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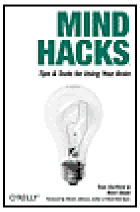

Mind Hacks

By Tom Stafford, Matt Webb

Publisher: O'Reilly
Pub Date: November 2004
ISBN: 0-596-00779-5
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- Table of Contents
- Index
- Reviews
- Reader Reviews
- Errata
- Academic
- Paying Attention (or Not) to the Flickr Daily Zeitgeist

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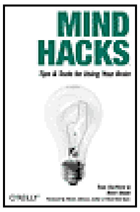

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Dedication

"What to do with too much information is the great riddle of our time."
Theodore Zeldin, *An Intimate History of Humanity*

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PREVIOUS NEXT

Preface

Think for a moment about all that's happening while you read this text: how your eyes move to center themselves on the words, how you idly scratch your arm while you're thinking, the attention-grabbing movements, noises, and other distractions you're filtering out. How does all this work? As one brain speaking to another, here's a secret: it isn't easy.

The brain is a fearsomely complex information-processing environment. Take the processing involved in seeing, for instance. One of the tasks involved in seeing is detecting the motion in every tiny portion of vision, in such and such a direction and at such and such a speed, and representing that in the brain. But another task is seeing a face in the light that falls on the retina, figuring out what emotion it's showing, and representing that concept in the brain, somehow, too.

To an extent, the brain is modular, so that should give us a way in, but it's not that clean-cut. The processing subsystems of the brain are layered on top of one another, but their functionality mingles rather than being organized in a distinct progression. Often the same task is performed in many different places, in many different ways. It's not a clear mechanical system like clockwork or like a computer program; giving the same input won't always give the same output. Automatic and voluntary actions are highly meshed, often inextricable. Parts of vision that appear fully isolated from conscious experience suddenly report different results if conscious expectations change.

The information transforms in the brain are made yet more complicated by the constraints of history, computation, and architecture. Development over evolutionary time has made it hard for the brain to backtrack; the structure of the brain must reflect its growth and repurposing. Computation has to occur as fast as possiblewe're talking subsecond responsesbut there are limits on the speed at which information can travel between physical parts of the brain. These are all constraints to be worked with.

All of which leaves us with one question: how can we possibly start to understand what's going on?

Cognitive neuroscience is the study of the brain biology behind our mental functions. It is a collection of methods (like brain scanning and computational modeling) combined with a way of looking at psychological phenomena and discovering where, why, and how the brain makes them happen. It is neither classic neurosciencea low-level tour of the biology of the brainnor is it what many people think of as psychologya metaphorical exploration of human inner life; rather, it's a view of the mind that looks at the fundamental elements and rules, acting moment by moment, that makes up conscious experience and action.

By focusing both on the biological substrate and on the high-level phenomenon of consciousness, we can pick apart the knot of the brain. This picking apart is why you don't need to be a cognitive neuroscientist to reap the fruit of the field.

This book is a collection of probes into the moment-by-moment works of the brain. It's not a textbookmore of a buffet, really. Each hack is one probe into the operation of the brain, one small demonstration. By seeing how the brain responds, we pick up traces of the structures present and the design decision made, learning a little bit more about how the brain is put together.

Simultaneously we've tried to show how there isn't a separation between the voluntary "me" feeling of the mind and the automatic nature of the brainthe division between voluntary and automatic behavior is more of an ebb and flow, and we wield our cognitive abilities with unconscious flourishes and deliberate movements much as we wield, say, our hands, or a pen, or a lathe.

In a sense, we're trying to understand the capabilities that underpin the mind. Say we understand to what extent the holes in our vision are continually covered up or what sounds and lights willwithout a doubtgrab our attention (and also what won't): we'll be able to design better tools, and create better interfaces that work with the grain of our mental architecture and not against it. We'll be able to understand ourselves a little better; know a little more, in a very real sense, about what makes us tick.

Plus it's fun. That's the key. Cognitive neuroscience is a fairly new discipline. The journey into

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Why Mind Hacks?

The term "*hacking*" has a bad reputation in the media. They use it to refer to those who break into systems or wreak havoc with computers as their weapons. Among people who write code, though, the term "*hack*" refers to a "quick-and-dirty" solution to a problem, or a clever way to get something done. And the term "*hacker*" is taken very much as a compliment, referring to someone as being "*creative*," having the technical chops to get things done. The Hacks series is an attempt to reclaim the word, document the good ways people are hacking, and pass the hacker ethic of creative participation on to the uninitiated. Seeing how others approach systems and problems is often the quickest way to learn about a new technology.

The brain, like all hidden systems, is prime territory for curious hackers. Thanks to relatively recent developments in cognitive neuroscience, we're able to satisfy a little of that curiosity, making educated explanations for psychological effects rather than just pointing those effects out, throwing light on the internal workings of the brain.

Some of the hacks in this collection document the neat tricks the brain has used to get the job done. Looking at the brain from the outside like this, it's hard not to be impressed at the way it works. Other hacks point to quirks of our own minds that we can exploit in unexpected ways, and that's all part of learning our way round the wrinkles in this newly exposed technology.

Mind Hacks is for people who want to know a bit more about what's going on inside own heads and for people who are going to assemble the hacks in new ways, playing with the interface between ourselves and the world. It's wonderfully easy to get involved. We've all got brains, after all.

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How to Use This Book

You can read this book from cover to cover if you like, but each hack stands on its own, so feel free to browse and jump to the different sections that interest you most. If there's a prerequisite you need to know, a cross-reference will guide you to the right hack.

We've tried out all the demonstrations in this book, so we know that for most people they work just as we say they do; these are real phenomena. Indeed, some are surprising, and we didn't believe they'd work until we tried them ourselves. The explanations are summaries of the current state of knowledgeoften snapshots of debates in progress. Keep an open mind about these. There's always the chance future research will cause us to revise our understanding.

Often, because there is so much research on each topic, we have linked to web sites, books, and academic papers to find out more. Follow these up. They're fantastic places to explore the wider story behind each hack, and will take you to interesting places and appear interesting connections.

With regard to academic papers, these are bedrock of scientific knowledge. They can be hard to get and hard to understand, but we included references to them because they are the place to go if you really need to get to the bottom of a story (and to find the cutting edge). What's more, for many scientists, evidence doesn't really exist until it has been published in a scientific journal. For this to happen, the study has to be reviewed by other scientists working in the field, in a system called peer review. Although this system has biases, and mistakes are made, it is this that makes science a collective endeavor and provides a certain guarantee of quality.

The way journal articles are cited is quite precise, and in this book we've followed the American Psychological Association reference style (http://www.apastyle.org). Each looks something like this:

- Lettvin, J., Maturana, H., McCulloch, W., & Pitts, W. (1959). What the frog's eye tells the frog's brain. *Proceedings of the IRE, 47*(11), 1940-1951.

Before the year of publication (which is in parentheses), the authors are listed. After the year is the title of the paper, followed by the journal in which you'll find it, in italics. The volume (in italics) and then the issue number (in parentheses) follow. Page numbers come last. (There's a crib sheet online: http://www.liu.edu/cwis/cwp/library/workshop/citapa.htm.) One convention you'll often see in the text is "et al." after the main author of a paper. This is shorthand for "and others."

Many, but not all, journals have an electronic edition, and some you can access for free. Most are subscription-based, although some publishers will let you pay per paper. If you go to a library, generally a university library, make sure it not only subscribes to the journal you want, but also has the year in which the paper you're after was published.

If you're lucky, the paper will also be reprinted online. This is often the case with classic papers and with recent papers, which the authors may have put on their publications page. A good query to use at Google (http://www.google.com) for papers online in PDF format using a query like:

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"What the Frog's Eye Tells the Frog's Brain" filetype:pdf
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Alternately, search for a researcher's name followed by the word "publications" for papers, demonstrations, and as-yet-unpublished research, a gold mine if you're learning more about a particular topic.

Recommended Reading

If you're interested in getting a general overview, rather than chasing the details of a particular story, you might like to start by reading a book on the subject. Here are some of our favorite books on our own pet topics, all of which make specialist material accessible for the rest of us:

- *Descartes' Baby: How the Science of Child Development Explains What Makes Us*

How This Book Is Organized

The book is divided into 10 chapters, organized by subject:

Chapter 1, *Inside the Brain*

> The question is not just "How do we look inside the brain?" but "How do we talk about what's there once we can see it?" There are a number of ways to get an idea about how your brain is structured (from measuring responses on the outside to taking pictures of the inside)that's half of this chapter. The other half speaks to the second question: we'll take in some of the sights, check out the landmarks, and explore the geography of the brain.

Chapter 2, *Seeing*

> The visual system runs all the way from the way we move our eyes to how we reconstruct and see movement from raw images. Sight's an important sense to us; it's high bandwidth and works over long distances (unlike, say, touch), and that's reflected in the size of this chapter.

Chapter 3, *Attention*

> One of the mechanisms we use to filter information before it reaches conscious awareness is attention. Attention is sometimes voluntary (you can pay attention) and sometimes automatic (things can be attention-grabbing)here we're looking at what it does and some of its limitations.

Chapter 4, *Hearing and Language*

> Sounds usually correspond to events; a noise usually means something's just happened. We'll have a look at what our ears are good for, then move on to language and some of the ways we find meaning in words and sentences.

Chapter 5, *Integrating*

> It's rare we operate using just a single sense; we make full use of as much information as we can find, integrating sight, touch, our propensity for language, and other inputs. When senses agree, our perception of the world is sharper. We'll look at how we mix up modes of operating (and how we can't help doing so, even when we don't mean to) and what happens when senses disagree.

Chapter 6, *Moving*

> This chapter covers the bodyhow the image the brain has of our body is easy to confuse and also how we use our body to interact with the world. There's an illusion you can walk around, and we'll have a little look at handedness too.

Chapter 7, *Reasoning*

> We're not built to be perfect logic machines; we're shaped to get on as well as possible in the world. Sometimes that shows up in the kind of puzzles we're good at and the sort of things we're duped by.

Chapter 8, *Togetherness*

> The senses give us much to go by, to reconstruct what's going on in the universe. We can't perceive cause and effect directly, only that two things happen at roughly the same time in roughly the same place. The same goes for complex objects: why see a whole person instead of a torso, head, and collection of limbs? Our reconstruction of objects and causality follow simple principles, which we use in this chapter.

Chapter 9, *Remembering*

> We wouldn't be human if we weren't continually learning and changing, becoming different people. This chapter covers how learning begins at the level of memory over

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Conventions Used in This Book

The following typographical conventions are used in this book:

Italics

Used to indicate URLs, filenames, filename extensions, and directory/folder names. For example, a path in the filesystem will appear as */Developer/Applications*.

You should pay special attention to notes set apart from the text with the following icons:

> This is a tip, suggestion, or general note. It contains useful supplementary information about the topic at hand.

> This is a warning or note of caution, often indicating that your money or your privacy might be at risk.

This is an aside, a tangential or speculative comment. We thought it interesting, although not essential.

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Chapter 1. Inside the Brain

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1.1. Hacks 1-12

It's never entirely true to say, "This bit of the brain is solely responsible for function X." Take the visual system [Hack #13], for instance; it runs through many varied parts of the brain with no single area solely responsible for all of vision. Vision is made up of lots of different subfunctions, many of which will be compensated for if areas become unavailable. With some types of brain damage, it's possible to still be able to see, but not be able to figure out what's moving or maybe not be able to see what color things are.

What we can do is look at which parts of the brain are active while it is performing a particular taskanything from recognizing a face to playing the pianoand make some assertions. We can provide input and see what output we getthe black box approach to the study of mind. Or we can work from the outside in, figuring out which abilities people with certain types of damaged brains lack.

The latter, part of neuropsychology [Hack #6], is an important tool for psychologists. Small, isolated strokes can deactivate very specific brain regions, and also (though more rarely) accidents can damage small parts of the brain. Seeing what these people can no longer do in these pathological cases, provides good clues into the functions of those regions of the brain. Animal experimentation, purposely removing pieces of the brain to see what happens, is another.

These are, however, pathology-based methodsless invasive techniques are available. Careful experimentationmeasuring response types, reaction times, and response changes to certain stimuli over timeis one such alternative. That's cognitive psychology [Hack #1], the science of making deductions about the structure of the brain through reverse engineering from the outside. It has a distinguished history. More recently we've been able to go one step further. Pairing techniques from cognitive psychology with imaging methods and stimulation techniques [Hack#2] through [Hack#5], we can manipulate and look at the brain from the outside, without having to, say, remove the skull and pull a bit of the cerebrum out. These imaging methods are so important and referred to so much in the rest of this book, we've provided an overview and short explanation for some of the most common techniques in this chapter.

In order that the rest of the book make sense, after looking at the various neuroscience techniques, we take a short tour round the central nervous system [Hack #7], from the spine, to the brain [Hack #8], and then down to the individual neuron [Hack #9] itself. But what we're really interested in is how the biology manifests in everyday life. What does it really mean for our decision-making systems to be assembled from neurons rather than, well, silicon, like a computer? What it means is that we're not software running on hardware. The two are one and the same, the physical properties of our mental substrate continually leaking into everyday life: the telltale sign of our neurons is evident when we respond faster to brighter lights [Hack #11], and our biological roots show through when blood flow has to increase because we're thinking so hard [Hack #10] .

And finally take a gander at a picture of the body your brain thinks you have and get in touch with your inner sensory homunculus [Hack #12] .

Hack 1. Find Out How the Brain Works Without Looking Inside

How do you tell what's inside a black box without looking in it? This is the challenge the mind presents to cognitive psychology.

Cognitive psychology is the psychology of the basic mental processesthings like perception, attention, memory, language, decision-making. It asks the question, "What are the fundamental operations on which mind is based?"

The problem is, although you can measure what goes into someone's head (the input) and measure roughly what they do (the output), this doesn't tell you anything about what goes on in between. It's a black box, a classic reverse engineering problem.[1] How can we figure out how it works without looking at the code?

These days, of course, we can use neuroimaging (like EEG **[Hack 2]**, PET **[Hack #3]**, and fMRI **[Hack #4]**) to look inside the head at the brain, or use information on anatomy and information from brain-damaged individuals **[Hack #6]** to inform how we think the brain runs the algorithms that make up the mind. But this kind of work hasn't always been possible, and it's never been easy or cheap. Experimental psychologists have spent more than a hundred years refining methods for getting insight into how the mind works without messing with the insides, and these days we call this cognitive psychology.

There's an example of a cognitive psychology-style solution in another book from the hacks series, *Google Hacks* (http://www.oreilly.com/catalog/googlehks). Google obviously doesn't give access to the algorithms that run its searches, so the authors of *Google Hacks*, Tara Calishain and Rael Dornfest, were forced to do a little experimentation to try and work it out. Obviously, if you put in two words, Google returns pages that feature both words. But does the order matter? Here's an experiment. Search Google for "reverse engineering" and then search for "engineering reverse." The results are different; in fact, they are sometimes different even when searching for words that aren't normally taken together as some form of phrase. So we might conclude that order does make a difference; in some way, the Google search algorithm takes into account the order. If you try to whittle a search down to the right terms, something that returned only a couple of hits, perhaps over time you could figure out more exactly how the order mattered.

This is basically what cognitive psychology tries to do, reverse engineering the basic functions of the mind by manipulating the inputs and looking at the results. The inputs are often highly restricted situations in which people are asked to make judgments or responses in different kinds of situations. *How many words from the list you learned yesterday can you still remember? How many red dots are there? Press a key when you see an X appear on the screen*. That sort of thing. The speed at which they respond, the number of errors, or the patterns of recall or success tell us something about the information our cognitive processes use, and how they use it.

A few things make reverse engineering the brain harder than reverse engineering software, however.

Biological systems are often complex, sometimes even chaotic (in the technical sense). This means that there isn't necessarily a one-to-one correspondence in how a change in input affects output. In a logic-based or linear system, we can clearly see causes and effects. The mind, however, doesn't have this orderly mapping. Small things have big effects and sometime big changes in circumstance can produce little obvious difference in how we respond. Biological functionsincluding cognitionare often supported by multiple processes. This means they are robust to changes in just one supporting process, but it also means that they don't always respond how you would have thought when you try and influence them.

People also aren't consistent in the same way software or machines usually are. Two sources of variability are noise and learning. We don't automatically respond in the same way to the same stimulus every time. This sometimes happens for no apparent reason, and we call this randomness *noise*. But sometimes our responses change for a reason, not because of noise, and that's because the very act of responding first time around creates feedback that informs our response pattern for the next time (for example, when you get a new bike, you're

Hack 2. Electroencephalogram: Getting the Big Picture with EEGs

EEGs give you an overall picture of the timing of brain activity but without any fine detail.

An *electroencephalogram* (EEG) produces a map of the electrical activity on the surface of the brain. Fortunately, the surface is often what we're interested in, as the cortexresponsible for our complex, high-level functionsis a thin sheet of cells on the brain's outer layer. Broadly, different areas contribute to different abilities, so one particular area might be associated with grammar, another with motion detection. Neurons send signals to one another using electrical impulses, so we can get a good measure of the activity of the neurons (how busy they are doing the work of processing) by measuring the electromagnetic field nearby. Electrodes outside the skull on the surface of the skin are close enough to take readings of these electromagnetic fields.

Small metal disks are evenly placed on the head, held on by a conducting gel. The range can vary from two to a hundred or so electrodes, all taking readings simultaneously. The output can be a simple graph of signals recorded at each electrode or visualised as a map of the brain with activity called out.

1.3.1. Pros

- The EEG technique is well understood and has been in use for many decades. Patterns of electrical activity corresponding to different states are now well-known: sleep, epilepsy, or how the visual cortex responds when the eyes are in use. It is from EEG that we get the concepts of alpha, beta, and gamma waves, related to three kinds of characteristic oscillations in the signal.
- Great time resolution. A reading of electrical activity can be taken every few milliseconds, so the brain's response to stimuli can be precisely plotted.
- Relatively cheap. Home kits are readily available. OpenEEG (http://openeeg.sourceforge.net), EEG for the rest of us, is a project to develop low-cost EEG devices, both hardware and software.

1.3.2. Cons

- Poor spatial resolution. You can take only as many readings in space as electrodes you attach (up to 100, although 40 is common). Even if you are recording from many locations, the electrical signals from the scalp don't give precise information on where they originate in the brain. You are getting only information from the surface of the skull and cannot perfectly infer what and where the brain activity was that generated the signals. In effect this means that it's useful for looking at overall activity or activity in regions no more precise than an inch or so across.

Myles Jones & Matt Webb

Hack 3. Positron Emission Tomography: Measuring Activity Indirectly with PET

PET is a radioactivity-based technique to build a detailed 3D model of the brain and its activity.

Positron emission tomography (PET) is more invasive than any of the other imaging techniques. It requires getting a radioactive chemical into the bloodstream (by injection) and watching for where in the brain the radioactivity ends upthe "positron emission" of the name. The level of radioactivity is not dangerous, but this technique should not be used on the same person on a regular basis.

When neurons fire to send a signal to other neurons, they metabolize more energy. A few seconds later, fresh blood carrying more oxygen and glucose is carried to the region. Using a radioactive isotope of water, the amount of blood flow to each brain location can be monitored, and the active areas of the brain that require a lot of energy and therefore blood flow can be deduced.

1.4.1. Pros

- A PET scan will produce a 3D model of brain activity.

1.4.2. Cons

- Scans have to take place in bulky, expensive machinery, which contain the entire body.
- PET requires injecting the subject with a radioactive chemical.
- Although the resolution of images has improved over the last 30 years, PET still doesn't produce as fine detail as other techniques (it can see activity about 1 cm across).
- PET isn't good for looking at how brain activity changes over time. A snapshot can take minutes to be assembled.

Myles Jones & Matt Webb

Hack 4. Functional Magnetic Resonance Imaging: The State of the Art

fMRI produces high-resolution animations of the brain in action.

Functional magnetic resonance imaging (fMRI) is the king of brain imaging. Magnetic resonance imaging is noninvasive and has no known side effectsexcept, for some, claustrophobia. Having an MRI scan requires you to lie inside a large electromagnet in order to be exposed to the high magnetic field necessary. It's a bit like being slid inside a large white coffin. It gets pretty noisy too.

The magnetic field pushes the hydrogen atoms in your brain into a state in which they all "line up" and spin at the same frequency. A radio frequency pulse is applied at this exact frequency, making the molecules "resonate" and then emit radio waves as they lose energy and return to "normal." The signal emitted depends on what type of tissue the molecule is in. By recording these signals, a 3D map of the anatomy of the brain is built up.

MRI isn't a new technology (it's been possible since the '70s), but it's been applied to psychology with BOLD functional MRI (abbreviated to fMRI) only as recently as 1992. To obtain functional images of the brain, BOLD (blood oxygen level dependent) fMRI utilizes the fact that deoxygenated blood is magnetic (because of the iron in hemoglobin) and therefore makes the MRI image darker. When neurons become active, fresh blood washes away the deoxygenated blood in the precise regions of the brain that have been more active than usual.

While structural MRI can take a long time, fMRI can take a snapshot of activity over the whole brain every couple of seconds, and the resolution is still higher than with PET **[Hack #3]**. It can view activity in volumes of the brain only 2 mm across and build a whole map of the brain from that. For a particular experiment, a series of fMRI snapshots will be animated over a single high-resolution MRI scan, and experimenters can see in exactly which brain areas activity is taking place.

Much of the cognitive neuroscience research done now uses fMRI. It's a method that is still developing and improving, but already producing great results.

1.5.1. Pros

- High spatial resolution and good enough time resolution to look at changing patterns of activity. While not able to look at the changing brain as easily as EEG **[Hack #2]**, its far greater spatial resolution means fMRI is suitable for looking at which parts of the brain are active in the process of recalling a fact, for example, or seeing a face.

1.5.2. Cons

- Bulky, highly magnetic, and very expensive machinery.
- fMRI is still new. It's a complex technique requiring computing power and a highly skilled team with good knowledge both of physics and of the brain.

Myles Jones & Matt Webb

Hack 5. Transcranial Magnetic Stimulation: Turn On and Off Bits of the Brain

Stimulate or suppress specific regions of the brain, then sit back and see what happens.

Transcranial magnetic stimulation (TMS) isn't an imaging technique like EEG **[Hack 2]** or fMRI **[Hack #4]**, but it can be used along with them. TMS uses a magnetic pulse or oscillating magnetic fields to temporarily induce or suppress electrical activity in the brain. It doesn't require large machines, just a small device around the head, andso far as we knowit's harmless with no aftereffects.

Neurons communicate using electrical pulses, so being able to produce electrical activity artificially has its advantages. Selected regions can be excited or suppressed, causing hallucinations or partial blindness if some part of the visual cortex is being targeted. Both uses help discover what specific parts of the brain are for. If the subject experiences a muscle twitching, the TMS has probably stimulated some motor control neurons, and causing hallucinations at different points in the visual system can be used to discover the order of processing (it has been used to discover where vision is cut out during saccades **[Hack #17]**, for example).

Preventing a region from responding is also useful: if shutting down neurons in a particular area of the cortex stops the subject from recognizing motion, that's a good clue as to the function of that area. This kind of discovery was possible before only by finding people with localized brain damage; now TMS allows more structured experiments to take place.

Coupled with brain imaging techniques, it's possible to see the brain's response to a magnetic pulse ripple through connected areas, revealing its structure.

1.6.1. Pros

- Affects neural activity directly, rather than just measuring it.

1.6.2. Cons

- Apparently harmless, although it's still early days.

1.6.3. See Also

- "Savant For a Day" by Lawrence Osbourne (http://www.nytimes.com/2003/06/22/magazine/22SAVANT.html or http://www.cognitiveliberty.org/neuro/TMS_NYT.html, an alternative URL), an article in the *New York Times*, which describes Lawrence Osborne's experience of TMS, having higher-level functions of his brain suppressed, and a different type of intelligence exposed.

Myles Jones & Matt Webb

Hack 6. Neuropsychology, the 10% Myth, and Why You Use All of Your Brain

Neuropsychology is the study of what different parts of the brain do by studying people who no longer have those parts. As well as being the oldest technique of cognitive neuroscience, it refutes the oft-repeated myth that we only use 10% of our brains.

Of the many unscientific nuggets of wisdom about the brain that many people believe, the most common may be the "fact" that we use only 10% of our brains.

In a recent survey of people in Rio de Janeiro with at least a college education, approximately half stated that the 10% myth was true.[1] There is no reason to suppose the results of a similar survey conducted anywhere else in the world would be radically different. It's not surprising that a lot of people believe this myth, given how often it is claimed to be true. Its continued popularity has prompted one author to state that the myth has "a shelf life longer than lacquered Spam".[2]

Where does this rather popular belief come from?

It's hard to find out how the myth started. Some people say that something like it was said by Einstein, but there isn't any proof. The idea that we have lots of spare *capacity* is certainly true and fits with our aspirational culture, as well as with the Freudian notion that the mind is mostly unconscious. Indeed, the myth was being used to peddle self-help literature as early as 1929.[3] The neatness and numerological potency of the 10% figure is a further factor in the endurance of the myth.

A.B.

Neuropsychology is the study of patients who have suffered brain damage and the psychological consequences of that brain damage. As well as being a vital source of information about which bits of the brain are involved in doing which things, neuropsychology also provides a neat refutation of the 10% myth: if we use only 10% of our brains, which bits would you be happy to lose? From neuropsychology, we know that losing *any* bit of the brain causes you to stop being able to do something or being able to do it so well. It's all being used, not just 10% of it.

Admittedly we aren't clear on exactly what each bit of the brain does, but that doesn't mean that you can do without 90% of it.

Neuropsychology has other uses aside from disproving unhelpful but popularly held trivia. By looking at which psychological functions remain after the loss of a certain brain region, we can tell what brain regions are and are not necessary for us to do different things. We can also see how functions group and divide by looking at whether they are always lost together or lost only in dissimilar cases of brain damage. Two of the famous early discoveries of neuropsychology are two distinct language processing regions in the brain. *Broca's area* (named after the neuropsychologist Paul Broca) is in the frontal lobe and supports understanding and producing structure in language. Those with damage to Broca's area speak in stilted, single words. *Wernicke's area* (on the junction between the temporal and parietal lobes and named after Carl Wernicke) supports producing and understanding the semantics of language. People with brain damage to Wernicke's area can produce grammatically correct sentences, but often with little or no meaning, an incomprehensible "word salad."

Another line of evidence against the 10% myth is brain imaging research [**[Hack#2]** through **[Hack#4]**], which has grown exponentially in the last couple of decades. Such techniques allow the increased blood flow to be measured in certain brain regions during the performance of cognitive tasks. While debate continues about the degree to which it is sensible to infer much about functional localization from imaging studies, one thing they make abundantly clear is that there are no areas of the brain that are "black holes"areas that never "light up" in response to some task or other. Indeed, the neurons that comprise the cortex of the brain are active to some degree all the time, even during sleep.

A third line of argument is that of evolutionary theory. The human brain is a very expensive

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Hack 7. Get Acquainted with the Central Nervous System

Take a brief tour around the spinal cord and brain. What's where, and what does what?

Think of the central nervous system like a mushroom with the spinal cord as the stalk and the brain as the cap. Most of the hacks in this book arise from features in the cortex, the highly interconnected cells that make a thin layer over the brain...but not all. So let's start outside the brain itself and work back in.

Senses and muscles all over the body are connected to nerves, bundles of neurons that carry signals back and forth. Neurons come in many types, but they're basically the same wherever they're found in the body; they carry electric current and can act as relays, passing on information from one neuron to the next. That's how information is carried from the sensory surface of the skin, as electric signals, and also how muscles are told to move, by information going the other way.

Nerves at this point run to the spinal cord two by two. One of each pair of nerves is for receptors (a sense of touch for instance) and one for *effectors*these trigger actions in muscles and glands. At the spinal cord, there's no real intelligence yet but already some decision-makingsuch as the withdrawal reflexoccurs. Urgent signals, like a strong sense of heat, can trigger an effector response (such as moving a muscle) before that signal even reaches the brain.

The spinal cord acts as a conduit for nerve impulses up and down the body: sensory impulses travel up to the brain, and the motor areas of the brain send signals back down again. Inside the cord, the signals converge into 31 pairs of nerves (sensory and motor again), and eventually, at the top of the neck, these meet the brain.

At about the level of your mouth, right in the center of your head, the bundles of neurons in the spinal cord meet the brain proper. This tip of the spinal cord, called the *brain stem*, continues like a thick carrot up to the direct center of your brain, at about the same height as your eyes.

This, with some other central regions, is known as the *hindbrain*. Working outward from the brain stem, the other large parts of the brain are the *cerebellum*, which runs behind the soft area you can feel at the lower back of your head, and the *forebrain*, which is almost all the rest and includes the cortex.

Hindbrain activities are mostly automatic: breathing, the heartbeat, and the regulation of the blood supply.

The cerebellum is old brainalmost as if it were evolution's first go at performing higher-brain functions, coordinating the senses and movement. It plays an important role in learning and also in motor control: removing the cerebellum produces characteristic jerky movements. The cerebellum takes input from the eyes and ears, as well as the balance system, and sends motor signals to the brain stem.

Sitting atop the hindbrain is the *midbrain*, which is small in humans but much larger in animals like bats. For bats, this corresponds to a relay station for auditory informationbats make extensive use of their ears. For us, the midbrain acts as a connection layer, penetrating deep into the forebrain (where our higher-level functions are) and connecting back to the brain stem. It acts partially to control movement, linking parts of the higher brain to motor neurons and partially as a hub for some of the nerves that don't travel up the spinal cord but instead come directly into the brain: eye movement is one such function.

Now we're almost at the end of our journey. The *forebrain*, also known as the *cerebrum*, is the bulbous mass divided into two great hemispheresit's the distinctive image of the brain that we all know. Buried in the cerebrum, right in the middle where it surrounds the tip of the brain stem and midbrain, there's the limbic system and other primitive systems. The limbic system is involved in essential and automatic responses like emotions, and includes the very tip of the temporal cortex, the hippocampus and the amygdala, and, by some reckonings, the hypothalamus. In some animals, like reptiles, this is all there is of the forebrain. For them, it's

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Hack 8. Tour the Cortex and the Four Lobes

The forebrain, the classic image of the brain we know from pictures, is the part of the brain that defines human uniqueness. It consists of four lobes and a thin layer on the surface called the cortex.

When you look at pictures of the human brain, the main thing you see is the rounded, wrinkled bulk of the brain. This is the *cerebrum*, and it caps off the rest of the brain and central nervous system **[Hack #7]**.

To find your way around the cerebrum, you need to know only a few things. It's divided into two hemispheres, left and right. It's also divided into four lobes (large areas demarcated by particularly deep wrinkles). The wrinkles you can see on the outside are actually folds: the cerebrum is a very large folded-up surface, which is why it's so deep. Unfolded, this surfacethe *cerebral cortex*would be about 1.5 m^2 (a square roughly 50 inches on the side), and between 2 and 4 mm deep. It's not thick, but there's a lot of it and this is where all the work takes place. The outermost part, the top of the surface, is *gray matter*, the actual neurons themselves. Under a few layers of these is the *white matter*, the fibers connecting the neurons together. The cortex is special because it's mainly where our high-level, human functions take place. It's here that information is integrated and combined from the other regions of the brain and used to modulate more basic functions elsewhere in the brain. The folds exist to allow many more neurons and connections than other animals have in a similar size area.

1.9.1. Cerebral Lobes

The four cerebral lobes generally perform certain classes of function.

You can cover the *frontal lobe* if you put your palms on your forehead with your fingers pointing up. It's heavily involved in planning, socializing, language, and general control and supervision of the rest of the brain.

The *parietal lobe* is at the top and back of your head, and if you lock your fingers together and hook your hands over the top back, that's it covered there. It deals a lot with your senses, combining information and representing your body and movements. The object recognition module for visual processing **[Hack #13]** is located here.

You can put your hands on only the ends of the *temporal lobe*it's right behind the ears. It sits behind the frontal lobe and underneath the parietal lobe and curls up the underside of the cerebrum. Unsurprisingly, auditory processing occurs here. It deals with language too (like verbal memory), and the left hemisphere is specialized for this (non-linguistic sound is on the right). The curled-up ends of the temporal lobe join into the limbic system at the hippocampus and are involved in long-term memory formation.

Finally, there's the *occipital lobe*, right at the back of the brain, about midway down your head. This is the smallest lobe of the cerebrum and is where the visual cortex is located.

The two hemispheres are joined together by another structure buried underneath the lobes, called the *corpus callosum*. It's the largest bundle of nerve fibers in the whole nervous system. While sensory information, such as vision, is divided across the two hemispheres of the brain, the corpus callosum brings the sides back together. It's heavily coated in a fatty substance called *myelin*, which speeds electrical conduction along nerve cells and is so efficient that the two sides of the visual cortex (for example) operate together almost as if they're adjacent. Not bad considering the corpus callosum is connecting together brain areas a few inches apart when the cells are usually separated by only a millimeter or two.

1.9.2. Cerebral Cortex

The cortex, the surface of these lobes, is divided into areas performing different functions. This isn't exact, of course, and they're highly interconnected and draw information from one another, but more or less there are small areas of the surface that perform edge detection for visual information or detect tools as opposed to animate objects in much higher-level areas of the brain.

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Hack 9. The Neuron

There's a veritable electrical storm going on inside your head: 100 billion brain cells firing electrical signals at one another are responsible for your every thought and action.

A *neuron*, a.k.a. *nerve cell* or *brain cell*, is a specialized cell that sends an electrical impulse out along fibers connecting it, in turn, to other neurons. These guys are the wires of your very own personal circuitry.

What follows is a simplistic description of the general features of nerve cells, whether they are found sending signals from your senses to your brain, from your brain to your muscles, or to and from other nerve cells. It's this last class, the kind that people most likely mean when they say "neurons," that we are most interested in here. (All nerve cells, however, share a common basic design.)

> Don't for a second think that the general structure we're describing here is the end of the story. The elegance and complexity of neuron design is staggering, a complex interplay of structure and noise; of electricity, chemistry, and biology; of spatial and dynamic interactions that result in the kind of information processing that cannot be defined using simple rules.[1] For just a glimpse at the complexity of neuron structure, you may want to start with this free chapter on nerve cells from the textbook *Molecular Cell Biology* by Harvey Lodish, Arnold Berk, Lawrence S. Zipursky, Paul Matsudaira, David Baltimore, and James Darnell and published by W. H. Freeman (http://www.ncbi.nlm.nih.gov/books/bv.fcgi?call=bv.View..ShowSection&rid=mcb.chapter.6074), but any advanced cell biology or neuroscience textbook will do to give you an idea of what you're missing here.

The neuron is made up of a cell body with long offshootsthese can be very long (the whole length of the neck, for some neurons in the giraffe, for example) or very short (i.e., reaching only to the neighboring cell, scant millimeters away). Signals pass only one way along a neuron. The offshoots receiving incoming transmissions are called *dendrites*. The outgoing end, which is typically longer, is called the *axon*. In most cases there's only one, long, axon, which branches at the tip as it connects to other neuronsup to 10,000 of them. The junction where the axon of one cell meets the dendrites of another is called the *synapse*. Chemicals, called *neurotransmitters*, are used to get the signal across the synaptic gap. Each neuron will release only one kind of neurotransmitter, although it may have receptors for many different kinds. The arrival of the electric signal at the end of the axon triggers the release of stores of the neurotransmitter that move across the gap (it's very small, after all) and bind to receptor sites on the other side, places on the neuron that are tuned to join with this specific type of chemical.

Whereas the signal between neurons uses neurotransmitters, internally it's electrical. The electrical signal is sent along the neuron in the form of an *action potential*.[2] This is what we mean when we say *impulses*, *signals*, *spikes*, or refer, in brain imaging speak, to the *firing* or *lighting up* of brain areas (because this is what activity looks like on the pictures that are made). Action potentials are the fundamental unit of information in the brain, the universal currency of the neural market.

The two most important computational features are as follows:

- They are binary. A neuron either fires or doesn't, and each time it fires, the signal is the same size (there's more on this later). Binary signals stop the message from becoming diluted as neurons communicate with one another over distances that are massive compared to the molecular scale on which they operate.

- Neurons encode information in the rate at which they send signals, not in the size of the signals they send. The signals are always the same size, information encoded in the frequency at which signals are sent. A stronger signal is indicated by a higher frequency of spikes, not larger single spikes. This is called *rate coding*.

Hack 10. Detect the Effect of Cognitive Function on Cerebral Blood Flow

When you think really hard, your heart rate noticeably increases.

The brain requires approximately 20% of the oxygen in the body, even during times of rest. Like the other organs in our body, our brain needs more glucose, oxygen, and other essential nutrients as it takes on more work. Many of the scanning technologies that aim to measure aspects of brain function take advantage of this. Functional magnetic resonance imaging (fMRI) **[Hack #4]** benefits from the fact that oxygenated blood produces slightly different electromagnetic signals when exposed to strong magnetic fields than deoxygenated blood and that oxygenated blood is more concentrated in active brain areas. Positron emission tomography (PET) **[Hack #3]** involves being injected with weakly radioactive glucose and reading the subsequent signals from the most active, glucose-hungry areas of the brain.

A technology called *transcranial Doppler sonography* takes a different approach and measures blood flow through veins and arteries. It takes advantage of the fact that the pitch of reflected ultrasound will be altered in proportion to the rate of flow and has been used to measure moment-to-moment changes in blood supply to the brain. It has been found to be particularly useful in making comparisons between different mental tasks. However, even without transcranial Doppler sonography, you can measure the effect of increased brain activity on blood flow by measuring the pulse.

1.11.1. In Action

For this exercise you will need to get someone to measure your *carotid pulse*, taken from either side of the front of the neck, just below the angle of the jaw. It is important that only very light pressure be useda couple of fingertips pressed lightly to the neck, next to the windpipe, should enable your friend to feel your pulse with little trouble.

First you need to take a measure of a resting pulse. Sit down and relax for a few minutes. When you are calm, ask your friend to count your pulse for 60 seconds. During this time, close your eyes and try to empty your mind.

With a baseline established, ask your friend to measure your pulse for a second time, using exactly the same method. This time, however, try and think of as many species of animals as you can. Keeping still and with your eyes closed, think hard, and if you get stuck, try thinking up a new strategy to give you some more ideas.

During the second session, your pulse rate is likely to increase as your brain requires more glucose and oxygen to complete its task. Just how much increase you'll see varies from person to person.

1.11.2. How It Works

Thinking of as many animals as possible is a type of *verbal fluency* task, testing how easily you can come up with words. To complete the task successfully, you needed to be able to coordinate various cognitive skills, for example, searching your memory for category examples, generating and using strategies to think up more names (perhaps you thought about walking through the jungle or animals from your local area) and checking you were not repeating yourself.

Neuropsychologists often use this task to test the *executive system*, the notional system that allows us to coordinate mental tasks to solve problems and work toward a goal, skills that you were using to think up examples of animals. After brain injury (particularly to the frontal cortex), this system can break down, and the verbal fluency task can be one of the tests used to assess the function of this system.

Research using PET scanning has shown similar verbal fluency tasks use a significant amount of brain resources and large areas of the cortex, particularly the frontal, temporal, and parietal areas.[1]

Interestingly, in this study people who did best used less blood glucose than people who did

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Hack 11. Why People Don't Work Like Elevator Buttons

More intense signals cause faster reaction times, but there are diminishing returns: as a stimulus grows in intensity, eventually the reaction speed can't get any better. The formula that relates intensity and reaction speed is Pieron's Law.

It's a common illusion that if you are in a hurry for the elevator you can make it come quicker by pressing the button harder. Or more often. Or all the buttons at once. It somehow feels as if it ought to work, although of course we know it doesn't. Either the elevator has heard you, or it hasn't. How loud you call doesn't make any difference to how long it'll take to arrive.

But then elevators aren't like people. People *do* respond quicker to more stimulation, even on the most fundamental level. We press the brake quicker for brighter stoplights, jump higher at louder bangs. And it's because we all do this that we all fall so easily into thinking that things, including elevators, should behave the same way.

1.12.1. In Action

Give someone this simple task: she must sit in front of a screen and press a button as quickly as she can as soon as she sees a light flash on. If people were like elevators, the time it takes to press the button wouldn't be affected by the brightness of the light or the number of lights.

But people aren't like elevators and we respond quicker to brighter lights; in fact, the relationship between the physical intensity of the light and the average speed of response follows a precise mathematical form. This form is captured by an equation called Pieron's Law. Pieron's Law says that the time to respond to a stimulus is related to the stimulus intensity by the formula:

`Reaction Time`

$$R_0 + kI^{-\beta}$$

`Reaction Time` is the time between the stimulus appearing and you responding. I is the physical intensity of the signal. R_0 is the minimum time for any response, the asymptotic value representing all the components of the reaction time that don't vary, such as the time for light to reach your eye. k and β are constants that vary depending on the exact setup and the particular person involved. But whatever the setup and whoever the person, graphically the equation looks like Figure 1-2.

Figure 1-2. How reaction time changes with stimulus intensity

1.12.2. How It Works

In fact, Pieron's Law holds for the brightness of light, the loudness of sound, and even the strength of taste.[1] It says something fundamental about how we process signals and make decisionsthe physical nature of a stimulus carries through the whole system to affect the nature of the response. We are not binary systems! The actual number of photons of light or the amplitude of the sound waves that triggers us to respond influences how we respond. In fact, as well as affecting response time, the physical intensity of the stimulus also affects response force as well (e.g., how hard we press the button).

A consequence of the form of Pieron's Law is that increases in speed are easy for low-intensity stimuli and get harder as the stimulus gains more intensity. It follows a log scale, like a lot of things in psychophysics. The converse is also true: for quick reaction times, it's easier to slow people down than to speed them up.

Pieron's Law probably results because of the fundamental way the decisions have to be made with uncertain information. Although it might be clear to you that the light is either there or not, that's only because your brain has done the work of removing the uncertainty for you. And on a neural level, everything is uncertain because neural signals always have noise in them.

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Hack 12. Build Your Own Sensory Homunculus

All abilities are skills; practice something and your brain will devote more resources to it.

The sensory homunculus looks like a person, but swollen and out of all proportion. It has hands as big as its head; huge eyes, lips, ears, and nose; and skinny arms and legs. What kind of person is it? It's you, the person in your head. Have a look at the sensory homunculus first, then make your own.

1.13.1. In Action

You can play around with Jaakko Hakulinen's homunculus applet (http://www.cs.uta.fi/~jh/homunculus.html; Java) to see where different bits of the body are represented in the sensory and motor cortex. There's a screenshot of it in Figure 1-3.

Figure 1-3. The figure shown is scaled according to the relative sizes of the body parts in the motor and sensory cortex areas; motor is shown on the left, sensory on the right

This is the person inside your head. Each part of the body has been scaled according to how much of your sensory cortex is devoted to it. The area of cortex responsible for processing touch sensations is the *somatosensory cortex*. It lives in the parietal lobe, further toward the back of the head than the motor cortex, running alongside it from the top of the head down each side of the brain. Areas for processing neighboring body parts are generally next to each other in the cortex, although this isn't always possible because of the constraints of mapping the 3D surface of your skin to a 2D map. The area representing your feet is next to the area representing your genitals, for example (the genital representation is at the very top of the somatosensory cortex, inside the groove between the two hemispheres).

The applet lets you compare the motor and sensory maps. The motor map is how body parts are represented for movement, rather than sensation. Although there are some differences, they're pretty similar. Using the applet, when you click on a part of the little man, the corresponding part of the brain above lights up. The half of the man on the left is scaled according to the representation of the body in the primary motor cortex, and the half on the right is scaled to represent the somatosensory cortex. If you click on a brain section or body part, you can toggle shading and the display of the percentage of sensory or motor representation commanded by that body part. The picture of the man is scaled, too, according to how much cortex each part corresponds to. That's why the hands are so much larger than the torso.

Having seen this figure, you can see the relative amount of your own somatosensory cortex devoted to each body part by measuring your touch resolution. To do this, you'll need a willing friend to help you perform the two-point discrimination test.

Ask your friend to get two pointy objectstwo pencils will doand touch one of your palms with both of the points, a couple of inches apart. Look away so you can't see him doing it. You'll be able to tell there are two points there. Now get your friend to touch with only one pencilyou'll be able to tell you're being touched with just one. The trick now is for him to continue touching your palm with the pencils, sometimes with both and sometimes with just one, moving the tips ever closer together each time. At a certain point, you won't be able to tell how many pencils he's using. In the center of your palm, you should be able to discriminate between two points a millimeter or so apart. At the base of your thumb, you've a few millimeters of resolution.

Now try the same on your backyour two-point discrimination will be about 4 or 5 centimeters.

To draw a homunculus from these measurements, divide the actual width of your body part by the two-point discrimination to get the size of each part of the figure.

My back's about 35 centimeters across, so my homunculus should have

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Chapter 2. Seeing

2.1. Hacks 13-33

The puzzle that is vision lies in the chasm between the raw sensation gathered by the eyelight landing on our retinasand our rich perception of color, objects, motion, shape, entire 3D scenes. In this chapter, we'll fiddle about with some of the ways the brain makes this possible.

We'll start with an overview of the visual system **[Hack #13]**, the limits of your vision **[Hack #14]**, and the active nature of visual perception **[Hack #15]** .

There are constraints in vision we usually don't notice, like the blind spot **[Hack #16]** and the 90 minutes of blindness we experience every day as vision deactivates while our pupils jump around **[Hack #17]** . We'll have a look at both these and also at some of the shortcuts and tricks visual processing uses to make our lives easier: assuming the sun is overhead **[Hack #20]** and **[Hack #21]**, jumping out of the way of rapidly expanding dark shapes **[Hack #32]** (a handy shortcut for faster processing if you need to dodge quickly), and tricks like the use of noisy neurons **[Hack #33]** to extract signal out of visual noise.

Along the way, we'll take in how we perceive depth **[Hack #22]** and **[Hack #24]**, and motion **[Hack #25]** and **[Hack #29]**. (That's both the correct and false perception of motion, by the way.) We'll finish off with a little optical illusion called the Rotating Snakes Illusion **[Hack #30]** that has all of us fooled. After all, sometimes it's fun to be duped.

Hack 13. Understand Visual Processing

The visual system is a complex network of modules and pathways, all specializing in different tasks to contribute to our eventual impression of the world.

When we talk about "visual processing," the natural mode of thinking is of a fairly self-contained process. In this model, the eye would be like a video camera, capturing a sequence of photographs of whatever the head happens to be looking at at the time and sending these to the brain to be processed. After "processing" (whatever that might be), the brain would add the photographs to the rest of the intelligence it has gathered about the world around it and decide where to turn the head next. And so the routine would begin again. If the brain were a computer, this neat encapsulation would be how the visual subsystem would probably work.

With that (admittedly, straw man) example in mind, we'll take a tour of vision that shows just how nonsequential it all really is.

And one need go no further than the very idea of the eyes as passive receptors of photograph-like images to find the first fault in the straw man. Vision starts with the entire body: we walk around, and move our eyes and head, to capture depth information **[Hack #22]** like parallax and more. Some of these decisions about how to move are made early in visual processing, often before any object recognition or conscious understanding has come into play.

This pattern of vision as an interactive process, including many feedback loops before processing has reached conscious perception, is a common one. It's true there's a progression from raw to processed visual signal, but it's a mixed-up, messy kind of progression. Processing takes time, and there's a definite incentive for the brain to make use of information as soon as it's been extracted; there's no time to wait for processing to "complete" before using the extracted information. All it takes is a rapidly growing dark patch in our visual field to make us flinch involuntarily **[Hack #32]**, as if something were looming over us. That's an example of an effect that occurs early in visual processing.

But let's look not at the mechanisms of the early visual system, but how it's used. What are the endpoints of all this processing? By the time perception reaches consciousness, another world has been layered on top of it. Instead of seeing colors, shapes, and changes over time (all that's really available to the eyes), we see whole objects. We see depth, and we have a sense of when things are moving. Some objects seem to stand out as we pay attention to them, and others recede into the background. Consciously, we see both the world and assembled result of the processing the brain has performed, in order to work around constraints (such as the eyes' blind spot **[Hack #16]**), and to give us a head start in reacting with best-guess assumptions. The hacks in this chapter run the whole production line of visual processing, using visual illusions and anomalies to point out some detail of how vision works.

But before diving straight into all that, it's useful to have an overview of what's actually meant by the *visual system*. We'll start at the eye, see how signals from there go almost directly to the primary visual cortex on the back of the brain, and from there are distributed in two major streams. After that, visual information distributes and merges with the general functions of the cortex itself.

2.2.1. Start at the Retina

In a sense, light landing on the retinathe sensory surface at the back of the eyeis already inside the brain. The whole central nervous system (the brain and spinal column **[Hack #7]**) is contained within a number of membranes, the outermost of which is called the *dura mater*. The white of your eye, the surface that protects the eye itself, is a continuation of this membrane, meaning the eye is inside the same sac. It's as if two parts of your brain had decided to bulge out of your head and become your eyes, but without becoming separate organs.

The retina is a surface of cells at the back of your eye, containing a layer of *photoreceptors*, cells that detect light and convert it to electrical signals. For most of the eye, signals are

Hack 14. See the Limits of Your Vision

The high-resolution portion of your vision is only the size of your thumbnail at arm's length. The rest of your visual input is low res and mostly colorless, although you seldom realize it.

Your vision isn't of uniform resolution. What we generally think of as our visual ability, the sharpness with which we see the world, is really only the very center of vision, where resolution is at its highest. From this high-resolution center, the lower-resolution periphery, and using continual movements of our head and eyes **[Hack #15]**, we construct a seamlessand uniformly sharppicture of the universe. But how much are we compensating? What is the resolution of vision?

The eye's resolution is determined by the density of light-sensitive cells on the *retina*, which is a layer of these cells on the back of the eye (and also includes several layers of cells to process and aggregate the visual signals to send on to the rest of the brain). If the cells were spread evenly, we would see as well out of the corners of our eyes as directly ahead, but they're not. Instead, the cells are most heavily packed right in the center of the retina, a small region called the *fovea*, so the highest-resolution part of the vision is in the middle of your visual field. The area corresponding to this is small; if you look up at the night sky, out of everything you see, your fovea just about covers the full moon. Away from this, in your peripheral vision, resolution is much coarser.

Color also falls off in peripheral vision. The light-sensitive cells, called *photoreceptors*, come in different types according to what kinds of light they convert into neural signals. Almost all the photoreceptors that can discriminate colors of light are in the fovea. Outside of this central area you can still make out color, but it's harder; the oter type of cell, more sensitive but able to recognize only brightness, is more abundant.

2.3.1. In Action

Figure 2-1 is a variant of the usual eye chart you will have encountered at the optometrist, constructed by Stuart Anstis. Hold it in front of you, and rest your gaze on the central dot. The letters in the chart are smallest in the middle and largest at the outer edge; they scale up at a rate to exactly compensate for your eyes' decrease in resolution from the central fovea to the periphery.

Figure 2-1. When you fixate on the center of this chart, all the letters are scaled to have the same resolution[1]

That means that, holding your gaze on the center of the chart, it should be as easy for you to read one of the letters near the middle as one of the bigger ones at the edge.

What this eye chart doesn't show is our relative decrease in color-sensing ability as we edge toward peripheral vision. Have a friend hold pieces of colored card up to the side of your face while you keep your head, and eyes, looking forward. Notice that, while you can see that she's moving the card off in the corner of your eye, you can't tell what color the card is.

Because peripheral vision is still good at brightness, you'll need to use pieces of card that won't give you any clues simply from how bright the card looks. A dull yellow and a bright blue will do. If you'd like to perform a more rigorous experiment, the Exploratorium museum provides instructions on how to make yourself a collar to measure the angles at which your color vision becomes useful (http://www.exploratorium.edu/snacks/peripheral_vision.html).

Since trying this experiment, I've been playing a similar game walking along the side of the road. When cars are coming from behind me, and I'm looking strictly ahead, at what point can I see there's something there, and how much later is it that I can tell the color? I know a car's in my peripheral vision for a surprisingly long time before I can make the color out. Even though it would be in the name of science, please do be careful not to get run over.

M.W.

Hack 15. To See, Act

Think of perception as a behavior, as something active, rather than as something passive. Perception exists to guide action, and being able to act is key to the construction of the high-resolution illusion of the world we experience.

The other hacks in this chapter could give the impression that seeing is just a matter of your brain passively processing the information that comes in through the eyes. But perception is far more of an active process. The impression we have of the world is made up by sampling across times, as well as just by sampling across the senses. The sensation we receive at any moment prompts us to change our head position, our attention, maybe to act to affect something out in the world, and this gives us different sensations in the next moment to update our impression of the world.

It's easier for your brain to take multiple readings and then interpolate the answers than it is to spend a long time processing a single scene. Equally important, if you know what you want to do, maybe you don't need to completely interpret a scene; you may need to process it just enough to let you decide what to do next and in acting give yourself a different set of sensations that make the scene more obvious.

This school of thought is an "ecological" approach to perception and is associated with the psychologist J. J. Gibson.[1] He emphasized that perception is a cognitive process and, like other cognitive processes, depends on interacting with the world. The situations used by vision scientists in which people look at things without moving or reaching out to touch them are extremely unnatural, as large as the difference between a movie at the theater directed by someone else and the freewill experience of regular real life.

If you want people to see something clearly, give them the chance to move it around and see how it interacts with other objects. Don't be fooled into thinking that perception is passive.

2.4.1. In Action

One example of active vision that always happens, but that we don't normally notice, is moving our eyes. We don't normally notice our blind spots **[Hack #16]** or our poor peripheral vision **[Hack #14]**, because our gaze constantly flits from place to place. We sample constantly from the visual world using the high-resolution center of the eyethe *fovea* and our brain constructs a constant, continuous, consistent, high-resolution illusion for us.

Constant sampling means constant eye movement: automatic, rapid shifts of gaze called *saccades*. We saccade up to five times a second, usually without noticing, even though each saccade creates a momentary gap in the flow of visual information into our brains **[Hack #17]** . Although the target destination of a saccade can be chosen consciously, the movement of the eyes isn't itself consciously controlled. A saccade can also be triggered by an event we're not even consciously aware ofat least not until we shift our gaze, placing it at the center of our attention. In this case, our attention's been captured involuntarily, and we had no choice but to saccade to that point **[Hack #37]** .

Each pause in the chain of saccades is called a *fixation*. Fixations happen so quickly and so automatically that it's hard to believe that we don't actually hold our gaze on anything. Instead, we look at small parts of a scene for just fractions of a second and use the samples to construct an image.

Using eye tracking devices, it is possible to construct images of where people fixate when looking at different kinds of objectsa news web site, for instance. The Poynter Institute's Eyetrack III project (http://www.poynterextra.org/eyetrack2004/) investigates how Internet news readers go about perusing news online (Figure 2-3) and shows the results of their study as a pattern of where eye gaze lingers while looking over a news web site.

Figure 2-3. The pattern of eye fixations looking over a news web site; the brighter patches show where eyes tend to fixate[2]

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Hack 16. Map Your Blind Spot

Find out how big your visual blind spot is and how your brain fills the hole so you don't notice it.

Coating the back of each eye are photoreceptors that catch light and convert it to nerve impulses to send to the brain. This surface, the *retina*, isn't evenly spread with receptorsthey're densest at the center and sparse in peripheral vision **[Hack #14]** . There's also a patch that is completely devoid of receptors; light that falls here isn't converted into nerve signals at all, leaving a blind spot in your field of viewor actually two blind spots, one for each eye.

2.5.1. In Action

First, here's how to notice your blind spot (later we'll draw a map to see how big it is). Close your left eye and look straight at the cross in Figure 2-6. Now hold the book flat about 10 inches from your face and slowly move it towards you. At about 6 inches, the black circle on the right of the cross will disappear, and where it was will just appear grey, the same color as the page around it.

Figure 2-6. A typical blind spot pattern

You may need to move the book back and forth a little. Try to notice when the black circle reappears as you increase the distance, then move the book closer again to hide the circle totally. It's important you keep your right eye fixed on the cross, as the blind spot is at a fixed position from the center of vision and you need to keep it still to find it.

Now that you've found your blind spot, use Jeffrey Oristaglio and Paul Grobstein's Java applet at the web site Serendip (http://serendip.brynmawr.edu/bb/blindspot; Java) to plot its size.

The applet shows a cross and circle, so, as before, close your left eye, fix your gaze on the cross, and move your head so that the circle disappears in your blind spot. Then click the Start button (at the bottom of the applet) and move your cursor around within the blind spot. While it's in there, you won't be able to see it, but when you can (only just), click, and a dot will appear. Do this a few times, moving the cursor in different directions starting from the circle each time.

Again, be careful not to move your head, and keep focused on the cross. You'll end up with a pattern like Figure 2-7. The area inside the ring of dots is your blind spot.

Figure 2-7. Matt's blind spot mapped

Here's a fun way of playing with your blind spot. In a room of people, close one eye and focus on your index finger. Pick a victim and adjust where your finger is until your blind spot makes his head disappear and the background takes its place. Not very profitable, but fun, and not as obvious as making as if to crush his head between your thumb and index finger.

T.S.

2.5.2. How It Works

The blind spot for each eye corresponds to a patch on the retina that is empty of photoreceptors. With no photoreceptors, there's nothing to detect light and turn it into information for use by the visual system, hence the blind spot.

Each receptor cell is connected to the brain via a series of cells that aggregate the signal before reporting it to the brain by an information-carrying fiber called an *axon* (see **[Hack #9]**). Bizarrely, the part of the photoreceptor responsible for detecting light is *behind* the fibers for carrying the information into the brain. That's rightthe light-sensitive part is on the side

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Hack 17. Glimpse the Gaps in Your Vision

Our eyes constantly dart around in extremely quick movements called saccades. During each movement, vision cuts out.

Despite the fact that the eye has a blind spot, an uneven distribution of color perception, and can make out maximal detail in only a tiny area at the center of vision, we still manage to see the world as an uninterrupted panorama. The eye jumps about from point to point, snapshotting high-resolution views, and the brain assembles them into a stunningly stable and remarkably detailed picture.

These rapid jumps with the eyes are called *saccades*, and we make up to five every second. The problem is that while the eyes move in saccade all visual input is blurred. It's difficult enough for the brain to process stable visual images without having to deal with motion blur from the eye moving too. So, during saccades, it just doesn't bother. Essentially, while your eyes move, you can't see.

2.6.1. In Action

Put your face about 6 inches from a mirror and look from eye to eye. You'll notice that while you're obviously switching your gaze from eye to eye, you can't see your own eyes actually movingonly the end result when they come to rest on the new point of focus. Now get someone else to watch you doing so in the mirror. They can clearly see your eyes shifting, while to you it's quite invisible.

With longer saccades, you can consciously perceive the effect, but only just.

Hold your arms out straight so your two index fingers are at opposite edges of your vision. Flick your eyes between them while keeping your head still. You can just about notice the momentary blackness as all visual input from the eyes is cut off. Saccades of this length take around 200 ms (a fifth of a second), which lies just on the threshold of conscious perception.

What if something happens during a saccade? Well, unless it's really bright, you'll simply not see it. That's what's so odd about saccades. We're doing it constantly, but it doesn't look as if the universe is being blanked out a hundred thousand times a day for around a tenth of a second every time.

Saccadic suppression may even be one of the ways some magic tricks work. We know that sudden movements grab attention **[Hack #37]** . The magician's flourish with one hand grabs your attention, and as your eyes are moving, you aren't able to see what he does with the other hand to pull off the trick.

N.H.

2.6.2. How It Works

Saccadic suppression exists to stop the visual system being confused by blurred images that the eye gets while it is moving rapidly in a saccade. The cutout begins just before the muscles twitch to make the eyes move. Since that's before any blur would be seen on the retina, we know the mechanism isn't just blurred images being edited out at processing time. Instead, whatever bit of the brain prepares the eyes to saccade must also be sending a signal that suppresses vision. Where exactly does that signal come from? That's not certain yet.

One recent experiment proves that suppression definitely occurs before any visual information gets to the cortex. This isn't the kind of experiment that can be done at home, unfortunately, as it requires *transcranial magnetic stimulation* (TMS). TMS **[Hack #5]** essentially lets you turn on, or turn off, parts of the brain that are close enough to the surface to be affected by a magnet. The device uses rapid electromagnetic pulses to affect the cells carrying signals in the brain. Depending on the frequency of the pulses, you can enhance or suppress neuronal activity.

Kai Thilo and a team from Oxford University[1] used TMS to give volunteers small illusionary

Hack 18. When Time Stands Still

Our sense of time lends a seamless coherence to our conscious experience of the world. We are able to effortlessly distinguish between the past, present, and future. Yet, subtle illusions show that our mental clock can make mistakes.

You only have to enjoy the synchrony achieved by your local orchestra to realize that humans must be remarkably skilled at judging short intervals of time. However, our mental clock does make mistakes. These anomalies tend to occur when the brain is attempting to compensate for gaps or ambiguities in available sensory information.

Such gaps can be caused by self-generated movement. For example, our knowledge about how long an object has been in its current position is compromised by the suppression of visual information **[Hack #17]** that occurs when we move our eyes toward that objectwe can have no idea what that object was actually doing for the time our eyes were in motion. This uncertainty of position, and the subsequent guess the brain makes, can be felt in action by saccading the eyes toward a moving object.

2.7.1. In Action

Sometimes you'll glance at a clock and the second hand appears to hang, remaining stationary for longer than it ought to. For what seems like a very long moment, you think the clock may have stopped. Normally you keep looking to check and see that shortly afterward the second hand starts to move again as normalunless, that is, it truly has stopped.

This phenomenon has been dubbed the *stopped clock illusion*. You can demonstrate it to yourself by getting a silently moving clock and placing it off to one side. It doesn't need to be an analog clock with a traditional second hand; it can be a digital clock or watch, just so long as it shows seconds. Position the clock so that you aren't looking at it at first but can bring the second hand or digits into view just by moving your eyes. Now, flick your eyes over to the clock (i.e., make a saccade **[Hack #15]**). The movement needs to be as quick as possible, much as might happen if your attention had been grabbed by a sudden sound or thought **[Hack #37]** ; a slow, deliberate movement won't cut it. Try it a few times and you should experience the "stopped clock" effect on some attempts at least.

> Whether or not this works depends on exactly when your eyes fall on the clock. If your eyes land on the clock just when the second hand is on the cusp of moving (or second digits are about to change), you're less likely to see the illusion. On the other hand, if your eyes land the instant after the second hand has moved, you're much more likely to experience the effect.

2.7.2. How It Works

When our gaze falls on an object, it seems our brain makes certain assumptions about how long that object has been where it is. It probably does this to compensate for the suppression of our vision that occurs when we move our eyes **[Hack #17]** . This suppression means vision can avoid the difficult job of deciphering the inevitable and persistent motion blur that accompanies each of the hundred thousand rapid saccadic eye movements that we make daily. So when our gaze falls on an object, the brain assumes that object has been where it is for at least as long as it took us to lay eyes on it. Our brain *antedates* the time the object has been where it is. When we glance at stationary objects like a lamp or table, we don't notice this antedating process. But when we look at a clock's second hand or digits, knowing as we do that they ought *not* be in one place for long, this discord triggers the illusion.

This explanation was supported and quantified in an experiment by Keilan Yarrow and colleagues at University College, London and Oxford University.1 They asked people to glance at a number counter. The participants' eye movements triggered the counter, which then began counting upward from 1 to 4. Each of the numerals 2, 3, and 4 was displayed for 1 second, but the initial numeral 1 was displayed for a range of different intervals, from 400 ms

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Hack 19. Release Eye Fixations for Faster Reactions

It takes longer to shift your attention to a new object if the old object is still there.

Shifting attention often means shifting your eyes. But we're never fully in control of what our eyes want to look at. If they're latched on to something, they're rather stubborn about moving elsewhere. It's faster for you to look at something new if you don't have to tear your eyes awayif what you were originally looking at disappears and then there's a short gap, it's as if your eyes become unlocked, and your reaction time improves. This is called the *gap effect*.

2.8.1. In Action

The gap effect can be spotted if you're asked to stare at some shape on a screen, then switch your gaze to a new shape that will appear somewhere else on the screen. Usually, switching to the new shape takes about a fifth of a second. But if the old shape vanishes shortly before the new shape flashes up, moving your gaze takes less time, about 20% less.

It has to be said: the effecton the order of just hundredths of a secondis tiny in the grand scheme of things. You're not going to notice it easily around the home. It's a feature of our low-level cognitive control: voluntarily switching attention takes a little longer under certain circumstances. In other words, voluntary behavior isn't as voluntary as we'd like to think.

2.8.2. How It Works

We take in the world piecemeal, focusing on a tiny part of it with the high-resolution center of our vision for a fraction of a second, then our eyes move on to focus on another part. Each of these mostly automatic moves is called a saccade **[Hack #15]** .

We make saccades continuouslyup to about five every secondbut that's not to say they're fluid or all the same. While you're taking in a scene, your eyes are locked in. They're resistant to moving away, just for a short time. So what happens when another object comes along and you want to move your eyes toward it? You have to overcome that inhibition, and that takes a short amount of time.

Having to overcome resistance to saccades is one way of looking at why focusing on a new shape takes longer if the old one is still there. Another way to look at it is to consider what happens when the old shape disappears. Then we can see that the eyes are automatically released from their fixation, and no longer so resistant to making a saccadewhich is why, when the old shape disappears before the new shape flashes up, it's faster to gaze-shift. In addition, the disappearing shape acts as a warning signal to the early visual system ("There's something going on, get ready!"), which serves to speed up the eyes' subsequent reaction times. It's a combination of both of these factorsthe warning and the eyes no longer being held back from movingthat results in the speedup.

2.8.3. In Real Life

Just for completeness, it's worth knowing that the old point of fixation should disappear 200 milliseconds (again, a fifth of a second) before the new object appears, to get maximum speedup. This time is used for the brain to notice the old object has vanished and get the eyes ready to move again. Now, in the real world, objects rarely just vanish like this, but it happens a lot on computer screens. So it's worth knowing that if you want someone to shift his attention from one item to another, you can make it an easier transition by having the first item disappear shortly before the second appears (actually vanish, not just disappear behind something, because we keep paying attention to objects even when they're temporarily invisible **[Hack #36]**). This will facilitate your user's disengagement from the original item, which might be a dialog box or some other preparatory display and put her into a state ready for whatever's going to need her attention next.

2.8.4. See Also

- Taylor, T. L., Kingstone, A., & Klein, R. M. (1998). The disappearance of foveal and non-foveal stimuli: Decomposing the gap effect. *Canadian Journal of Experimental*

Hack 20. Fool Yourself into Seeing 3D

How do you figure out the three-dimensional shape of objects, just by looking? At first glance, it's using shadows.

Looking at shadows is one of many tricks we use to figure out the shape of objects. As a trick, it's easy to foolshading alone is enough for the brain to assume what it's seeing is a real shadow. This illusion is so powerful and so deeply ingrained, in fact, that we can actually feel depth in a picture despite knowing it's just a flat image.

2.9.1. In Action

Have a look at the shaded circles in Figure 2-8, following a similar illustration in Kleffner and Ramachandran's "On the Perception of Shape from Shading."[1]

Figure 2-8. Shaded figures give the illusion of three-dimensionality

I put together this particular diagram myself, and there's nothing to it: just a collection of circles on a medium gray background. All the circles are gradient-filled black and white, some with white at the top and some with white at the bottom. Despite the simplicity of the image, there's already a sense of depth.

The shading seems to make the circles with white at the top bend out of the page, as though they're bumps. The circles with white at the bottom look more like depressions or even holes.

To see just how strong the sense of depth is, compare the shaded circles to the much simpler diagram in Figure 2-9, also following Kleffner and Ramachandran's paper.

Figure 2-9. Binary black-and-white "shading" doesn't provide a sense of depth

The only difference is that, instead of being shaded, the circles are divided into solid black and white halves. Yet the depth completely disappears.

2.9.2. How It Works

Shadows are identified early in visual processing in order to get a quick first impression of the shape of a scene. We can tell it's early because the mechanism it uses to resolve light source ambiguities is rather hackish.

Ambiguities occur all the time. For instance, take one of the white-at-top circles from Figure 2-8. Looking at it, you could be seeing one of two shapes depending on whether you imagine the shape was lit from the top or the bottom of the page. If light's coming from above, you can deduce it's a bump because it's black underneath where the shadows are. On the other hand, if the light's coming from the bottom of the page, only a dent produces the same shading pattern. Bump or dent: two different shapes can make the same shadow pattern lit from opposite angles.

There's no light source in the diagram, though, and the flat gray background gives no clues as to where the light might be coming from. That white-at-top circle should, by rights, be ambiguous. You should sometimes see a bump and sometimes see a dent.

What's remarkable is that people see the white-at-top circles as bumps, not dents, despite the two possibilities. Instead of leaving us in a state of confusion, the brain has made a choice: light comes from above.[2]

Assuming scenes are lit from above makes a lot of sense: if it's light, it's usually because the sun is overhead. So why describe this as a hackish mechanism?

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Hack 21. Objects Move, Lighting Shouldn't

Moving shadows make us see moving objects rather than assume moving light sources.

Shadows get processed early when trying to make sense of objects, and they're one of the first things our visual system uses when trying to work out shape. **[Hack #20]** further showed that our visual system makes the hardwired assumption that light comes from above. Another way shadows are used is to infer movement, and with this, our visual system makes the further assumption that a moving shadow is the result of a moving object, rather than being due to a moving light source. In theory, of course, the movement of a shadow could be due to either cause, but we've evolved to ignore one of those possibilitiesrapidly moving objects are much more likely than rapidly moving lights, not to mention more dangerous.

2.10.1. In Action

Observe how your brain uses shadows to construct the 3D model of a scene. Watch the ball-in-a-box movie at:

- http://gandalf.psych.umn.edu/~kersten/kersten-lab/images/ball-in-a-box.mov (small version)
- http://gandalf.psych.umn.edu/~kersten/kersten-lab/demos/BallInaBox.mov (large version, 4 MB)

> If you're currently without Internet access, see Figure 2-12 for movie stills.

The movie is a simple piece of animation involving a ball moving back and forth twice across a 3D box. Both times, the ball moves diagonally across the floor plane. The first time, it appears to move along the floor of the box with a drop shadow directly beneath and touching the bottom of the ball. The second time the ball appears to move horizontally and float up off the floor, the shadow following along on the floor. The ball actually takes the same path both times; it's just the path of the shadow that changes (from diagonal along with the ball to horizontal). And it's that change that alters your perception of the ball's movement. (Figure 2-12 shows stills of the first (left) and second (right) times the ball crosses the box.)

Figure 2-12. Stills from the "ball-in-a-box" movie

Now watch the more complex "zigzagging ball" movie (http://www.kyb.tue.mpg.de/links/demo.html; Figure 2-13 shows a still from the movie), again of a ball in motion inside a 3D box.

Figure 2-13. A still from the "zigzagging ball" movie[1]

This time, while the ball is moving in a straight line from one corner of the box to the other (the proof is in the diagonal line it follows), the shadow is darting about all over the place. This time, there is even strong evidence that it's the light sourceand thus the shadowthat's moving: the shading and colors on the box change continuously and in a way that is consistent with a moving light source rather than a zigzagging ball (which doesn't produce any shading or color changes!). Yet still you see a zigzagging ball.

2.10.2. How It Works

Your brain constructs an internal 3D model of a scene as soon as you look at one, with the influence of shadows on the construction being incredibly strong. You can see this in action

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Hack 22. Depth Matters

Our perception of a 3D world draws on multiple depth cues as diverse as atmospheric haze and preconceptions of object size. We use all together in vision and individually in visual design and real life.

Our ability to see depth is an amazing feature of our vision. Not only does depth make what we see more interesting, it also plays a crucial, functional role. We use it to navigate our 3D world and can employ it in the practice of visual communication design to help organize what we see through depth's ability to clarify through separation[1].

Psychologists call a visual trigger that gives us a sense of depth a *depth cue*. Vision science suggests that our sense of depth originates from at least 19 identifiable cues in our environment. We rarely see depth cues individually, since they mostly appear and operate in concert to provide depth information, but we can loosely organize them together into several related groups:

Binocular cues (stereoscopic depth, eye convergence)

With binocular (two-eye) vision, the brain sees depth by comparing angle differences in the images from each eye. This type of vision is very important to daily life (just try catching a ball with one eye closed), but there are also many monocular (single-eye) depth cues. Monocular cues have the advantage that they are easier to employ for depth in images on flat surfaces (e.g., in print and on computer screens).

Perspective-based cues (size gradient, texture gradient, linear perspective)

The shape of a visual scene gives cues to the depth of objects within it. Perspective lines converging/diverging or a change in the image size of patterns that we know to be at a constant scale (such as floor tile squares) can be used to inform our sense of depth.

Occlusion-based cues (object overlap, cast shadow, surface shadow)

The presence of one object partially blocking the form of another and the cast shadows they create are strong cues to depth. See **[Hack #20]** for examples.

Focus-based cues (atmospheric perspective, object intensity, focu

Greater distance usually brings with it a number of depth cues associated with conditions of the natural world, such as increased atmospheric haze and physical limits to the eye's focus range. We discuss one of these cues, object intensity, next.

Motion-based cues (kinetic depth, a.k.a. motion parallax)

As you move your head, objects at different distances move at different relative speeds. This is a very strong cue and is also the reason a spitting cobra sways its head from side to side to work out how far away its prey is from its position.

There isn't room to discuss all of these cues here, so we'll look in detail at just two depth cues: object intensity and known size (a cue that is loosely connected to the prespective-based cue family). More information on depth cues and their use in information design can be found in the references at the end of this hack.

2.11.1. Object Intensity

Why do objects further away from us appear to be faded or faint? Ever notice that bright objects seem to attract our attention? It's all about intensity.

If we peer into the distance, we notice that objects such as buildings or mountains far away appear less distinct and often faded compared to objects close up. Even the colors of these distant objects appear lighter or even washed out. The reason for this is something psychologists call atmospheric perspective or object intensity. It is a visual cue our minds use to sense depth; we employ it automatically as a way to sort and prioritize information about

Hack 23. See How Brightness Differs from Luminance: The Checker Shadow Illusion

A powerful illusion of brightness shows how our brain takes scene structure and implied lighting into account when calculating the shade of things.

A major challenge for our vision is the reconstruction of a three-dimensional visual world from a two-dimensional retinal picture. The projection from three to two dimensions irrevocably loses information, which somehow needs to be reconstructed by the vision centers in our brain. True, we have two eyes, which helps a bit in the horizontal plane, but the vivid self-experience of seeing a 3D world clearly persists after covering one eye **[Hack #22]** .

In the process of reconstructing 3D from 2D, our brain cleverly relies on previous experience and assumptions on the physics of the real world. Since information is thus fabricated, the process is prone to error, especially in appropriately manipulated pictures, which gives rise to various large classes of optical illusions. We will concentrate here on a fairly recent example, Ted Adelson's checker shadow illusion.[1]

2.12.1. In Action

Take a look at Adelson's checker shadow illusion in Figure 2-19.

Figure 2-19. Adelson's checker shadowwhich is brighter, A or B?

We would all agree that one sees a checkerboard with a pillar standing in one corner. Illumination obviously comes from the top-right corner, as the shadow on the checkerboard tells us immediately (and we know how important shadows are for informing what we see **[Hack #20]**). All of this is perceived at one rapid glance, much faster than this sentence can be read (lest written!).

Now let's ask the following question: which square is brighter, A or B? The obvious answer is B, and I agree. But now change the context by looking at Figure 2-20. The unmasked grays are from the two squares A and B, and unquestioningly the two shades of gray are identical (in fact, the entire figure was constructed just so).

Figure 2-20. This checkerboard is the same as the first, except for the added barsnow does A look brighter than B?

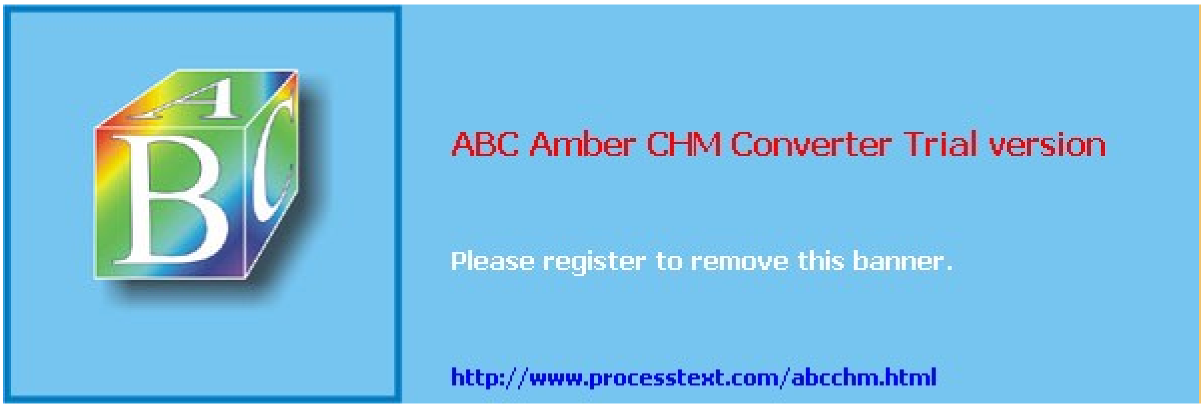
You can prove it to yourself by cutting out a mask with two checker square-size holes in it, one for A and one for B, and putting it over the original checkerboard (Figure 2-19).

2.12.2. How It Works

If squares A and B in the first case have clearly differing brightness and in the second case they have the same, what gives? Surely the two alternatives exclude each other? The solution in a nutshell: brightness depends on context.

There is a good reason that visual scientists describe their experiments using the term *luminance* rather than brightness. Luminance is a physical measure, effectively counting the number of light quanta coming from a surface, then weighting them by wavelength with regard to their visibility. (The unit of measurement, by the way, is candela per square meter, cd/m2. A candela was originally defined as the light from a standard candle 1 foot away.)

Brightness, on the other hand, is a subjective measuresomething your brain constructs for your conscious experience. It depends on previous history (light adaptation), the immediate surroundings (contrast effects), and context (as here). It has no dimension but can be measured using psychophysical techniques.



Hack 24. Create Illusionary Depth with Sunglasses

We can use a little-known illusion called the Pulfrich Effect to hack the brain's computation of motion, depth, and brightnessall it takes is a pair of shades and a pendulum.

This is a journey into the code the visual system uses to work out how far away things are and how fast they are moving. Both of the variablesdepth and velocitycan be calculated by comparing measurements of object position over time. Rather than have separate neural modules to figure out each variable, performing the same fundamental processing, the brain combines the two pieces of work and uses some of the same cells in calculating both measures. Because depth and motion are jointly encoded in these cells, it's possible (under the right circumstances) to convert changes in one into changes in another. An example is the *Pulfrich Effect*, in which a moving pendulum and some sunglasses create an illusion of the pendulum swinging in ellipses rather than in straight lines. It works because the sunglasses create an erroneous velocity perception, which gets converted into a depth change by the time it reaches your perception. It's what we'll be trying out here.

2.13.1. In Action

Make a pendulum out of a piece of string and something heavy to use as a weight, like a bunch of keys. You'll also need a pair of sunglasses or any shaded material.

Ask a friend to swing the pendulum in front of you in a perpendicular plane, and make sure it's going exactly in a straight line, left to right. Now, cover one of your eyes with the shades (this is easiest if you have old shades and can poke one of the lenses out). Keep both eyes open! You'll see that the pendulum now seems to be swinging back and forth as well as side to side, so that it appears to move in an ellipse. The two of you will look something like Figure 2-21.

Figure 2-21. Matt and Tom use sunglasses and a pendulum made out of a bootlace to test the Pulfrich Effect

Show your friend swinging the pendulum how you see the ellipse, and ask her to swing the pendulum in the opposite manner to counteract the illusion. Now the pendulum appears to swing in a straight line, and the thing that seems odd is not the distance from you, but the velocity of the pendulum. Because it really is swinging in an elliptical pattern, it covers perceived distance at an inconsistent rate. This makes it seem as if the pendulum is making weird accelerations and decelerations.

2.13.2. How It Works

The classic explanation for the Pulfrich is this: the shading slows down the processing of the image of the object in one eye (lower brightness means the neurons are less stimulated and pass on the signal at a slower rate **[Hack #11]**); in effect, the image reaches one eye at a delay compared to when it reaches the other eye. Because the object is moving, this means the position of the image on the retina is slightly shifted. The difference in image perception between the two retinas is used by the visual system to compute depth **[Hack #22]** . The slight displacement of the image on the retina of the shaded eye is interpreted as an indication of depth, as in Figure 2-22.

Figure 2-22. The geometry of the Pulfrich Effect: although the pendulum is, in reality, at point 1, the delay in processing makes it appear to be at point 2 to the shaded eye. When the eyes are taken together, the pendulum therefore appears to be at point 3, at a different length.

This explanation puts the confounding of depth and motion on the geometry of the

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Hack 25. See Movement When All Is Still

Aftereffect illusions are caused by how cells represent motion in the brain.

Why, when the train stops, does the platform you are looking at out the window appear to creep backward? The answer tells us something important about the architecture of the visual system and about how, in general, information is represented in the brain.

The phenomenon is the *motion aftereffect*. Just as when you go from very bright sunlight to the indoors, everything looks dark, or if you are in a very quiet environment, loud noises seem even louder, so continuous motion in a certain direction leaves us with a bias in the otheran aftereffect.

2.14.1. In Action

Watch the video of a waterfall (http://www.biols.susx.ac.uk/home/George_Mather/Motion/MAE.HTML; QuickTime) for a minute or so, staring at the same position, then hit pause. You'll have the illusion of the water flowing upward. It works best with a real waterfall, if you can find one, although pausing at the end is harder, so look at something that isn't moving instead, like the cliff next to the waterfall.

The effect doesn't work for just continuous downward motion. Any continuous motion will create an opposite aftereffect; that includes spiral motion, such as in the Flash demo at http://www.at-bristol.org.uk/Optical/AfterEffects_main.htm.

The effect works only if just part of your visual field is moving (like the world seen through the window of a train). It doesn't occur if everything is moving, which is why, along with the fact that your motion is rarely continuous in a car, you don't suffer an aftereffect after driving.

2.14.2. How It Works

Part of what makes this effect so weird is the experience of motion without any experience of things actually changing location. Not only does this feel pretty funny, but it suggests that motion and location are computed differently within the architecture of the brain.

Brain imaging confirms this. In some areas of the visual cortex, cells respond to movement, with different cells responding to different types of movement. In other areas of the visual cortex, cells respond to the location of objects in different parts of the visual field. Because the modules responsible for the computation of motion and the computation of location are separate, it is possible to experience motion without anything actually moving.

The other way is to be able to perceive static images but be unable to experience motion, and this happens to some stroke victims whose motion module is damaged. Their life is experienced as a series of strobe-like scenes, even thoughtheoreticallytheir visual system is receiving all the information it would need to compute motion (that is, location and time).

You don't need brain imaging to confirm that this effect takes place at the cortex, integrating all kinds of data, rather than being localized at each eye. Look at the movie image of the waterfall again but with one eye closed. Swap eyes when you pause the videoyou'll still get the effect even with the eye that was never exposed to motion. That shows that the effect is due to some kind of central processing and is not happening at the retina.

To understand why you get aftereffects, you need to know a little about how information is represented in the brain. Different brain cells in the motion-sensitive parts of the visual system respond, or "fire," to different kinds of motion. Some fire most for quick sideways motion, some most to slow motion heading down to the bottom left at an angle of 27 degrees, and so on for different angles and speeds. Each cell is set to respond most to a different type of motion, with similar motions provoking almost as much response, and they won't respond at all to motions with completely different angles and speeds.

The kind of motion we perceive depends on the pattern of activation across the whole range

Hack 26. Get Adjusted

We get used to things because our brain finds consistency boring and adjusts to filter it out.

My limbs feel weightless. I can't feel my clothes on my body. The humming of my laptop has disappeared. The flicker of the overhead light has faded out of my consciousness. I know it all must still be happeningI just don't notice it anymore.

In other words, it's just another normal day in the world with my brain.

Our brains let us ignore any constant input. A good thing too; otherwise, we'd spend all our time thinking about how heavy our hands are, how exactly our T-shirts feel on our backs, or at precisely what pitch our computers are humming, instead of concentrating on the task at hand.

The general term for this process of adjusting for constant input is called *adaptation*. Combined with relative representation of input, adaptation gives us aftereffects. The motion aftereffect is a good example of a complex adaptation process, so we'll walk through a detailed story about that here in a moment.

> Both relative representation and the motion aftereffect are described in **[Hack #25]** . Simply put, how much "movement up" we perceive depends on the activation of up-sensitive neurons compared against the activation of down-sensitive neurons, not just the absolute level of activity.

Adaptation is a feature of all the sensory systems. You'll notice it (or, on the contrary, most likely not notice it) for sound, touch, and smells particularly. It affects vision **[Hack #25]**, too. If you stop to consider it for a moment, you'll appreciate just how little of the world you actually notice most of the time.

Adaptation is a general term for number of processes. Some of these processes are very basic, are of short term, and occur at the level of the individual sense receptor cells. An example is neuronal fatigue, which means just what it sounds as if it means. Without a break, individual neurons stop responding as vigorously to the same input. They get tired. Strictly speaking, ion channels in the membrane that regulate electrical changes in the cell become inactivated, but "tired" is a close enough approximation.

The most basic form of memory is a kind of adaptation, called habituation. This is just the diminishing of a response as the stimulus that provokes it happens again. The shock of a cold shower might make you gasp at first, but with practice you can get in without flinching. It was neuroscientists using a similar kind of situationpoking sea slugs until they got used to itthat first demonstrated that learning happens due to changes in the strength and structure of connections between individual neurons.

2.15.1. In Action

Aftereffects are the easiest way to see adaptation occurring. You can have aftereffects with most thingssounds, touch pressure, brightness, tilt, and motion are just some. Some, like the motion aftereffect **[Hack #25]**, are due to adaptation processes that happen in the cortex. But others happen at the point of sensation. The adaptation of our visual system to different light levels happens directly in the eyes, not in the cortex.

To see this, try adapting to a darkened room with both eyes and then walking into a bright room with only one eye open. If you then return to the darkened room, you will be able to see nothing with one eye (it has quickly adapted to a high level of light), yet plenty with the eye you kept closed in the light room (this eye is still operating at the dark-adapted baseline). The effect is very strong as you switch between having alternate eyes open and the whole lighting and tone of the room you're looking at changes instantly.

2.15.2. Why It Works

Hack 27. Show Motion Without Anything Moving

Find out why static pictures can make up a moving image on your TV screen.

The motion aftereffect **[Hack #25]** shows that motion is computed in your brain separately from location. For instance, becoming accustomed to the moving surface of a waterfall causes you to see stationary surfaces as moving the other way, although they're quite still. In theory, motion can be calculated from position and time information, but that's not how your brain does itthere's a specialized brain region for detecting motion directly. Since location and motion are perceived separately, this can lead to some odd illusions, the motion aftereffect chief among them: you get the illusion of motion *without anything actually changing position*.

The motion aftereffect relies on an initial moving scene to set it up, but we can go one better and get an impression of movement when there's been no actual thing present, moving or otherwise. The effect is *apparent motion*, and even if you haven't heard of it, you'll have experienced it.

Look at two pictures one after the other, very rapidly, showing objects in slightly different positions. Get the timing right, and your brain fills in the gap: You get an illusion of the objects in the first picture moving smoothly to their position in the second. There's no single, moving object out there in the world, but your brain's filling in of the assumed path of movement gives you that impression.

Sound familiar? It should; it's the effect that all television and cinema is based on, of course.

2.16.1. In Action

The easiest way to experience this effect is, of course, to turn on your television or go to the cinema. Movie projectors show 24 frames (pictures) a second, and that's good enough for everyone to perceive continuous motion in the change from one frame to the next.

> In the old days of cinema, the film had 16 frames a second, which were projected using a three-bladed shutter to increase the flicker frequency above the rate necessary for flicker fusion. Despite seeing the same frame three times, your brain would fill in the gaps between the images, whether they were the same or different, so that you'd get the impression of continuous motion.

Television and computer screens are more complex cases, because the refresh doesn't happen for the whole image at once as it does with cinema but the principle is the same.

To demonstrate the effect to yourself in a more low-tech way, try this old child's game. Take a notebook and in the page corners draw the successive frames of a moving scene. I'm not very good at drawing stickmen, so when I did it I just tried drawing small, filled circles moving up from the bottom corner to the top of the page. Alternately, you may find a flip book in your local bookshop.

Flip through the pages of the book using your thumb andat a particular speedyou'll see the scene come to life. They're not just single pictures any more; together they form an animation. In my case, I see the little dot shoot up the side of the page. If I flip through the pages more slowly, the dot moves more slowlybut still continuously, as if it moves through every position on its path. Then, as I slow down even more, there comes a certain point at which the feeling of watching a single moving circle disappears and I'm just looking at a bunch of pages populated with slightly different shapes in slightly different positions.

2.16.2. How It Works

This apparent motion effect is also sometimes called the phi phenomenon. The simplest form in which you've probably encountered it before is two lights flashing at such an interval that you see one light moving from the first position to the second, as on an LED ticker display.

Hack 28. Motion Extrapolation: The "Flash-Lag Effect"

If there's a flash of light on a moving object, the flash appears to hang a little behind.

How quickly we can act is slow compared to how quickly things can happen to usespecially when you figure that by the time you've decided to respond to something that is moving it will already be in a new position. How do you coordinate your slow reactions to deal with moving objects? One way is to calibrate your muscles to deal with the way you expect things to be, so your legs are prepared for a moving escalator **[Hack #62]**, for example, before you step on it, to avoid the round-trip time of noticing the group is moving, deciding what to do, adjusting your movements, and so on. Expectations are built into your perceptual system as well as your motor system, and they deal with the time delay from sense data coming in to the actual perception being formed. You can see this coping strategy with an illusion called the flash-lag effect.[1]

2.17.1. In Action

Watch Michael Bach's Flash Lag demo at http://www.michaelbach.de/ot/mot_flashlag1 (Flash). A still from it is shown in Figure 2-23. In it, a blue-filled circle orbits a crosshold your eyes on the cross so you're not looking directly at the moving circle. This is to make sure the circle is moving across your field of view.

Figure 2-23. In the movie, the circle orbits the cross and flashes from time to time

Occasionally the inside of the ring flashes yellow, but it looks as if the yellow flash happens slightly behind the circle and occupies only part of the ring. This is the flash-lag illusion. You can confirm what's happening by clicking the Slow button (top right). The circle moves slower and the flash lasts longer, and it's now clear that the entire center of the circle turns yellow and the lag is indeed only an illusion.

2.17.2. How It Works

The basic difficulty here is that visual perception takes time; almost a tenth of a second passes between light hitting your retina to the signal being processed and reaching your cortex (most of this is due to how long it takes the receptors in the eye to respond). The circle in Bach's demo moves a quarter of an inch in that time, and it's not even going that fast. Imagine perpetually interacting with a world that had already moved on by the time you'd seen it.

So we continuously extrapolate the motion of anything we see, and our brain presents us with a picture of where the world most likely is now, rather than where it was a fraction of a second ago. This applies only to moving objects, not to stationary ones, and that's why the disparity opens up between the moving blue circle and the static yellow flashone is being extrapolated; the other isn't.

Straightforward extrapolation of the path of moving objects is one way in which this effect can take place, and this happens as early as the retina itself during visual processing. The cells in the eye compensate for its slow response by being most active at the front edge of a moving object. (Without this, the most active cells would be the ones that had been exposed to the object the longest, that is, the ones at the back.[2])

That's one way in which the flash-lag effect could come about, because the delay for visual processing is compensated for with moving objects, but flashes still pay the penalty and are seen later. But that doesn't explain the demonstration movies constructed by David Eagleman and Terrence Sejnowski (http://nba.uth.tmc.edu/homepage/eagleman/flashlag; QuickTime). Essentially the same as Bach's demo, these movies have an erratically moving ring that should confuse the brain's motion prediction.

In Experiment 1 (http://nba.uth.tmc.edu/homepage/eagleman/flashlag/r1.html; QuickTime), the ring abruptly changes direction at the same time as the flash. Still we see the flash lag

Hack 29. Turn Gliding Blocks into Stepping Feet

Motion detection uses contrast information first, not color.

The moral of this story is that if you want people to see moving objects, make them brighter or darker than the background, not just a different color.

Motion is important stuff for the brain. Information about movement gets routed from the eye to the visual cortexthe final destination for all visual informationalong its own pathway (you can take a tour round the visual system **[Hack #13]**), the *magnocellular pathway*. (Like a lot of things in neuroscience, this sounds more technical than it is; *magnocellular* means "with large cells.")

Color and form information travels along the *parvocellular pathway* (yup, "small cells") to the visual cortex, which means any motion has to be processed without access to that information. This functional division makes sense for a brain that wants to know immediately if there's a movement, and only secondly what exactly that moving something looks like. Problems arise only when movement processing is trying to figure out what sort of motion is occurring but the clues it needs are encoded in color and so not available.

2.18.1. In Action

Stuart Anstis has constructed just such a problematic situation, and it leads to the nifty stepping feet illusion[1] (http://psy.ucsd.edu/~sanstis/Foot.html; Shockwave). Blue and yellow blocks move smoothly in tandem from side to side. Click the Background button to bring up the striped background, and look again. It should look like Figure 2-24.

Figure 2-24. The stepping feet illusion, with the striped background

Even though they're still moving in the same direction, the blocks now appear to be alternately jerking forward, like little stepping feet. Like a lot of illusions, the effect is stronger in your peripheral vision; fix the center of your gaze at the cross off to the side and the stepping feet will be even clearer.

2.18.2. How It Works

The easiest way to see why the stepping feet occur is to look at the same pattern, but without any colorthe yellow becomes white and the blue becomes black. Michael Bach's animation of stepping feet (http://www.michaelbach.de/ot/mot_feet_lin; Flash) allows you to remove the color with a click of the Color Off button.

With no color, there's no illusion: the moving blocks appear like stepping feet even when you look straight at them. When the black (previously blue) block overlaps a black stripe, you can't see its leading edge so it isn't apparent that it's moving. Given no cues, your motion processing centers assume no movement. Then as the black block begins to move over a white stripe, you can suddenly see the leading edge again, and it's moved from where you brain had thought it was. That's when you see the block apparently jump forward and then move normallyat least until it overlaps the black stripe again. The same is true for the white (previously yellow) block over white stripes, only it moves when the black block looks still and vice versa.

So that's what the blocks look like in black and white. Losing the movement information of the leading edge over one stripe in two makes the blocks look like stepping feet. And that's what the motion-sensitive and color-insensitive magnocellular pathway sees. The color information is added back in only later, reattached in the visual cortex after the motion has been computed. In the end, you're able to simultaneously see the stepping feet motion via one pathway and the colors via the other.

> Low-contrast patterns in general produce a less vigorous response from the motion-sensitive parts of the brain,[2] which may explain why objects seen in fog appear to drift serenely, even though they may actually be

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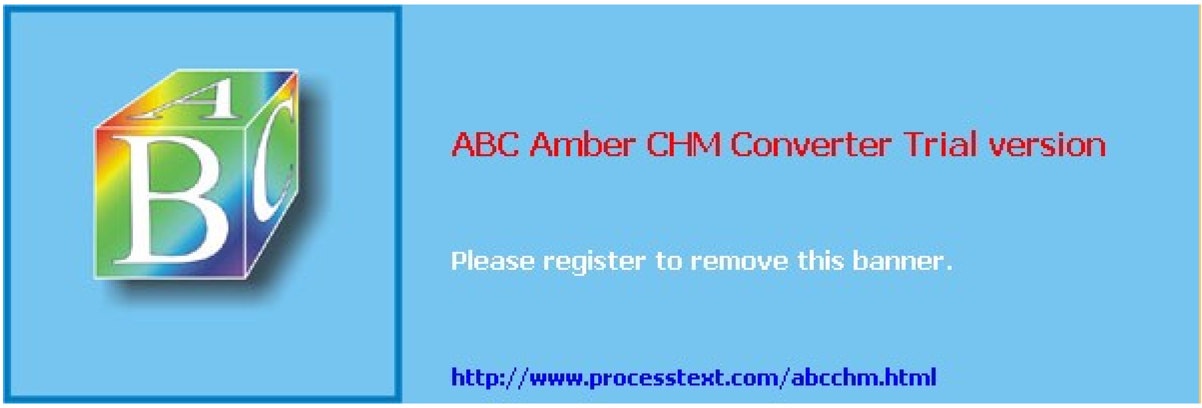

Hack 30. Understand the Rotating Snakes Illusion

Shading in pictures combined with the continuous random jiggling our eyes make can generate compelling movement illusions.

We've all seen optical illusions in which parts of a completely static picture appear to drift and swirl. One of the most famous examples is Professor Akiyoshi Kitaoka's rotating snake illusion (Figure 2-25), commonly passed around via email, but, sadly, rarely with explanation.

Figure 2-25. The rotating snake illusion, Akiyoshi Kitaoka © 2003, is available in color at http://www.ritsumei.ac.jp/~akitaoka/index-e.html

This is really a story about why you don't see everything moving all the time rather than about why you see movement sometimes when it isn't there. Your eyes constantly move in your head **[Hack #15]**, your head moves on your body, and your body moves about space. Your brain has to work hard to disentangle those movements in incoming visual information that are due to your movement and those due to real movement in the world.

The Vestibular-Ocular Reflex

One way your brain cuts down on confusion is shutting down visual input during rapid eye movements **[Hack #17]** .

Another mechanism is used to cancel out visual blur that results from head movements. Signals from how your head is moving are fed to the eyes to produce opposite eye movements that keep the visual image still.

Try this experiment. Hold the book in one hand and shake your head from side to side. You can still read the book. Now shake the book from side to side at the same speed at which you shook your head. You can't read a word, even though the words are moving past your head in the same way, and at the same speed, as when you were shaking your head. The *vestibular-ocular reflex* feeds a signal from your inner ear **[Hack #47]** to your eyes in such a way that they move in the opposite direction and at the correct rate to correct the visual displacement produced by the movement of your head.

You can readily demonstrate that this is a reflex hardwired to your inner ear, rather than a clever compensatory mechanism that depends on the motor signals you are sending to shake your head. If you get a friend to move your head from side to side while you relax completely (be sure your friend is careful and gentle!), you'll see that you can still read. This compensation doesn't depend on your knowing to where your head is going to move.

Another source of confusion for our visual system is a constant random drift in the exact focus of our eyes.1 This happens between saccades (see Figure 2-5, for example, in **[Hack #15]**). Our muscles are constantly sending little corrective signals to keep our eyes in the same place. These signals never keep the eyes exactly still, producing so-called *fixational movements*. This is a good thing. If visual input is completely constant (i.e., if your eyes become paralyzed), the neurons in the eye stop responding to the constant input (because that is what they do **[Hack #26]**) and everything fades out.

Normally your brain uses the structure of the current scene combined with the assumption that small random movements are due to eye movement so as not to get distracted by these slight constant drifts. To actually see these fixational movements, you have to look at something without any structure and without any surrounding frame of reference.

2.19.1. In Action

We need to get a handle on various principles of vision and motion computation before we

Hack 31. Minimize Imaginary Distances

If you imagine an inner space, the movements you make in it take up time according to how large they are. Reducing the imaginary distances involved makes manipulating mental objects easier and quicker.

Mental imagery requires the same brain regions that are used to represent real sensations. If you ask someone to imagine hearing the first lines to the song "Purple Haze" by Jimi Hendrix, the activity in her auditory cortex increases. If you ask someone to imagine what the inside of a teapot looks like, his visual cortex works harder. If you put a schizophrenic who is hearing voices into a brain scanner, when she hears voices, the parts of the brain that represent language sounds really are activeshe's not lying; she really is hearing voices.

Any of us can hear voices or see imaginary objects at will; it's only when we lose the ability to suppress the imaginings that we think of it as a problem.

When we imagine objects and places, this imagining creates mental space that is constrained in many of the ways real space is constrained. Although you can imagine impossible movements like your feet lifting up and your body rotating until your head floats inches above the floor, these movements take time to imagine and the amount of time is affected by how large they are.

2.20.1. In Action

Is the left shape in Figure 2-28 the same as the right shape?

Figure 2-28. Is the left shape the same as the right shape?

How about the left shape in Figure 2-29is it the same as the right shape?

Figure 2-29. Is the left shape the same as the right shape?

And is the left shape in Figure 2-30 the same as the one on the right?

Figure 2-30. Is the left shape the same as the right shape?

To answer these questions, you've had to mentally rotate one of each pair of the shapes. The first one isn't too hardthe right shape is the same as the left but rotated 50°. The second pair is not the same; the right shape is the mirror inverse of the left and again rotated by 50°. The third pair is identical, but this time the right shape has been rotated by 150°. To match the right shape in the third example to the left shape, you have to mentally rotate 100° further than to match the first two examples. It should have taken you extra seconds to do this. If you'd like try an online version, see the demonstration at http://www.uwm.edu/People/johnchay/mrp.htm (requires Shockwave). When we tried it, the long version didn't save our data (although it claimed it did) so don't get excited about being able to analyze your results; at the moment, you can use it only to get a feel for how the experiment works.

2.20.2. How It Works

These shapes are similar to the ones used by Robert Shepard and Jacqueline Metzler[1] in their seminal experiments on mentally rotation. They found that the time to make a decision about the shapes was linearly related to the angle of rotation. Other studies have shown the mental actions almost always take up an amount of time that is linearly related to the amount of imaginary movement required.

Team LiB

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Hack 32. Explore Your Defense Hardware

We have special routines that detect things that loom and make us flinch in response.

Typically, the more important something is, the deeper in the brain you find it, the earlier in evolution it arose, and the quicker it can happen.

Avoiding collisions is pretty important, as is closing your eyes or tensing if you can't avoid the collision. What's more, you need to do these things to a deadline. It's no use dodging after you've been hit.

Given this, it's not surprising that we have some specialized neural mechanisms for detecting collisions and that they are plugged directly into motor systems for dodging and defensive behavior.

2.21.1. In Action

The startle reaction is pretty familiar to all of usyou blink, you flinch, maybe your arms or legs twitch as if beginning a motion to protect your vulnerable areas. We've all jumped at a loud noise or thrown up our arms as something expands toward us. It's automatic. I'm not going to suggest any try-it-at-home demonstrations for this hack. Everyone knows the effect, and I don't want y'all firing things at each other to see whether your defense reactions work.

2.21.2. How It Works

Humans can show response to a collision-course stimulus within 80 ms.[1] This is far too quick for any sophisticated processing. In fact, it's even too quick for any processing that combines information across both eyes.

It's done, instead, using a classic hacka way of getting good-enough 3D direction and speed information from crude 2D input. It works like this: symmetrical expansion of darker-than-background areas triggers the startle response.

"Darker-than-background" because this is a rough-and-ready way of deciding what to count as an object rather than just part of the background. "Symmetrical expansion" because this kind of change in visual input is characteristic of objects that are coming right at you. If it's not expanding, it's probably just moving, and if it's not expanding symmetrically, it's either changing shape or not moving on a collision course.

These kind of stimuli capture attention **[Hack #37]** and cause a startle response. Everything from reptiles to pigeons to human infants will blink and/or flinch their heads when they see this kind of input. You don't get the same effects with contracting patches, rather than expanding patches, or with light patches, rather than dark patches .[2]

Looming objects always provoke a reaction, even if they are predictable; we don't learn to ignore them as we learn to ignore other kinds of event.[3] This is another sign that they fall in a class for which there is dedicated neural machineryand the reason why is pretty obvious as well. A looming object is always potentially dangerous. Some things you just shouldn't get used to.

In pigeons, the cells that detect looming exist in the midbrain. They are very tightly tuned so that they respond only to objects that look as if they are going to collidethey don't respond to objects that are heading for a near miss, even if they are still within 5º of collision.[4] These neurons fire at a consistent time before collision, regardless of the size and velocity of the object.

This, and the fact that near misses don't trigger a response, shows that path and velocity information is extracted from the rate and shape of expansion. Now this kind of calculation can be done cortically, using the comparison of information from both eyes, but for high-speed, non-tiny objects at anything more that 2 m away, it isn't.[5] You don't need to compare information from both eyes; the looming hack is quick and works well enough.

2.21.3. End Notes

Hack 33. Neural Noise Isnt a Bug; Its a Feature

Neural signals are innately noisy, which might just be a good thing.

Neural signals are always noisy: the timings of when they fire, or even whether they fire at all, is subject to random variation. We make generalizations at the psychological level, such as saying that the speed of response is related to intensity by a certain formulaPieron's Law **[Hack #11]** . And we also say that cells in the visual cortex respond to different specific motions **[Hack #25]** . But both of these are true only *on average*. For any single cell, or any single test of reaction time, there is variation each time it is measured. Not all the cells in the motion-sensitive parts of the visual cortex will respond to motion, and those that do won't do it exactly the same each time we experience a particular movement.

In the real world, we take averages to make sense of noisy data, and somehow the brain must be doing this too. We know that the brain is pretty accurate, despite the noisiness of our neural signals. A prime mechanism for compensating for neural noise is the use of lots of neurons so that the average response can be taken, canceling out the noise.

But it may also be the case that noise has some useful functions in the nervous system. Noise could be a feature, rather than just an inconvenient bug.

2.22.1. In Action

To see how noise can be useful, visit Visual Perception of Stochastic Resonance (http://neurodyn.umsl.edu/~simon/sr.html; Java) designed by Enrico Simonotto,[1] which includes a Java applet.

A grayscale picture has noise added and the result filtered through a threshold. The process is repeated and results played like a video. Compare the picture with various levels of noise included. With a small amount of noise, you see some of the gross features of the picturethese are the parts with high light values so they always cross the threshold, whatever the noise, and produce white pixelsbut the details don't show up often enough for you to make them out. With lots of noise, most of the pixels of the picture are frequently active and it's hard to make out any distinction between true parts of the picture and pixels randomly activated by noise.

But with the right amount of noise, you can clearly see what the picture is and all the details. The gross features are always there (white pixels), the fine features are there consistently enough (with time smoothing they look gray), and the pixels that are supposed to be black aren't activated enough to distract you.

2.22.2. How It Works

Having evolved to cope with noisy internal signals gives you a more robust system. The brain has developed to handle the odd anomalous data point, to account for random inputs thrown its way by the environment. We can make sense of the whole even if one of the parts doesn't entirely fit (you can see this in our ability to simultaneously process information **[Hack #52]**, as well). "Happy Birthday" sung down a crackly phone line is still "Happy Birthday." Compare this with your precision-designed PC; the wrong instruction at the wrong time and the whole thing crashes. The ubiquity of noise in neural processing means your brain is more of a statistical machine than a mechanistic one.

That's just a view of noise as something to be worked around, however. There's another function that noise in neural systems might be performingit's a phenomenon from control theory called *stochastic resonance*. This says that adding noise to a signal raises the maximum possible combined signal level. Counterintuitively, this means that adding the right amount of noise to a weak signal can raise it above the threshold for detection and make it easier to detect and not less so. Figure 2-32 shows this in a graphical form. The smooth curve is the varying signal, but it never quite reaches the activation threshold. Adding noise to the signal produces the jagged line that, although it's messy, still has the same average values *and* raises it over the threshold for detection at certain points.

Figure 2-32. Adding noise to a signal brings it above threshold, without

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Chapter 3. Attention

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3.1. Hacks 34-43

It's a busy world out there, and we take in a lot of input, continuously. Raw sense data floods in through our eyes, ears, skin, and more, supplemented by memories and associations both simple and complex. This makes for quite a barrage of information; we simply haven't the ability to consider all of it at once.

How, then, do we decide what to attend to and what else to ignore (at least for now)?

Attention is what it feels like to give more resources over to some perception or set of perceptions than to others. When we talk about attention here, we don't mean the kind of concentration you give to a difficult book or at school. It's the momentary extra importance you give to whatever's just caught your eye, so to speak. Look around the room briefly. What did you see? Whatever you recall seeinga picture, a friend, the radio, a bird landing on the windowsillyou just allocated attention to it, however briefly.

Or perhaps attention isn't a way of allocating the brain's scarce processing resources. Perhaps the limiting factor isn't our computational capacity at all, but, instead, a physical limit on action. As much as we can perceive simultaneously, we're able to act in only any one way at any one time. Attention may be a way of throwing away information, of narrowing down all the possibilities, to leave us with a single conscious experience to respond to, instead of millions.

It's hard to come up with a precise definition of attention. Psychologist William James,[1] in his 1890 *The Principles of Psychology*, wrote: "Everyone knows what attention is." Some would say that a more accurate and useful definition has yet to been found.

That said, we can throw a little light on attention to see how it operates and feels. The hacks in this chapter look at how you can voluntarily focus your visual attention **[Hack #34]**, what it feels like when you do (and when you remove it again) **[Hack #36]**, and what is capable of overriding your voluntary behavior and grabbing attention **[Hack #37]** automatically. We'll do a little counting **[Hack #35]** too. We'll also test the limits of shifting attention **[Hack #38]** and **[Hack #39]** and run across some situations in which attention lets you down **[Hack#40]** and **[Hack#41]**. Finally, we'll look at a way your visual attention capacity can be improved **[Hack #43]** .

3.1.1. End Note

1. The Stanford Encyclopedia of Philosophy has a good biography of William James (http://plato.stanford.edu/entries/james).

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Hack 34. Detail and the Limits of Attention

Focusing on detail is limited by both the construction of the eye and the attention systems of the brain.

What's the finest detail you can see? If you're looking at a computer screen from about 3 meters away, 2 pixels have to be separated by about a millimeter or more for them not to blur into one. That's the highest your eye's resolution goes.

But making out detail in real life isn't just a matter of discerning the difference between 1 and 2 pixels. It's a matter of being able to focus on fine-grain detail among enormously crowded patterns, and that's more to do with the limits of the brain's visual processing than what the eye can do. What you're able to see and what you're able to look at aren't the same.

3.2.1. In Action

Figure 3-1 shows two sets of bars. One set of bars is within the resolution of attention, allowing you to make out details. The other obscures your ability to differentiate particularly well by crowding .[1]

Figure 3-1. One set of bars is within the resolution of attention (right), the other is too detailed (left)[1]

Hold this book up and fix your gaze on the cross in the middle of Figure 3-1. To notice the difference, you have to be able to move your focus around without moving your eyesit does come naturally, but it can feel odd doing it deliberately for the first time. Be sure not to shift your eyes at all, and notice that you can count how many bars are on the righthand side easily. Practice moving your attention from bar to bar while keeping your eyes fixed on the cross in the center. It's easy to focus your attention on, for example, the middle bar in that set.

Now, again without removing your gaze from the cross, shift your attention to the bars on the lefthand side. You can easily tell that there are a number of bars therethe basic resolution of your eyes is more than good enough to tell them apart. But can you count them or selectively move your attention from the third to the fourth bar from the left? Most likely not; they're just too crowded.

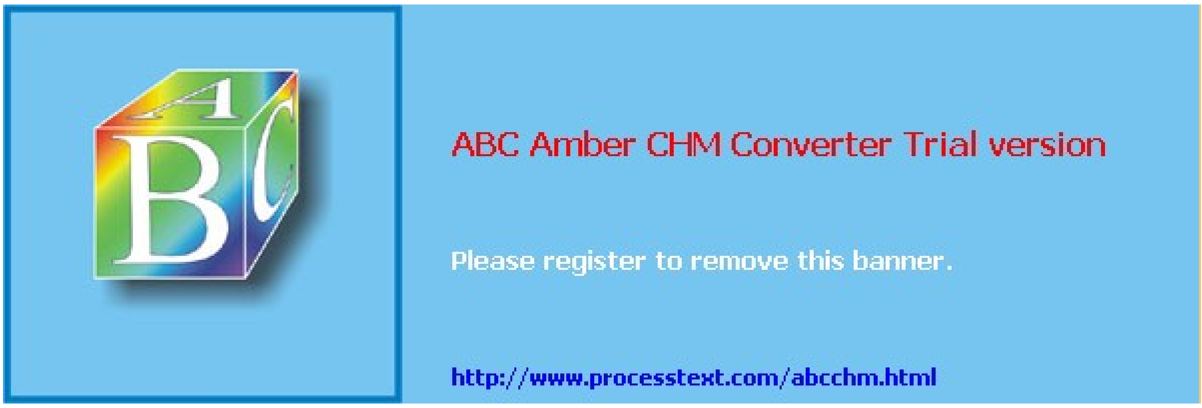
3.2.2. How It Works

The difference between the two sets of bars is that the one on the left is within the resolution of *visual selective attention* because it's spread out, while the one on the right is too crowded with detail.

"Attention" in this context doesn't mean the sustained concentration you give (or don't give) the speaker at a lecture. Rather, it's the prioritization of some objects at the expense of others. Capacity for processing is limited in the brain, and attention is the mechanism to allocate it. Or putting it another way, you make out more detail in objects that you're paying attention to than to those you aren't. Selective attention is being able to apply that processing to a particular individual object voluntarily. While it feels as if we should be able to select anything we can see for closer inspection, the diagram with the bars shows that there's a limit on what can be picked out, and the limit is based on how fine the detail is.

We can draw a parallel with the resolution of the eye. In the same way the resolution of the eye is highest in the center **[Hack #14]** and decreases toward the periphery, it's easier for attention to select and focus on detail in the center of vision than it is further out. Figure 3-2 illustrates this limit.

Figure 3-2. Comparing a pattern within the resolution of attention (left) with one that is too fine (right)



Hack 35. Count Faster with Subitizing

You don't need counting if a group is small enough; subitizing will do the job, and it's almost instant.

The brain has two methods for counting, and only one is officially called counting. That's the regular waywhen you look at a set of items and check them off, one by one. You have some system of remembering which have already been countedyou count from the top, perhapsand then increment: 7, 8, 9...

The other way is faster, up to five times faster per item. It's called *subitizing*. The catch: subitizing works for only really small numbers, up to about 4. But it's fast! So fast that until recently it was believed to be instantaneous.

3.3.1. In Action

See how many stars there are in the two sets in Figure 3-3. You can tell how many are in set A just by looking (there are three), whereas it takes a little longer to see there are six in set B.

Figure 3-3. The set of stars on the left can be subitized; the one on the right cannot

I know this feels obvious, that it takes longer to see how many stars there are in the larger set. After it, there are more of them. But that's exactly the point. If you can tell, and it feels like immediately, how many stars there are when there are three of them, why not when there are six? Why not when there are 100?

3.3.2. How It Works

Subitizing and counting do seem like different processes. If you look at studies of how long it takes for a person to look at some shapes on the screen and report how many there are, the time grows at 40-80 ms per item up to four, then increases at 250-350 milliseconds beyond that.[1] Or to put it another way, assessing the first four items takes only a quarter of a second. It takes another second for every four items after that. That's a big jump.

The difference between the two is borne out by the subjective experience. Counting feels to be a very deliberate act. You must direct your attention to each item. Your eyes move from star to star. Subitizing, on the other hand, feels preattentive. Your eyes don't need to move from star to star at all. There's no deliberate act required; you just know that there are four coffee mugs on the table or three people in the lobby, without having to check. You just look. It's this that leads some researchers to believe that subitizing isn't an act in itself, but rather a side effect of visual processing.

We know that we are able to keep track of a limited number of objects automatically and follow them as they move around and otherwise change. Like looking at shadows to figure out the shape of the environment **[Hack #20]**, object tracking seems to be a built-in feature of visual processingan almost involuntary ability to keep persistent files open for objects in vision **[Hack #36]** . The limit on how many objects can be tracked and how many items can be subitized is curiously similar. Perhaps, say some, the reason subitizing is so quick is that the items to be "counted" have already been tagged by the visual processing system, and so there's no further work required to figure out how many there are .[2]

In this view, counting is an entirely separate process that occurs only when the object tracking capacity is reached. Counting then has to remember which items have been enumerated and proceed in a serial way from item to item to see how many there are. Unfortunately, there's no confirmation of this view when looking at which parts of the brain are active while each of the two mechanisms is in use.[1] Subitizing doesn't appear to use any separate part of the brain that isn't also used when counting is employed. That's not to say the viewpoint of fast subitizing as a side effect is incorrect, only that it's still a conjecture.

Hack 36. Feel the Presence and Loss of Attention

Following seemingly identical objects around with your eyes isn't an easy job. Concentrating, it's possible, and the brain can even track objects when they momentarily pass behind things and disappear, but only in certain circumstances.

The problem with attention as a mechanism is that we use it continuouslyit's an intrinsic part of perceptionand consequently it's very hard to spot what it actually does or what giving attention to something actually feels like.

This hack has a go at showing you what allocating attention actually feels like, by getting you to voluntarily give attention to some fairly generic objectsin this case, you'll be tracking small, colored shapes as they move around. And you'll be able to feel what happens to these shapes when you take attention away. These are humble beginningsattention allocation to moving shapesbut we use these mechanisms for following any *thing* as it moves around: tennis balls, dogs, ants, and cursors.

3.4.1. In Action

Watch the sequence of *multiple object tracking* (MOT) demonstrations at Dr. Zenon Pylyshyn's Visual Attention Lab (http://ruccs.rutgers.edu/finstlab/demos.htm).[1] Multiple object tracking is a class of experiment based around trying to keep track of many objects (small circles in the first demonstration) simultaneously, as they jiggle about. It tests the limits of your attention and specialized tracking skills.

> Just in case you're not online at the moment, Figures Figure 3-4 through Figure 3-6 provide screenshots of the experiments for your convenience.

Figure 3-4. You have to track four of these circles as they move around the screen

Start with the General MOT experiment (http://ruccs.rutgers.edu/finstlab/mot.mov; QuickTime; Figure 3-4). In this demo, you're required to track four of the eight circles as they move around; you're told which four as they flash briefly at the beginning of the movie.

The point of this demonstration is simply to point out that you can indeed attend to more than one object at a time. It's not a trivial matter to follow all four circles around simultaneously, but you'll find that you can gaze at the center of the screen and track your four chosen circles fairly easily, without even having to stare directly at each in turn.

In the Occluder task (http://ruccs.rutgers.edu/finstlab/mot-occ-occlusion.mov; QuickTime; Figure 3-5), the circles have been replaced by identical white squares, and now they disappear occasionally behind bars placed over the field of movement.

Figure 3-5. Tracking the moving shapes becomes harder when they periodically move behind the black bars (outlined in white)

Aside from the newly introduced bars, the experiment is the same as the General MOT experiment; four of the eight squares flash at the beginning, your task being to track those four for the duration of the movie. This certainly isn't as easy as the general MOT experiment and may take a couple of attempts, but you should be able to complete the task.

The Virtual Occluder MOT movie (http://ruccs.rutgers.edu/finstlab/mot-occ-virtocc.mov; QuickTime; Figure 3-6), on the other hand, requires serious concentration. Now instead of sliding behind visible bars, the white squares momentarily vanish. The occludersthe bars that occlude, or hide, the squares behind themare now the same color as the background and

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Hack 37. Grab Attention

Sudden movement or light can grab your attention, thanks to a second region for visual processing.

What are you paying attention to? These words? In a minute it could switch to a friend or to making coffee or to the person on the bus who just stood up and you noticed out of the corner of your eye. We don't pay attention to everything we see or experience. Following two conversations at the same time is hard, even though we hear both perfectly well, and, likewise, it's simply not possible to read every word on the page of a book simultaneously, although they're all in plain view.

While your senses work overtime to provide as much input as possible, there's a bottleneck in the brain's limited capacity for attention. So we consciously decide which line of text to focus on and read across and down the page, line by line. And this happens at the expense of all the other stimuli we could have attended to, such as the color of the walls or the traffic noise from the road outside.

Choosing what to give attention to is voluntary...mostly. But attention can also be captured.

3.5.1. In Action

Stand so that you're facing a crowded scene. Watching a crowded theater settle down is ideal. A busy street corner is a good choice, too. A TV screen or video game will do as well, as long as there's a lot going on in the frame.

Don't try to direct your attention; just let it wander and feast your eyes on the full field of view.

Notice that when a person waves, or stands up, your attention is grabbed and snaps to focus on the person's position. It's not so much that you notice the waving or standing up itself; the event simply captures your attention and you properly focus on that place a fraction of a second afterward.

Since you're relaxed, your attention soon drifts away, until someone else moves and captures it again. Your attention scintillates across your whole field of view, darting from point to point.

3.5.2. How It Works

After visual information leaves the eye, it doesn't just go to one place for processing; the signal divides. Our conscious appreciation of visual information is provided by processing done in the visual cortex. It sits at the back of the brain in the area called the *occipital lobe* and performs what we typically associate with the job of vision: figuring out exactly what shape the thing you're looking at is, what color, if it's moving, then in what direction and how fast, what it means, and so onproviding the raw information needed to put names to faces and avoid stepping in front of a car while crossing a road.

Attention capture, on the other hand, relies on processing done by a region of the brain called the *superior colliculus*. It gets a copy of the same visual information the visual cortex does from the retina, but processes it in a different way. This region is evolutionarily ancient, which means the basic structure was established and refined in brains far simpler than our own, through many species of animals. (Rather than relegating it to second place, fish and amphibians do most of their visual processing with their equivalent of the superior colliculus, called the *optic lobe*.) So as one might expect, it's not particularly sophisticated, compared to the visual cortex. And it doesn't use much of the information it receives; the superior colliculus looks at a black-and-white world through frosted glass. Then again, it doesn't need much. This processing is for rapid response, when it appears something potentially dangerous is happening and urgent action is needed quicker than the complex visual cortex can respond. It's just useful enough to guide reflex movements, tell the head and body to orient in a particular direction, and force attention to snap to important-seeming events.

> The visual cortex and superior colliculus aren't the only regions of the brain that process signals from the eye; there are about 10 in total.

Hack 38. Don't Look Back!

Your visual attention contains a basic function that puts the dampers on second glances.

There are layers and layers of functions and processing in the brain. Oneattentionis a collaborative exercise between voluntary application of attention and automatic mechanisms to snap attention to where it's needed **[Hack #37]** . Even the voluntary application of attention is a negotiation with what evolution has taught the brain is most sensible. In particular, the brain doesn't like to return attention to a place or object it has just left. This phenomenon is called *inhibition of return*.

3.6.1. In Action

Like negative priming **[Hack #42]**, which is how contextual features are suppressed from attention, inhibition of return is such a low-level effect that it's hard to show without precision timing equipment. Again, just like those other effects, it turns up in all kinds of cases because attention is so widely employed.

Imagine you're taking part in an experiment in which an icon flashes up on a screen and you have to touch that position. It'll take you longer to move and touch the icon if some other icon had previously, and recently, been in that position.

Inhibition doesn't kick in immediately. Let's say you're playing Whack-A-Mole,[1] in which moles emerge from holes and you have to hit them with a hammer. A hole could light up momentarily before the mole appears. This would be a prime candidate for the inhibition-of-return effect. If the brightening occurs very shortly before the mole appears, only a fifth of a second or so, it serves to draw your attention to that place and you'll actually respond to the mole faster.

If, on the other hand, the brightening occurs and then there's a longer pausemore than a fifth of a second and up to 3 or 4 secondsthat's enough time for your attention to be dragged to the brightness change then shift away again. Inhibition of return kicks in, and when the mole appears in that same spot, you have to overcome the inhibition. It'll take longer for you to react to the mole (although it's not likely you'll miss it. Reaction time increases only on the order of a twentieth of a second or soenough to make a difference in some circumstances, but hard to spot.) One caveat: if the brightening happens before the mole pops up every single time, you're going to learn that pattern and end up being better at whacking the mole every time instead.

3.6.2. How It Works

The big question is why this happens. One possibility is that it's because we prefer novelty and want to suppress distracting stimuli. An attention-grabbing event is good if it's useful, but if it's not the event we're looking for, then we're better off focusing our attention elsewhere in the future and ignoring that distracting location.

Raymond Klein, in his review paper "Inhibition of Return,"[2] gives the example of efficient foraging for food. He suggests that potential locations that have been found bare should be remembered as places to be avoided, and this acts as a mechanism to orient toward novel locations. This could be used just standing in one place and looking ahead to find edible plants on the ground. For a task like visually searching straight ahead, it would be extremely useful to have a mechanism that allows you to briefly look harder (for a fifth of a second) and helps you to look for novel locations (for a few seconds after).

Current research indicates there may be two ways in which inhibition of return is produced. One is at a very low level, subcortically in the *superior colliculus*, which does rapid visual processing (but isn't responsible for our conscious visual processing **[Hack #13]**, which takes longer) and helps orient the pupils and body. Indeed, damage to this part of the brain stops inhibition of return from taking place[3], at least for stopping the eyes moving back to locations they've previously been.

Inhibition of return could also be triggered by higher-level operations in the allocation of attention. The fact that the inhibition remains in place even when the objects are moving

Hack 39. Avoid Holes in Attention

Our ability to notice things suffers in the half-second after we've just spotted something else.

A good way to think about *attention* is as the brain's way of paring down the sheer volume of sensory input into something more manageable. You can then concentrate your resources on what's important (or at least perceived to be so on first blush) and ignore the rest. If processing capacity weren't limited, perhaps we wouldn't need attention at all-we'd be able to give the same amount of concentration to everything in our immediate environment, simultaneously.

Another reason we continually pare down perception, using attention as a final limiting stage before reaching conscious awareness, could be that perception causes action. Maybe processing capacity doesn't intrinsically need to be limited, but our ability to act definitely is: we can do only one major task at a time. Attention might just be a natural part of conflict resolution over what to do next.

M.W.

Attention isn't the end of the chain, however. There's conscious awareness too. The difference between the two is subtle but important. Think of walking down a street and idly looking at the faces going by. Each face as it passes has a moment of your attention, but if you were asked how many brown-haired people you'd seen, you wouldn't have the slightest idea.

Say somebody you recognize passes. Suddenly this semiautomatic, mostly backgrounded looking-at-faces routine jumps to the foreground and pushes the face into conscious awareness. This is the act of *noticing*.

It turns out the act of noticing takes up resources in the brain too, just as paying attention does. Once you've noticed a face in the crowd, there's a gap where your ability to consciously notice another face is severely reduced. It's a big gap tooabout half a second. This phenomenon has been dubbed the *attentional blink*, drawing a parallel with the physical eye blink associated with visual surprise.

Attentionjust like vision, which cuts out during eye movements **[Hack #17]** is full of holes that, as a part of everyday life, we're built to ignore.

3.7.1. In Action

There's a standard experiment used to induce the attentional blink, using a technique called rapid serial visual presentation (RSVP). RSVP consists of projecting black letters onto a gray screen, one at a time, at about 10 letters a second.

You're instructed to watch the stream of letters and be on the lookout for two particular targets: a white letter and the letter *X*. Spotting either on its own is easy enough. One-tenth of a second (the length of time a letter is on-screen) is enough time for recognition and awareness. Spotting the targets when they're close together in time, however, is much harder.

If the letter *X* follows the white letter by five places or fewer, you'll probably miss it. Spotting the white letter, the first target, stops the second target, the *X*, from reaching conscious awareness. That's the attentional blink.

Obviously this isn't an easy test to do at home, but we can approximate it using speed-reading software. Speed-reading software often has a function to run through a text file, flashing the words up sequentiallyand that's what we'll use here.

You can use whichever software you like. I used AceReader Pro (http://www.stepware.com/acereader.html; $49.95; trial version available).

> Although the AceReader Pro trial version is suitable for this small test, it

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Hack 40. Blind to Change

We don't memorize every detail of a visual scene. Instead, we use the world as its own best representationcontinually revisiting any bits we want to think about. This saves the brain time and resources, but can make us blind to changes.

Both our vision **[Hack 14]** and attention **[Hack #34]** have far coarser resolutions than we'd have thought. What's more, there are gaps in our vision across time **[Hack #17]** and in space **[Hack #16]**, but our brains compensate for these gaps and knit together a rather seamless impression of the world.

And this gapless impression is utterly convincing. Most of the time we don't even realize that there are holes in the information we're getting. And so we believe we experience more of the world than we actually do. There are two possibilities as to what's going on here. The first is that we build a model inside our heads of the world we can see. You can test to see whether this is the case.

Imagine you are looking at a picture. There's a flicker as the picture disappears and appears again. What's different? If we made and kept a full internal representation of the visual world inside our heads, it would be easy to spot the difference. In theorybefore memory decay set init should be as easy as comparing two pictures (before and after) side by side on a page. But it isn't.

So that puts paid to the first possibility. The other is that you don't build a full internal model of what you're seeing at allyou just think you do. The illusion is maintained by constant sampling as you move your eyes around, a part of what is called active vision **[Hack #15]** . After all, why bother to store information about the world in your head when the information is freely available right in front of your very eyes?

The proof of the pudding for *active vision* is testing the consequence that, if true, you should find it very difficult to spot changes between two scenes, even with just a short flicker in between. Since most of the two separated images aren't stored in memory, there's no way to compare them. And, true enough, spotting any difference is very difficultso hard, in fact, that the phenomenon's been labeled *change blindness*.

3.8.1. In Action

You can try an animated GIF demo, which we made, at http://www.mindhacks.com/book/44/changeblindness.gif, both frames of which are shown in Figure 3-8. Shown side by side, the difference between the two versions of this picture is obvious.

Figure 3-8. The difference is easy to spot when you're allowed to look at both versions of the "same" picture at once[1]

But if you don't know what you're looking for, it can be impossible to spot. Load the images in the following URLs and have a look. If you're finding the first one hard, have a look at the man's noseyou can be looking right at the change in the image and still not spot it for a frustratingly long time.

- http://nivea.psycho.univ-paris5.fr/ASSChtml/couple.gif (an animated GIF)
- http://www.usd.edu/psyc301/Rensink.htm (a Java applet)

3.8.2. How It Works

You need the momentary blink between the pictures so you are actually forced to compare the two pictures in memory rather than noticing the change as it happens. Interestingly enough, the blink doesn't actually even need to cover the feature that's changing, as another demonstration at http://nivea.psycho.univ-paris5.fr/ASSChtml/dottedline.gif shows. Rather than blanking out the entire image, distracting patterns momentarily appear overlaid

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Hack 41. Make Things Invisible Simply by Concentrating (on Something Else)

What you pay attention to determines what you see, so much so that you can miss things that are immensely obvious to otherslike dancing gorillas, for instance.

Attention acts as a kind of filter, directing all resources to certain tasks and away from others. Nowhere is the impact of attention on what you actually see more evident than in the various experiments on *inattention blindness*.

Inattention blindness comes up when you're focusing as much attention as you can on a particular task and trying really hard to ignore distractions. It's the name given to the phenomenon of not noticing those distractions, however blatant and bizarre they become. In the most famous experiment on this subject, subjects had to watch a video of a crowd playing basketball. Concentrating on a spurious task, a good number of them were completely blind to the gorilla that walked into view halfway through the game.

3.9.1. In Action

You can watch the basketball video used in the gorilla experiment by Daniel Simons and Christopher Chabris.[1] Find it from the University of Illinois Visual Cognition Lab's page at http://viscog.beckman.uiuc.edu/media/mindhacks.html.[2]

OK, because you know what's going to happen, this isn't going to work for you, but here's the procedure anyway. Watch the basketball game, and count the number of passes made by the team in white shirts only. Find a friend and set her on the task.

If you were a subject in this experiment for real, counting those passes, what happens next would be completely unexpected: a woman in a gorilla suit walks through the group playing the game and stands in the middle of the screen before walking off again. About half the observers tested in Simons and Chabris's experiment missed the gorilla.

3.9.2. How It Works

Following the passes in the game and counting only some of them is a difficult task. There are two balls and six players, everyone's moving around, and the balls are often obscured. It's all your brain can do to keep up.

Actually, there's a little too much to keep up with. The bottleneck is in visual short-term memory, where the results of visual processing have to be stashed while the actual analysislooking for passes by players in white shirtshappens.

Visual short-term memory , or VSTM, can hold only a small amount of information. Its capacity is limited to the equivalent of about four objects. Now, there are tricks we can use to temporarily increase the size of short-term memory. Repeating a word over and over can lengthen the time it's remembered, for example. When two researchers at Vanderbilt University, J. Jay Todd and René Marois, performed experiments to measure the size of short-term memory,3 they devised their task in such a way that tricks weren't possible. Not only did subjects taking part have to do the memory experimentlooking at a pattern of colored dots and answering a question on it a second laterthey also had to speak numbers out loud for the duration, preventing the word repeating trick from being used. While the full load of the experiment was on VSTM, Todd and Marois looked at their subjects' brain activity using functional magnetic resonance imaging **[Hack #4]**, a technique that produces images in which busy parts of the brain show up brighter.

What they found was a small area on the back surface, in a region called the *posterior parietal cortex* where the activity increased as the pattern presented in the experiment became more complex. They could see that, as the pattern contained more colored dots, the brain activity grew proportionatelybut only up to four dots. At that point, not only did activity reach its peak, but performance in the short-term memory task did too. This points to a real capacity limit in VSTM.

The capacity is a major factor in counting passes in the basketball game too. There's simply

Hack 42. The Brain Punishes Features that Cry Wolf

The act of focusing on just one object goes hand in hand with actively suppressing everything you have to ignore. This suppression persists across time, in a phenomenon called negative priming.

In the story "The Boy Who Cried Wolf," the young shepherd repeatedly claims a wolf has come to attack his flock. There's no wolf there. The boy just enjoys seeing all the villagers run up the hill, coming to save him and the sheep. The villagers, naturally, get a bit annoyed at getting panicked and trying to scare off the nonexistent wolf, so when they hear the boy cry, "Wolf!" again in the middle of the night, they don't bother getting up. But this time there is a wolf. Oh dear. I could say the boy learns his lesson, but he doesn't: he gets eaten. Morality tale, very sad, etc.

Negative priming is the tiniest psychological root of "The Boy Who Cried Wolf." A stimulus, such as a color, a word, a picture, or a sound acts like the cry of "Wolf!" The brain acts as the villagers did, and it has an inhibition to responding to meaningless cries, and this kicks in after only one cry. But nobody gets eaten.

3.10.1. In Action

Negative priming can be picked up only in experiments with careful timing and many trialsit's a small-scale effect, but it's been demonstrated in many situations.

Look at the flash card in Figure 3-9, and say what the gray picture is as fast as you can. Speak it out loud.

Figure 3-9. An example negative priming flash card

Now look at Figure 3-10, and do the same: name the gray picture, out loud, as quickly as possible.

Figure 3-10. The next flash card in the sequence

You may find the picture in the second flash card slightly harder to make out, although really you need a controlled situation to pick up the reaction time difference. Both cards have a gray drawing to pick out and a black drawing to ignore, and you suppress both the black ink and the black image in order to ignore it. If, as is the case here, the image you have to identify in the second flash card is the same as the one you had to ignore in the first, you'll take a little longer about it. Your brain is acting like the second time the villagers hear the boy shouting "Wolf!"they still get out of bed, but it takes slightly longer to pull their clothes on.

3.10.2. How It Works

Negative priming has been found in situations much wider than when two colored pictures overlap. In that case, it's one of the pictures that has been negatively primed. But if you set up the experiment so one feature is selected at the expense of another, you can get negative priming for color, location, or shape. All it requires is for a feature to have been in your visual field but actively ignored, then subsequently that feature will take slightly longer to attend to.

What's curious is, in the flash cards used earlier, you're concentrating on the ink color (gray or black), thus ignoring the black ink...but the negative priming occurs for the picture itself too. You've not even had to consciously ignore the distracter picture, because you can just look past the black ink, but it gets suppressed anyway.

In a more extreme way, this is what is happening in inattention blindness **[Hack #40]** . You're concentrating on a certain set of features (white T-shirts, fast-moving), so you

Hack 43. Improve Visual Attention Through Video Games

Some of the constraints on how fast we can task-switch or observe simultaneously aren't fixed. They can be trained by playing first-person action video games.

Our visual processing abilities are by no means hardwired and fixed from birth. There are limits, but the brain's nothing if not plastic. With practice, the attentional mechanisms that sort and edit visual information can be improved. One activity that requires you to practice lots of the skills involved in visual attention is playing video games.

So, what effect does playing lots of video games have? Shawn Green and Daphne Bavelier from the University of Rochester, New York, have researched precisely this question; their results were published in the paper "Action Video Game Modifies Visual Attention,"[1] available online at http://www.bcs.rochester.edu/people/daphne/visual.html#video.

Two of the effects they looked at we've talked about elsewhere in this book. The attentional blink **[Hack #39]** is that half-second recovery time required to spot a second target in a rapid-fire sequence. And *subitizing* is that alternative to counting for very low numbers (4 and below), the almost instantaneous mechanism we have for telling how many items we can see **[Hack #35]** . Training can both increase the subitization limit and shorten the attentional blink, meaning we're able to simultaneously spot more of what we want to spot, and do it faster too.

3.11.1. Shortening the Attentional Blink

Comparing the attentional blink of people who have played video games for 4 days a week over 6 months against people who have barely played games at all finds that the games players have a shorter attentional blink.

The attentional blink comes about in trying to spot important items in a fast-changing sequence of random items. Essentially, it's a recovery time. Let's pretend there's a video game in which, when someone pops up, you have to figure out whether it's a good guy or a bad guy and respond appropriately. Most of the characters that pop up are good guys, it's happening as fast as you can manage, and you're responding almost automaticallythen suddenly a bad one comes up. From working automatically, suddenly the bad guy has to be lifted to conscious awareness so you can dispatch him. What the attentional blink says is that the action of raising to awareness creates a half-second gap during which you're less likely to notice another bad guy coming along.

Now obviously the attentional blinkthis recovery timeis going to have an impact on your score if the second of two bad guys in quick succession is able to slip through your defenses and get a shot in. That's a great incentive to somehow shorten your recovery time and return from "shoot bad guy" mode to "monitor for bad guys" mode as soon as possible.

3.11.2. Raising the Cap on Subitizing

Subitizingthe measure of how many objects you can quantify without having to count themis a good way of gauging the capacity of visual attention. Whereas counting requires looking at each item individually and checking it off, subitizing takes in all items simultaneously. It requires being able to give a number of objects attention at the same time, and it's not easy; that's why the maximum is usually about four, although the exact cap measured in any particular experiment varies slightly depending on the setup and experimenter.

Green and Bavelier found the average maximum number of items their non-game-playing subjects could subitize before they had to start counting was 3.3. The number was significantly higher for games players: an average of 4.9nearly 50% more.

Again, you can see the benefits of having a greater capacity for visual attention if you're playing fast-moving video games. You need to be able to keep on top of whatever's happening on the screen, even when (especially when) it's getting stretching.

Team LiB ◄ PREVIOUS NEXT ►

Chapter 4. Hearing and Language

Team LiB ◄ PREVIOUS NEXT ►

Team LiB ◂ PREVIOUS NEXT ▸

4.1. Hacks 44-52

Your ears are not simply "eyes for sound." Sound contains quite different information about the world than does light. Light tends to be ongoing, whereas sound occurs when things change: when they vibrate, collide, move, break, explode! Audition is the sense of events rather than scenes. The auditory system thus processes auditory information quite differently from how the visual system processes visual information: whereas the dominant role of sight is telling where things are, the dominant role of hearing is telling when things happen **[Hack #44]** .

Hearing is the first sense we develop in the womb. The regions of the brain that deal with hearing are the first to finish the developmental process called *myelination*, in which the connecting "wires" of neurons are finished off with fatty sheaths that insulate the neurons, speeding up their electrical signals. In contrast, the visual system doesn't complete this last step of myelination until a few months after birth.

Hearing is the last sense to go as we lose consciousness (when you're dropping off to sleep, your other senses drop away and sounds seem to swell up) and the first to return when we make it back to consciousness.

We're visual creatures, but we constantly use sound to keep a 360° check on the world around us. It's a sense that supplements our visual experiencea movie without a music score is strangely dull, but we hardly notice the sound track normally. We'll look at how we hear some features of that sound track, stereo sound **[Hack #45]**, and pitch **[Hack #46]** .

And of course, audition is the sense of language. Hacks in this chapter show how we don't just hear a physical sound but can hear the meanings they convey **[Hack #49]**, even on the threshold of perception **[Hack #48]** . Just as with vision, what we experience isn't quite what is physically there. Instead, we experience a useful aural construction put together by our brains.

We'll finish up by investigating three aspects of understanding language: of the hidden sound symbolism in words **[Hack #50]**, of how we break sentences into phrases, **[Hack #51]**, and of how you know excalty waht tehse wrdos maen **[Hack #52]** .

Team LiB ◂ PREVIOUS NEXT ▸

Hack 44. Detect Timing with Your Ears

Audition is a specialized sense for gathering information from the fourth dimension.

If vision lets you see where something is, hearing tells you when it is. The time resolution of audition is way above that of vision. A cinema screen of 24 images a second looks like a constant display, rather than 24 brief images. A selection of 24 clicks a second sounds like a bunch of clicksthey don't blur into a constant tone.

4.2.1. In Action

Listen to these three sound files:

- 24 clicks per second, for 3 seconds (http://www.mindhacks.com/book/44/24Hz.mp3; MP3)
- 48 clicks per second, for 3 seconds (http://www.mindhacks.com/book/44/48Hz.mp3; MP3)
- 96 clicks per second, for 3 seconds (http://www.mindhacks.com//book/44/96Hz.mp3; MP3)

At a frequency of 24 frames per second, film blurs into a continuous image. At 24 clicks per second, you perceive the sound as separate clicks. At four times that rate, you still hear the sound as discontinuous. You may not be able to count the clicks, but you know that the sound is made up of lots of little clicks, not one continuous hum. Auditory "flicker" persists up to higher frequencies than visual flicker before it is integrated to a continuous percept.

4.2.2. How It Works

Specialization for timing is evident in many parts of the auditory system. However, it is the design of the sound receptor device (the ears) that is most crucial. In the eye, light is converted to neural impulses by a slow chemical process in the receptor cells. However, in the ear, sound is converted to neural impulses by a fast mechanical system.

Sound vibrations travel down the ear canal and are transmitted by the tiny ear bones (*ossicles*) to the snail-shaped *cochlea*, a piece of precision engineering in the inner ear. The cochlea performs a frequency analysis of incoming sound, not with neural circuitry, but mechanically. It contains a curled wedge, called the basilar membrane, which, due to its tapering thickness, vibrates to different frequencies at different points along its length. It is here, at the basilar membrane, that sound information is converted into neural signals, and even that is done mechanistically rather than chemically. Along the basilar membrane are receptors, called hair cells. These are covered in tiny hairs, which are in turn linked by tiny filaments. When the hairs are pushed by a motion of the basilar membrane, the tiny filaments are stretched, and like ropes pulling open doors, the filaments open many minute channels on the hairs. Charged atoms in the surrounding fluid rush into the hair cells, and thus sound becomes electricity, the native language of the brain. Even movements as small as those on the atomic scale are enough to trigger a response. And for low frequency sounds (up to 1500 cycles per second), each cycle of the sound can trigger a separate group of electrical pulses. For higher frequencies, individual cycles are not coded, just the average intensity of the cycles. The cells that receive auditory timing input in the brain can fire at a faster rate than any other neurons, up to 500 times a second.

This arrangement means that the auditory system is finely attuned to frequency and timing information in sound waves. Sounds as low as 20 Hz (1 Hz is one beat per second), and as high as 20,000 Hz can be represented. The timing sensitivity is exquisite; we can detect periods of silence in sounds of as little as 1 millisecond (thousandths of a second). Compare this with your visual system, which requires exposure to an image for around 30 milliseconds to report an input to consciousness. Furthermore, thanks to the specialized systems in the ear and in the brain, timing between the ears is even more exquisite. If sound arrives at one ear as little as 20 *microseconds* (millionths of a second) before arriving at the other, this tiny difference can be detected **[Hack #45]** . For perspective, an eye blink is in the order of 100,000 microseconds, 5000 times slower.

Hack 45. Detect Sound Direction

Our ears let us know approximately which direction sounds are coming from. Some sounds, like echoes, are not always informative, and there is a mechanism for filtering them out.

A major purpose of audition is telling where things are. There's an analogy used by auditory neuroscientists that gives a good impression of just how hard a job this is. The information bottleneck for the visual system is the ganglion cells that connect the eyes to the brain **[Hack #13]** . There are about a million in each eye, so, in your vision, there are about two million channels of information available to determine where something is. In contrast, the bottleneck in hearing involves just two channels: one eardrum in each ear. Trying to locate sounds using the vibrations reaching the ears is like trying to say how many boats are out on a lake and where they are, just by looking at the ripples in two channels cut out from the edge of the lake. It's pretty difficult stuff.

Your brain uses a number of cues to solve this problem. A sound will reach the near ear before the far ear, the time difference depending on the position of the sound's source. This cue is known as the *interaural* (between the ears) *time* difference. A sound will also be more intense at the near ear than the far ear. This cue is known as the *interaural level* difference. Both these cues are used to locate sounds on the horizontal plane: the time difference (delay) for low-frequency sounds and the level difference (intensity) for high-frequency sounds (this is known as the Duplex Theory of sound localization). To locate sounds on the vertical plane, other cues in the spectrum of the sound (spectral cues) are used. The direction a sound comes from affects the way it is reflected by the outer ear (the ears we all see and think of as ears, but which auditory neuroscientists call pinnae). Depending on the sound's direction, different frequencies in the sound are amplified or attenuated. Spectral cues are further enhanced by the fact that our ears are slightly different shapes, thus differently distort the sound vibrations.

The main cue is the interaural time difference. This cue dominates the others if they conflict. The spectral cues, providing elevation (up-down) information, aren't as accurate and are often misleading.

4.3.1. In Action

Echoes are a further misleading factor, and seeing how we cope with them is a good way to really feel the complexity of the job of sound localization. Most environmentsnot just cavernous halls but the rooms in your house tooproduce echoes. It's hard enough to work out where a single sound is coming from, let alone having to distinguish between original sounds and their reverberations, all of which come at you from different directions. The distraction of these anomalous locations is mitigated by a special mechanism in the auditory system.

Those echoes that arrive at your ears within a very short interval are grouped together with the original sound, which arrives earliest. The brain takes only the first part of the sound to place the whole group. This is noticeable in a phenomenon known as the Haas Effect, also called *the principle of first arrival* or *precedence effect*.

The Haas Effect operates below a threshold of about 30-50 milliseconds between one sound and the next. Now, if the sounds are far enough apart, above the threshold, then you'll hear them as two sounds from two locations, just as you should. That's what we traditionally call echoes. By making echoes yourself and moving from an above-threshold delay to beneath it, you can hear the mechanism that deals with echoes come into play.

You can demonstrate the Haas Effect by clapping at a large wall.[1] Stand about 10 meters from the wall and clap your hands. At this distance, the echo of your hand clap will reach your ears more than 50 milliseconds after the original sound of your clap. You hear two sounds.

Now try walking toward the wall, while still clapping every pace. At about 5 meterswhere the echo reaches your ears less than 50 ms after the original sound of the clapyou stop hearing sound coming from two locations. The location of the echo has merged with that of the original sound; both now appear to come as one sound from the direction of your original

Hack 46. Discover Pitch

Why we perceive pitch at all is a story in itself. Pitch exists for sounds because our brains calculate it, and to do that, they must have a reason.

All sounds are vibrations in air. Different amplitudes create different sound intensities; different frequencies of vibration create different pitches. Natural sounds are usually made up of overlaid vibrations that are occurring at a number of different frequencies. Our experience of pitch is based on the overall pattern of the vibrations. The pitch isn't, however, always a quality that is directly available in the sound information. It has to be calculated. Our brains have to go to some effort to let us perceive pitch, but it isn't entirely obvious why we do this at all. One theory for why we hear pitch at all is because it relates to object size: big things generally have a lower basic frequency than small things.

The pitch we perceive a sound having is based on what is called the *fundamental* of the sound wave. This is the basic rate at which the vibration repeats. Normally you make a sound by making something vibrate (say, by hitting it). Depending on how and what you hit (this includes hitting your vocal cords with air), you will establish a main vibrationthis is the fundamentalwhich will be accompanied by secondary vibrations at higher frequencies, called harmonics. These harmonics vibrate at frequencies that are integer multiples of the fundamental frequency (so for a fundamental at 4 Hz, a harmonic might be at 8 Hz or 12 Hz, but not 10 Hz). The pitch of the sound we hear is based on the frequency of the fundamental alone; it doesn't matter how many harmonics there are, the pitch stays the same.

Amazingly, even if the fundamental frequency isn't actually part of the sound we hear; we still hear pitch based on what it *should be*. So for a sound that repeats four times a second but that is made up of component frequencies at 8 Hz, 12 Hz, and 16 Hz, the fundamental is 4 Hz, and it is based upon this that we experience pitch.

It's not definite how we do this, but one theory runs like this[1]: the physical construction of the basilar membrane in the inner ear means that it vibrates at the frequency of the fundamental as it responds to higher component frequencies. Just the physical design of the cochlea as an object means that it can be used by the brain to reproducephysicallythe calculation needed to figure out the fundamentals of a sound wave. That discovered fundamental is then available to be fed into the auditory processing system as information of equal status to any other sound wave.[2]

So it looks as if a little bit of neural processing has leaked out into the physical design of the eara great example of what some people have called extelligence, using the world outside the brain itself to do cognitive work.

4.4.1. In Action

An illusion called the missing fundamental demonstrates the construction of sounds in the ear. The fundamental and then harmonics of a tone are successively removed, but the pitch of the tone sounds the same. Play the sound file at http://physics.mtsu.edu/~wmr/julianna.html, and you'll hear a series of bleeps. Even though the lower harmonics are vanishing, you don't hear the sound get higher. It remains at the same pitch.[3]

4.4.2. How It Works

The way pitch is computed from tones with multiple harmonics can be used to construct an illusion in which the pitch of a tone appears to rise continuously, getting higher and higher without ever dropping. You can listen to the continuously rising tone illusion and see a graphical illustration of how the sound is constructed at http://www.kyushu-id.ac.jp/~ynhome/ENG/Demo/2nd/05.html#20.

Each tone is made up of multiple tones at different harmonics. The harmonics shift up in frequency with each successive tone. Because there are multiple harmonics, evenly spaced, they can keep shifting up, with the very highest disappearing as they reach the top of the frequency range covered by the tones and with new harmonics appearing at the lowest frequencies. Because each shift seems like a step up on a normal scale, your brain gives you an experience of a continuously rising tone. This is reinforced because the highest and lowest

Hack 47. Keep Your Balance

The ear isn't just for hearing; it helps you keep your balance.

Audition isn't the only function of the inner ear. We have semicircular channels of fluid, two in the horizontal plane, two in the vertical plane, that measure acceleration of the head. This, our vestibular system, is used to maintain our balance.

Note that this system can detect only acceleration and deceleration, not motion. This explains why we can be fooled into thinking we're moving if a large part of our visual field moves in the same directionfor example, when we're sitting on a train and the train next to ours moves off, we get the impression that we've started moving. For slow-starting movement, the acceleration information is too weak to convince us we've moved.

It's a good thing the system detects only acceleration, not absolute motion, otherwise we might be able to tell that we are moving at 70,000 mph through space round the sun. Or, worse, have direct experience of relativitythen things would get really confusing.

T.S.

4.5.1. In Action

You can try and use this blind spot for motion next time you're on a train. Close your eyes and focus on the rocking of the train side to side. Although you can feel the change in motion side to side, without visual informationand if your train isn't slowing down or speeding upyou don't have any information except memory to tell you in which direction you are traveling. Imagine the world outside moving in a different way. See if you can hallucinate for a second that you are traveling very rapidly in the opposite direction. Obviously this works best with a smooth train, so readers in Japan will have more luck.

4.5.2. How It Works

Any change in our velocity causes the fluid in the channels of the vestibular system to move, bending hair cells that line the surface of the channels (these hair cells work the same as the hair cells that detect sound waves in the cochlea, except they detect distortion in fluid, not air). Signals are then sent along the vestibular nerve into the brain where they are used to adjust our balance and warn of changes in motion.

Dizziness can result from dysfunction of the vestibular system or from a disparity between visual information and the information from the vestibular system. So in motion sickness, you feel motion but see a constant visual world (the inside of the car or of the ship). In vertigo, you don't feel motion but you see the visual world move a lot more than it shouldbecause of parallax, a small movement of your head creates a large shift in the difference between your feet and what you see next to them. (Vertigo is more complex than just a mismatch between vestibular and visual detection of motion, but this is part of the story.)

This is why, if you think you might get dizzy, it helps to fix on a moving point if you are moving but your visual world is not (such as the horizon if you are on a ship). But if you are staying still and your visual world is moving, the best thing to do is not to look (such as during vertigo or during a motion sickness-inducing film).

I guess this means I'd have felt less nauseated after seeing the *Blair Witch Project* if I'd watched it from a vibrating seat.

T.S.

Hack 48. Detect Sounds on the Margins of Certainty

Can you sort the signal from the noise? Patterns and regularity are often deeply hidden, but we're surprisingly adept at finding them.

Our perceptual abilities and sensory acumen differ from one individual to another, making our threshold for detecting faint or ambiguous stimuli vary considerably. The brain is particularly good at making sense of messy data and can often pick out meaning in the noisiest of environments, filtering out the chaotic background information to pick out the faintest signals.

4.6.1. In Action

A sample of Bing Crosby's "White Christmas" has been hidden in the sound file on our book web site (http://www.mindhacks.com/book/48/whitechristmas.mp3;MP3). The sound file is 30 seconds long and is mostly noise, so you will have to listen carefully to detect when the song starts. The song will start either in the first, second, or third 10 seconds and will be very faint, so pay close attention.

> You'll get more out of this hack if you listen to the sound file before knowing how the music has been hidden, so you're strongly recommended not to read ahead to the next section until you've done so.

4.6.2. How It Works

If you managed to hear the strains of Bing Crosby in the noisy background of the sound file, you may be in for a surprise. The sound file is pure noise, and despite what we promised earlier, "White Christmas" is not hidden in there at all (if you read ahead without trying it out for yourself, try it out on someone else). Not everyone is likely to detect meaningful sounds in the background noise, but it's been shown to work on a certain subset of the population. An experiment conducted by Merckelbach and van de Ven[1] reported that almost a third of students reported hearing "White Christmas" when played a similar noisy sound track.

There's been a lot of debate about why this might happen and what sort of attributes might be associated with the tendency to detect meaning in random patterns. In the study mentioned earlier, the authors found that this ability was particularly linked to measures of fantasy pronenessa measure of richness and frequency of imagination and fantasyand hallucination pronenessa measure of vividness of imagery and unusual perceptual experiences. If you, or someone you tested, heard "White Christmas" amid the noise and are now worried, there's no need to be. The tendencies measured by Merckelbach and van de Ven's study were very mild and certainly not a marker of anything abnormal (after all, it worked in a third of people!), and we all hallucinate to some degree (not seeing the eye's blind spot **[Hack #16]** is a kind of hallucination).

However, there is evidence that people who believe in certain paranormal phenomena may be more likely to find patterns in unstructured information. Brugger and colleagues[2] found that people who believe in ESP are more likely to detect meaningful information in random dot patterns than people who do not. Skeptics are often tempted to argue that this sort of experiment *disproves* ESP and the like, but the other finding reported in the same study was that meaningful patterns were more likely to be detected if the random dot pattern was presented to the left visual field, regardless of the participant's belief in ESP. The left visual field crosses over to connect to the right side of the brain, meaning that random patterns presented to be preferentially processed by the right hemisphere, seem to be more "meaningful" than those presented either to both or to the left hemisphere alone. This demonstrates another aspect of hemispheric asymmetry **[Hack #69]** but also hints that people who have high levels of paranormal beliefs may be more likely to show greater activation in their right hemisphere than their left, an effect that has been backed up by many further studies.

This pattern of hemispheric activation is linked to more than paranormal beliefs. Researchers have argued that it may be linked to a cognitive style that promotes "loose" associations

Hack 49. Speech Is Broadband Input to Your Head

Once your brain has decided to classify a sound as speech, it brings online a raft of tricks to extract from it the maximum amount of information.

Speech isn't just another set of noises. The brain treats it very differently from ordinary sounds. Speech is predominantly processed on the left side of the brain, while normal sounds are mostly processed on the right.

> This division is less pronounced in women, which is why they tend to recover better from strokes affecting their left-sided language areas.

Knowing you're about to hear language prepares your brain to make lots of assumptions specially tailored to extract useful information from the sound. It's this special way of processing language-classified sounds that allows our brains to make sense of speech that is coming at us at a rate of up to 50 phonemes a seconda rate that can actually be produced only using an artificially sped-up recording.

4.7.1. In Action

To hear just how much the expectation of speech influences the sounds you hear, listen to the degraded sound demos created by Bob Shannon et al. at the House Ear Institute (http://www.hei.org/research/depts/aip/audiodemos.htm).

In particular, listen to the MP3 demo that starts with a voice that has been degraded beyond recognition and then repeated six times, each time increasing the quality (http://www.hei.org/research/depts/aip/increase_channels.mp3).

You won't be able to tell what the voice is saying until the third or fourth repetition. Listen to the MP3 again. This time your brain knows what to hear, so the words are clearer much earlier. However hard you try, you can't go back to hearing static.

4.7.2. How It Works

Sentences are broken into words having meaning and organized by grammar, the system by which we can build up an infinite number of complex sentences and subtle meanings from only a finite pool of words.

Words can be broken down too, into *morphemes*, the smallest units of meaning. "-ing" is a morpheme and makes the word "run" become "running." It imparts meaning. There are further rules at this level, about how to combine words into large words.

Morphemes, too, can be broken down, into *phonemes*. Phonemes are the basic sounds a language uses, so the word "run" has three: /r u n/. They don't map cleanly onto the letters of the alphabet; think of the phoneme at the beginning of "shine." Phonemes are different from syllables. So the word "running" is made up of two morphemes and has five phonemes, but just two syllables (and seven letters of course).

Languages have different sets of phonemes; English has about 40-45. There are more than 100 phonemes that the human mouth is capable of making, but as babies, when we start learning language, we tune into the ones that we encounter and learn to ignore the rest.

People speak at about 10-15 phonemes per second, 20-30 if they're speaking fast, and that rate is easily understood by native speakers of the same language (if you fast-forward recorded speech, we can understand up to 50 phonemes per second). Speech this fast can't contain each sound sequentially and independently. Instead, the sounds end up on top of one another. As you're speaking one phoneme, your tongue and lips are halfway to the position required to speak the next one, anticipating it, so words sound different depending on what words are before and after. That's one of the reasons making good speech recognition software is so hard.

Hack 50. Give Big-Sounding Words to Big Concepts

The sounds of words carry meaning too, as big words for big movements demonstrate.

Steven Pinker, in his popular book on the nature of language, *The Language Instinct*[1], encounters the frob-twiddle-tweak continuum as a way of talking about adjusting settings on computers or stereo equipment. The Jargon File, longtime glossary for hacker language, has the following under *frobnicate* (http://www.catb.org/~esr/jargon/html/F/frobnicate.html):

Usage: frob, twiddle, and tweak sometimes connote points along a continuum. `Frob' connotes aimless manipulation; twiddle connotes gross manipulation, often a coarse search for a proper setting; tweak connotes fine-tuning. If someone is turning a knob on an oscilloscope, then if he's carefully adjusting it, he is probably tweaking it; if he is just turning it but looking at the screen, he is probably twiddling it; but if he's just doing it because turning a knob is fun, he's frobbing it.[2]

Why frob first? Frobbing is a coarse action, so it has to go with a big lump of a word. Twiddle is smaller, more delicate. And tweak, the finest adjustment of all, feels like a tiny word. It's as if the actual sound of the word, as it's spoken, carries meaning too.

4.8.1. In Action

The two shapes in Figure 4-3 are a *maluma* and a *takete*. Take a look. Which is which?

> Don't spoil the experiment for yourself by reading the next paragraph! When you try this out on others, you may want to cover up all but the figure itself.

Figure 4-3. One of these is a "maluma," the other a "takete"which is which?

If you're like most people who have looked at shapes like these since the late 1920s, when Wolfgang Köhler devised the experiment, you said that the shape on the left is a "takete," and the one on the right is a "maluma." Just like "frob" and "tweak," in which the words relate to the movements, "takete" has a spiky character and "maluma" feels round.

4.8.2. How It Works

Words are multilayered in meaning, not just indices to some kind of meaning dictionary in our brains. Given the speed of speech, we need as many clues to meaning as we can get, to make understanding faster. Words that are just arbitrary noises would be wasteful. Clues to the meaning of speech can be packed into the intonation of a word, what other words are nearby, and the sound itself.

Brains are association machines, and communication makes full use of that fact to impart meaning.

In Figure 4-3, the more rounded shape is associated with big, full objects, objects that tend to have big resonant cavities, like drums, that make booming sounds if you hit them. Your mouth is big and hollow, resonant to say the word "maluma." It rolls around your mouth.

On the other hand, a spiky shape is more like a snare drum or a crystal. It clatters and clicks. The corresponding sound is full of what are called *plosives*, sounds like *t*- and *k*- that involve popping air out.

That's the association engine of the brain in action. The same goes for "frob" and "tweak." The movement your mouth and tongue go through to say "frob" is broad and coarse like the frobbing action it communicates. You put your tongue along the base of your mouth and make a large cavity to make a big sound. To say "tweak" doesn't just remind you of finely

Hack 51. Stop Memory-Buffer Overrun While Reading

The length of a sentence isn't what makes it hard to understand it's how long you have to wait for a phrase to be completed.

When you're reading a sentence, you don't understand it word by word, but rather phrase by phrase. Phrases are groups of words that can be bundled together, and they're related by the rules of grammar. A noun phrase will include nouns and adjectives, and a verb phrase will include a verb and a noun, for example. These phrases are the building blocks of language, and we naturally chunk sentences into phrase blocks just as we chunk visual images into objects.

What this means is that we don't treat every word individually as we hear it; we treat words as parts of phrases and have a buffer (a very short-term memory) that stores the words as they come in, until they can be allocated to a phrase. Sentences become cumbersome not if they're long, but if they overrun the buffer required to parse them, and that depends on how long the individual phrases are.

4.9.1. In Action

Read the following sentence to yourself:

- While Bob ate an apple was in the basket.

Did you have to read it a couple of times to get the meaning? It's grammatically correct, but the commas have been left out to emphasize the problem with the sentence.

As you read about Bob, you add the words to an internal buffer to make up a phrase. On first reading, it looks as if the whole first half of the sentence is going to be your first self-contained phrase (in the case of the first, that's "While Bob ate an apple")but you're being led down the garden path. The sentence is constructed to dupe you. After the first phrase, you mentally add a comma and read the rest of the sentence...only to find out it makes no sense. Then you have to think about where the phrase boundary falls (aha, the comma is after "ate," not "apple"!) and read the sentence again to reparse it. Note that you have to read again to break it into different phrases; you can't just juggle the words around in your head.

Now try reading these sentences, which all have the same meaning and increase in complexity:

- The cat caught the spider that caught the fly the old lady swallowed.
- The fly swallowed by the old lady was caught by the spider caught by the cat.
- The fly the spider the cat caught caught was swallowed by the old lady.

The first two sentences are hard to understand, but make some kind of sense. The last sentence is merely rearranged but makes no natural sense at all. (This is all assuming it makes some sort of sense for an old lady to be swallowing cats in the first place, which is patently absurd, but it turns out she swallowed a goat too, not to mention a horse, so we'll let the cat pass without additional comment.)

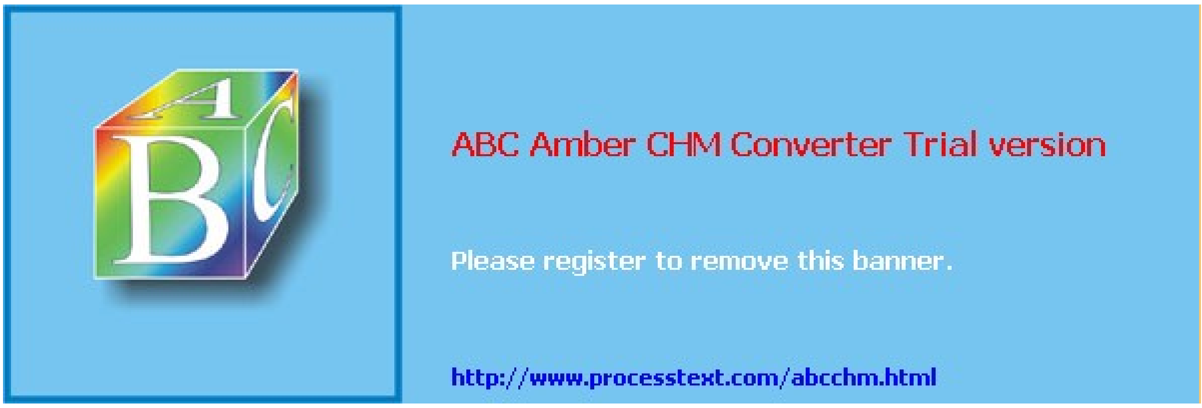
4.9.2. How It Works

Human languages have the special property of being recombinant. This means a sentence isn't woven like a scarf, where if you want to add more detail you have to add it at the end. Sentences are more like Lego. The phrases can be broken up and combined with other sentences or popped open in the middle and more bricks added.

Have a look at these rather unimaginative examples:

- This sentence is an example.
- This boring sentence is a simple example.

Team LiB
PREVIOUS NEXT



Hack 52. Robust Processing Using Parallelism

Neural networks process in parallel rather than serially. This means that as processing of different aspects proceeds, previously processed aspects can be used quickly to disambiguate the processing of others.

Neural networks are massively parallel computers. Compare this to your PC, which is a serial computer. Yeah, sure, it can emulate a parallel processor, but only because it is really quick. However quick it does things, though, it does them only one at a time.

Neural processing is glacial by comparison. A neuron in the visual cortex is unlikely to fire more than every 5 milliseconds even at its maximum activation. Auditory cells have higher firing rates, but even they have an absolute minimum gap of 2 ms between sending signals. This means that for actions that take 0.5 to 1 secondsuch as noticing a ball coming toward you and catching it (and many of the things cognitive psychologists test)there are a maximum of 100 consecutive computations the brain can do in this time. This is the so-called *100 step rule*.[1]

The reason your brain doesn't run like a PC with a 0.0001 MHz processor is because the average neuron connects onto between 1000 and 10,000 other neurons. Information is routed, and routed back, between multiple interconnected neural modules, all in parallel. This allows the slow speed of each neuron to be overcome, and also makes it natural, and necessary, that all aspects of a computational job be processed simultaneously, rather than in stages.

Any decision you make or perception you have (because what your brain decides to provide you with as a coherent experience is a kind of decision too) is made up of the contributions of many processing modules, all running simultaneously. There's no time for them to run sequentially, so they all have to be able to run with raw data and whatever else they can get hold of at the time, rather than waiting for the output of other modules.

4.10.1. In Action

A good example of simultaneous processing is in understanding language. As you hear or read, you use the context of what is being said, the possible meaning of the individual words, the syntax of the sentences, and how the sounds of each wordor the letters of each wordlook to figure out what is being said.

Consider the next sentence: "For breakfast I had bacon and ****." You don't need to know the last word to understand it, and you can make a good guess at the last word.

Can you tell the meaning of "Buy v!agra" if I email it to you? Of course you can; you don't need to have the correct letter in the second word to know what it is (if it doesn't get stopped by your spam filters first, that is).

4.10.2. How It Works

The different contributionsthe different clues you use in readinginform one another, to fill in missing information and correct mismatched information. This is one of the reasons typos can be hard to spot in text (particularly your own, in which the contribution of your understanding of the text autocorrects, in your mind, the typos before you notice them), but it's also why you're able to have conservations in loud bars. The parallel processing of different aspects of the input provides robustness to errors and incompleteness and allows information from different processes to interactively disambiguate each other.

Do you remember the email circular that went around (http://www.mrc-cbu.cam.ac.uk/personal/matt.davis/Cmabrigde) saying that you can write your sentences with the internal letters rearranged and still be understood just as well? Apparently, it deosn't mttaer in waht oredr the ltteers in a wrod are, the olny iprmoetnt tihng is taht the frist and lsat ltteer be at the rghit pclae. The rset can be a toatl mses and you can sitll raed it wouthit porbelm.

It's not true, of course. You understand such scrambled sentences only *nearly as well* as

Team LiB ◄ PREVIOUS NEXT ►

Chapter 5. Integrating

Team LiB ◄ PREVIOUS NEXT ►

Team LiB ◂ PREVIOUS NEXT ▸

5.1. Hacks 53-61

This chapter looks at how we integrate our perceptionsimages (Chapter 2), sounds (Chapter 4), our own mechanisms of attention (Chapter 3), and our other senses **[Hack #12]** into a unified perceptual experience.

For instance, how do we use our eyes and ears together? (We prefer to use our ears for timing and eyes for determining location **[Hack #53]** .) And what are the benefits of doing so? (We feel experiences that happen in two senses simultaneously as more intense **[Hack #57]** and **[Hack #58]**.)

Sometimes, we overintegrate. The Stroop Effect **[Hack #55]**, a classic experiment, shows that if we try to respond linguistically, irrelevant linguistic input interferes. In its eagerness to assimilate as much associated information, as much context, as possible, the brain makes it very hard to ignore even what we consciously know is unimportant.

We'll also look at one side effect and one curious limitation of the way we integrate sense information. The first goes to show that even the brain's errors can be useful and that we can actually use a mistaken conclusion about a sound's origin to better listen to it **[Hack #60]** . The second answers the question: do we really need language to perform what should be a basic task, of making a simple deduction from color and geometry? In some cases, it would appear so **[Hack #61]** .

Team LiB ◂ PREVIOUS NEXT ▸

Hack 53. Put Timing Information into Sound and Location Information into Light

The timing of an event will be dominated by the sound it makes, the location by where it looks as if it is happeningthis is precisely why ventriloquism works.

Hearing is good for timing **[Hack #44]** but not so good for locating things in space. On the flip side, vision has two million channels for detecting location in space but isn't as fast as hearing.

What happens when you combine the two? What you'd expect from a well-designed bit of kit: vision dominates for determining location, audition dominates for determining timing. The senses have specialized for detecting different kinds of information, and when they merge, that is taken into account.

5.2.1. In Action

You can see each of the two senses take control in the location and timing domains. In the first part, what you see overrules the conflicting location information in what you hear; in the second part, it's the other way around.

5.2.1.1 Vision dominates for localization

Go to the theater, watch a film, or play a movie on your PC, listening to it on headphones. You see people talking and the sound matches their lip movement **[Hack #59]** . It feels as if the sound is coming from the same direction as the images you are watching. It's not, of course; instead, it's coming at you from the sides, from the cinema speakers, or through your headphones.

The effect is strongest at public lectures. You watch the lecturer on stage talking and don't notice that the sound is coming at you from a completely different direction, through speakers at the sides or even back of the hall. Only if you close your eyes can you hear that the sounds aren't coming from the stage. The visual correspondence with the sounds you are hearing causes your brain to absorb the sound information into the same event as the image, taking on the location of the image. This is yet another example (for another, see **[Hack #58]**) of how our most important sense, vision, dominates the other senses.

Incidentally, this is how ventriloquism works. The ventriloquist knows that if the timings of the dummy's lip movements are close enough to the sounds you hear you will preconsciously locate the sounds as coming from the dummy. Every time we go to the cinema we are experiencing a ventriloquism effect, but it is so finessed that we don't even notice that it is part of the show.

T.S.

5.2.1.2 Audition dominates for timing

Vision doesn't always dominate. Watch Ladan Shams's "Sound-induced Illusory Flashing" movies at Caltec (http://neuro.caltech.edu/~lshams/demo.html; QuickTime).[1] They show a black dot flashing very briefly on a white background. The only difference between the movie on the left and the movie on the right is the sound played along with the flash of the dot. With one set you hear a beep as the dot appears; with another set you hear two beeps.

> On Ladan Shams's page, you have the option of watching a number of different pairs of movies. These correspond to different computer speeds. Start with the ones at the top and run them all until you find the one with the strongest effect.

Notice how the sound affects what you see. Two beeps cause the dot not to flash but to appear to flicker. Our visual system isn't so sure it is seeing just one event, and the evidence from hearing is allowed to distort the visual impression that our brain delivers for conscious

Hack 54. Don't Divide Attention Across Locations

Attention isn't separate for different senses. Where you place your attention in visual space affects what you hear in auditory space. Attention exists as a central, spatially allocated resource.

Where you direct attention is not independent across the senses. Where you pay attention to in space with one sense affects the other senses.[1] If you want people to pay attention to information across two modalities (a *modality* is a sense mode, like vision or audition), they will find this easiest if the information comes from the same place in space. Alternatively, if you want people to ignore something, don't make it come from the same place as something they are attending to. These are lessons drawn from work by Dr. Charles Spence of the Oxford University crossmodal research group (http://www.psych.ox.ac.uk/xmodal/default.htm). One experiment that everyone will be able to empathize with involves listening to speech while driving a car.[2]

5.3.1. In Action

Listening to a radio or mobile phone on a speaker from the back of a car makes it harder to spot things happening in front of you.

Obviously showing this in real life is difficult. It's a complex situation with lots of variables, and one of these is whether you crash your carnot the sort of data psychologists want to be responsible for creating. So Dr. Spence created the next best thing in his laban advanced driving simulator, which he sat people in and gave them the job of simultaneously negotiating the traffic and bends while repeating sets of words played over a speaker (a task called *shadowing*). The speakers were placed either on the dashboard in front or to the side.

Drivers who listened to sounds coming from the sides made more errors in the shadowing task, drove slower, and took longer to decide what to do at junctions.

You can see coping strategy in action if you sit with a driver. Notice how he's happy to talk while driving on easy and known roads, but falls quiet and pops the radio off when having to make difficult navigation decisions.

5.3.2. How It Works

This experimentand any experience you may have had with trying to drive with screaming kids in the backseat of a carshows that attention is allocated in physical space, not just to particular things arbitrarily and not independently across modalities. This is unsurprising, given that we know how interconnected cortical processing is **[Hack #81]** and that it is often organized in maps that use spatial coordinate frames **[Hack #12]** . The spatial constraints on attention may reflect the physical limits of modulating the activity in cortical processing structures that are themselves organized to mirror physical space.

5.3.3. In Real Life

Other studies of this kind of task, which involve complex real-world tasks, have shown that people are actually very good at coordinating their mental resources. The experiments that motivated this experiment proved that attention is allocated in space and that dividing it in space, even across modalities, causes difficulties. But these experiments tested subjects who weren't given any choice about what they didthe experimental setup took them to the limits of their attentional capacities to test where they broke down.

Whether these same factors had an effect in a real-world task like driving was another question. When people aren't at the limit of their abilities, they can switch between tasks, rather than doing both at onceallocating attention dynamically, shifting it between tasks as the demands of the task change. People momentarily *stop* talking when driving at sections of the road that are nonroutine, like junctions, in order to free up attention, avoiding getting trapped in the equivalent of Spence's shadowing task.

The driving experiment shows that despite our multitasking abilities the spatial demands of crossmodal attention do influence driving ability. The effect might be small, but when you're

Hack 55. Confuse Color Identification with Mixed Signals

When you're speaking, written words can distract you. If you're thinking nonlinguistically, they can't.

The Stroop Effect is a classic of experimental psychology. In fact, it's more than a classic, it's an *industry*. J. Ridley Stroop first did his famous experiment in 1935, and it's been replicated thousands of times since then. The task is this: you are shown some words and asked to name the ink color the words appear in. Unfortunately, the words themselves can be the names of colors. You are slower, and make more errors, when trying to name the ink color of a word that spells the name of a different color. This, in a nutshell, is the Stroop Effect. You can read the original paper online at http://psychclassics.yorku.ca/Stroop.

5.4.1. In Action

To try out the Stroop Effect yourself, use the interactive experiment available at http://faculty.washington.edu/chudler/java/ready.html[1] (you don't need Java in your web browser to give this a go).

Start the experiment by clicking the "Go to the first test" link; the first page will look like Figure 5-1, only (obviously) in color.

Figure 5-1. In the Stroop experiment, the color of the ink isn't necessarily the same as the color the word declares

As fast as you're able, read out loud the color of each wordnot what it spells, but the actual color in which it appears. Then click the Finish button and note the time it tells you. Continue the experiment and do the same on the next screen. Compare the times.

The difference between the two tests is that whereas the ink colors and the words correspond on the first screen, on the second they conflict for each word. It takes you longer to name the colors on the second screen.

5.4.2. How It Works

Although you attempt to ignore the word itself, you are unable to do so and it still breaks through, affecting your performance. It slows your response to the actual ink color and can even make you give an incorrect answer. You can get this effect with most people nearly all of the time, which is one reason why psychologists love it.

The other reason it's a psychologist's favorite is that, although the task is simple, it involves many aspects of how we think, and the experiment has variations to explore these. At first glance, the explanation of the task seems simplewe process words automatically, and this process overrides the processing of color information. But this isn't entirely true, although that's the reason still taught in many classes.

Reading the word interferes only if two conditions are fulfilled. First, the level and focus of your attention has to be broad enough that the word can be unintentionally read. Second, the response you are trying to give must be a linguistic one. In this case, the required response is spoken, so it is indeed linguistic.

Avoiding reading is easier when the color to report is disentangled from the word. If you have to respond to only the color of the first letter of each word and the rest are black, the confusion is reduced. Ditto if the word and block of color are printed separately. In these cases, we're able to configure ourselves to respond to certain stimuli (the color of the ink) and ignore certain others (the word). It's only when we're not able to divide the two types of information that the Stroop Effect emerges.

It's probably this kind of selective concentration that renders otherwise

Hack 56. Don't Go There

You're drawn to reach in the same direction as something you're reacting to, even if the direction is completely unimportant.

So much of what we do in everyday life is responding to something that we've seen or heardchoosing and clicking a button on a dialog box on a computer or leaping to turn the heat off when a pan boils over. Unfortunately, we're not very good at reacting *only* to the relevant information. The form in which we receive it leaks over into our response.

For instance, if you're reacting to something that appears on your left, it's faster to respond with your left hand, and it takes a little longer to respond with your right. And this is true even when location isn't important at all. In general, the distracting effect of location responses is called the Simon Effect,[1] named after J. Richard Simon, who first published on it in 1968 and is now Professor Emeritus at the University of Iowa.2

The Simon Effect isn't the only example of the notionally irrelevant elements of a stimulus leaking into our response. Similar is the Stroop Effect **[Hack #55]**, in which naming an ink color nets a slower response if the ink spells out the name of a different color. And, although it's brought about by a different mechanism, brighter lights triggering better reaction times **[Hack #11]** is similar in that irrelevant stimulus information modifies your response (this one is because a stronger signal evokes a faster neural response).

5.5.1. In Action

A typical Simon task goes something like this: you fix your gaze at the center of a computer screen and at intervals a light flashes up, randomly on the left or the rightwhich side is unimportant. If it is a red light, your task is to hit a button on your left. If it is a green light, you are to hit a button on your right. How long it takes you is affected by which side the light appears on, even though you are supposed to be basing which button you press entirely on the color of the light. The light on the left causes quicker reactions to the red button and slower reactions to the green button (good if the light is red, bad if the light is green). Lights appearing on the right naturally have the opposite effect. Even though you're supposed to disregard the location entirely, it still interferes with your response. The reaction times being measured are usually a half-second or less for this sort of experiment, and the location confusion results in an extension of roughly 5%.

It's difficult to tell what these reaction times mean without trying the experiment, but it is possible to feel, subjectively, the Simon Effect without equipment to measure reaction time.

You need stimuli that can appear on the left or the right with equal measure. I popped outside for 10 minutes and sat at the edge of the road, looking across it, so traffic could come from either my left or my right. (Figure 5-2 shows the view from where I was sitting.) My task was to identify red and blue cars, attempting to ignore their direction of approach.

Figure 5-2. The view from where I sat watching for red and blue cars

In choosing this task, I made use of the fact that color discrimination is poor in peripheral vision **[Hack #14]** . By fixing my gaze at a position directly opposite me, over the road, and refusing to move my eyes or my head, I would be able to tell the color of each car only as it passed directly in front of me. (If I had chosen to discriminate black cars and white cars, there's no color information required, so I would have been able to tell using my peripheral vision.) I wanted to do this so I wouldn't have much time to do my color task, but would be able to filter out moving objects that weren't cars (like people with strollers).

As a response, I tapped my right knee every time a red car passed and my left for blue ones, trying to respond as quickly as possible.

After 10 minutes of slow but steady traffic, I could discern a slight bias in my responses. My right hand would sometimes twitch a little if cars approached from that direction, and vice versa.

Hack 57. Combine Modalities to Increase Intensity

Events that affect more than one sense feel more intense in both of them.

The vision and audition chapters (Chapter 2 and Chapter 4, respectively) of this book look at the senses individually, just as a lot of psychologists have over the years. But interesting things begin to happen when you look at the senses as they interact with one another.[1]

Multisensory information is the norm in the real world, after all. Tigers smell strong and rustle as they creep through the undergrowth toward you. Fire shines and crackles as it burns. Your child says your name as she shakes your shoulder to wake you up.

These examples all suggest that the most basic kind of interaction between two senses should be the enhanced response to an event that generates two kinds of stimulation rather than just one. Information from one sense is more likely to be coincidence; simultaneous information on two senses is a good clue that you have detected a real event.

5.6.1. In Action

We can see the interaction of information hitting two senses at once in all sorts of situations. People sound clearer when we can see their lips **[Hack #59]** . Movies feel more impressive when they have a sound track. If someone gets a tap on one hand as they simultaneously see two flashes of light, one on each side, the light on the same side as the hand tap will appear brighter.

Helge Gillmeister and Martin Eimer of Birkbeck College, University of London, have found that people experience sounds as louder if a small vibration is applied to their index finger at the same time.[2] Although the vibration didn't convey any extra information, subjects rated sounds as up to twice as loud when they occurred at the same time as a finger vibration. The effect was biggest for quieter sounds.

5.6.2. How It Works

Recent research on such situations shows that the combination of information is wired into the early stages of sensory processing in the cortex. Areas of the cortex traditionally thought to respond to only a single sense (e.g., parts of the visual cortex) do actually respond to stimulation of the other senses too. This makes sense of the fact that many of these effects occur preconsciously, without any sense of effort or decision-making. They are preconscious because they are occurring in the parts of the brain responsible for initial representation and processing of sensationanother example (as in **[Hack #15]**) of our perception not being passive but being actively constructed by our brains in ways we aren't always aware of.

Macaluso et al.[3] showed that the effect can work the other way round from the one discussed here: touch can enhance visual discrimination. They don't suggest that integration is happening in the visual cortex initially, but instead that parietal cortex areas responsible for multisensory integration send feedback signals down to visual areas, and it is this that allows enhanced visual sensitivity.

For enhancement to happen, it has to be labeled as belonging to the same event, and this is primarily done by the information arriving simultaneously. Individual neurons **[Hack #9]** are already set up to respond to timing information and frequently respond strongest to inputs from different sources arriving simultaneously. If information arrives at different times, it can suppress the activity of cells responsible for responding to inputs across senses (senses are called *modalities*, in the jargon).

So, what makes information from two modalities appear simultaneous? Obviously arriving at the *exact* same time is not possible; there must be a resolution of the senses in time below which two events appear to be simultaneous.

Although light moves a million times faster than sound, sound is processed faster once it gets to the ear **[Hack #44]** than light is processed once it gets to the eye. The relative speed of processing of each sense, coupled with the speed at which light and sound travel, leads to a "horizon of simultaneity"[4] at about 10 meterswhere visual and auditory signals from the same

Hack 58. Watch Yourself to Feel More

Looking at your skin makes it more sensitive, even if you can't see what it is you're feeling. Look through a magnifying glass and it becomes even more sensitive.

The skin is the shortest-range interface we have with the world. It is the only sense that doesn't provide any information about distant objects. If you can feel something on your skin, it is next to you right now.

Body parts exist as inward-facing objectsthey provide touch informationbut they also exist as external objectswe can feel them with other body parts, see them, and (if you're lucky) feel and see those of other people. **[Hack #64]** and **[Hack #93]** explore how we use vision to update our internal model of our body parts. But the integration of the two senses goes deeper, so much so that looking at a body part enhances the sensitivity of that body part, even if you aren't getting any useful visual information to illuminate what's happening on your skin.

5.7.1. In Action

Kennett et al.[1] tested how sensitive people were to touch on their forearms. In controlled conditions, people were asked to judge if they were feeling two tiny rods pressed against their skin or just one. The subjects made these judgments in three conditions. The first two are the most important, providing the basic comparison. Subjects were either in the dark or in the light and looking at their armbut with a brief moment of darkness so they couldn't actually see their arm as the pins touched it. Subjects allowed to look at their arms were significantly more accurate, indicating that looking at the arm, even though it didn't provide any useful information, improved tactile sensitivity.

The third condition is the most interesting and shows exactly how pervasive the effect can be. Subjects were shown their forearm through a magnifying glass (still with darkness at the actual instant of the pinprick). In this condition, their sensitivity was nearly twice as precise as their sensitivity in the dark!

This is astounding for at least two reasons. First, it shows that visual attention can improve our sensitivity in another domain, in this case touch. There is no necessity for touch to interact like this with vision. The senses could be independent until far later in processing. Imagine if the double-click rate setting on your mouse changed depending on what was coming down your Internet connection? You'd think it was pretty odd. But for the brain this kind of interaction makes sense because we control where we look and events often spark input to more than one of our senses at a time.

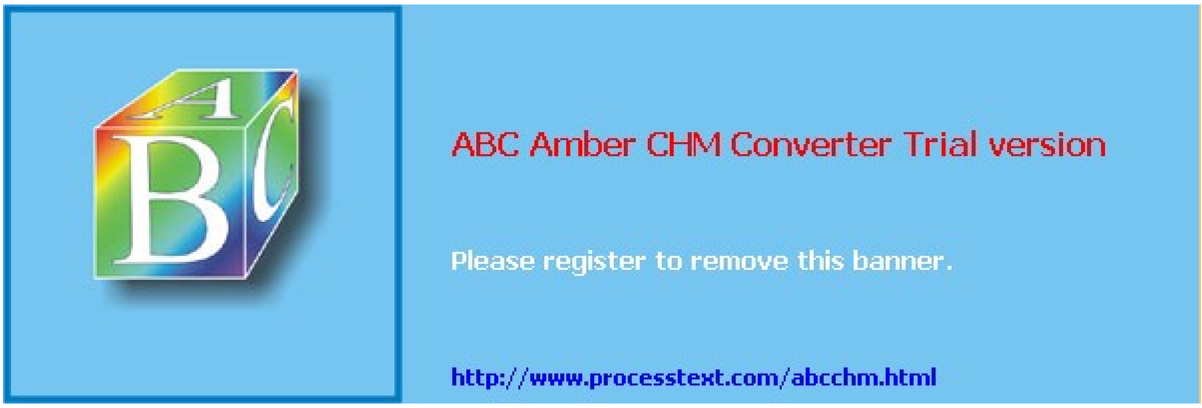
The second reason this is astounding is because it shows how a piece of technology (the magnifying glass) can be used to adjust our neural processing at a very fundamental level.

5.7.2. How It Works

Touch information is gathered together in the parietal cortex (consult the crib notes in **[Hack #7]** if you want to know where that is), in an area called the *primary somatosensory cortex*. You'll find neurons here arranged into a map representing the surface of your body **[Hack #12]**, and you'll find *polysensory neurons*. These respond in particular when visual and tactile input synchronize and suppress when the two inputs are discordant; it seems there's a network here that integrates information from both senses, either within the somatosensory map of the body or in a similar map nearby.

This theory explains why brain damage to the parietal cortex can result in distortions of body image. Some patients with damaged parietal lobes will point to the doctor's elbow when asked to point to their own elbow for example.

This hack and **[Hack #64]** show that short-term changes in our representation of our body are possible. Individual neurons in the cortex that respond to stimulation of the skin can be shown to change what area of skin they are responsible for very rapidly. If, for example, you anesthetize one finger so that it is no longer providing touch sensation to the cortical cells previously responsible for responding to sensation there, these cells will begin to respond to



Hack 59. Hear with Your Eyes: The McGurk Effect

Listen with your eyes closed and you'll hear one sound; listen and watch the speaker at the same time and you'll hear another.

If there were ever a way of showing that your senses combine to completely change your ultimate experience, it's the McGurk Effect. This classic illusion, invented by Harry McGurk (and originally published in 1976[1], makes you hear different sounds being spoken depending on whether or not you can see the speaker's lips. Knowing what's going to happen doesn't help: the effect just isn't as strong.

5.8.1. In Action

Watch Arnt Maas's McGurk Effect video (http://www.media.uio.no/personer/arntm/McGurk_english.html; QuickTime with sound). You can see a freeze frame of the video in Figure 5-3.

Figure 5-3. Arnt Maas's McGurk Effect video

When you play it with your eyes closed, the voice says "ba ba." Play the video again, and watch the mouth: the voice says "da da." Try to hear "ba ba" while you watch the lips move. It can't be done.

5.8.2. How It Works

The illusion itself can't happen in real life. McGurk made it by splicing the sound of someone saying "ba ba" over a video of him making a different sound, "ga ga." When you're not watching the video, you hear what's actually being spoken. But when you see the speaker too, the two bits of information clash. The position of the lips is key in telling what sound someone's making, especially for distinguishing between speech sounds (called phonemes) like "ba," "ga," "pa," and "da" (those which you make by popping air out).

Visual information is really important for listening to people speak. It's a cliché, but I know I can't understand people as well when I don't have my glasses on.

M.W.

We use both visual and auditory information when figuring out what sound a person is making and they usually reinforce each other, but when the two conflict, the brain has to find a resolution. In the world the brain's used to, objects don't usually look as if they're doing one thing but sound as if they're doing another.

Since visually you're seeing "ga ga" and audition is hearing "ba ba," these are averaged out and you perceive "da da" instead, a sound that sits equally well with both information cues. In other situations, visual information will dominate completely and change a heard syllable to the one seen in the lip movements.[2]

Remarkably, you don't notice the confusion. Sensory information is combined before language processing is reached, and language processing tunes into only certain phonemes **[Hack #49]** . The decision as to what you hear is outside your voluntary control. The McGurk Effect shows integration of information across the senses at a completely preconscious level. You don't get to make any decisions about this; what you hear is affected by what goes in through your eyes. It's a good thing that in most circumstances the visual information you get matches what you need to hear.

5.8.3. End Notes

1. McGurk, H., & MacDonald, J. (1976). Hearing lips and seeing voices. *Nature, 264*, 746-747.
2. Fusion of the sound and sight information is possible only when you have experience

Hack 60. Pay Attention to Thrown Voices

Sounds from the same spatial location are harder to separate, but not if you use vision to fool your brain into "placing" one of the sounds somewhere else.

Sense information is mixed together in the brain and sorted by location **[Hack #54]**, and we use this organization in choosing what to pay attention to (and therefore tune into). If you're listening to two different conversations simultaneously, it's pretty easy if they're taking place on either side of your headyou can voluntarily tune in to whichever one you want. But let's say those conversations were occurring in the same place, on the radio: it's suddenly much harder to make out just one.

Which is why we can talk over each other in a bar and still understand what's being said, but not on the radio. On the radio, we don't have any other information to disambiguate who says what and the sounds get confused with each other.

T.S.

Hang on...how do we decide on the spatial location of a sense like hearing? For sound alone, we use clues implicit in what we hear, but if we can *see* where the sound originates, this visual information dominates **[Hack #53]** .

Even if it's incorrect.

5.9.1. In Action

Jon Driver from University College London[1] took advantage of our experience with syncing language sounds with lip movements to do a little hacking. He showed people a television screen showing a person talking, but instead of the speech coming from the television, it was played through a separate amplifier and combined with a distracting, and completely separate, voice speaking. The television screen was alternately right next to the amplifier or some distance away. The subject was asked to repeat the words corresponding to the talking head on the television.

If they watched the talking head on screen nearby the amplifier, they made more errors than if they watched the talking head on the screen kept distant from the sound. Even though both audio streams were heard from the single amplifier in the two cases, moving the video image considerably changed the listener's ability to tune into one voice.

This experiment is a prime candidate for trying at home. An easy way would be with a laptop hooked up to portable speakers and a radio. Have the laptop playing a video with lots of speech where you can see lip movements. A news broadcast, full of talking heads, is ideal. Now put the radio, tuned into a talk station, and the laptop speaker, in the same location. That's the single amplifier in Driver's experiment. The two different cases in the experiment correspond to your laptop being right next to the speakers or some feet away. You should find that you understand what the talking heads on the video are saying more easily when the laptop is further away. Give it a go.

5.9.2. How It Works

It's easier to understand what's going on here if we think about it as two separate setups. Let's call them "hard," for the case in which you're looking at the television right by the amplifier and "easy," when you're looking at the screen put a little further away.

In the hard case, there's a video of a talking head on the television screen and two different voices, all coming from the same location. The reason it's hard is because it's easier to tune out of one information stream and into another if they're in different locations (which is what **[Hack #54]** is all about). The fact there's a video of a talking head showing in this case isn't really important.

The easy setup has one audio stream tucked off to the side somewhere, while a talking head and its corresponding audio play on the television. It's plain to see that tuning into the audio on the television is a fairly simple taskI do it whenever I watch TV while ignoring the noise of

PREVIOUS NEXT

Hack 61. Talk to Yourself

Language isn't just for talking to other people; it may play a vital role in helping your brain combine information from different modules.

Language might be an astoundingly efficient way of getting information into your head from the outside **[Hack #49]** , but that's not its only job. It also helps you think. Far from being a sign of madness, talking to yourself is something at the essence of being human.

Rather than dwell on the evolution of language and its role in rewiring the brain into its modern form,[1] let's look at one way language may be used by our brains to do cognitive work. Specifically we're talking about the ability of language to combine information in ordered structuresin a word: syntax.

Peter Carruthers, at the University of Maryland,[2] has proposed that language syntax is used to combine, simultaneously, information from different cognitive modules. By "modules," he means specialized processes into which we have no insight,3 such as color perception or instant number judgments **[Hack #35]** . You don't know *how* you know that something is red or that there are two coffee cups, you just *know*. Without language syntax, the claim is, we can't combine this information.

The theory seems pretty boldor maybe even wrongbut we'll go through the evidence Carruthers uses and the details of what exactly he means and you can make up your own mind. If he's right, the implications are profound, and it clarifies exactly how deeply language is entwined with thought. At the very least, we hope to convince you that *something* interesting is going on in these experiments.

5.10.1. In Action

The experiment described here was done in the lab of Elizabeth Spelke.[4] You could potentially do it in your own home, but be prepared to build some large props and to get dizzy.

Imagine a room like the one in Figure 5-4. The room is made up of four curtains, used to create four walls in a rectangle, defined by two types of information: geometric (two short walls and two long walls) and color information (one red wall).

Figure 5-4. Setup for Spelke's experimentsa rectangular room with one colored wall

Now, think about the corners. If you are using only geometric information, pairs of corners are identical. There are two corners with a short wall on the left and a long wall on the right and two corners the other way around. If you are using only color information, there are also two pairs of identical corners: corners next to a red wall and corners *not* next to a red wall.

Using just one kind of information, geometry or color, lets you identify corners with only 50% accuracy. But using both kinds of information in combination lets you identify any of the four corners with 100% accuracy, because although both kinds of information are ambiguous, they are not ambiguous in the same way.

So, here's a test to see if people can use both kinds of information in combination.[5] Show a person something he'd like, like some food, and let him see you hide it behind the curtains in one corner of the room. Now disorient him by spinning him around and ask him to find the food. If he can combine the geometric and the color information, he'll have no problem finding the foodhe'll be able to tell unambiguously which corner it was hidden in. If he doesn't combine information across modules, he will get it right 50% of the time and 50% of the time wrong on his first guess and need a second guess to find the food.

Where does language come into it? Well, language seems to define the kinds of subjects who can do this task at better than 50% accuracy. Rats can't do it. Children who don't have language yet can't do it. Postlinguistic children and adults can do it.

Chapter 6. Moving

Team LiB ◄ PREVIOUS NEXT ►

6.1. Hacks 62-69

The story of the brain is a story of embodiment, of how much the brain takes for granted the world we're in and the body that carries it about.

For instance, we assume a certain level of stability in the world. We make assumptions about how our body is able to move within the environment, and if the environment has changed **[Hack #62]**, we get confused.

As we assume stability in the world, so too do we assume stability from our body. Why should the brain bother remembering the shape of our own body when it's simply there to consult? But when our body's shape doesn't remain stable, the brain can get confused. You start by getting your fingers mixed up when you cross your hands **[Hack #63]** ; you end up convincing your brain that you're receiving touch sensations from the nearby table **[Hack #64]** .

This is also a story of how we interact with the world. Our brains continually assess and anticipate the movements we need to grasp objects, judging correctly even when our eyes are fooled **[Hack #66]** . We're built for activity, our brains perceiving the uses of an object, its affordances **[Hack #67]**, as soon as we look at itas soon as we see something, we ready ourselves to use it.

We'll finish on what we use for manipulation: our hands. What makes us right- or left-handed **[Hack #68]** ? And, while we're on the topic, what does all that left-brain, right-brain stuff really mean **[Hack #69]** ?

Team LiB ◄ PREVIOUS NEXT ►

Hack 62. The Broken Escalator Phenomenon: When Autopilot Takes Over

Your conscious experience of the world and control over your body both feel instantaneousbut they're not.

Lengthy delays in sensory feedback and in the commands that are sent to your muscles mean that what you see now happened a few moments ago and what you're doing now you planned back then. To get around the problem caused by these delays in neural transmission, your brain is active and constructive in its interactions with the outside world, endlessly anticipating what's going to happen next and planning movements to respond appropriately.

Most of the time this works well, but sometimes your brain can anticipate inappropriately, and the mismatch between what your brain thought was going to happen and what it actually encounters can lead to some strange sensations.

6.2.1. In Action

One such sensation can be felt when you walk onto a broken escalator. You know it's broken but your brain's autopilot takes over regardless, inappropriately adjusting your posture and gait as if the escalator were moving. This has been dubbed the *broken escalator phenomenon* .1 Normally, the sensory consequences of these postural adjustments are canceled out by the escalator's motion, but when it's broken, they lead to some self-induced sensations that your brain simply wasn't expecting. Your brain normally cancels out the sensory consequences of its own actions **[Hack #65]**, so it feels really weird when that doesn't happen.

To try it out yourself, the best place to look is somewhere like the London Underground (where you're sure to find plenty of broken escalators) or your favorite run-down mall. You need an escalator that is broken and not moving but that you're still allowed to walk up. You could also use the moving walkways they have at airports; again, you need one that's stationary but that you're still permitted to walk onto. Now, try not to think about it too much and just go ahead and walk on up the escalator. You should find that you experience an odd sensation as you take your first step or two onto the escalator. People often report feeling as though they've been "sucked" onto the escalator. You might even lose your balance for a moment. If you keep trying it, the effect usually diminishes quite quickly.

6.2.2. How It Works

Unless we've lived our lives out in the wilderness, most of us will have encountered moving escalators or walkways at least a few times. And when we've done so, our brain has learned to adapt to the loss of balance caused by the escalator's motion. It's done this with little conscious effort on our part, automatically saving us from falling over. So when we step onto an escalator or moving walkway now, we barely notice the transition, and continue fluidly on our way. The thing is, when the escalator is broken, our brain adjusts our balance and posture anyway, and it seems we can't stop it from doing so.

Until recently, evidence for this phenomenon was based only on urban anecdotes. But now the phenomenon has actually been investigated in the laboratory using a computer-controlled moving walkway.[1,2] Special devices attached to the bodies and legs of 14 volunteers recorded their posture and muscle activity. Each volunteer then walked 20 times from a fixed platform onto the moving walkway. After that, the walkway was switched off, the volunteers were told it would no longer move, and they then walked from the platform onto the stationary walkway 10 times.

The first time the subjects stepped onto the moving walkway, they lost their balance and grasped the handrail. But over the next few attempts, they learned to anticipate the unbalancing effect of the walkway by speeding up their stride and leaning their body forward.

Then crucially, when the volunteers first walked onto the walkway when it was switched off, they continued to walk at the increased speed and also continued to sway the trunk of their body forward. They performed these inappropriate adjustments even though they could see

Hack 63. Keep Hold of Yourself

How do we keep the sensations on our skin up to date as we move our bodies around in space?

When an insect lands on your skin, receptors in that area of skin fire and a signal travels up to your brain. The identity of the receptor indicates which part of your skin has been touched. But how do you know exactly where that bit of your body is so you can swat the fly? As we move our bodies around in space we have to remap and take account of our changes in posture to understand the sensations arriving at our skin; very different movements are required to scratch your knee depending on whether you're sitting down or standing up. This might seem like a trivial problem, but it is more complex than it seems at first. We have to integrate information from our joints and muscles about the current position of our body*proprioceptive information*as well as touch and vision, for example, to gauge that the sight of a fly landing and the sensation of it contacting your finger are coming from the same place.

6.3.1. In Action

Try closing your eyes and feeling an object on a table in front of you with the fingers of both hands. Now, cross your hands and return your fingers to the object. Despite swapping the point of contact between your two hands, you do not feel that the object has flipped around. The next two illusions attempt to make this remapping fail.

First, try crossing your index finger and middle finger and run the gap between them along the ridge and around the tip of your nose (make sure you do this quite slowly). You will probably feel as if you have two noses. This is because your brain has failed to take account of the fact that you have crossed your fingers. Notice that you are unable to overcome this illusion even if you consciously try to do so. This is sometimes called Aristotle's Illusion, as he was apparently the first person to record it.

Now, try out the *crossed hands illusion*. You'll need a friend to help. Cross your hands over in front of your chest, at arm's length. Then turn your palms inward, so your thumbs point downward and clasp your hands together, so your fingers are interleaved. Next, rotate your hands up toward your chest, until your thumbs are pointing away from you, as shown in Figure 6-1. Now, if a friend points to one of your fingers and asks you to move it, you will probably fail to move the correct finger and instead move the same finger but on the opposite hand. Again, you have failed to take account of your unusual posture; you assume that the finger you see corresponds to the finger that would be in that position if you had simply clasped your hands, without crossing them over. You may find that you are able to overcome the illusion if your friend indicates which finger he wants you to move by touching it. This can help you to remap and take your posture into account.

Figure 6-1. Tom tries out the crossed hands illusion

6.3.2. How It Works

Charles Spence and colleagues1 have shown that we can update how we bind together vision and touch when we cross our hands over. They asked people to attend to and make judgments about vibrations that they felt on their hands, while ignoring lights presented at the same time. When feeling a vibration on their right hand, the lights on the right sideclosest to their right handinterfered much more (made people slower to carry out the task), than lights on their left side. That is, we tend to bind together vision and touch when they come from the same part of the outside world. So what happened when they crossed their hands over? The interaction between vision and touch changed over: lights over on the left side of their body were now closest to their right hand and interfered more with the right hand than the lights over on the right side. So, when we change where our hands are in space, we integrate different sets of visual and tactile signals.

But remapping can sometimes fail, even without intertwining our fingers. Two recent experiments[2,3] have shown that we are particularly bad at dealing with information in quick

Hack 64. Mold Your Body Schema

Your body image is mutable within only a few minutes of judiciousand misleadingvisual feedback.

Our brains are constantly updated with information about the position of our bodies. Rather than relying entirely on one form of sensory feedback, our bodies use both visual and tactile feedback in concert to allow us to work out where our limbs are likely to be at any one moment. *Proprioception*generated by sensory receptors located in our joints and muscles that feed back information on muscle stretch and joint positionis another sense that is specifically concerned with body position.

The brain combines all this information to provide a unified impression of body position and shape known as the *body schema*. Nevertheless, by supplying conflicting sensory feedback during movement, we can confuse our body schema and break apart the unified impression.

6.4.1. In Action

Find a mirror big enough so you can stand it on its edge, perpendicular to your body, with the mirrored side facing left. Put your arms at your sides (you'll probably need a friend to hold the mirror). This whole setup is shown in Figure 6-2. Look sideways into the mirror so you can see both your left hand and its reflection in the mirror, so that it appears at first blush to be your hidden right hand. While keeping your wrists still and looking into the mirror, waggle your fingers and move both your hands in synchrony for about 30 seconds. After 30 seconds, keep your left hand moving but stop your right. You should sense a momentary feeling of "strangeness," as if disconnected from your right hand. It looks as if it is moving yet feels as if it has stopped.

Figure 6-2. Matt confuses his body schema using a mirror and curtain rail (being in dire need of a haircut isn't essential for the experiment)

> One easy way of moving your hands together is to run a curtain rail under the mirror, if you have one handy, and place each hand on a curtain ring (this is what I'm doing in Figure 6-2). Move your hands toward and away from the mirror for 30 seconds, until your brain has confused your right hand and your reflected left hand in the mirrorthen release the curtain ring from your right hand. You can feel the ring has gone, but in the mirror it looks as though you're still holding it. To me, the disconnect felt like pins and needles, all through my right hand.

Alternatively, you can manipulate your body schema into incorporating a table as part of yourself.[1] Sit at a table with a friend at your side. Put one hand on your knee, out of sight under the table. Your friend's job is to tap, touch, and stroke your hidden hand andwith identical movements using her other handto tap the top of the table directly above. Do this for a couple of minutes. It helps if you concentrate on the table where your friend is touching, and it's important you don't get hints of how your friend is touching your hidden hand. The more irregular the pattern and the better synchronized the movements on your hand and on the table, the greater the chance this will work for you. About 50% of people begin to feel as if the tapping sensation is arising from the table, where they can see the tapping happening before their very eyes. If you're lucky, the simultaneous touching and visual input have led the table to be incorporated into your body image.

6.4.2. How It Works

These techniques provide conflicting touch and visual feedback, making it difficult to maintain a consistent impression of exactly where body parts are located in space. They're similar to the crossed hands illusion **[Hack #63]**, in which twisting your hands generates visual feedback contradictory to your body schema. In the crossed hands illusion, this leads to

Hack 65. Why Can't You Tickle Yourself?

Experiments with tickling provide hints as to how the brain registers self-generated and externally generated sensations.

Most of us can identify a ticklish area on our body that, when touched by someone else, makes us laugh. Even chimpanzees, when tickled under their arms, respond with a sound equivalent to laughter; rats, too, squeal with pleasure when tickled. Tickling is a curious phenomenon, a sensation we surrender to almost like a reflex. Francis Bacon in 1677 commented that "[when tickled] men even in a grieved state of mind . . . cannot sometimes forebear laughing." It can generate both pleasure and pain: a person being tickled might simultaneously laugh hysterically and writhe in agony. Indeed, in Roman times, continuous tickling of the feet was used as a method of torture. Charles Darwin, however, theorized that tickling is an important part of social and sexual bonding. He also noted that for tickling to be effective in making us laugh, the person doing the tickling should be someone we are familiar with, but that there should also be an element of unpredictability.

As psychoanalyst Adam Phillips commented, tickling "cannot be reproduced in the absence of another." So, for tickling to induce its effect, there needs to be both a tickler and a ticklee. Here are a couple of experiments to try in the privacy of your own homeyou'll need a friend, however, to play along.

6.5.1. Tickle Predicting

First, you can look at why there's a difference between being tickled by yourself and by someone else.

6.5.1.1 In action

Try tickling yourself on the palm of your hand and notice how it feels. It might feel a little ticklish. Now, ask a friend to tickle you in the same place and note the difference. This time, it tickles much more.

6.5.1.2 How it works

When you experience a sensation or generate an action, how do you know whether it was you or someone else who caused it? After all, there is no special signal from the skin receptors to tell you that it was generated by you or by something in the environment. The sensors in your arm cannot tell who's stimulating them. The brain solves this problem using a prediction system called a *forward model*. The brain's motor system makes predictions about the consequences of a movement and uses the predictions to label sensations as self-produced or externally produced.

Every time an action is made, the brain generates an *efference copy* of the actual motor command in parallel. The efference copy is just like a carbon copy, or duplicate, of the real motor command and is used to make a prediction about the effect of the action, for example, the tickling effect of a finger stroke. The predicted sensory effect of the efference copy and the actual sensory effect of the motor command are compared (Figure 6-3). If there is a mismatch, the sensation is labeled as externally generated.

Figure 6-3. Forward model: an internal predictor uses information about movements to distinguish between self-produced and externally produced sensations

Your accurate prediction of the consequences of the self-tickle reduces the sensory effects (the tickliness) of the action, but this does not happen when someone else tickles you. This explains why the sensation is usually more intense when another person touches your arm compared with when you touch your own arm.

Neuroimaging studies using a tickling machine (Figure 6-4) at University College London[1] suggest that the distinction between self and other is hardwired in the brain. This device was

Hack 66. Trick Half Your Mind

When it comes to visual processing in the brain, it's all about job delegation. We've got one pathway for consciously perceiving the worldrecognizing what's whatand another for getting involvedusing our bodies to interact with the world out there.

The most basic aspects of the visual world are processed altogether at the back of your brain. After that, however, the same visual information is used for different purposes by two separate pathways. One pathway flows forward from the back of your brain to the *inferior temporal cortex* near your ears, where memories are stored about what things are. The other pathway flows forward and upward toward the crown of your head, to the *posterior parietal cortex*, where your mental models of the outside world reside. Crudely speaking, the first pathway (the "ventral" pathway) is for recognizing things and consciously perceiving them, whereas the second (the "dorsal" pathway) is for interacting with them. (Well, that's according to the dual-stream theory of visual processing **[Hack #13]** .)

The idea was developed by David Milner and Melvyn Goodale in the 1990s, inspired in part by observation of neurological patients with damage to one pathway but not the other. Patients with damage to the temporal lobe often have difficulty recognizing thingsa toothbrush, saybut when asked to interact with the brush they have no problems. In contrast, patients with damage to the parietal lobe show the opposite pattern; they often have no trouble recognizing an object but are unable to reach out and grasp it appropriately.

Since then, psychologists have found behavioral evidence for this separation of function in people without neurological problems, using visual illusions.

6.6.1. In Action

In the mid-'90s, Salvatore Aglioti1 and colleagues showed that when people are presented with the Ebbinghaus illusion (see Figure 6-6) they find the disk surrounded by smaller circles seems larger than an identically sized disk surrounded by larger circles, and yet, when they reach for the central disks, they use the same, appropriate, finger-thumb grip shape for both disks. The brain's conscious perceptual system (the ventral pathway) appears to have been tricked by the visual illusion, whereas the brain's visuomotor (hand-eye) system (the dorsal pathway) appears immune.

Figure 6-6. The Ebbinghaus Illusion. Both central circles are the same size; although they don't look it to your perceptual system, your visuomotor system isn't fooled

There are many examples of situations in which our perception seems to be tricked while our brain's visuomotor system remains immune. Here's one you can try. You'll need a friend and a tape measure. Find a sandy beach so you can draw in the sand or a tarmac area where you can draw on the ground with chalk. Tell your friend to look away while you prepare things.

6.6.1.1 Part 1

Draw a line in the sand, between 2 and 3 meters long. Now draw a disk at the end, about 70 cm in diameter, as in Figure 6-7A. Ask your friend to stand so her toes are at the start of the line, with the disk at far end, and get her to estimate how long the line is, using whichever units she's happy with. Then blindfold her, turn her 90°, and get her to pace out how long she thinks the line is. Measure her "walked" estimate with your tape measure.

Figure 6-7. A draw-it-yourself visual illusion

6.6.1.2 Part 2

Tell your friend to look away again, get rid of the first line, and draw another one of identical length. (You could use another length if you think your friend might suspect what's going onit

Hack 67. Objects Ask to Be Used

When we see objects, they automatically trigger the movements we'd make to use them.

How do we understand and act upon objects around us? We might perceive the shape and colors of a cup of coffee, recognize what it is, and then decide that the most appropriate movement would be to lift it by the handle toward our mouth. However, there seems to be something rather more direct and automatic going on. In the 1960s, James Gibson developed the idea of object *affordances*. Objects appear to be associated with (or *afford*) a particular action or actions, and the mere sight of such an object is sufficient to trigger that movement in our mind. There are obvious advantages to such a system: it could allow us to respond quickly and appropriately to objects around us, without having to go to the bother of consciously recognizing (or thinking about) them. In other words, there is a direct link between perceiving an object and acting upon it. I don't just see my cup of coffee; it also demands to be picked up and drunk.

6.7.1. In Action

You may not believe me yet, but I'm sure you can think of a time when your movements appeared to be automatically captured by something in your environment. Have you ever seen a door handle with a "Push" sign clearly displayed above it, yet found yourself automatically pulling the door toward you? The shape of the pullable handle suggests that you should pull it, despite the contradictory instruction to push it. I go through such a door several times a week and still find myself making that same mistake!

Try finding such a door near where you live or work. Sit down and watch how people interact with it. What happens if you cover up the "Push" sign with a blank piece of paper? Or cover it with a piece of paper labeled "Pull"; does this appear to affect how often people pull rather than push, or is the shape of the handle all they're really paying attention to?

Perhaps you've found yourself picking up a cup or glass from the table in front of you, even though you didn't mean to (or even knowing that it belonged to someone else)?

Effects of object affordances have been found in experiments: Tucker and Ellis[1] asked subjects to press a button with their left or right hand, to indicate whether a picture of an object was the right way up or inverted. Even though subjects were not thinking about the action they would use for that object, it had an effect. If they saw a cup with a handle pointing toward the rightevoking a right-hand graspthey were faster to react if their response also happened to require a right-hand response. That is, the reaction time improved if the hand used for the button press coincided with the hand that *would* be used for interacting with the object. This is called a *compatibility effect*. (The Simon Effect **[Hack #56]** shows that reaction times improve when stimuli and response match in the more general case. What's happening here is that the stimulus includes not just what you perceive directly, but what affordances you can perceive too.)

The graspability of objects can affect judgments, even when people are not making any kind of movement. de'Sperati and Stucchi[2] asked people to judge which way a moving screwdriver was rotating on a computer screen. People were slower to make a judgment if the handle were in a position that would involve an awkward grasping movement with their dominant hand. That is, although they had no intention to move, their own movement system was affecting their perceptual judgment.

6.7.2. How It Works

Brain imaging has helped us to understand what is happening when we see action-relevant objects. Grèzes and Decety[3] looked at which brain areas are active when people do the Tucker and Ellis judgment task. Bits of their brain become active, like the supplementary motor area and the cerebellum, which are also involved in making real movements. In related research in monkeys, cells have also been discovered that respond both when the monkey sees a particular object and also when it observes the type of action that object would require.

Hack 68. Test Your Handedness

We all have a hand preference when undertaking manual tasks. But why is this so? And do you always prefer the same hand, or does it vary with what you are doing? Does the way people vary their hand preference differ between right- and left-handers?

The world is a right-handed one, as will be obvious to left-handers. Most tools are made for right-handed people. Implements such as scissors, knives, coffee pots, and so on are all constructed for the right-handed majority. In consequence, the accident rate for left-handers is higher than for rightand not just in tool use; the rate of traffic fatalities among left-handers is also greater than for right.[1]

The word "sinister," which now means "ill-omened," originally meant "left-handed." The corresponding word for "right-handed" is "dexter," from which we get the word "dexterous."

T.S.

Nine out of 10 people are right-handed.[2] The proportion appears to have been stable over thousands of years and across all cultures in which handedness has been examined. Anthropologists have been able to determine the incidence of handedness in ancient cultures by examining artifacts, such as the shape of flint axes. Based on evidence like this and other evidence such as writing about handedness in antiquity, our species appears always to have been a predominantly right-handed one.

But even right-handers vary in just how right-handed they are, and this variation may have a link to how you use the different sides of your brain **[Hack #69]** .

6.8.1. In Action

Have a go at the following tests to determine which is your dominant hand and just how dominant it is. Do each test twiceonce with each handand record your score, in seconds, both times. You don't have to do all of them; just see which you can do given the equipment you have on hand.

Darts

> Throw three darts at a dartboard. (Be very careful when doing this with your off-hand!) Add up the distances from the bull's-eye.

Handwriting

> Measure the time that it takes to write the alphabet as one word, six times. Start with the hand you normally write with and rest for 1 minute before starting with the other hand.

Drawing

> Measure the time that it takes to draw a line between two of the lines of some lined paper. Add a penalty of 2 seconds for each time your line touches one of the ruled lines.

Picking up objects with tweezers

> Using tweezers, measure the time that it takes to pick up and transfer 12 pieces of wire from one container to another.

Stoppering bottles

> Measure the time, in seconds, it takes to put the lids on five jars, the corks back in five wine bottles, or the cap back on five beer bottles.

Here's how to calculate your handedness quotient:

Hack 69. Use Your Right Brainand Your Left, Too

The logical left brain and intuitive right brain metaphor is popular, but the real story of the difference between the two halves of your brain is more complex and more interesting.

There's a grain of truth in all the best myths, and this is true for the left-brain/right-brain myth. Our cortex is divided into left and right hemispheres, and they do seem to process information differently, but exactly how they do this isn't like the story normally told by management gurus and the self-help literature. As with many scientific myths, the real story is less intuitive but more interesting.

Our brains follow the general pattern of the rest of our bodies: two of everything down the sides and one of everything down the middle. With the brain, the two halves are joined directly in the *subcortex*, but in the cortex the two halves, called *hemispheres*, have a gap between them. They are connected by a tight bunch of some 250 million nerve fibers, called the *corpus callosum*, which runs between the two hemispheres (it's not the only way for information to cross the hemispheres, but it's the most important).

Each hemisphere is wired up to sense and act on the opposite side of the body. So information from your right goes to the left side of the visual cortex, and signals from your left motor cortex control your right hand. For higher functions, in which information from both senses is combined, the two hemispheres seem to have different strengths and weaknesses, so that for certain tasks one hemisphere or the other will be dominant.

The origins of the popular myth were studies of patients who had their corpus callosum severed as part of a radical surgical intervention for epilepsy. These "split-brain" patients could function seemingly normally on many tasks, but displayed some quirks when asked to respond to the same material with different hands or when speaking (left brain) rather than pointing with their left hand (right brain).[1]

A simple distinction between a left brain specialized for language and cold logic and an oppressed right brain that specializes in intuition grew into the myth we know today. Similar to the 10% myth **[Hack #6]**, this led to the further conclusion that most of us use only half of our brains. Although this distinction may or may not be a useful metaphor in talking about styles of thinking, it is certainly not a useful metaphor for conducting research nor for giving insight into the true differences between the hemispheres.

Any real difference between the hemispheres may be the opposite of what people raised on the left brain bad, right brain good myth would expect. Michael Gazzaniga, who was part of the team that did the original split-brain experiments and is now a very senior cognitive neuroscientist, recently wrote in *Scientific American* of an "inventive and interpreting" left brain, a hemisphere for structure and meaning, and a "truthful, literal" right brain, limited by a preoccupation with general surface features.[2] In his research, he found that the right hemisphere contained modules specializing for computationally analyzing perceptions, in a very straightforward way, not looking for any deeper meaning. It's not good at smart search strategies, for example. The left hemisphere is better at high-level associations and problem solving, including language, looking for meaning, and patterns.

6.9.1. In Action

Many of the original demonstrations of hemispheric specialization involve showing an image to just one *hemifield* of the eyes. Information from both eyes is processed by both hemispheres of the brain, but in both eyes, the information to the left of the focal point is processed by the right hemisphere and vice versa. By making sure someone is looking straight ahead, you can control which hemisphere processes an image by presenting it to the left or the right of his focal pointone hemifield. You have to do it very quickly; as soon as an image appears before them, people will move their eyes to look at it and thus feed the information to both hemispheres. Since this is difficult to do with vision, here's a nonvisual demo you can try at home.[3]

The left hemisphere is better at processing rapidly occurring sounds and seems better at keeping rhythm; it can hold fancier rhythms and keep them synchronized with a beat better

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Chapter 7. Reasoning

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7.1. Hacks 70-74

We consider ourselves pretty rational animals, and we can indeed be pretty logical when we put our minds to it. But you only have to scratch the surface to find out how easily we're misled by numbers **[Hack #70]**, and it's well-known that statistics are really hard to understand **[Hack #71]** . So how good are we at being rational? It depends: our logic skills aren't too hot, for instance, until we need to catch people who might be cheating on us **[Hack #72]** instead of just logically solving sums. And that's the point. We have a very pragmatic kind of rationality, solving complex problems as long as they're real-life situations.

Pure rationality is overrated anyway. Figuring out logic is slow going when we can have gut feelings instead, and that's a strategy that works. Well, the placebo effect **[Hack #73]** works at leastbelief is indeed a powerful thing. And we have a strong bias toward keeping the status quo **[Hack #74]** too. It's not rational, that's for sure, but don't worry; the "If it ain't broke, don't fix it" policy is a pragmatic one, at least.

Hack 70. Use Numbers Carefully

Our brains haven't evolved to think about numbers. Funny things happen to them as they go into our heads.

Although we can instantly appreciate how many items comprise small groups (small meaning four or fewer **[Hack #35]**), reasoning about bigger numbers requires counting, and counting requires training. Some cultures get by with no specific numbers higher than 3, and even numerate cultures took a while to invent something as fundamental as zero.[1]

So we don't have a natural faculty to deal with numbers explicitly; that's a cultural invention that's hitched onto natural faculties we do have. The difficulty we have when thinking about numbers is most apparent when you ask people to deal with very large numbers, with very small numbers, or with probabilities **[Hack #71]** .

This hack shows where some specific difficulties with numbers come from and gives you some tests you can try on yourself or your friends to demonstrate them.

The biases discussed here and, in some of the other hacks in this chapter, don't affect everyone all the time. Think of them as forces, like gravity or tides. All things being equal, they will tend to push and pull your judgments, especially if you aren't giving your full attention to what you are thinking about.

7.2.1. In Action

How big is:

```
9 x 8 x 7 x 6 x 5 x 4 x 3 x 2 x 1
```

How about:

```
1 x 2 x 3 x 4 x 5 x 6 x 7 x 8 x 9
```

Since you've got both in front of you, you can easily see that they are equivalent and so must therefore equal the same number. But try this: ask someone the first version. Tell her to estimate, not to calculatehave her give her answer within 5 seconds. Now find another person and ask him to estimate the answer for the second version. Even if he sees the pattern and thinks to himself "ah, 9 factorial," unless he has the answer stored in his head, he will be influenced by the way the sum is presented.

Probably the second person you asked gave a smaller answer, and both people gave figures well below the real answer (which is a surprisingly large 362,880).

7.2.2. How It Works

When estimating numbers, most people start with a number that comes easily to mindan "anchor"and adjust up or down from that initial base. The initial number that comes to mind is really just your first guess, and there are two problems. First, people often fail to adjust sufficiently away from the first guess. Second, the guess can be easily influenced by circumstances. And the initial circumstance, in this case, is the number at the beginning of the sum.

In the previous calculations, anchors people tend to use are higher or lower depending on the first digit of the multiplication (which we read left to right). The anchors then unduly influence the estimate people make of the answer to the calculation. We start with a higher anchor for the first series than for the second. When psychologists carried out an experimental test of these two questions, the average estimate for the first series was 4200, compared to only 500 for the second.

Both estimates are well below the correct answer. Because the series as a whole is made up of small numbers, the anchor in both cases is relatively low, which biases the estimate most people make to far below the true answer.

Hack 71. Think About Frequencies Rather than Probabilities

Probability statistics are particularly hard to think about correctly. Fortunately you can make it easier by presenting the same information in a way that meshes with our evolved capacity to reason about how often things happen.

Mark Twain once said, "People commonly use statistics like a drunk uses a lamppost: for support rather than for illumination."[1] Things haven't changed. It's strange, really, given how little people trust them, that statistics get used so much.

Our ability to think about probabilities evolved to keep us safe from rare events that would be pretty serious if they did happen (like getting eaten) and to help us learn to make near-correct estimates about things that aren't quite so dire and at which we get multiple attempts (like estimating the chances of finding food in a particular part of the valley for example). So it's not surprising that, when it comes to formal reasoning about single-case probabilities, our evolved ability to estimate likelihood tends to fail us.

One example is that we overestimate low-frequency events that are easily noticed. Just ask someone if he gets more scared traveling in a car or by airplane. Flying is about the safest form of transport there is, whether you calculate it by miles flown or trips made. Driving is pretty risky in comparison, but most people would say that flying feels like the more dangerous of the two.

Another thing we have a hard time doing is accounting for the basic frequency at which an event occurs, quite aside from the specific circumstances of its occurrence on the current occasion. Let me give an example of this in action . . .

7.3.1. In Action

This is a famous demonstration of how hard we find it to work out probabilities. When it was published in *Parade* magazine in 1990, the magazine got around 10,000 letters in response92% of which said that their columnist, Marilyn vos Savant, had reached the wrong conclusion.[2] Despite the weight of correspondence, vos Savant *had* reached the correct conclusion, and here's the confusing problem she put forward, based roughly on the workings of the old quiz show *Let's Make a Deal* presented by Monty Hall.

Imagine you're a participant on a game show, hoping to win the big prize. The final hoop to jump through is to select the right door from a choice of three. Behind each door is either a prize (one of the three doors) or a booby prize (two of the doors). In this case, the booby prizes are goats.

You choose a door.

To raise the tension, the game-show host, Monty, looks behind the other doors and throws one open (not yours) to reveal a goat. He then gives you the choice of sticking with your choice or switching to the remaining unopened door.

Two doors are left. One *must* have a goat behind it, one *must* have a prize. Should you stick, or should you switch? Or doesn't it matter?

> This is not a trick question, like some lateral thinking puzzles. It's the statistics that are tricky, not the wording.

Most people get this wrongeven those with formal mathematics training. Many of the thousands who wrote to Marilyn vos Savant at *Parade* were university professors who were convinced that she had got it wrong and insisted she was misleading the nation. Even the famous Paul Erdos, years before the *Parade* magazine incident, had got the answer wrong and he was one of the most talented mathematicians of the century (and inspiration for Erdos numbers, which you may have heard of3).

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Hack 72. Detect Cheaters

Our sense of logic is much better when applied to social situations than used in abstract scenarios.

Despite the old saying that we're ruled by our emotions, it's tempting to believe that we have at least *some* intuitive sense of logic. The various forms of logic such as syllogisms and deductive and inductive reasoning[1] seem so simple and fundamental that you might expect that the rules are hardwired into our brains. After all, since we're constantly told that our neurons are the equivalent of computer processors, shouldn't our brains be able to handle a little bit of logic?

See how you do on these logical puzzles.

7.4.1. In Action

Each of the cards in Figure 7-1 has a letter on one side and a number on the reverse. If I told you there was a rule stating that a card with a vowel on one side must have an even number on the reverse, which of these cards would you need to turn over to prove or disprove this rule?

Figure 7-1. Each card has a letter on one side and a number on the reverse

Give it a whirl before reading on.

Many people turn over A and 2but that's not quite right. While turning over A will tell you whether "one side" of the rule is true (*if* vowel, *then* even number), turning over 2 won't tell you any more. It doesn't matter whether 2 has a K or an A on its reversethe rules doesn't specify either being true. Along with A, the other card you need to turn over is 7. If 7 has an *A* on its reverse, then the rule is disproved no matter what the A has on its reverse. You *need* to turn over A and 7.

Very few people solve this riddle on the first try. It shows that humans do not possess an innate set of abstract logic rules. Yet somehow we manage to get by without those rules. Try this similar puzzle, in Figure 7-2.

Figure 7-2. Four people sit at a bar drinking beer or cola, the cards show age on one side and beverage on the otherwho's breaking the rules?

Say there's a rule that you must be over 21 to drink beer. Whose drinks and ages would you need to check to see if this bar is flouting the rules?

By simply swapping drinks and ages for cards A, K, 2, and 7, it's obvious this time around that there's no point checking what the 21 year old (think 2 card) is drinkingit wouldn't make any difference to the rule if she were drinking cola or beer, whereas the 16 year old's (think 7 card) drink is of much more interest.

7.4.2. How It Works

Why are logic problems so much easier when they're expressed as real-life situations rather than in abstract terms? One early hypothesis called *memory cuing* proposed that we solve logic problems by drawing on personal experience, without using any deductive reasoning. We've all experienced the problems of drinking ages enough times that we don't even have to

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Hack 73. Fool Others into Feeling Better

Many of the unpleasant phenomena associated with injury and infection are in fact produced by the brain to protect the body. Medical assistance shifts the burden of protection from self to other, which allows the brain to reduce its self-imposed unpleasantness.

Injury or infection triggers a coordinated suite of physiological responses involving the brain, hormones, and immune system. The brain generates pain and fever, stress hormones mobilize energy from fat, and immune cells cause local swelling and redness. These processes are collectively known as the *acute phase response* because they occur rapidly and tend to subside after a few days. Medical assistance can help these unpleasant signs and symptoms to subside more quickly, even when that assistance is completely bogussuch as a witch doctor waving a rattle at you or a quack prescribing a sugar pill. This is known as the *placebo effect*.

7.5.1. In Action

It's hard to invent a placebo and try it on yourself, because the effect relies crucially on the sincerely held belief that it will work. Several experiments have shown that pure placebos such as fake ultrasound produce no pain relief when they are self-administered. So unless you can fool yourself that other people are caring for you when they are not, your experiments with placebos will have to involve other people.

Moreover, you will also probably have to lie. The placebo effect depends not just on other people, but also on the belief that those people are providing bona fide medical assistance. If you don't believe that the assistance provided by those around you is going to help you recover, you won't experience a placebo effect.

Sometimes a placebo effect seems to be triggered despite the absence of other people and the absence of deception. If you have ever felt better after taking a homeopathic remedy, for example, or after applying dock leaves to the pain caused by a stinging nettle, that was almost certainly a placebo effect, because it has been scientifically proven that such treatments are completely bogus. The essential factor, however, must still be presenta belief that this kind of treatment will help. Once you discover the truth about such bogus treatments, therefore, they cease to be capable of producing placebo effects.

Because it is hard (some might say impossible) to deceive yourself into believing something that you know to be false, deception is important for most placebo experiments. This plays a central role in many psychological experiments, and raises serious ethical problems. In universities and other research environments, an ethics committee must, quite rightly, approve experiments before they are allowed to proceed. It is therefore advisable to conduct the following experiment in the privacy of your own home, where ethics committees have no jurisdiction.

First, take an old medicine bottle and clean it thoroughly. Then fill it with a solution of tap water, sugar, and food coloring. The next time someone you know gets a headache or is stung by a stinging nettle, tell her that you have a special remedy that will help. If she asks what it is, tell her that it is a special solution of water and sugar and food coloring, and say that you have read somewhere (in this book) that this will help her feel better (that way, you won't even be lying!). Give her the colored water and ask her to drink a teaspoonful (if she has a headache) or to rub a small amount onto the affected area (if she has been stung by a nettle). See if it helps her feel better.

It will, if she believes it will*and* if there's nothing really wrong with her (be careful here; don't delay medical treatment for someone who is hurt because you want to see if you can placebo-cure her).

Studies have shown that for some people in some situations the placebo effect can be as strong as morphine. In one particularly striking study,[1] patients who had undergone tooth extraction were treated with ultrasound to investigate whether this would reduce the postoperative pain. Unknown to both doctors and patients, however, the experimenters had fiddled with the machine, and half the patients never received the ultrasound. Since

Hack 74. Maintain the Status Quo

People don't like change. If you really want people to try something new, you should just coerce them into giving it a go and chuck the idea of persuading them straight off.

By default, people side with what already is and what happened last time. We're curious, as animals go, but even humans are innately conservative. Like the Dice Man, who delegates all decisions to chance in Luke Rhinehart's classic 1970s novel of the same name, was told: "It's the way a man chooses to limit himself that determines his character. A man without habits, consistency, redundancyand hence boredomis not human. He's insane."[1]

In this hack we're going to look at our preference for the way things are and where this tendency comes from. I'm not claiming that people don't changeobviously this happens all the time and is the most interesting part of lifebut, in general, people are consistent and tend toward consistency. Statistically, if you want to predict what people will do in a familiar situation, the most useful thing you can measure is what they did last time. Past action correlates more strongly with their behavior than every other variable psychologists have tried to measure.[2] If you're interested in predicting who people will vote for, what they will buy, what kind of person they will sleep with, anything at all really, finding out what tendencies they've exhibited or what habits they've formed before is the most useful information at your disposal. You're not after what they *say* they will donot what party, brand, or sexual allegiance they tick on a formnor the choice they think they're feeling pressured into making. Check out what they actually did last time and base your prediction on that. You won't always be right, but you will be right more often by basing your guess upon habit than upon any other single variable.

This bias is the result of a number of factors, not least the fact that people's previous choice is often the best one or the one that best reflects their character. But also we have mental biases,3 like the mental biases we have about numbers **[Hack #70]**, which produce consistent habits and an innate conservativism.

Biases in reasoning are tendencies, not absolutes. They make up the mental forces that push your conclusions one way or the other. No single force ever rules completely, and in each case, several forces compete. We're mostly trying to be rational so we keep a look out for things that might have biased us so we can discount them. Even if we know we can't be rational, we mostly try to be at least consistent. This means that often you can't give the same person the same problem twice if it's designed to evoke different biases. They'll spot the similarity between the two presentations and know their answers should be the same.

I'm carelessly using the word "rational" here, in the same way that logicians and people with a faith in pure reason might. But the study of heuristics and biases should make us question what a psychological meaning of "rational" could be. In some of the very arbitrary situations contrived by psychologists, people can appear to be irrational, but often their behavior would be completely reasonable in most situations, and even rational considering the kind of uncertainties that normally accompany most choices in the everyday world.

T.S.

But some biases are so strong that you can feel them tugging on your reason even when the rational part of your mind knows they are misleading. These "cognitive illusions" work even when you present two differently biased versions of the choice side by side. The example we're going to see in action is one of these.

7.6.1. In Action

I'm going to tell you in advance that the two versions of the problem are logically identical, but I knowbecause your brain evolved in the same way mine didthat you'll feel as if you want to answer them differently despite knowing this. If your supreme powers of reason don't let you feel the tug induced by the superficial features of the problem (the bit that conveys the bias), take the two versions and present them to two different friends.

Here we go . . .

7.6.1.1 Version 1

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Chapter 8. Togetherness

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8.1. Hacks 75-80

What makes "this" a word, rather than being simply the adjacently written letters *t*, *h*, *i*, *s*? Or, to ask a similar question, why should we see a single dog running across a field rather than a collection of legs, ears, hair, and a wet nose flying over the grass? And why, when the dog knocks us over, do we know to blame the dog?

To put these questions another way: how do we group sensations into whole objects, and how do we decide that a certain set of perceptions constitutes cause and effect?

It's not a terribly easy problem to solve. The nature of causality isn't transmitted in an easy-to-sense form like color is in light. Rather than sense it directly, we have to gues. We have built-in heuristics to do just that, and these heuristics are based on various forms of togetherness. The word "this" hangs together well because the letters are in a straight line, for example, and they're closer to one another than the letters in the surrounding words. Those are both principles by which the brain performs grouping. To take the second question, we see the parts of the dog as a single animal because they move together. That's another heuristic.

This recognition acuity lets us see human forms from the tiniest of clues, but it alsoas we'll see in **[Hack #77]** is not perfect and can be duped. We'll see how we can perceive animacythe aliveness shown by living creatureswhere none exists and how we can ignore the cause in cause and effect. Sometimes that's the best way to find out what our assumptions really are, to see when they don't quite match what's happening in the real world.

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Hack 75. Grasp the Gestalt

We group our visual perceptions together according to the gestalt grouping principles. Knowing these can help your visual information design to sit well with people's expectations.

It's a given that we see the world not as isolated parts, but as groups and single objects. Instead of seeing fingers and a palm, we see a hand. We see a wall as a unit rather than seeing the individual bricks. We naturally group things together, trying to make a coherent picture out of all the individual parts. A few fundamental grouping principles can be used to do most of the work, and knowing them will help you design well-organized, visual information yourself.

8.2.1. In Action

Automatic grouping is such second nature that we really notice only its absence. When the arrangement of parts doesn't sit well with the grouping principles the brain uses, cracks can be seen. Figure 8-1 shows some of these organizational rules coming into play.[1]

Figure 8-1. Two groups of triangles that point different ways and a middle triangle that can appear to point either way, depending on which group you see it being part of[2]

You don't see 17 triangles. Instead, you see two groups of eight and one triangle in the middle. Your similarity drive has formed the arrangement into rows and columns of the shapes and put them into two groups: one group points to the bottom left, the other points off to the right.

Each group belongs together partly because the triangles are arranged into a pattern (two long rows pointing in a direction) and partly because of proximity (shapes that are closer together are more likely to form a group). The triangle in the middle is a long way from both groups and doesn't fall into the same pattern as either. It's left alone by the brain's grouping principles.

You can, however, voluntarily group the lone triangle. By mentally putting it with the left-hand set, it appears to point down and left along with the other triangles. You can make it point right by choosing to see it with the other set.

8.2.2. How It Works

The rules by which the brain groups similar objects together are called *gestalt grouping principles* in psychology. Although there's no direct German-to-English translation, "gestalt" means (roughly) "whole." When we understand objects and the relationships between them in a single, coherent pattern rather than as disconnected items, we understand the group as a gestalt. We have a gestalt comprehension of each of the sets of triangles in Figure 8-1, for instance.

Four of the most commonly quoted grouping principles are proximity, similarity, closure, and continuation. An example of each is shown in Figure 8-2.

Figure 8-2. The four most quoted gestalt grouping principles

Proximity

We preconsciously group items that are close together, so in the picture you see columns rather than rows or a grid. This principle is the cause of the triangles in the original diagram coming together into two sets and the reason the lone triangle didn't feel part of either of them.

Hack 76. To Be Noticed, Synchronize in Time

We tend to group together things that happen at the same time or move in the same way. It's poor logic but a great hack for spotting patterns.

It's a confusing, noisy world out there. It's easier to understand the world if we perceive a set of objects rather than just a raw mass of sensations, and one way to do this is to group together perceptions that appear to have the same cause. The underlying assumptions involved manifest as the *gestalt grouping principles*, a set of heuristics used by the brain to lump things together (see **[Hack #75]** for the simplest of these, used for vision).

Perhaps the most powerful of these assumptions is termed *common fate*. We group together events that occur at the same time, change in the same way, or move in the same direction. Imagine if you saw, from far off, two points of light that looked a bit like eyes in the dark. You might think they were eyes or you could just put it down to a coincidence of two unrelated lights. But if the points of light moved at the same time, in the same direction, bounced with the characteristic bounce of a person walking, you'd *know* they were eyes. Using behavior over time allows you to stringently test spatial data for possible common cause. If the bouncing lights pass the common fate test, they're almost certainly a single object. Visual system tags this certainty by providing you with a correspondingly strong perceptual experience; if some things move together, it is almost impossible to see them as separate items instead of a coherent whole.

8.3.1. In Action

"IllusionMotion CaptureGrouping" (http://psy.ucsd.edu/chip/illu_mot_capt_grpng.html; a Real video requiring Real Player) demonstrates just how completely your perception of a single item is altered by global context and common fate. Watch the video for at least 30 seconds. At first you see just a dot blinking on and off next to a square. But then other dots are added in the surrounding area, and as the first dot blinks off, they all shift right. Now your unavoidable impression is of the first dot moving behind the square. The appearance of the other dots, and their behavior, gives your visual system correlations that are just too strong to ignore. The single dot is still blinking on and offyou just can't see it like that any more.

"A Time Gestalt Principle Example: Common Fate" (http://tepserver.ucsd.edu/~jlevin/gp/time-example-common-fate; a Java applet),1 shown in Figure 8-3, is an interactive demonstration of how your visual system deduces the shape of objects from movement, without any color or shading clues to help out.

Figure 8-3. When the circle hidden in the pattern is moving, it's clearly seen; printed like this, it's invisible

You see a shape with a static-like texture moving across a similarly randomized background. Click anywhere in the image to start and stop the demo. Frozen, there is no pattern to see; you see just a random mess. This is the real force of common fate. The correlations exist only across time, in movementit's only when the demo is moving that you can see an object among the noise.

8.3.2. How It Works

The gestalt grouping inferences are so preconscious and automatic that it's hard to imagine perceiving a world that the brain *hasn't* organized into objects. There's something very clever going on here; we are taking in very little information (only how the pattern changes over time), yet, in combination with an assumption that accidental correlations of visual patterns are unlikely, we construct a compelling perception of an object. In these demos, you just can't ignore the object. You are utterly unable to make yourself see a moving collection of dots instead of the shape in motion because the construction of the object is happening before the level of consciousness.

Common fate can lead to some sophisticated inferences. "Kinetic Depth" (http://www.biols.susx.ac.uk/home/George_Mather/Motion/KDE.HTML ; a QuickTime video)

Hack 77. See a Person in Moving Lights

Lights on the joints of a walking person are enough to give a vivid impression of the person, carrying information on mood, gender, and other detailsbut only while the person keeps moving.

Visual perception has special routines for grouping things that move along together into single objects **[Hack #76]** . That's why we see cars as cars and not a collection of wheels, glass, and side-view mirrors just happening to travel along in the same direction. That's all well and good, but humans live not just in a world of objects like trees and cars, but a world full of *people*. Given how social we are, and how tricky other people can be, it's not surprising we also have specialized routines for grouping things that move like people together into single objects too. Looking at only a constellation of moving points of light attached to knees, elbows, and other parts of the body, we a get vivid perception of a person, a perception that doesn't exist at all when the points of light are still.

8.4.1. In Action

Open up your browser and point it at http://www.lifesci.sussex.ac.uk/home/George_Mather/Motion/BM.HTML[1] or http://www.at-bristol.org.uk/Optical/DancingLights_main.htm (both are QuickTime movies). What do you see?

Both are just points of light moving in two dimensions. Yet the first is clearly a person walking, and the second obviously two people dancing, fighting, and otherwise performing.

As with the common fate demos **[Hack #76]** of how we group objects by their behavior over time, you can remove the effect by pausing the movies. This information only makes sense when it is moving (shame we can't have animations in the book, really), which is why Figure 8-4 (a frame of the first movie) looks more like a random star constellation than a human figure.

Figure 8-4. If this were moving, it'd look like a person walking

The vivid impression of a walking human shows that we are able to integrate the correlations of the light points and match them to some kind of template we have developed for moving humans. It is orientation-specific, by the way. Watch the video upside down (it's easier if you have a laptop), and you won't see anything resembling human motion at all.

And we don't perceive just abstract form from the moving lights. The demo at http://www.bml.psy.ruhr-uni-bochum.de/Demos/BMLwalker.html, shown in Figure 8-5, allows you to vary the gender, direction, weight, mood, and energy levels of the walker using the sliders on the left.

Figure 8-5. A happy heavyset man, as represented by points of light

You can tell if the moving lights are from a heavyset man who's happy or if they are from a medium-build woman who is slightly afraid. All just from way the lights move.

8.4.2. How It Works

The effect is obvious. That we can perceive the human formeven mood and genderjust from moving lights demonstrates that we automatically extract underlying patterns from the normal human forms we see every day.

Through a combination of experience and specialized neural modules, we have learned the underlying commonalities of moving human formsthe relationships in time and space between the important features (the joints) of the human body. Our brain can then use this template to facilitate recognition of new examples of moving bodies. Being able to do this provides (for

Hack 78. Make Things Come Alive

Add a few tweaks to the way a thing moves, and you can make objects seem as if they have a life of their own.

Sometimes, when there isn't evidence of causation, your perceptual system detects self-causation and delivers up an impression of animacythat quality of having active purpose that makes objects seem alive.

Animacy is simultaneously easy to see but hard to think about, and both for the same reason. We have evolved to live in a world of animals and objects. But living things are more difficult and more dangerous than objects, so our minds are biased in lots of ways to detect agencythings happening because someone or something wanted them to happen for a purpose (better to assume something happened for a reason than to ignore it completely, right?). This specialization for making sense of agency means we're disposed to detect it even if it isn't strictly thereit is natural for us to use the language of intentions to describe events when there are no intentions. If you say that water "wants" to find the quickest way down the mountain, people understand you far easier than if you start talking about energy minimization, even though the water doesn't strictly "*want*" anything. It's natural to feel as if your computer hates you, just as it is natural to feel that people are deliberately making things hard for you,[1] when the sad fact is that most people probably aren't spending too much time thinking about you at all, and your computer certainly isn't thinking about you.

We can take advantage of our disposition to detect agency in objects, making them appear to be alive by adding just a few simple characteristics to the way they move.

8.5.1. In Action

One way of showing that something is pretty psychologically fundamental is to show that children do it. As soon as children can see, they expect to find animate objects in their environment and prefer to watch them than simple moving objects.[2] So we'll show how fundamental it is to perceive animate objects by showing some movement to a young kid and seeing how he interprets it.

Of course, you'll need a young kid to try this on, the younger the better, as long as he can understand and answer your questions.

> If you can't get ahold of one, you can give this a whirl yourself, sitting yourself in front of the Internet, following the links provided in the next section "How It Works" and watching the movies yourself.

Get two objects: it doesn't really matter what they are as long as they definitely aren't alive and don't look remotely like anything aliveit will help if they are different sizes; two rocks or wooden building blocks will work rather nicely. Put the two objects on a table and ask the child to pay attention to what you're about to do. Move the bigger object slowly toward the smaller. When they're within 2 inches of each other, move the small object very quickly to another part of the table. Immediately, have the large object change direction and head toward the new location of the small object. The large object always moves slowly toward wherever the small object is; the small object always stays at least 2 inches away.

Now, ask the child "What's happening here?"

It should be obvious to you from reading this description, and it will be obvious to the child, that the large object is trying to catch the small object. Just from physical movements the child will infer a guiding purpose and attach it to some kind of inner belief that is a property of the objects ("the large rock wants to catch the small rock"). He could just as easily say "You are moving the rocks around in a funny way," but he probably won't. He prefers the explanation that involves the rocks having intentions.

8.5.2. How It Works

Hack 79. Make Events Understandable as Cause and Effect

By following a couple of simple rules, you can show a clear pattern of cause and effect, and ensure your viewer is able to make the connection between separate things happening at the same time.

Research suggests that just as the visual system works to recover the physical structure of the world by inferring properties such as 3-D shape, so too does it work to recover the causal and social structure of the world by inferring properties such as causality and animacy.[1]

Perception is finding structure in sensations. Finding a structure to things lets you hold them in mind and store them in a memory-efficient way. If the structure corresponds to reality, it can also be used to provide predictions about the thing you're representing. So it's easier to think of several sections of cable on your desk as all being part of the same mouse lead, and once you've assumed that it's easy to find the mouse, you just follow the cable away from the stack.

We've already seen that the brain looks for structure in space **[Hack #75]** and structure in time **[Hack #76]** to organize perceptions. These principles apply to the basic perception of physical objects, as well as helping us understand how we make sense of our body images **[Hack #64]** and the bodies of other people **[Hack #77]** .

But our visual system doesn't look for just static physical structuresit can also pick up on causal relationships between things. You don't see two things happening but rather one event: you don't stop to wonder why the plate smashed just at the same moment that it hit the floor.

This ability to detect causation and animacy **[Hack #78]** is a perceptual phenomenon, different from our slow deliberate reasoning about what causes what ("Hmm...why does my computer crash only after I have written at least 2000 words without saving?" is a different kind of nonperceptual, causal reasoning).

When our visual perception picks up on causes it does so quickly and without any conscious effort on our part. Like with many visual illusions, it happens without your consent and without any ability on your part to stop it, even if you wanted to and know that it is illusion.

8.6.1. In Action

Here's one way of seeing what I mean when I talk about the perception of causation. Make a pendulum, using whatever you have lying around and find something of similar size to whatever you use as a weight. It doesn't really matter what you use; I am using the cord from my camera with my keys as the weight. You'll also need another small object; I'm using a large red bottle lid from a drink bottle.

Hold the pendulum up in front of you and set it swinging left to right. Now take the other object in your free hand and wave it around at the side of the pendulum. It doesn't feel like anything special, does it? Now move the other object (in my case the bottle cap) in time with the pendulum, trying to keep it a fixed distance, say 5 inches, from the swinging weight. If you get the timing right, you should get the unmistakable impression that the object in your free hand is pulling the pendulum weight along and then pushing it back. This happens even though your body has direct evidence that the two events are causally unrelated: the pendulum moves itself and your own hand moves the unconnected object.

Notice that you don't just see the two things as moving together. You get a feeling, manufactured by your perceptual system and delivered direct into consciousness, that one thing causes another.

8.6.2. How It Works

The rules that govern the perception of causation are those you might expect. Events that happen in close succession and those that have a consistent relationship appear to be

Hack 80. Act Without Knowing It

How do we experience our actions as self-caused? It's not automatic; in fact, the feeling of consciousness may indeed have been added to our perception of our actions *after* our brains had already made the decision to act.

Place your hand on the table. Look at it as an object, not unlike just about anything else on the table. Now, raise one of your fingers. Why did you raise that one? Can you say? Was it a free choice? Or was the decision made somewhere else, somewhere in your brain you don't have access to? You experienced your finger being raised by *you*, but what was it in you that caused it?

If you record EEG readings **[Hack #2]** from the scalps of people just about to decide to raise their fingers and at the same time make them watch a timer and remember at what time they experienced deciding to raise their finger, they're found to report that the experience of deciding to raise their finger comes around 400 ms *after* the EEG shows that their brain began to prepare to raise their finger.1 Stimulating particular parts of the brain using transcranial magnetic stimulation **[Hack #5]**, you can influence which finger people choose to move,[2] yet they still experience their choice as somehow willed by them, somehow "theirs."

This is an example of how an action we feel we own may be influenced by things outside of our conscious deliberation. The feeling of conscious will isn't always a good indication that we consciously willed something. And the reverse can also be true. We can disown actions we are responsible for, doing things we don't feel are caused by our own will.

8.7.1. In Action

Draw a cross on a piece of paper. Next, make a pendulum out of something light: a button and a length of string is ideal. Now hold the pendulum over the cross and ask a question ("Is the button on this pendulum blue?" or "Is it lunchtime yet?" perhaps). Know that to indicate "yes" the pendulum will swing clockwise, and to answer "no" the pendulum will swing counterclockwise. Don't rest your arm or elbow on anything as it holds the pendulum. Just watch the pendulum as it begins to swing to answer to your question.

Odds are, the pendulum swung in the way that answered the question correctly.

8.7.2. How It Works

What you've just experienced is called the *ideomotor* effect.[3] It is the ideomotor effect that lies behind Ouija boards, dowsing wands, and facilitated communication (when helpers supposedly channel messages from the severely physically handicapped). There are no demons involved, except for the ordinary everyday human ones.

The movements produced in these cases are entirely self-caused (and, in the case of the Ouija board, self-caused *and shared* by a group of people)but because we don't feel we've consciously caused the movement, we're able to disown the action and it appears to have an external cause, as if it has nothing to do with us. Spooky! We do (in case you were still worried) have everything to do with it. Muscle readings from people playing with Ouija boards show that self-generated signals move the marker; the marker does not move the people's hands attached to it. Ouija boards only provide answers that the participants already knoweven if that knowledge is false. Some people have had conversations with "dead" people who have turned out to still be alive. Blindfolded participants for whom the board is rotated without their knowledge move the marker to the old, unrotated positions.

So when do we experience an action as self-caused? When don't we? Daniel Wegner of Harvard University4 has suggested that "we experience conscious will when we interpret our own thought as the cause of the action." In other words, we infer our feeling of conscious will when we notice that our intention to act went hand in hand with whatever happened. That means that if we had no such intention, the feeling of conscious will doesn't occur and, conversely, that we can feel an event was self-caused even if it had nothing to do with us. It's similar to the feeling of causation **[Hack #79]**, which we deduce from our perception of eventswe have to, because it's impossible to perceive cause and effect directly. Our senses are all we have to work with.

Team LiB ◄ PREVIOUS NEXT ►

Chapter 9. Remembering

Team LiB ◄ PREVIOUS NEXT ►

Team LiB ◀ PREVIOUS NEXT ▶

9.1. Hacks 81-92

The idea of priming comes up more than once in this book. Given a single concept being activated in the brain, other associated concepts are quietly activated too, ready to impinge on consciousness or experience. Automatic associations lie behind the Stroop Effect **[Hack #55]**, and the measurement of a type of priming is how we know that we unconsciously ready ourselves to make use of an object, just by laying eyes on it **[Hack #67]** .

We dive into priming **[Hack #81]** in the first hack of this chapter, and from there, we'll see it manifested as subliminal perception **[Hack #82]** and implicated in the creation of false memory. For memory is the main topic here. We'll look at how false memories and familiarity come about **[Hack#83]**, **[Hack#84]** and **[Hack #85]**, by using priming to activate concepts that have not been directly experienced.

We'll also look at how to build strong, true memories too, in the form of learning. Learning implicitly involves context, the situation you're in while you're doing the learning (that's another appearance of the associative nature of the mind). Exploiting this feature can help you learn better to begin with **[Hack #86]** and improve your recall skills in the future **[Hack #87]** . There's even a nifty trick on how to improve your memory using your built-in navigational skills too **[Hack #89]** .

Along the way, we'll take in a grab bag of hacks on the reality of imagination. Such as how thinking about your muscles can make them stronger **[Hack #88]**, or at least improve your control of them. Such as why you live your life from behind your eyes, but often remember it like a movie, in the third person **[Hack #90]** . And why you should fall asleep on the train to let your imagination run riot **[Hack #91]** .

Last, butparticularly in the hacker crowdcertainly not least: caffeine. Why do people get so upset if you make their coffee the wrong way, and what's that got to do with learning anyway? Understand this, and make the caffeine habit taste good **[Hack #92]** .

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PREVIOUS NEXT

Hack 81. Bring Stuff to the Front of Your Mind

Just because you're not thinking of something doesn't mean it isn't there just waiting to pop into your mind. How recently you last thought of it, and whether you've thought of anything related to it, affects how close to the surface an idea is.

Things aren't just in your thoughts or out of them. It seems as if some things are nearer the surface while others are completely in the dark, tucked deep down in your mind.

The things near the surface jump out into the light without much prompting; they connect to other things you're thinking about, volunteer themselves for active duty in your cognitive processes, so to speak. This isn't always a good thing, as anyone who has tried to put an upcoming exam or interview out of mind will attest.

So what affects how deeply submerged mental items are? It probably wouldn't surprise you to hear that how recently something was last used is one of the key variables. Association is another factor: activating a mental item brings related items closer to the surface. Not always right to the surface, into conscious awareness, but closer at least, so that if you later reach for the general concept of the related item, the specific one will be more easily at hand. Psychologists use measures of the pre-preparedness of mental items to get a handle on the limitations of perception and on the associations between different concepts that your mind has absorbed.

9.2.1. In Action

We found this amusing when we were at school, so maybe you'll get the best results if you pick one of your more childish friends to try it out. For dramatic effect, claim beforehandas we used tothat you can read your friend's mind. Then, ask her the following questions in quick succession:

1. What is 5 + 1?
2. What is 3 + 3?
3. What is 2 + 4?
4. What is 1 + 5?
5. What is 4 + 2?
6. What is the first vegetable you can think of?

Most people, most of the time, say "carrot."[1]

Here's something similar. Like the carrot game, it works best if you can get the person answering the question to hurry.

Tell her to say "milk" 20 times as quickly as she can, and then, just as she finishes, snap the question, "What do cows drink?" at her. If you've caught her off guard, she'll say "milk," even though the answer is truly "water."[2]

9.2.2. How It Works

Both of these examples take advantage of the principle that thingswords, in this caseare not all equally accessible to consciousness. Some throw themselves into the limelight of awareness, while others are more reluctant to step forward.

Carrot is pretty much at the front of our minds when the topic is vegetables (especially after a bunch of arithmetic questions have flushed out other thoughts). With the cow question, saying "milk" 20 times puts that word right at the front of our mind, so much so that it gets out before we correctly parse the question.

This is all well and good if you want to know that a carrot is most people's prototypical vegetable or that they can be easily flustered if you get them to do something ridiculous like

Hack 82. Subliminal Messages Are Weak and Simple

Subliminal perception sneaks underneath the level of consciousness and can influence your preferencesbut only a little.

Being exposed to a photograph for two-hundredth of a second can't really be called seeing, because you won't even be consciously aware of it. But having a photo flashed at you like this works it into your subliminal perception and means that next time you see it you'llvery slightly, mindprefer it to one you've never been exposed to before.

9.3.1. In Action

Proving that mere exposure can change your preferences isn't easy to do at home, so it's best to look at the experiments. Robert Bornstein and Paul D'Agostino exposed a group of volunteers to images, either photographs or unfamiliar shapes, and then asked each person to rate the images according to how much he or she liked them.[1]

If you were one of those volunteers, you'd have spent 5-10 minutes at the beginning of the experiment being exposed to images for only 5 milliseconds each. That's a tiny amount of time for vision, only as long as a quarter of one frame of television. Exposed to a picture for that long, you're not even aware you've seen it. As a volunteer, you could be shown the picture later to look at, and it's as if you're seeing it for the first time.

When you're asked which images you prefer out of a larger selection, you'll rate images you were exposed to but can't recall seeing higher.

9.3.2. In Real Life

The rating exercise is a little like the game Hot or Not (http://www.hotornot.com) but with some of the photos flashed up at you faster than you can make them out beforehand. In Hot or Not, you see a photo of a person and rate it: 10 being Hot and 1 being Not. The web page then immediately reloads with another photo for you to rate, and you can also see how your score on the previous photo compared to what everyone else said.

All else being equalall the photos being equally attractivelet's pretend you're rating all the photos 5 on average.

If you'd had the photo flashed up at you 20 times in that initial batch of image exposure, for only 5 ms each time (less than a tenth of a second in total!), you might rate that photo not a 5, but a 6.

Given this works for mere exposure, below the level of awareness, the same effect should come about if the photo is presented in some other fashion that doesn't require your attention. Thinking of Hot or Not still, incorporating a photo into a banner ad (now we're all trained not to look at banners) for a few pages before you actually have to rate the photo should mean you like the photo more.

M.W.

9.3.3. How It Works

Two things are going on here. The first is subliminal perception. The visual system has just enough time to get the image presented into the brain, but not enough to process it fully to conscious awareness. In addition to subliminal perception, there is a priming **[Hack #81]** effect. Whenever some perception reaches the brain, the neurons that are involved in that representation persist in their activity for a while, and if you experience that thing again, your neurons respond more readily to it.

So when your perception of a particular face has been subliminally primed, when you see the photograph again, properly, your brain reports a very slight sense of familiarity. But because you can't actually recall seeing the photo before, you misinterpret this feeling as preference: you like the face in the photo more than you otherwise would have done.

Hack 83. Fake Familiarity

Hack memory to make people feel they've seen something before.

The memory system is chockablock with hacks. The information that our environment constantly provides exceeds any viable storage capacity, so memory employs a variety of methods that allow it to be choosy. One memory experience we all know is the feeling of familiarity for previously seen things or people. The process beneath it is quick and feels automatic, with an almost perceptual flavor. As we will see, that is not too far from the truth. However, there are hidden layers that contribute to this process, and these can be revealed by the use of a memory illusion.

9.4.1. In Action

Try this teasing task, using stimuli from Whittlesea and Williams' 1998 study.1 Or better yet find a volunteer to tax instead. Look at the words in Table 9-1, one at a time (around 2-3 seconds a word), in both columns. Then take a breather for a minute or two.

Table 9-1. Study each word for 2 to 3 seconds each

MACHINE	ISOLATE
DAISY	FRAMBLE
FISSEL	SUBBEN
PNAFTED	STOFWUS
FAMILIAR	VASSIL
COELEPT	DETAIL
HADTACE	GERTPRIS
STATION	MEUNSTAH
PLENDON	HENSION

Now turn to the second list of words, Table 9-6, at the very end of this chapter. Go through the second list and check/tick with a pencil those that feel familiar (if you like, you can put a cross by those you definitely didn't see).

What did you experience? Most people find that while the real words were easy to identify one way or another, certain of the nonwords had a creeping feeling of familiarity. Possibly you checked/ticked some that, in fact, you hadn't seen. If so, your recognition memory has just been royally messed with.

9.4.2. How It Works

This test is a good way to bring out the heuristic, fast-and-loose nature of recognition memory. When we encounter something we have experienced before, familiarity can hit us extremely rapidly. This feeling need not be accompanied by extensive memory information, which shows it isn't due to deep memory retrieval. Instead, recognition memory seems to be piggybacking on the rapid incoming sensory information to flood us with this sense of "having seen." What qualities of perception might be useful? Well, as seen before, items that have been seen recently are processed faster and more easily **[Hack #81]** we can call this *fluent*

Team LiB

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Hack 84. Keep Your Sources Straight (if You Can)

When memory serves up information upon request, it seems to come packaged with its origin and sender. But these details are often produced ad hoc and may not fully match the true source.

Every memory has a sourceor at least it ought to. That said, memories can often float loose from their moorings, making it some achievement that we manage to anchor mnemonic detail to their origins.

9.5.1. In Action

This test involves word stems, the idea being to complete the beginning of each stem in Table 9-2 with a word of your choice. So *ple*___ (complete it with any number of letters) could be "please," or equally "pledge," "pleat," and so on. Complete the odd-numbered stems (the ones on the left) out loud; for the even-numbered ones (on the right), merely *imagine* saying the words. Use a different word for each stem (i.e., don't use "please" twice if you run across the *ple*___ stem twice).

Table 9-2. Stem completion task. Think of a word to complete each stem. Speak the ones on the left out loud, but the ones on the right just in your head.

Complete out loud	Imagine completing out loud
1. BRE___	
	2. MON___
3. FLA___	
	4. TAR___
5. SAL___	
	6. FAL___
7. SPE___	
	8. BRE___
9. TAR___	
	10. SPE___
11. MON___	
	12. SAL___

Take a break! This is a memory test, so you need to pause for 1 or 2 minutes before reading on.

Hack 85. Create False Memories

Here is one way of creating memories of things that you haven't actually experienced.

We've seen how memory's way of orienting us to our surroundings has all the ingredients for a hack **[Hack #83]** a fast-and-loose process that is expressed through gut sensation. Here we will see that even more measured and absolute experiences, like recalling an event or information, can also be fooled. The processes that sit behind familiarity, or word recall (in this example), use a whatever-works principle. They're ad hoc, not carefully designed filing systems that pack away memories and bring them out later for comparison or regurgitation. By seeing where these processes break down, here by constructing very simple false memories, we can shed light on how memory works.

9.6.1. In Action

Let's show false memory construction with a couple of word lists. First wrap your eyes around the words in Table 9-3, read them out loud once, then close the book and try to list all the words you saw.

Table 9-3. Read these words aloud straight off, and then close the book and write down all you can remember

THREAD	POINT	HURT
PIN	PRICK	INJECTION
EYE	THIMBLE	SYRINGE
SEWING	HAYSTACK	CLOTH
SHARP	THORN	KNITTING

Do the same with the next set listed in Table 9-4: read the words aloud, then close the book and make a list.

Table 9-4. As before, read these words aloud, and then write down all you can remember

BED	WAKE	SNORE
REST	SNOOZE	NAP
AWAKE	BLANKET	PEACE
TIRED	DOZE	YAWN
DREAM	SLUMBER	DROWSY

> Make your lists before reading ahead to get the most out of this hack.

Hack 86. Change Context to Build Robust Memories

When you learn something, you tend to store context as well. Sometimes this is a good thing, but it can mean your memories don't lend themselves to being recalled in different circumstances.

This situation should sound familiar to almost all of you: you're trying to remember the name of the guy who wrote that book you read at some point in the not-too-distant past. You can't remember his name, but you can remember that he's a Canadian who moved to the United States and also writes about politics and has affairs with minor celebrities. You had a copy of the book about 5 years ago, the cover was reddish, and you packed it into a box when you moved and haven't seen it since then. You remember reading the book in the old café that they've since turned into a video rental store. You remember an amazing amount about the book and loads of information associated with it...just not the name of the guy who wrote it. What gives?

Often, you don't know in advance what details you need to remember for later recall. There aren't any clean boundaries between relevant and not relevant, and there are no tags reading "You will be tested on this later." So instead of remembering only what you choose to learn or are sure to need later, your brain files away many intricate details of context.

To you, this is just the context, but in your memory, it isn't necessarily sharply defined as such. Your memory is a set of interlinked and interleaved representations **[Hack #87]**, so that in a fundamental sense the context can be part of the memory as much as the thing intended to be learned is part of the memory.

One consequence of this is that reinstating the original context helps you recall what you originally learned in that context. Another is that any consistent context associated with the learned item will become part of the memory for that item. Sometimes this can be a good thing, as is the case when you're trying to recall details you didn't know were going to be useful at the time or when you are trying to reproduce a skilled behavior in exactly the same circumstances in which you learned it. Other times it can hinder your recall of the memory in isolationwhen you're out of that context.

9.7.1. In Action

Here's an example of how the automatic encoding of context affects learningin this case, skill learning (skills are memories too). It's called the *contextual interference effect*, and it goes like this: practicing a collection of skills in a random order is better than practicing them in runs.

So, for example, if you are learning Japanese, writing each character of the hiragana (one of the three alphabets used in Japanese) is a separate motor skill. So it might be better to practice your hiragana by writing all of them out together, rather than copying out a hundred copies of one character, then a hundred copies of the next, and so on. You learn slower this way, but you remember better.

Ste-Marie et al. used this technique when teaching grade two students handwriting, practicing writing the letters *h*, *a*, and *y*.[1] After writing each letter only 24 times, the students who practiced the letters in a mixed-up fashion had better handwriting (i.e., better motor memories) than the students who practiced in blocks, as soon as the very next day. You can acquire new skills more effectively even after this short a time.

Even better, skills you have learned like this transfer better to new situations. If you learn by repeating the same skill again and again, you're going to learn it in the context of repetition rather than how to do it one-off. Practicing with a series of one-offs means you learn in many different contexts, and the memorized skill is more sharply defined. It's easier to recall and apply to a new context because it isn't interwoven as tightly with the learned context.

9.7.2. How It Works

Most of the research on the contextual interference effect has involved simple motor memoriesthese are skill memories, the kind you use in throwing Frisbees, juggling, or swinging

Hack 87. Boost Memory Using Context

Your memories aren't stored discretely like objects in a filing cabinet; rather, they are interleaved with other things in memory. This explains why you're good with faces but not with names, why you should go back to your hometown to better remember your school days, and maybe even why you dream, too.

Human memory is not organized like a filing cabinet or a hard disk drive. In these storage systems, each memory is neatly indexed and stored so that it doesn't affect any other memory. The items in a computer memory don't affect processing unless they are explicitly retrieved, and to retrieve them, you have to consult an index to work out where they are. If you don't know where they are or if you don't have the right tag by which to access the files, you're out of luckyou're stuck with a brute force look through each file, one by one. The same holds for finding related itemsyou do it through some form of indexing system or again resort to a brute-force search. The system is content-blind.

But human memory is even further unlike any filing cabinet or computer memory system. This is the fundamental difference: *human memories are stored as changes in the connections between neurons, the self-same neurons that actually do the processing*.

So there are no passive storage locations: the processing-storage distinction fundamental to conventional computer architecture1 doesn't hold. Instead, memories about things are stored by the same units that are responsible for processing them. As you look at a face, your brain doesn't need to send away for information on whether you've seen the face before, and it doesn't need to store or index that face so that it can be recognized later. The ease with which that face was processed by your neural units provides a signature that can be used to calculate familiarity **[Hack #83]** . If you see the face once, it makes it easier for the neurons that respond to that particular combination of features to respond together, effectively acting as a key for recognizing it later.

So it should be clear why recognizing faces is easier than recalling names. When recognizing faces, your brain is presented with some input (a face) and can tell if it is familiar just by checking whether the neurons for representing that face easily coactivate. (If all the neurons representing a face activate together easily, that means they've activated together in the past. That is, you've seen the face before.) For recalling the name, you have to recognize the face and then hope that the association with the word information you heard at the same time (the name) as you first met the face is strong enough to allow that to be activated. It's a different process (recall versus recognition) in a different modality (image versus words); no wonder it's so much harder.

Of course, if human memory *were* organized like computer memory, then recognizing faces would be an equivalent task to recalling names. Both would involve checking the input (the other person's face) against everything you've got stored. If you've got the face stored, bingo!you recognize it. And the information you retrieve to recognize it would be automatically linked to the name, so recalling the name would be just as easy as recognizing the face. Unfortunately, on the flip side, recalling a face would be just as difficult as recalling a name.

T.S.

The second important consequence of this fundamental difference is that memories are distributed between many neurons, all of which are involved in storing many other memories. This means that memories aren't stored independently of one another; so, learning something new can interfere with your memory of something old (and, of course, the things you already know affect what you remember about new material).

9.8.1. In Action

Forgetting something isn't just a matter of information falling out of your brain, as if your brain were a filing cabinet turned over. Traces remain of any information that is forgotten. This is why relearning things is easier than learning them for the first time. And because memories are fundamentally entangled with on another, remembering or relearning something brings related memories closer to the surface too.

Hack 88. Think Yourself Strong

You can train your strength and skill with imagination alone, showing that there's a lot more to limb control than mere muscle size.

How your brain controls your muscles is something you don't notice until it goes wrong. When you drop a plate for no good reason, when disease or age rob you of the ability to will your muscles to move just like that, when you can't stop your legs trembling (even though that is possibly the least useful thing they could be doing in your situation), *then* you notice the gap between what you want to happen and what your muscles do. Normally the coordination of body movement happens so smoothly and (seemingly) instantaneously that it's hard to really believe there are any gaps in these processes. Hold your finger up in front of your face. Watch it carefully. And . . . ready . . . curl it. Magic. How did that happen? It's impossible to truly introspect about the control system involved: our bodies appear to be the ultimate pieces of invisible technology.

But that doesn't mean there isn't a very complex system of control in place. It needs to be complex for the range of jobs done, at the speeds they're done. The standard *visuomotor feedback loop* (the delay between acting and getting visual information to update or correct that action) is 100-200 milliseconds,[1] so much of this control has to happen without the aid of direct guidance from the senses. Movement must be controlled, at least in part, by processes that do not require immediate sensory feedback.

There's that number again: 100-200 ms! It occurs all over this book, and I think this may be the root of it; the commonly found window for conscious experience **[Hack #27]** may be this size because of the uncertainty introduced by the delay between our senses and reactions. So this is the range over which our brain has developed the ability to predict, by simulation, the outcome of our actions.

T.S.

The thing is, movements are often so quick it doesn't feel as if feedback loops are intimately responsible. Rather, it often *does* feel as if you send a "go" signal to your hand to stretch a finger or catch a ball. So how can we show this is actually what's happening? One way is to work on developing the control system itself and see how that influences the resulting movement. If these systems do indeed exist, then developing them without simultaneously developing your muscles should still improve performance.

9.9.1. In Action

Using your imagination alone you can train the motor signals from your brain so that you are stronger, faster, and more skillful. This example takes 3 months to work, so you may want to just listen to how the experiment was done rather than doing it yourself. It's taken from a study led by Vinoth Ranganathan,[2] who was following up on a study done 12 years previously by Guang Yue in the Lerner Research Institute department of biomedical engineering.[3]

The study involved volunteers training, in two different ways, the muscle responsible for pushing outward the little finger. (To see what they were doing, put your hand palm downward on the table, fingers together, then imagine you're pushing a weight out by moving your little finger only to the side). They trained for 12 weeks, 15 minutes a day, 5 days a week. Some volunteers trained by actually tensing the muscle, but others were instructed to merely *imagine* doing so.

After 12 weeks, Ranganathan measured the force that the volunteers could exert with their little finger muscle. Both groups had become stronger, those actually tensing their muscles during training improving by 53%, those using imagination by 35%. That's not a large gap, especially if you consider that training just using your imagination is probably the harder task to do.

9.9.2. How It Works

The Ranganathan study used the little finger muscle because it is not used much. It is easier to see changes in strength here than in more primary muscles, such as those in the arms or

Hack 89. Navigate Your Way Through Memory

A 2,500-year-old memory trick shows how our memory for events may be based on our ability to remember routes to get to places.

Remembering where you are and what is currently happening are (as you might expect) both rather important. It turns out that orienting yourself in space may rely on some of the same brain areas as are used for remembering what has happened to youareas that originally evolved to help animals find their way around, but now allow us to retain the episodes that make up our personal narratives.

The demonstration we'll use is a famous memory trick used to remember a list of arbitrary things, with the added bonus that the things are remembered in order. It's called the *method of loci* and involves remembering things according to where they are positioned along a route. Simply take your list of things to remember and place them along a familiar route, imagining each item (or something that will remind you of it) at key points on the route.

9.10.1. In Action

How many words do you think you could remember if given an arbitrary list and around 10 seconds per word in which to learn them? Knowing that my memory isn't all that good, I thought perhaps I could remember around 10. So I decided to use the method of loci to remember 20 words, twice that number. I didn't want to come up with my own list, because it would be easier for me to remember, so I used the 20 most common words appearing in the lyrics of the songwriter Tom Waits, as kindly provided by the excellent Tom Waits Supplement (http://www.keeslau.com/TomWaitsSupplement/Lyrics/common.htm) and shown in Table 9-5.

Table 9-5. Imagine an item for each word at points along a route that is familiar to you. Rehearse for 4 minutes and then test yourself

1. NIGHT	8. HOME	15. DRINK
2. TIME	9. RAIN	16. STREET
3. LOVE	10. HEART	17. BLOOD
4. DAY	11. DEATH	18. RED
5. EYE	12. DOG	19. HAIR
6. DREAM	13. BLUE	20. GIRL
7. MOON	14. ROAD	

Perhaps you think 20 is too easy; feel free to use a longer list or give yourself less time, if you're so inclined. But 20 in 4 minutes seemed daunting enough for me. Starting with "night" (131 mentions across Tom Waits' entire discography) and finishing with "girl" (40 mentions), I imagined something to do with each item at each point of the journey from the front room of my house, where I was sitting, to my nearest subway station.

After mentally doing the journey and noting the items strewn along the way (a "love" letter at the foot of the stairs, a "drink" of coffee at the café on the corner, and so forth) and checking that I thought I'd remembered them all, my 4 minutes were up and I pulled out my notebook and got my pen ready to write down the list of items.

Normally with things like this my mind goes blank as soon as the thing I'm supposed to be remembering leaves my sight. But, using the method of loci, I was impressed with how quick and easy it was to remember all the words. (Yeah, yeah, I know I'm supposed to know that it

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Hack 90. Have an Out-of-Body Experience

Our regular experience of the world is first person, but in some situations, we see ourselves from an external perspective. These out-of-body experiences may even have a neurological basis.

We are used to experiencing the world from a first-person perspective, looking out through our eyes with our bodies at the center of our consciousness. This is sometimes known as the *Cartesian theater*.

Some people, however, claim to have out-of-body experiences, in which their consciousness seems separated from their body, sometimes to the extent that people feel as if they are looking down on themselves from a third-person perspective, rather than looking out from the inside. These claims are not common, but most people can experience similar out-of-body phenomena, in the form of memories of past events. Furthermore, research has identified certain specific brain areas that may be involved in producing the egocentric, "looking out of our eyes" perspective and found that out-of-body experiences can be induced by unusual activity there.

9.11.1. In Action

Remember back to when you were last lying down reading something: perhaps it was on holiday at the beach, in a local park, or just on the couch at home. Try and fix that image in your mind.

Now, notice where your "mind's eye" is. Are you looking at yourself from an external point of viewmuch like someone wandering by might have seen youor are you remembering yourself looking out through your own eyes as you are while reading this book right now?

The majority of people remember a scene like this from a seemingly disembodied third-person perspective, despite originally having experienced it from a first-person point of view.

9.11.2. How It Works

The first study to explore this effect in detail was published in 1983 by Nigro and Neisser.[1] They made the link between the likelihood of recalling a memory as either a first-person or third-person image and emotions and discovered that asking someone to focus on their feelings at the time of the event was more likely to result in a first-person memory. The example in the preceding "In Action" section focused on a situation and was probably a fairly neutral emotional experience, so is likely to produce a third-person memory in most people.

Although this is a common experience when remembering the past, the majority of people do not have out-of-body experiences in the present. People who have recounted out-of-body experiences have sometimes been suspected of being overimaginative or worse, but such experiences are a well-known phenomenon in certain types of epilepsy and with specific forms of brain injury. This does not mean that people who experience out-of-body states necessarily have epilepsy or brain injury, but these sorts of conditions suggest that normal, but usually hidden, aspects of brain function may be involved in producing such experiences.

A study by Blanke and colleagues[2] examined five neurological patients who had frequent out-of-body experiences. On one occasion, a surgeon managed to reliably induce such an experience by electrically stimulating the cortex of a patient during brain surgery. When the surgeon stimulated the *tempero-parietal junction* (the area of the brain where the temporal and parietal lobes meet **[Hack #8]**), the patient reported that she felt an instantaneous sensation of floating near the ceiling and experienced the operating theater as if she were looking down on it, "seeing" the top of the doctors' heads and herself on the operating table. Ceasing the stimulation "returned" the patient to her body, and resuming it caused her to feel disembodied once more.

Brain imaging studies have shown that the tempero-parietal junction is activated in situations that involve calculating point of view from an egocentric perspective and mentally switching between views to understand a scene (for example, mentally working out a good place to stand to get the best view of a football game). With this in mind, it is perhaps not so

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Hack 91. Enter the Twilight Zone: The Hypnagogic State

On the edge of sleep, you may enter hypnagogia, a state of freewheeling thoughts and sometimes hallucinations.

Hypnagogia, or the *hypnagogic state*, is a brief period of altered consciousness that occurs between wakefulness and sleep, typically as people "doze off" on their way to normal sleep. During this period, thoughts can become loosely associated, whimsical, and even bizarre. Hallucinations are very common and may take the form of flashes of lights or colors, sounds, voices (hearing your own name being called is quite common), faces, or fully formed pictures. Mental imagery may become particularly vivid and fantastical, and some people may experience *synaesthesia*, in which experiences in one sense are experienced in anothersounds, for example, may be experienced as visual phenomena.

It is a normal stage of sleep and most people experience it to some degree, although it may go unnoticed or be very brief or quite subdued in some people. It is possible, however, to be more aware of the hypnagogic state as it occurs and to experience the effects of the brain's transition into sleep more fully.

9.12.1. In Action

Although there is no guaranteed technique to extend or intensify the hypnagogic state, sometimes it can be enough to simply make a conscious effort to be aware of any changes in consciousness as you relax and drop off, if practiced regularly. Trying to visualize or imagine moving objects and scenes, or passively noting any visual phenomena during this period might allow you to notice any changes that take place. Extended periods of light sleep seem more likely to produce noticeable hypnagogia, so being very tired may mean you enter deep sleep too quickly. For this reason, afternoon dozing works well for some.

Some experimenters have tried to extend or induce hypnagogia by using light arousal techniques to prevent a quick transition into deep sleep. A microphone and speaker were used in one study to feed the sound of breathing back to the sleeper. Another method is the use of "repeat alarm clocks" (like the snooze function on many modern alarm clocks)on entering sleep, subjects are required to try and maintain enough awareness to press a key every 5 minutes; otherwise, a soft alarm sounds and rouses them.

Try this yourself on public transport. Because of the low background noise and occasional external prompting, if you manage to fall asleep, dozing on buses and trains can often lead to striking hypnagogic states. In spite of this, this is not always the most practical technique, as you can sometimes end up having to explore more than your own consciousness if you miss your stop.

9.12.2. How It Works

Very little research has been done on brain function during the hypnagogic state, partly because conducting psychology experiments with semiconscious people is difficult at the best of times and partly because many of the neuroimaging technologies are not very soporific. fMRI **[Hack #4]** scanning tends to be noisy and PET scanning **[Hack #3]** often involves having a drip inserted into a vein to inject radioactive tracer into the bloodstreamhardly the most relaxing of experiences. As a result, most of the research has been done with EEG (electroencephalogram) readings **[Hack #2]** that involve using small scalp electrodes to read electrical activity from the brain.

Hideki Tanaka and colleagues[1] used EEG during sleep onset and discovered that the brain does not decrease its activity evenly across all areas when entering sleep. A form of alpha wave activity (electrical signals in the frequency range of 8-12 Hz that are linked to relaxed states) spreads from the front of the brain to the other areas before fading away. The frontal cortex is associated with attention (among other things), and it may be that the hypnagogic state results from the progressive defocusing of attention. This could cause a reduction in normal perception filtering, resulting in loosely connected thoughts and unusual experiences.

Hack 92. Make the Caffeine Habit Taste Good

Caffeine chemically hacks the brain's reward system, boosting the value we give not only to the morning cuppa, but also to everything associated with it.

I couldn't even begin to write this for you until I'd made myself a coffee. Some days I drink tea, but coffee is my normal stimulant of choice, and a cup of that ol' "creative lighter fluid" is just what I need to get started on my morning writing.

After you've drunk a cup of tea or coffee, the caffeine diffuses around your body, taking less than 20 minutes to reach every cell, every fluid (yes, *every* fluid[1]) of which you're made. Pretty soon the neurotransmitter messenger systems of the brain are affected too. We know for certain that caffeine's primary route of action is to increase the influence of the neurotransmitter dopamine, although exactly how it does this is less clear.[2] Upshifting the *dopaminergic* system is something caffeine has in common with the less socially acceptable stimulants cocaine and amphetamine, although it does so in a different way.[3]

> Neurons **[Hack #9]** use neurotransmitters to chemically send their signals from one neuron to the next, across the synapse (the gap between two neurons). There are many different neurotransmitters, and they tend to be used by neurons together in systems that cross the brain. The neurons that contain dopamine, the dopaminergic system, are found in systems dealing with memory, movement, attention, and motivation. The latter two are what concern us here.

Via the dopaminergic system, caffeine stimulates a region of the subcortex (the brain beneath the cerebral cortex **[Hack #8]**) called the *nucleus accumbens*, a part of the brain known to be heavily involved in feelings of pleasure and reward. Sex, food, all addictive drugs, and even jokes cause an increased neural response in this area of the brain. What happens with addictive drugs is that they chemically hack the brain's evolved circuitry for finding things rewardingthe ability to recognize the good things in life and learn to do more of them.

The jury is still out on whether most caffeine addicts are really benefiting from their compulsion to regularly consume a brown, socially acceptable, liquid stimulant. While some killjoys claim that most addicts are just avoiding the adverse effects of withdrawal, it is more likely that most people use caffeine more or less optimally to help them manage their lives. One study even went so far as to say "regular caffeine usage appears to be beneficial, with higher users having better mental functioning."[4] So it's not just pleasure-seeking, it's performance-enhancing.

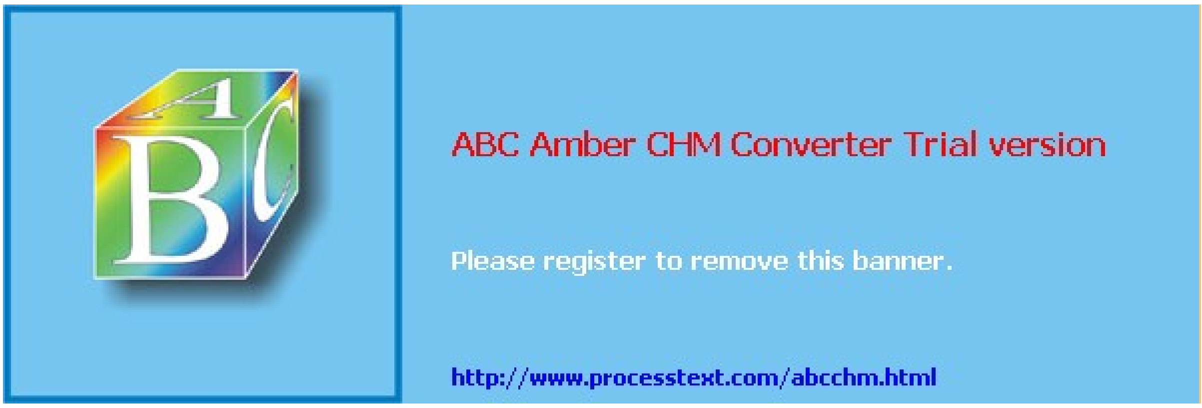
Coffee is strongly associated with two things: keeping you awake and helping you do useful mental work. In fact, it can even be shown to help physical performance.[5] The association with creative mental work is legendary, although the cognitive mechanisms by which this works are not clear. As early as 1933, experiments had shown that a cup of coffee can help you solve chess problems,[6] but the need for experiments has been considered minimal given the massive anecdotal evidence. As the mathematician Paul Erdos said, "A mathematician is a device for turning coffee into theorems." Academics, designers, programmers, and creative professionals everywhere will surely empathize.

But this isn't a hack about the addictive effects of caffeine, or even about the mental stimulation it can provide. This is about how coffee can work its magic on me without passing my lips. It's having its effect while it's still brewing. I need to make a cup to get started, but I haven't begun drinking it yet.

9.13.1. In Action

Just knowing you have a caffeine hit coming tends to perk you up. We value more than just the chemicals here. To see this in action, find someone who is a certified caffeine addict. It doesn't matter if she is into tea or coffee, as long as she is *really* into it. I'd wager that she is also rather particular about how she takes it too. Does she have a favorite mug? Does she

Chapter 10. Other People



10.1. Hacks 93-100

We don't live in a lifeless worldwe live in a world of other people. It's other people, not rocks or trees, that have minds of their own, minds just as capable as ours. It's other people with whom we gang together to fight off threats, build knowledge, build cities, and sustain life. It's other people we need to fit in with.

A good deal of this book has been about the patterns of the world as they're reflected in our minds, as assumptions and expectations. Assumptions like the direction of sunlight, as comes through in our specialized routines for processing shadows on objects **[Hack #20]** . And, to pick another example, our observation and subsequent assumption that cause and effect tend to sit together in both time and space **[Hack #79]**, which we use as a heuristic to make sense out of the universe. These are good assumptions to make. It's their very robustness that has lodged them in the functioning of the brain itself.

So how do our assumptions about other people, as constituents of our universe, manifest themselves in the deep operations of the mind? We'll look at how we have a dedicated module for processing faces **[Hack #93]** and how eye gaze tugs at our reaching response **[Hack #97]** just like any physical location Simon Effect task **[Hack #56]** .

We'll look at how we signal emotion, how emotion is induced, and how we use it to develop common feeling in a group **[Hack #94]** and **[Hack #95]**.

And, speaking of fitting in, we'll finish by seeing how exposure to photographs of faces and the written word triggers our drive to imitate **[Hack #98]**, **[Hack #99]**, and **[Hack #100]**, from mirroring gestures to automatic mimicry of social stereotypes.

Hack 93. Understand What Makes Faces Special

We have dedicated neural machinery for recognizing faces from just a few basic features arranged in the right configuration.

It's an important evolutionary skill to be able to quickly and efficiently recognize faces that are important to us. This allowed our ancestors to conform to the social hierarchies of the groups in which they lived, to keep checks on who was stronger and who was weaker than they were, and to track potential mates.

While faces are very important things to recognize, they are also all remarkably similar. Eyes, noses, and mouthsand it is these features that we rely on most when we discriminate between facesall look pretty much alike, and the ratios of the spacing between them do not leave too much scope for differing widely either. Nevertheless, it is remarkably easy for us to distinguish between faces.

10.2.1. In Action

Take a look at the two pictures in Figure 10-1.

Figure 10-1. Two upside-down faces, but you should have no problem recognizing who it is[1]

While you might detect some sort of difference between them, the odds are that both will look like pretty normal upside-down pictures of a face (and you might well be able to identify who it is, too). Now turn the book upside down. The face on the right is a grotesque: its eyes and mouth have been inverted. But you probably didn't notice this (and it certainly is not as striking as when the faces are the right way up). This is a neat demonstration of the fact that faces are normally processed *holistically*. When they are the right way up, we "understand" faces as a whole based on their internal components; turning them upside down disrupts this ability. We then have to rely on componential encoding instead and judge the face simply in terms of the individual items that make it up. This makes it much harder to detect that something is "wrong" than when we are able to use holistic processing. While, of course, we rely on differences in hairstyle and color and other factors when identifying people in the real world, experiments have shown that we rely most on the central features of faces.

Another example of the way in which we are "primed" for the ability to recognize faces is how difficult it feels to look at the face shown in Figure 10-2.

Figure 10-2. It's difficult to look at this double face

This is because the two sets of internal features are competing with each other to allow us to make sense of the face. Neither set can win, so our visual system can't settle on the stimuli and make sense of it the way it would with a normal face.

10.2.2. How It Works

So how does the brain recognize faces? It turns out that there is a section of the brain that is specialized for recognizing facelike stimuli. In imaging studies,[2] it has been shown that a section of the *fusiform gyrus*, which borders the temporal and occipital lobes, is more active when participants view images of faces than when they view other pictures. This area is now termed the *fusiform facial area*. It is specialized for viewing faces in an upright orientation, suggesting that faces as they are normally seen are treated as a specialized type of object by the brain. It is easy to recognize partial or degraded images, though, such as with low-quality CCTV images.3 Again, this would make sense in allowing us to identify people in low lighting or among other objects such as trees.

When looking at faces, our eyes dart most around the mouth and eyes **[Hack #15]**, the two

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Hack 94. Signal Emotion

Emotions are powerful on the inside but often displayed in subtle ways on the outside. Are these displays culturally dependent or universal?

We find our emotional lives impossible to untangle from ourselves and examine critically. They're a core part of who we are. If you could imagine it, a life without feelings would be far more alien than any Mr. Spock. Emotions prepare us for situations both physiologically and cognitively too, and emerge from multiple dedicated systems that interact below the level of consciousness. Advances in psychology and neuroscience unveil these systems, and reveal how we signal our emotional states to others and decode even subtle emotional expressions.

10.3.1. In Action

Take a stroll down an imaginary lane in a distant, foreign land. You've no knowledge of the language spoken and no idea of the local customs and practices. Before you is a fork in the road with no clear sign of which direction leads to where. Thankfully, you spy a local working the land. Hungry for information to guide you, you point to the first path. His mouth broadens until his teeth are visible. After taking this in, you point to the second. His brow furrows as his mouth becomes small and tight. Lo and behold, despite any language and cultural barriers, you most likely have enough information to know that the first is probably a better bet.

Try it yourself. Consider the photo in Figure 10-3.

Figure 10-3. What emotion is this face signaling?[1]

I'm sure there is no doubt in your mind what is being expressed here. At the very least, it's a very different face from that shown in Figure 10-4.

Figure 10-4. What emotion is this second face signaling?[2]

It's clear that the first face is happy and the second is in a less than positive mood.

Obvious, you say?

It might feel so, but before you dismiss this disambiguation out of hand, you should know that many of the cues are fairly subtle and there's a lot more going on behind the scenes than you might realize. In fact, these cues can slip by brain-damaged patients entirely, even those whose perception is otherwise fairly good. Let's dig a little deeper.

10.3.2. How It Works

We may take it for granted, but the existence of a universal emotion expression system is an impressive feat. Masses of evidence show that our brains are wired to distinguish and respond to expressions of a number of emotional states. The *basic emotions*, a concept born of lauded psychologist Sylvan Tomkins, are anger, fear, disgust, sadness, surprise, and happiness. We can be confident that these are really universal thanks to the cross-cultural work of Paul Ekman, the leading proponent of basic emotion theory, whose work with tribes in New Guinea confirm what our example asserts: despite some cultural nuances, a smile is a smile worldwide.

Furthermore, it turns out that this capacity is not only universal, but also innate. The ubiquity of our expressions is not purely a consequence of convergence by imitation, as they are present to some extent even when there is no input.[3] German ethologist Irenäus Eibl-Eibesfeldt conducted research in the 1960s that showed that congenitally blind children still produced emotional expressions via the face, even those who were also severely cognitively-impaired. This preserved ability of the sensory impaired has been noted often, including Charles Darwin's comment that blind children can "blush with shame."

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Hack 95. Make Yourself Happy

Turn on your affective system by tweaking your face musclesor getting an eyeful of someone else doing the same.

Find yourself a pen, preferably a nontoxic, nonleaky one. We're going to use this little item to improve your quality of life and give you a little pleasure.

10.4.1. In Action

Put the pen between your teeth, in far enough so that it's stretching the edges if your mouth back without being uncomfortable. Feeling weird? Just hold it there for a little, and appraise your level of mood. You should find that you end up feeling just a little happier.

If you want to go for the reverse effect, remove the pen (maybe give it a wipe), then trap it between your upper lip and nose like a mustache. If you're feeling anything, it's likely to be a touch of gloom, particularly in contrast to when you had the pen in your mouth.

Alternatively, if you're pen-averse, refer to the pictures in **[Hack #94]** and scrutinize the smiling face for a while. You should find yourself perked upwhile the unhappy photo will likely send you downhill if you stare at it a little.

10.4.2. How It Works

Emotional expressions are much more than just by-products of our *affective system*, the system that deals with emotions. Expressions serve as agents that transmit emotions to other individuals and are crucial in creating and maintaining our own emotional experience. And while aspects of this may be conscious and deliberatemy girlfriend may throw me a grin to let me know she's not mad that I've been glued to the computer all evening, and that reassurance will make me happythere is a deeply automatic component. This is termed *primitive contagion* and is characterized as a three-stage process: it begins with perception, which triggers mimicry, which itself produces emotion. **[Hack #94]** deals with how we perceive emotions, so here we`ll unpack the other two stages: mimicry and resulting emotion.

10.4.2.1 Mimicry

An array of experiments shows that, when emotional faces are presented, subjects produce corresponding facial expressions. For example, subjects can tell from recordings of their faces which emotions they must have been looking at originally. Additionally, facial EMG changes occur after only a few hundred milliseconds: the *zygomatic muscles* (in the cheeks) used for smiling show more activity after seeing a happy face, while the *corrugator* muscles (between the eyes, at the top of the nose) used for frowning are more active after viewing anger.

> Electromyogram (EMG) is a measure of small electrical currents muscles produce when they're active. Thus, EMG changes in a particular place indicate that a muscle there is being used.

It seems this is something we just can't help. Show emotional faces (photographs in newspapers usually fit the bill) to a friend and look for the flicker of mimicry his face invariably betrays. The stronger the expression portrayed in the picture, the stronger your subject's emotional response. The phenomenon can even be found when a face is shown subliminally Section 9.3 and **[Hack #99]** and the viewer is unaware of seeing any kind of expressive face; the facial muscles betray the effect.

10.4.2.2 Resulting emotion

The act of making an emotional expression has an effect on our emotional state. This has been shown experimentally, most convincingly when the experience is divorced as much as possible from labels like "smiling" (as in the case of pushing back on your lip): simply activating critical muscles produces the effect. This deep coupling to the motor system (a fundamental and ancient function of the brain) underlines the primitive nature of emotions.

Hack 96. Reminisce Hot and Cold

Find the fire that's cooking your memory systems.

Our emotional system contributes not just to how we respond to the world at a given moment, but how we store representations of what has happened in the past. The makeup of our memories is not decided dispassionately by an impartial documentary reel in our brain, but by passionate, loaded mechanisms that draw out the aspects with the most juice.

10.5.1. In Action

Read the following two tales.[1] There will be a quiz at the end of class.

10.5.1.1 Tale 1

"A mother and her son are leaving home in the morning. She is taking him to visit his father's workplace. The father is a laboratory technician at Victory Memorial Hospital. While walking along, the boy sees some wrecked cars in a junkyard, which he finds interesting.

"At the hospital, the staff are preparing for a practice disaster drill, which the boy will watch. Makeup artists were able to create realistic-looking injuries on actors for the drill.

"After the drill, while the father watched the boy, the mother left to phone her other child's preschool. Running a little late, she phones the preschool to tell them she will soon pick up her child. Heading to pick up her child, she hails a taxi at the number 9 bus stop."

10.5.1.2 Tale 2

"A mother and her son are leaving home in the morning. She is taking him to visit his father's workplace. The father is a laboratory technician at Victory Memorial Hospital.

"While crossing the road, the boy is caught in a terrible accident, which critically injures him. At the hospital, the staff prepares the emergency room, to which the boy is rushed. Specialized surgeons were able to reattach the boy's severed feet.

"After the surgery, while the father stayed with the boy, the mother left to phone her other child's preschool. Feeling distraught, she phones the preschool to tell them she will soon pick up her child. Heading to pick up her child, she hails a taxi at the number 9 bus stop."

OK, it's a very easy quiz: which tale stands out more for you? It's likely to be Tale 2.

Cahill and McGaugh's study[1] used extended versions of these tales, in order to investigate our current hack: the special status of emotional events in memory. It's generally the second story that is more memorable, particularly the central sectionthis is peculiar because other memory studies indicate that we're typically better at remember events at the beginning and at the end of a story like this. This, along with evidence coming from similar studies, suggests that we have a specialized memory response to emotional stimuli.

The central section of the story isn't more memorable because it contains an unusual emotional event (we remember unusual events better), it's more memorable because of the physical effect emotion has on you. If you did this test while on propranolol, a drug that prevents physiological arousal by blocking beta-adrenergic receptors (preventing increase in heart rate and release of adrenaline), you would find the emotional parts of the story no more memorable than the dull parts. On the flip side, if you were given yohimbine, a drug that increases arousal by stimulating the activity of the adrenaline product norepireprine and so causing a more rapid heart rate, the memory for these sections would be even greater. We don't find it emotional because it is objectively memorable, but it becomes memorable because we are allowed (in the absence of drugs like propanonol) to find it emotional.

10.5.2. How It Works

It's indisputably very useful for the memory system to give special status to events that set off our affective, emotional system. Fearful stimuli, disgusting food sources, kith who have angered youall are elements worth remembering. However, a memory system totally

Hack 97. Look Where I'm Looking

We are innately programmed to follow other people's eye gaze to see what they are looking at. It's so deeply ingrained that even cartoon eyes can interfere with our mental processing of direction.

Eyes are special. They're part of a two-way sense. Wherever I look, you can tell what I'm looking at. You can tell if I'm paying attention to you or not, as well as hazarding a good guess as to what I'm really thinking about. Following gaze isn't a learned behavior. As far as the brain's concerned, gaze direction is a first-class citizen of the real world, as important as location. In the case of location, the Simon Effect **[Hack #56]** demonstrates that we have a tendency to react to a prompt in the same direction as that stimulus. This hack shows that we interpret gaze direction in much the same way as location: a cartoon pair of eyes looking in one direction has the same effect.

10.6.1. In Action

A team at the University of Padua in Italy constructed an experiment to see the effect of gaze.1 They drew a pair of cartoon eyesjust two ovals with a colored oval (the iris) within each, as shown in Figure 10-5. The irises were colored either blue or green, and the cartoon could be looking either straight ahead or to one of the sides.

Figure 10-5. Cartoon eyes similar to the ones used in the experiment: show this page to someone and watch what her eyes dosee if you can catch her just flicking off to the right as the cartoon eyes trigger her automatic gaze-following routine

People taking part in the experiment had to report the color of the irises, hitting a button on the left for blue and on the right for green. The apparent gaze direction wasn't important at all. Despite that, it was faster to hit the button for green on the right when the eyes were looking the same way (to the right) and slower when they were looking the other way. The same held true for blue and the eyes looking left.

Thinking this might be nothing to do with the ovals looking like eyes, to investigate further, the team put together another task. Instead of ovals, the cartoon "eyes" were squares, with square "irises" in each, and looked much less like eyes (as shown in Figure 10-6). And sure enough, the significant reaction time difference (between gaze pointing in the same direction as the response key and in the opposite direction) went away.

Figure 10-6. Square "eyes" similar to the ones used in the experiment: we don't follow the gaze of robot eyes

It's possible this is why the X Windows toy "xeyes," which puts a pair of eyes on your computer desktop that follow your mouse cursor around, is so uncannily handy for avoiding losing your pointer.[2]

R.D.

10.6.2. How It Works

Essentially, this experiment shares a mechanism with the Simon Effect **[Hack #56]** . Given that the brain translates gaze direction into location, the same effect gets triggered: if attention has already been directed to the left because of the stimulus, it takes a very short time more to make a response on the right.

It makes sense that we treat gaze with such respect. If someone's looking at us, it usually means that some kind of interaction, for good or ill, is in motion. And if there are a few people looking at the same place, they've probably spotted something you should know about. Gaze

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Hack 98. Monkey See, Monkey Do

We mimic accents, gestures, and mannerisms without even noticing, and it seems it's the mere act of perception that triggers it.

We're born imitators, even without knowing we're doing it. I have a British accent, but whenever I spend a couple of weeks in North America, I start to pick up the local pronunciation. It's the same with hanging around certain groups of friends and ending up using words common in that group without realizing I'm picking them up.

Imitation doesn't require immersion in a culture. You can start mirroring people's movements without realizing it in moments.

10.7.1. In Action

I find a lot of psychology experiments a little mean, because they often involve telling the participants the experiment is about one thing, when actually it's about something else entirely. Tanya Chartrand and John Bargh's experiments on what they dub the Chameleon Effect fall into this category of keeping the participants in the dark (but are harmless enough not to be mean).[1]

Chartrand and Bargh had volunteers take part in a dummy task of describing photographs while sitting in pairs, taking turns looking at each photo and speaking outloud their free associations. What the volunteers didn't know was that describing the photographs wasn't the point of the experiment and that their partner wasn't a volunteer but a confederate in league with the experiment organizers. The confederate exhibited some subtle behavior, either rubbing his face or shaking his foot for the 10-minute duration of the experiment.

What the experimenters were actually watching was how often a subject would rub her own face or shake her own footultimately, how much a person could have her behavior influenced by the confederate, a person she hadn't met before and had no requirement to be friends with. The answer: behavior is influenced a lot.

Sitting with a face-rubbing confederate, a volunteer would rub her own face once every 100 seconds, on average. Normally, away from exposure to face-rubbing, she'd have about 30 seconds longer between touches.

The results are similar and more dramatic for foot shakinga doubling of shaking from just over once every 3 minutes to once every 80 seconds, just while sitting for about 10 minutes with someone who is shaking his foot every so often.

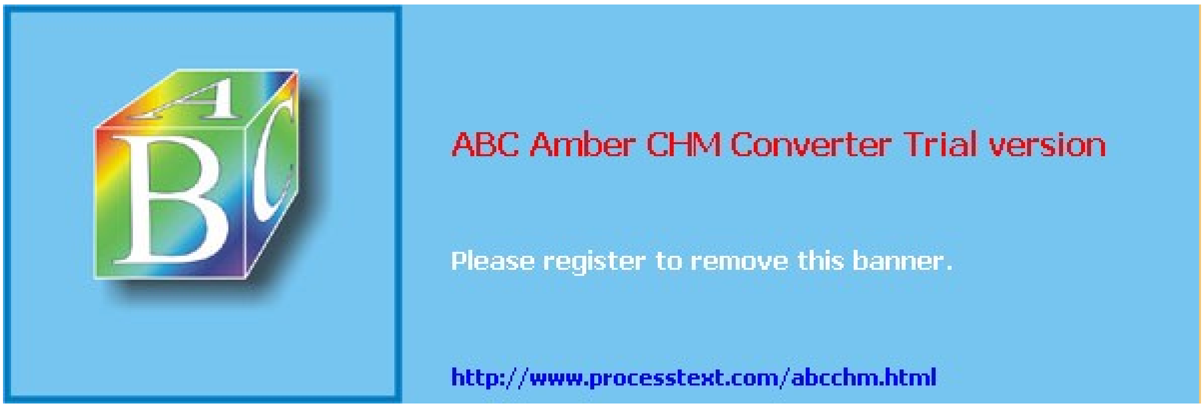
Given that this works, you've a chance to be rather mean. Next time you're in a café with friends, or at dinner, try scratching or touching your face and see what happens. Triggering a very particular response like a nose scratch may be rarer, but you can definitely get whoever you're with to do a bit of face touching.

You can be quite subtle too. In the experiments, the subjects were asked whether they'd noticed any standout behavior from the confederates: they hadn't. So it's not a matter of deliberate mimicry.

10.7.2. How It Works

Nonconscious imitation isn't limited to gestures. We adopt the same tone of voice and even the same sentence structure as conversational partners, and so in this way couples who have been married for a long time really do come to resemble each other.[2]

> There's a great example of hownonconsciouslywe mimic facial expressions, found when O'Toole and Dubin[3] watched mothers feeding their children. The mother would usually open her mouth, ostensibly as a signal for the kid to open his mouth too. But it turned out that, 80% of the time, the mother opened her mouth *after* the child did so. The child was opening his mouth just because food was on the way; the mother was mimicking without knowing it, just following her child's lead.



Hack 99. Spread a Bad Mood Around

Have you ever found yourself in a confrontational mood for no reason? It could come down to what you've been reading.

We know our moods are affected by the world around us. It's easy to come home from a day at work when everything's gone wrong and stay grumpy for the rest of the evening. Then there are days when your mood is good or bad for no apparent reason at all. I've had miserable-mood days because I've finished a really great, but sad, novel in the morning and not even connected my mood with the book until that night. Thinking about mood like this, the regular way, makes us consider moods as long-timescale phenomena that we just have to live with, like the weather. Like the weather, moods in this frame seem impenetrable to understanding. Instead, it's good to take a different approach: how do moods begin? What's the smallest thing we can do that has an effect on our mood?

That's what this hack is about, showing that the words we encounter can make us ruder people in a matter of minutesand not words that are meant to elicit a strong emotional response or ones that are taken to heart, but ones in the context of an innocuous word puzzle.

10.8.1. In Action

Puzzles are an excellent way to get people to keep words in mind for a substantial time. One such puzzle is the scrambled sentence test. Given a scrambled sentence of five words, such as "he it hides finds instantly," you have to make as many four-word sentences as you can, as fast as you can.

John Bargh, Mark Chen, and Lara Burrows used this test style[1] and incorporated 15 words to do with impolite behavior: "aggressively," "intrude," "brazen," and so on. They also had polite and neutral versions of the test. The subjects were unaware there were different forms of the test at this time and also unaware of the real point of the experiment.

Each subject spent about 5 minutes doing the puzzle, but that (of course) wasn't the point of the experiment. The critical point came when a subject stepped out of the room to say he'd finished, only to see the person running the experiment engaged in conversation. The question was: would he interrupt? Only just over 15% of those who'd been puzzling over polite words interrupted within 10 minutes, while of those who'd been using words like "obnoxious," more than 60%*four times as many* interrupted in that same 10-minute period.

Participants who did interrupt also did so faster if they'd been using the words about impoliteness: they took an average of $5^{1}/_{2}$ minutes to intrude versus more than 9 minutes for everyone else, even when you discounted the 85% of the politely primed group who didn't interrupt at all.

You can try a more subjective version of this procedure by using a technique called the Velten Procedure[2] to automatically induce moods in groups of people, then see if you can spot the difference. This technique uses, as developed by Velten in the 1960s, sheets of paper full of either positive or negative statements. So make a bunch of copies of two sets of statements (there are some samples online at http://www.dur.ac.uk/m.j.eacott/cogmem3.txt). The positive page should say things like "I am a worthwhile person," "I feel good about myself," and "People like me." The negative one should have phrases like "Nothing I do ever turns out right," "People feel contempt for me," and "I am a bad person."

Choose a sheet and read it to yourself for 5 minutes. By the time you finish, you really will feel happier or glummer. It's amazing how strong the effect is.

The effect is stronger still with a roomful of people. So, find such a room, and leave everybody with a positive Velten and tell them to read it to themselves for 5 minutes. When you come back, everyone should be jubilant. But try leaving another group the negative Velten. The atmosphere will be distinctly cold on your return. It goes to show the importance of social feedback in creating and amplifying mood.

In my final year of college, I made myself a "study Velten" to take to the library: "I like revising," "My concentration is in top form today," "Nothing will distract me from work today,"

Hack 100. You Are What You Think

Thinking about how certain stereotypes behave can make you walk slower or get a higher score in a general knowledge quiz.

The concept of priming **[Hack #93]** runs all the way through explanations of how perception influences behavior. Subliminal perception of photographs can prime you to prefer those photos in the future **[Hack #82]**, and simply spending time with someone who is, say, rubbing his face can infect you with his mannerism **[Hack #98]** . It's not necessary to consciously perceive the photographs or the gestures for them to automatically alter our behavior.

Nowhere is this truer than in *exemplar activation*: being exposed to ideas of stereotypes of people (the exemplars), not even the people themselves, will prime the characteristic traits of those people, and you'll begin to act in that way. It's very odd, and very cool.

10.9.1. In Action

Here's what John Bargh, Mark Chen, and Lara Burrows did[1]: they gave 30 psychology undergraduates word puzzles to do (undergraduates are the raw material for most psychology studies). In half of the experiments, the puzzles included words associated with the elderly, like "careful," "wise," "ancient," and "retired." In the other half, all the puzzle words were neutral and not deliberately associated with any single concept. Immediately after individual students had completed the puzzle, they were free to go.

Bargh and team timed, using a hidden stopwatch, how long it took each undergraduate to walk down the corridor to the elevator. Students who had been given the puzzle featuring elderly related words took, on average, a whole second longer to make the walkan increase from 7.3 to 8.3 seconds. They had picked up one of the perceived traits of the elderly: slower walking speed.

10.9.2. How It Works

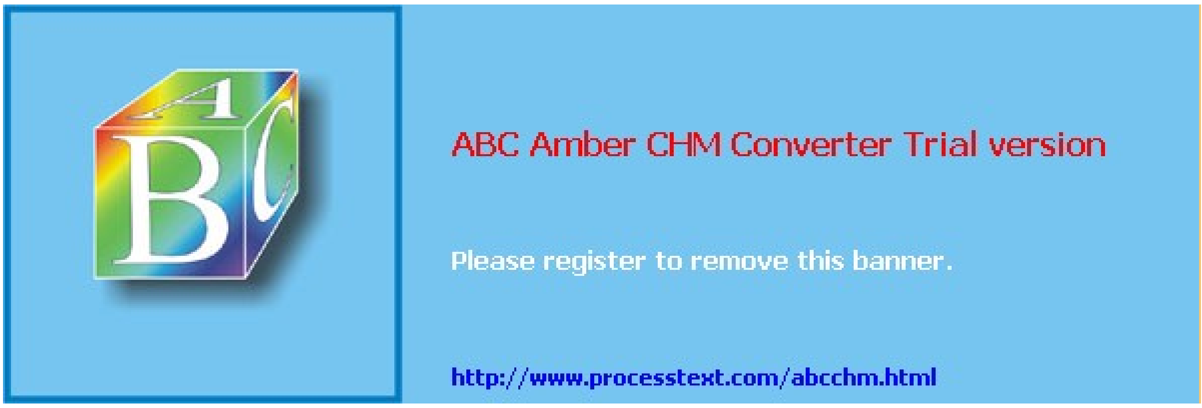
The specifics of how exemplar activation works is still an open question, but the basic mechanism is the same as how we pick up mannerisms **[Hack #98]** . It's a feature of the brain that perceiving something requires activating some kind of physical representation of the thing being perceived: simply making that representation primes that behavior, making us more likely to do what we see. Exemplar activation takes this a little further than we're used to, because it's the reading of wordsin an apparently unrelated task to walking along the corridorthat primes the concept of "the elderly," which then goes on to influence behavior. But the principle is the same.

Slow walking is only the half the story, though. Ap Dijskerhuis and Ad van Knippenberg[2] performed similar experiments. Instead of influencing their subjects with an "elderly" stereotype, they set up an experiment in which participants had to spend 5 minutes describing either professors or secretaries. (The subjects, again, were undergraduates.)

This time the experiment measured general knowledge, so the next stage of the experiment had the subjects answering Trivial Pursuit questions. They weren't aware the two stages were connected.

What happened is almost unbelievable: subjects who had previously described professorsknown for their perceived intelligenceattained, on average, 60% correct answers, against 46% for the people who had to describe secretaries.

It could be that people who have been considering the professor stereotype are more likely to trust their own judgment; the particular attribute of this stereotype that is causing the response isn't really known. The people exposed to the secretary stereotype didn't do any worse than they should have done: compared to people who hadn't been primed at all, they got about the same number of questions correct and worked their way through the questionnaire in only 6 minutes (compared to an 8-minute average). So in this case it turns out that both stereotypes have good qualities going for them. Secretaries are efficient. But it isn't always the case that stereotypes are positive.



Colophon

Our look is the result of reader comments, our own experimentation, and feedback from distribution channels. Distinctive covers complement our distinctive approach to technical topics, breathing personality and life into potentially dry subjects.

The tool on the cover of *Mind Hacks* is an incandescent light bulb. While many assume that Thomas Alva Edison invented the light bulb in 1879, Edison's actual achievement was to advance the design of the light bulb from a patent he purchased in 1875 from Canadian inventors Henry Woodward and Matthew Evans. Edison's improvement was to place a carbon filament in a vacuum bulb, which then burned for 40 hours. An English chemist, Humphrey Davy, invented the first electric light-an arc lamp-by connecting two wires to a battery and attaching a strip of charcoal in the middle of the circuit. Other inventors continued to make various incremental improvements in such areas as the filaments and the process for creating a vacuum in the bulb, but in 1879, Edison developed a triple threat: a carbon filament, lower voltage, and an improved vacuum in the bulb.

In 1882, Pearl Street Station, in New York City, was the first central electricity-generating station constructed to support the light bulb invention. Although the alternating-current method of generating electricity proposed by Nikola Tesla proved to be the superior technical solution, Edison was engaged in a battle for control of America's electric infrastructure. Edison declared that his direct current system was safe and that alternating current was a deadly menace.

But in 1893, when alternating current was used at the Chicago World's Fair to light 100,000 incandescent lightbulbs, the nearly 27 million people who attended the Columbian Exposition saw the safe and impressive demonstration of that technology. The event signaled the demise of direct current systems in the United States.

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Team LiB PREVIOUS NEXT

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