept similar to that of architect Chang’s sliding doors so that whatever you were doing was the focus of the space. But we’ve got an important tweak on Chang’s sliding doors that borrows from hydraulic stagecraft: you know, where stage sets rise from flat floors.

Plan A shows all features ascended. Plan B shows only couch and seats ascended.
own interpretations. Our interpretation is simple: the monolith represents the unlocking of the working memory advantage.

The Missing Intellectual Link

A shocking and profound improvement in working memory transformed the fortunes of Kubrick’s hominin and our real-life evolutionary ancestors. Before the dawn of the working memory advantage, Kubrick’s hominin may have walked past piles and piles of bones, but never did it occur to him that they could be used to accomplish specific tasks. He may have even picked up a bone before the arrival of the monolith and thrown it or smashed something with it. But it is only after the appearance of the monolith that he is able to link things together: the action of smashing with the bone and crushing the tapir’s skull, smashing with the bone and driving off his competitors.

This process is what psychologists refer to as “conjunctive binding,” when more than one piece of information, sometimes disparate, is joined together to create a novel concept.

Conjunctive Binding
Knapping: The image on the left is a prepared core being struck, and the image on the right shows the resulting flake.

Prat is so good at this technique that he once made nine flakes from a single core—the most ever found in history. If they had a *Guinness Book* of prehistoric world records, Prat’s proud face would be pictured with his nine flakes. The process requires a steady hand and some forward planning. To do it successfully, he has to use his working memory to hold in mind two pieces of information:

1. What an ideally prepared core looks like.
2. A calculation of how to make the core he is working on look like that ideal.

To let everyone know that Prat is the group’s most skilled toolmaker, Gurk fashions some ornamental shell beads for him to wear. Only the best spearhead producers get to wear them. Gurk herself has earned a place of respect in the group after giving birth to yet another live baby. She swells with pride whenever she hears the others utter the sound “Durg” to her, which means strong babies. Both the physical (bead) and the verbal (spoken word) symbols require working memory to bring two things together—the beads and the status, the sound and the thing to which it refers.
those depicted in Bedrock. Thanks to their enhanced working memory, our ancestors like Snare Maker and Fish Finder didn’t just live off the land; they managed and exploited the land and the water around them to suit their needs. They did so with their specialized tools, Stone Age machines, cleverly engineered devices, and sophisticated techniques. With their own version of industrialization, early modern humans weren’t just scraping by; they were thriving.

For example, Fish Finder and the other men in his group may have participated in industrial-scale fishing. A rod, line, and hook are great for a single fisherman, but Fish Finder and his clan knew that if they wanted to feed their whole group, they would need something bigger. What they possibly created is something akin to a fish weir, a complex machine that uses the river current and precisely designed obstructions like poles or netting, allowing fishermen standing on platforms in the river to scoop up the confined fish. Imagine Fish Finder and his buddies carting away dozens of fish and laughing at poor Prat, one of the few remaining Neandertals, limping back to the cave from an unsuccessful mammoth hunt.

Fish weir: The fish are caught in the trap as they swim downstream.

Inventing and adapting this fishing technology was no simple task. It required careful calculation and visual spatial manipulation using the working memory to make crucial design decisions. The possible fish
weir suggests that Fish Finder and other early modern humans weren’t thinking on a small scale; they were thinking on an industrial scale.

One of the more exciting pieces of evidence of advance planning indicative of enhanced working memory is the desert kite, which Wynn and Coolidge cite in their work. Here’s how they are believed to have worked. Fish Finder and the other men in his group would create long walls of stone arranged in a V pattern to funnel and trap herds of gazelles. Fish Finder may have found inspiration in natural gorges, which restricted the movement of herds, and replicated their confining properties in areas where the herds were known to gather. Of course, after trapping a large herd, they would have killed the entire herd, which would have far exceeded what they could eat in one sitting. Perhaps Snare Maker and the other women would have been charged with cutting away the meat and preserving it for later use, when game was hard to find.

Desert kite: The animals are herded into a narrowing trap and are caught in the corral at the end.

This suggests that their working memory was strong enough to give them the ability to inhibit their desire to gorge on a limited supply of food. If you’ve ever brought home a bag of miniature-sized Snickers with the intention of storing them in the kitchen cupboard for a few days until you can hand them out for Halloween, you know just how hard it can be to stop yourself from ripping open the bag and eating every last one of them.
developed graphical narrative. They draw attention to a painting in the Chauvet Cave where a hunting narrative runs from left to right, from lions stalking their prey, to rushing a herd of bison. Such visual and narrative sophistication suggests a fierce intelligence capable of combining multiple elements in order to tell a story.

Chauvet Cave art: Eight-Legged Bison. As a flickering torch was passed over the drawing, it would illuminate different legs, giving the perception of cinematic movement. Reproduced with permission from Marc Azéma and Gilles Tosello

Just imagine the excitement Fish Finder and Snare Maker must have felt in that cave as the light from their torches danced across the walls, making the images practically come to life. But more than that, they would have shared a unified menagerie of animals: bison, rhinos, lions, birds, horses, and bears. Was this fixation on the animal world a compendium of dangerous animals, animals that held some spiritual significance, a part of shamanistic practices, or something yet to be revealed?

Regardless of the meaning, Chauvet Cave holds clues about the working memory power of early humans. The world represented on the walls is not random or arbitrary. Instead, it reflects an intentional and selective process that required the use of working memory to hold in mind the possible animals and then choose what and what not to represent. For example, there are no trees, no rivers, no spears, no hills depicted. Perhaps more intriguingly, there are no humans. We may never know the exact meaning of these images, but we can easily see how they would have fascinated our cave-dwelling ancestors.
Once you have refined your end goal, work backward to figure out what you need to do to get there. If publishing an Android App is your goal, put that at the top and below that, write out all of the previous steps necessary, all the way back to the starting point. For example:

**Goal: Android App**

- Review App
- Hire Programmer
- Develop App Idea

This process may seem simple, but that is the point. By simplifying the steps and writing them down, it transitions from “Oh, that’d be a great idea, but it’ll never happen” to “I can do this.” By actualizing your ideas, you are giving your working memory something concrete to work with.

This tactic can be effective at every level throughout the corporate ranks—helping mailroom interns streamline the mail delivery process while cutting postage costs and helping CEOs determine how to reach a company’s financial goals.

Teachers can also use this strategy. For example:

**Goal: C students get Bs**

- Review test material with class
- Focus on test topics
- Integrate working memory principles.
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Goal: C students get Bs

➔ Review test material with class

➔ Focus on test topics

➔ Integrate working memory principles.
Memorizing names. If you need to remember the names of people that you meet at a coffee break at a conference, where everyone is just milling around, the loci method isn’t as useful. These situations tend to be a little more fluid, and it is easy to forget the name of a person who just introduced herself. Make people stick in your head by associating them with either a familiar word or image. If you tend to recall what you see better than what you hear, focus on the visual elements of that person and unite them with something that is visual and familiar to you, such as a color. For example, Bob drives a blue car, so make him “Blue Bob.” If you tend to remember what you hear better than what you see, bring together information that you talk about, such as where a person lives, with their name. In this case, Bob, who is also from California, will be remembered as “California Bob.”

Multiply on the Fly

Mental multiplication is a great stretch for your working memory because it requires you to hold a number of variables at the same time. A great way to do mental math is to multiply across the numbers, from left to right, adding up the results in between.

39 x 7 would be solved this way:

- 30 x 7 = 210
- 9 x 7 = 63
- 210 + 63 = 273

25 x 13 would be solved this way:

- 20 x 10 = 200
- 20 x 3 = 60
- 200 + 60 = 260
- 5 x 10 = 50
- 260 + 50 = 310
- 5 x 3 = 15
- 310 + 15 = 325
<table>
<thead>
<tr>
<th>2 Words</th>
<th>3 Words</th>
</tr>
</thead>
<tbody>
<tr>
<td>computer</td>
<td>flower</td>
</tr>
<tr>
<td>confident</td>
<td>delight</td>
</tr>
<tr>
<td>fortunate</td>
<td>bright</td>
</tr>
<tr>
<td>confident</td>
<td>flower</td>
</tr>
<tr>
<td>fortunate</td>
<td>guilty</td>
</tr>
<tr>
<td>afraid</td>
<td>scissors</td>
</tr>
<tr>
<td>anguish</td>
<td>coerced</td>
</tr>
<tr>
<td>afraid</td>
<td>coerced</td>
</tr>
<tr>
<td>anguish</td>
<td>bright</td>
</tr>
<tr>
<td>camera</td>
<td>dismal</td>
</tr>
<tr>
<td>inspire</td>
<td>mad</td>
</tr>
<tr>
<td>hug</td>
<td>bright</td>
</tr>
<tr>
<td>inspire</td>
<td>dismal</td>
</tr>
<tr>
<td>joy</td>
<td>pain</td>
</tr>
<tr>
<td>lawnmower</td>
<td>confident</td>
</tr>
<tr>
<td>safe</td>
<td>tile</td>
</tr>
<tr>
<td>lawnmower</td>
<td>guilty</td>
</tr>
<tr>
<td>inspire</td>
<td>confident</td>
</tr>
<tr>
<td>inspire</td>
<td>tile</td>
</tr>
</tbody>
</table>
Now that your working memory is consciously assessing the emotional impact of words, you can make it familiar with filtering out the negative ones and focusing on the positive ones. In this exercise, connect the positive words by drawing a line between them, being careful not to touch the negative or neutral words. If you struggle with this exercise, have a few cups of coffee or tea, and see if it is easier for you to focus on the positive, as research shows that caffeine improves how fast and how accurately you can recognize positive words.

Support Working Memory at All Ages

Your working memory is an amazing tool, but just like any tool, it needs care. If you don't sharpen a knife, you can't complain that it doesn't cut. Just like a knife, your working memory requires maintenance to stay in top working order. In these exercises we offer tips on how to give your—or your child's or your students’—working memory the TLC it needs.
Size Up Your Audience

When giving instructions to students or children, don’t give them more than their working memory can handle. By knowing how many instructions various age groups can hold in mind at one time, you can increase the likelihood that they will be able to carry out your instructions successfully. The following table shows how much you can expect according to age.

<table>
<thead>
<tr>
<th>Age</th>
<th>Working Memory and Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 to 6</td>
<td>2 instructions</td>
</tr>
<tr>
<td>7 to 9</td>
<td>3 instructions</td>
</tr>
<tr>
<td>10 to 12</td>
<td>4 instructions</td>
</tr>
<tr>
<td>13 to 15</td>
<td>5 instructions</td>
</tr>
<tr>
<td>16 to 30s</td>
<td>6 instructions</td>
</tr>
<tr>
<td>40s</td>
<td>5 instructions</td>
</tr>
<tr>
<td>50s</td>
<td>4 instructions</td>
</tr>
<tr>
<td>60s to 70s</td>
<td>3 instructions</td>
</tr>
</tbody>
</table>

Switch It Off!

One of the most important things you can do to support your child’s working memory is to turn off the TV. Research shows that the more television children are exposed to the greater the risk for developing attention problems, suggesting an abnormal development of working memory. How to do it? Be open and explain to them that it can undermine their ability to focus, which may have a negative impact on other aspects of their lives. Television should be a rare treat.

Sleep Yourself Smarter

When you skimp on sleep, your working memory gets as tired as you do. Plus, while it’s fatigued it has to perform double duty, trying to make up for the slack when other areas of your brain are too pooped.
to perform as needed. Here's a repeat of the helpful list of the sleep you should be getting.

### How Much Sleep Do You Need?

<table>
<thead>
<tr>
<th>Age</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toddlers (1 to 3 years)</td>
<td>12 to 14 hours</td>
</tr>
<tr>
<td>Preschoolers (3 to 5 years)</td>
<td>11 to 13 hours</td>
</tr>
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</tr>
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<td>Teens</td>
<td>8.5 to 9.25</td>
</tr>
<tr>
<td>Adults</td>
<td>7 to 9 hours</td>
</tr>
</tbody>
</table>

### Run for Your Working Memory

Science shows that running gives your PFC a workout. In part it's because running triggers greater blood flow to the PFC. We have found encouraging evidence that barefoot running may be one of the most beneficial forms of running in terms of working memory. Whether you prefer to lace up your shoes or go barefoot, making running a regular habit can enhance working memory. Just check with your physician before starting any exercise program.

### Learn to Speak Français, Español, or Deutsch

Learning a new language is a working-memory-intensive skill. You have to use your working memory to shift a host of new words, sounds, and meanings into your long-term memory and then become familiar with manipulating them correctly. This works best for new languages. If you're already bilingual, become trilingual. If you know English, give another language a try.