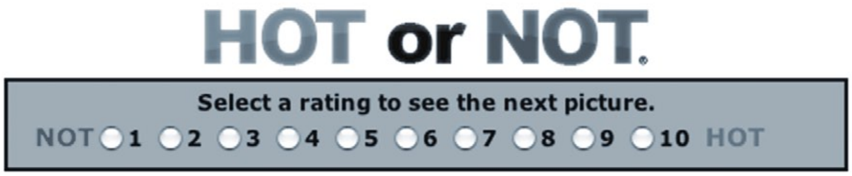
Knowing What You Like

By Marcus Woo

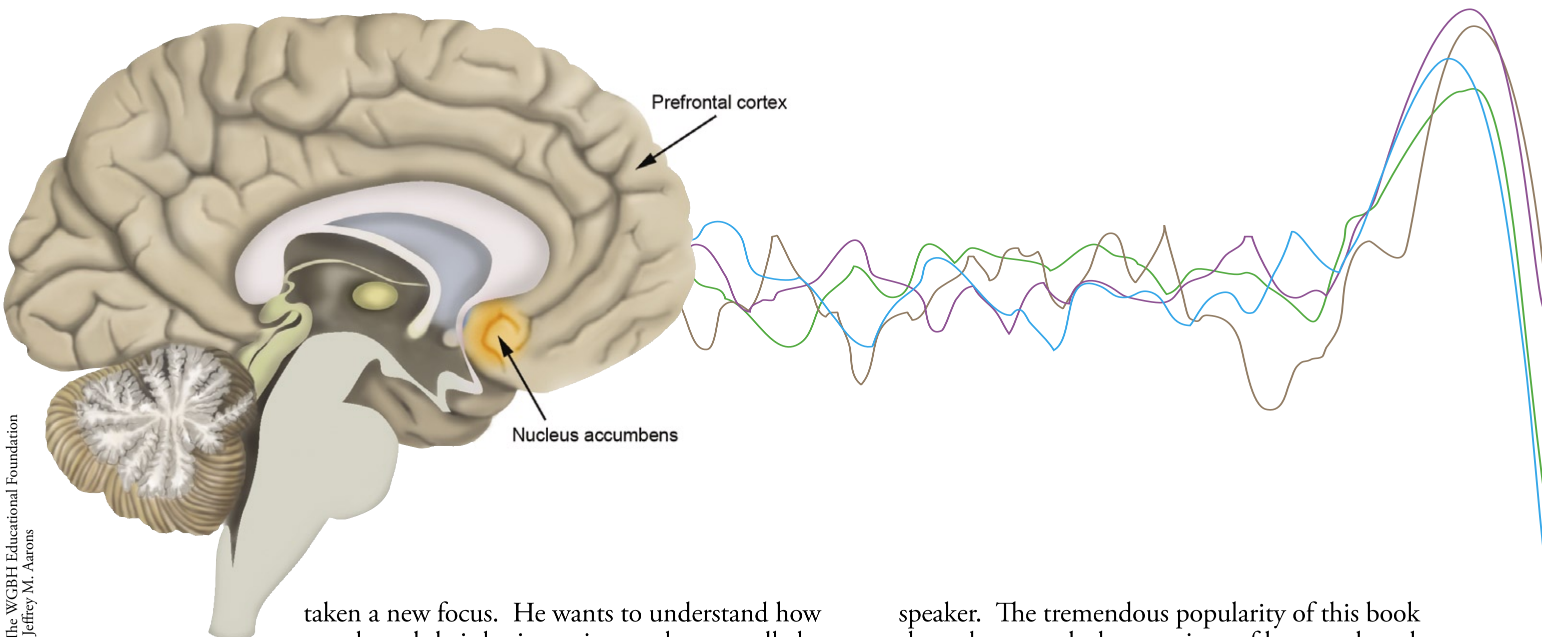


The site is simple, but it can be addictive. Picture after picture of people and faces offer themselves for your honest judgment. With a click of the mouse, you can rate the attractiveness of strangers on a scale from one to ten. Immensely popular when it first hit the Web in 2000, hotornot.com lets anyone upload photos of themselves to find out, based on ratings from thousands of Web surfers, how good-looking they are. Motivated by curiosity or an ill-conceived bet, you may even have put up your own picture. If not, you may have at least perused the site, clicking away. He's a nine, you may have said. She's a six. This other one was more of a seven, you think. You know the site is nothing more than silly fun, pandering to vanity and superficial beauty. But underneath this playful clicking between you and the pictures, something subtler is going on.

How did you decide to rate the second face higher than the first? You pause and think. You liked the gentle slope of her nose, you say. Or maybe it was her wispy eyebrows. Either way, you are confident in your rationale. You made a conscious choice supported on reasonable grounds. But did you really?

It turns out the latest developments in psychology, cognitive science, and neuroscience suggest otherwise. In fact, Professor of Biology Shinsuke Shimojo's lab is showing that your body and brain may already be making decisions before you are even aware of them. Through a series of diverse experiments, including one similar to the exercise offered by hotornot.com, Shimojo and his colleagues are finding that the unconscious behavior of the mind and body may significantly determine how people end up choosing what they like. "Your body persuades your mind," Shimojo says. "It's almost as though your body decides before your mind does."

Shimojo's lab does a variety of research in psychology, cognitive science, and neuroscience. In the last few years, however, his interests have



The squiggly lines emanating from this cross section of the brain represent electrical activity, which is measured with electroencephalography (EEG).

taken a new focus. He wants to understand how people and their brains arrive at what are called emotional and preference decisions. People make these choices daily: whether to have soup or salad, or whether to watch *The Simpsons* or the evening news. These decisions rarely have a right or wrong answer, and are often innocuous. But at the same time, they help define people as individuals—and as human beings.

The lab is attacking the problem from many directions, including an experiment in which subjects are asked to choose the better looking of two faces. By tracking their eye movements, the researchers are discovering that the quick, instinctive movements of the eyes substantially influence the subject's eventual decision. Additionally, the advent of noninvasive technologies to monitor the brain allows scientists to zoom inside the cranium to dissect the neural mechanism behind preference decision making. Shimojo's lab, in collaboration with Associate Professor of Psychology John O'Doherty's lab, is also developing techniques to train people to activate or suppress specific areas of their brain. It may sound like brainwashing, but it is not. Researchers call it neural conditioning, and it requires the subject's willing cooperation for it to work. As such, it is far from any sort of mind control—but the process is provocative, a kind of high-risk and high-reward research with potentially powerful clinical and scientific applications.

I don't think, therefore I decide

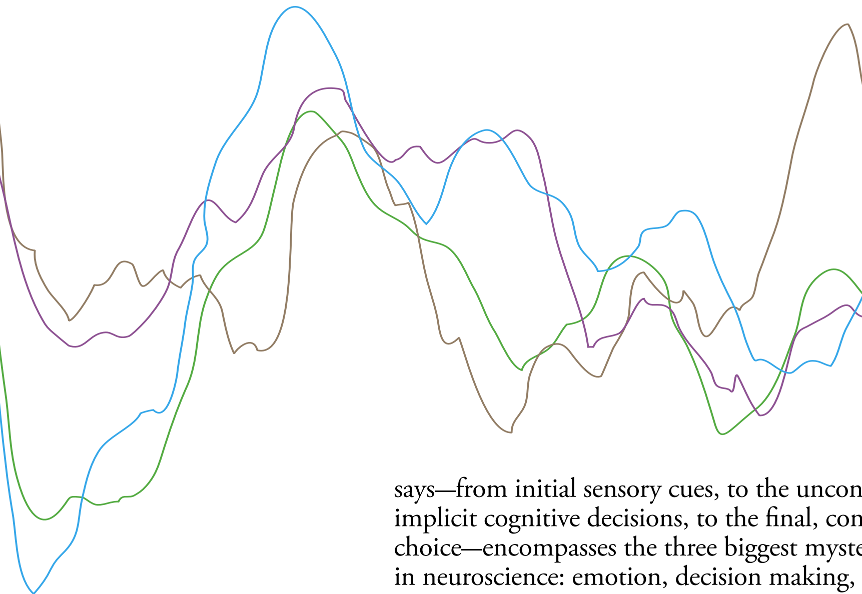
In 2005, Malcolm Gladwell published *Blink: The Power of Thinking Without Thinking*, a book about the power of first impressions in making decisions. Occupying best-seller lists for months, the book has been translated into 25 languages and propelled Gladwell to prominence. He was named one of *Time* magazine's 100 Most Influential People and has enjoyed a lucrative second career as a public speaker. The tremendous popularity of this book shows how much the questions of human thought and decision making fascinate the public. After all, Shimojo says, understanding how people make decisions—and especially preference decisions—is relevant to everyone.

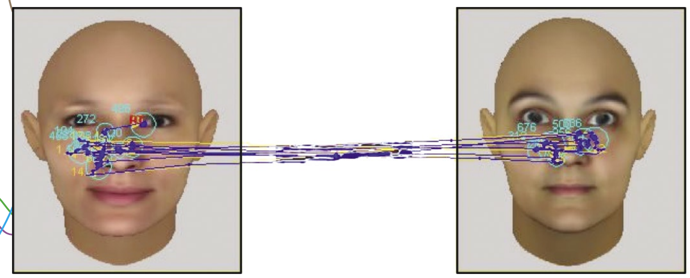
Although these decisions are common, it is still a mystery how the body and brain work together to make them, he says. "Everybody's doing this every day without effort, like when you go to the shop and buy something, or when you go to the cafeteria and choose what you want to eat," he says. But the reasons people give for buying that pair of shoes, ordering that turkey sandwich—or choosing an attractive face—are not necessarily the whole truth, and might even have been invented after the fact, Shimojo says.

Many other factors—many of which happen unconsciously—influence the decision-making process. A classic example is the "mere exposure effect": repeated exposures influence people to choose the more familiar object. Advertising agencies take advantage of this psychological effect. For example, when choosing between a well-advertised product—say, a bar of Dove soap—and a largely unknown, generic brand, people will tend to opt for the known brand. But when asked why they chose that particular bar of soap, people might say they preferred the packaging or that it was cheaper. They are not aware that exposure may have played the biggest part in their choice.

Shimojo describes a psychology experiment in which male college students were asked to rate sexy photos of women. They were then allowed to take one of the pictures home. Although the subjects were not aware, the gift was part of the experiment, and it turned out they often did not choose the photos they claimed they preferred. "There are lots of studies similar to this kind of experiment," Shimojo says. "It turns out people's behavior often betrays their conscious cognition."

Understanding the entire process, Shimojo





Eye-tracking data overlayed on the faces the subject is choosing between. Lines trace the eye movements and numbers indicate how many milliseconds the eyes lingers over a certain spot.

says—from initial sensory cues, to the unconscious, implicit cognitive decisions, to the final, conscious choice—encompasses the three biggest mysteries in neuroscience: emotion, decision making, and consciousness. All three come into play, whether you are choosing a sandwich for lunch or choosing a mate to marry, and all three drive the lab's work.

Even when he was young, Shimojo was captivated by perception and how it relates to the mind. He would sometimes squint at the patterns on the ceiling in search of a stereogram, one of those optical tricks in which an embedded three-dimensional image pops out. He wanted to study how people perceive reality. "I became interested in my own mind," he says.

Fascinated with the mind, he studied experimental psychology and neuroscience. For much of his career, he focused on visual perception, and his lab has traditionally focused on psychophysics, the branch of psychology that deals with how people interpret what they see, hear, feel, smell, and taste. Lab researchers are still involved with sensory perception—including the development of perception and cognition in infants. Meanwhile, Shimojo is applying many of the techniques he developed in his earlier work toward understanding preference decision making. One such method tracks eye movements. The eyes, after all, are like windows into the mind, Shimojo says. In this experiment, the test subject wears a head brace fitted with small cameras that monitor every eye twitch. Tracking their eyes' movements while people pick pretty faces, Shimojo and his colleagues discovered beauty might literally be in the eye of the beholder.

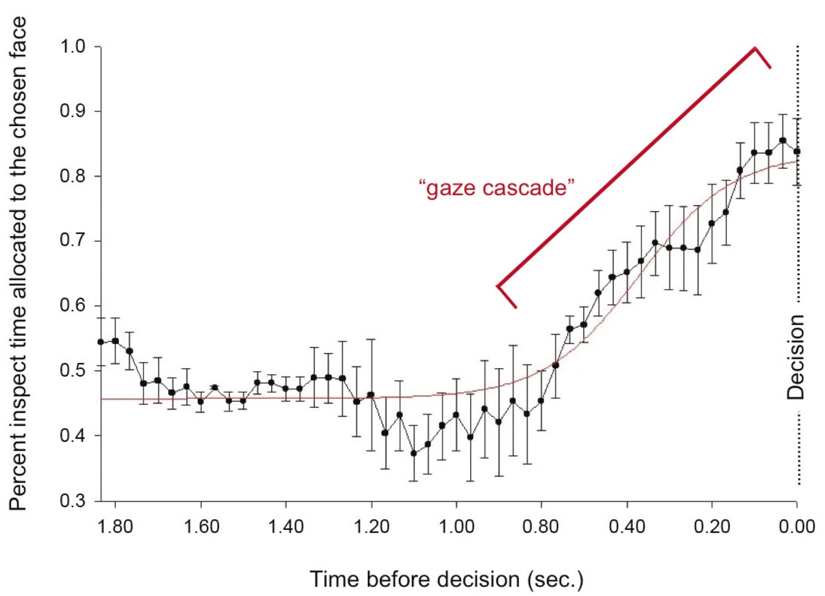
Yasuki Noguchi, visitor in biology, wears the eye-tracking device while comparing two faces.

Going face to face

Two faces, floating side by side on the computer screen, stare back at the subject. The eye-tracking headgear records the subject's eye positions 30 times per second. Meanwhile, the subject takes as much time as needed to pick out the more attractive face. Then he or she pushes a button to mark the decision. Shimojo, Claudiu Simion (BS '99, PhD '05), and their colleagues found that before people pushed the button, their eyes fell on the chosen faces more frequently than the rejected faces. Furthermore, the likelihood that their eyes would be directed at the preferred face increased as the subject neared the time of decision.

What's going on, the researchers say, may be partly a version of the mere exposure effect, in which greater exposure—such as seeing more commercials for a brand of soap—increases preference. In what they call the gaze cascade effect, the more someone looks at a face, the more he or she wants to look at it. As a result, the subject will look at that face even more, causing a rapidly rising probability that he or she will be looking at the selected face before the conscious, final decision (see the figure on the following page). But while the mere exposure effect is the result of passive behavior, the gaze cascade effect involves active and spontaneous eye movements.

Of course, there could be alternative explanations. Having already made up their mind, perhaps people lock in on the chosen face to confirm their decision. But when the researchers performed



This plot, called a likelihood curve, illustrates the gaze cascade effect. The probability of the subjects' eyes falling on the eventually chosen face rises as the subject nears the time of decision. Researchers recorded whether the subject was looking at the chosen face or not, assigning a value of one or zero. They then averaged these values over all five subjects and trials to arrive at the likelihood.

a control test, in which they asked subjects to choose which face they thought was rounder, they found different behavior. The likelihood that the subject's eyes fell on the chosen face started off at random chance, at around 50 percent, and started to rise. For the roundness test, the likelihood leveled off at 60 percent. But in the attractiveness case, the likelihood continued to increase until the moment of decision, eventually reaching more than 80 percent. If the gaze cascade effect was just the result of people focusing in on their choices, then the effect should be similar regardless of whether they were asked to choose the rounder or more attractive face.

The case was strengthened when the researchers found they could influence the subjects' choices by manipulating the gaze—by limiting how long subjects could look at the faces. In this experiment, only one face appeared, alternating between the left and right sides of the screen. Each repetition lasted either 900 or 300 milliseconds, and afterward, the subjects had to choose the most attractive face. In trials with six or more repetitions, the subjects chose the faces that appeared longer 60 percent of the time; a longer gaze seemed to cause a preferred choice.

The key factor, however, is not just the length of time, but also the active eye movements of the gaze itself. When the subjects were told to keep their eyes on the center of the screen, there was no preference bias toward the face shown for a longer time. This happened both when the faces appeared at the sides and in the middle of the screen. The researchers were unable to influence the subjects' choices, implying that the eye movements affect decision making. The researchers were also unable to manipulate the gaze cascade effect in the roundness test. These various lines of evidence lead to a conclusion that the gaze cascade effect is likely unique to preference decisions.

Furthermore, the effect probably happens for all preference decisions. For example, the same gaze cascade appeared when subjects had to choose their favorite geometric shapes. Another factor researchers tested for was novelty, since the gaze effect might only happen when people see faces for the first time. To test this, the team inserted a single-day delay, showing subjects the same face pairings as they did two days earlier. In nearly a quarter of the trials, the subjects changed their minds about which face they thought was more attractive, which itself was not too surprising, since people change their minds all the time. What was surprising was that all cases showed the same gaze cascade behavior, offering persuasive evidence that the gaze cascade effect is an intrinsic part of the decision-making process.

Without your consciously telling them to, your eyes scan your surroundings in rapid leaps called saccades, quickly gathering information as they move several times per second. Called orienting, this behavior also happens in response to something that grabs your attention, such as a flash of light. The evolutionary advantage of orienting is obvious, as it is crucial for basic survival tasks like finding food and avoiding predators. But researchers say orienting has also been shown to be the basis of higher-level brain functions such as decision making, and it certainly seems to be the case with this experiment.

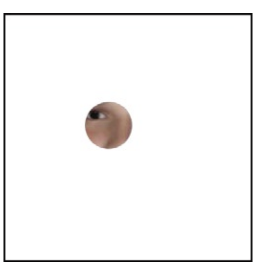
According to Shimojo and his team, the spontaneous movements of the eyes work in concert with more deliberate, cognitive tasks to make the final choice. Consistent with this idea, the researchers found a stronger gaze cascade effect when subjects had to choose between similarly attractive faces. When figuring out whether Angelina Jolie looks better than a troll, the cognitive part of your brain can handle most of the decision making without relying too much on the gaze cascade effect. But when forced to make a harder decision, say comparing Brad Pitt and George Clooney, the instinctual movements of the eyes contribute more to the decision process.

The researchers now seemed to have established a reasonable, albeit counterintuitive, model of preference decision making. But of course, as in all scientific pursuits, many questions remained.

More evidence

When you look at a face, you usually see the face as a whole. Unless the person has some odd feature, like a giant nose or cross-eyes, you do not

Choosing between Angelina Jolie and a troll; Brad Pitt and George Clooney.



In the peephole experiment, a subject only sees a small part of a face when evaluating its attractiveness.

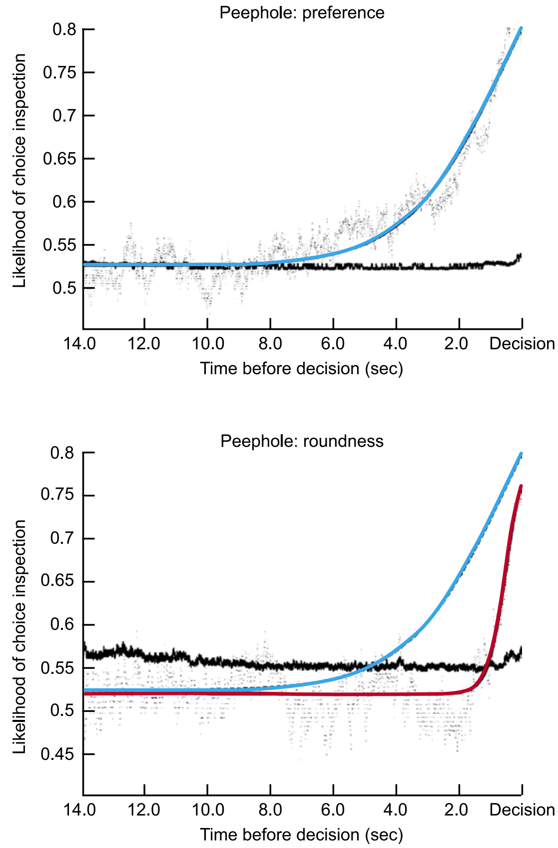
focus on specific parts of the face. This kind of overall perception is called holistic, and analyzing a face is known to be among the most holistic exercises in human perception, Shimojo says. The implication, then, is that the holistic nature of face preference might be connected to the gaze cascade effect. According to Shimojo, if the researchers could somehow remove the holistic aspect—that is, if they could force the subject to focus in on specific parts of the face—then maybe the gaze cascade effect would disappear.

In their next experiment, the researchers only allowed a small circular patch of each face to be visible. The patch followed the direction of the eye, so that the subject could only see a single facial feature, such as an eye or a nose, at a given time. The subjects were forced to evaluate the face through what amounted to a peephole on the computer screen. What the researchers discovered was unexpected.

"We got a big bonus—a big finding," Shimojo says. Not only was the gaze cascade effect present, which meant a holistic evaluation of the face was not needed for the cascade behavior to happen, but it started early. The likelihood of looking at the chosen face was already beginning to rise eight seconds before the button was pushed. By limiting the amount of information available to the subjects, the peephole forced them to take more time in creating a mental image of the faces before making their decisions. The gaze cascade effect was stretched in time. The presence of the effect was not too surprising, but the fact that the effect was present so early invalidates a common model of decision making, Shimojo says.

Many in the field have traditionally thought of decision making as a series of steps, in what is called the sequential box model. In this model, for example, the brain might undergo the following steps: (1) identify individual facial features, (2) integrate the features together to paint a picture of the entire face, (3) incorporate memory and experience to help evaluate how good it looks, (4) respond emotionally, (5) tell the finger to press the button. In this model, Shimojo says, each step has to be completed before the next. The early appearance of the gaze cascade effect shows the decision-making process already started even while the eyes and brain were still collecting sensory information on particular facial features. "This really requires people to change their philosophy on how they look at the brain," Shimojo says.

Furthermore, the differences between the attractiveness and roundness tests further convinced Shimojo and his colleauges that the gaze effect is not just a result of subjects locking in on their chosen faces. For the attractiveness test, the gaze cascade effect began eight seconds before decision. For the roundness test, the likelihood did not start rising until less than one second before decision (see figure on the right). The researchers argue this difference rebuts the alternative explanation of a selection bias,

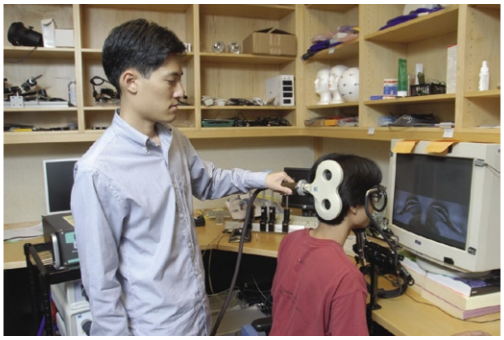


From Simion and Shimojo, *Vision Research*, vol. 46, no. 20, pp. 3331-5, 2006.

The likelihood curves (colored lines) from the peephole experiment show that the gaze cascade effect begins a lot earlier for the attractiveness test (top) than for the roundness test (bottom). The gaze cascade starts when the likelihood curve crosses the black line, which is called the significance threshold. The curve for the attractiveness test (blue) is superimposed on the roundness-test plot for comparison.

in which subjects dwell on the chosen face—regardless of whether they were asked to choose the rounder or more attractive one. Otherwise, both experiments should have shown the same effect.

The researchers next wanted to know what would happen if they interrupted the gaze cascade effect. Namely, what would happen if the pictures of faces suddenly disappeared while the subjects were still evaluating them? In this experiment, the images disappeared at random times. Even if the faces vanished before the button was pressed, the subject still had to make a decision—only now with a blank screen. The data was split into two categories: trials when subjects decided before the faces disappeared, and trials when subjects decided after the faces disappeared. In the late-decision trials, when decisions were made after the faces vanished, the data still showed a gaze cascade effect. In other words, people were still looking at the location where their preferred face had been, even though it was now empty. Since there was no



Above: Postdoc Daw-An Wu demonstrates how to induce electrical activity in graduate student Neil Halelamien's brain with transcranial magnetic stimulation. Right: A subject being prepared to undergo an MRI brain scan.

reason for people to gaze at the chosen faces, the researchers concluded the gaze cascade effect had to happen in order for people to make their decisions. It is an unavoidable and inevitable part of preference decision making, Shimojo says.

This experiment also refuted another alternative explanation: people like to look at pretty faces, and will keep on looking at their favorite face. But in the early-decision trials, people stopped looking at their preferred face after they made their decision, even though it was still there. The allure of an attractive face was not strong enough to induce this phenomenon.

The results were also consistent with an idea in perception psychology that the location of an object in your field of view is tied in with what you perceive to be more attractive. In the experiment, when they had to decide after the face disappeared, people still looked at the empty area on the screen formerly occupied by the more attractive face. The possible implication is that preferences and judgments of attractiveness depend on where the face is in your field of view.

A nagging question, however, is whether the gaze caused the decision or vice versa. In other words, which came first, the decision or the gaze? The answer is likely neither, Shimojo says. The brain might have made an internal decision long before it told the finger to press the button, and even before the gaze cascade effect started. But Shimojo does not see a way in which anyone can define and measure the precise moment a choice is made. For practical and scientific purposes, the act of pressing a button is the best marker of a decision, and he says he doubts there is a singular, decision-making moment. He likens it to a snowball rolling down the hill. The snowball of decision making keeps on growing as the gaze bias increases. Then, after passing a certain threshold, you become aware of your decision and you press the button. "It offers you a different view of decision making," Shimojo says. "In daily life, you naively expect decision making to be one moment. We're saying it's spreading over time, and that it involves the body."

An array of experiments

This work in preference decision making is still relatively new, and researchers are in the middle of an array of experiments. Scientists are probing whether an analogy of the gaze cascade effect happens with senses other than vision. Postdoc Junghyun Park is beginning a set of experiments in which blindfolded subjects touch two surfaces and decide which one they like better. He is now analyzing the data.

Park, in collaboration with biology researcher Eiko Shimojo and other lab members, is also exploring the role of familiarity versus novelty in preference decision making. People often like new things: new cell phones, new movies, new books. But people sometimes prefer the familiar: old friends, childhood photographs, and TV reruns. The researchers' preliminary studies involve images of natural landscapes and geometric shapes, in addition to faces. By incorporating videos into similar kinds of experiments, the scientists also want to uncover the mysteries of channel surfing—how do people decide what they like to watch? Additionally, the researchers are beginning experiments with animals, which would allow for a more detailed and deeper analysis of how the brain regulates the mind and body.

High-tech tools

Recent technological advances have led to a surge of research on the human brain over the last 10 to 15 years, according to Shimojo. "One of the biggest triumphs in the field is that now we're capable of playing with the human brain," he says. Armed with noninvasive techniques, scientists can probe the human brain without having to stick it with electrodes or crack the skull open. Functional magnetic resonance imaging, or fMRI, pinpoints particular parts of the brain that are activated during different tasks and processes. Electroencephalography, or EEG, can measure quick changes in electrical brain activity, and transcranial magnetic stimulation, or TMS, uses rapidly changing magnetic fields to induce electrical activity in the brain, allowing researchers to activate, inhibit, and study specific parts of the brain.

Founded in 2003, Caltech's Brain Imaging Center resides inside the stainless steel and travertine outer walls of the Broad Center for the Biological Sciences. The fMRI machine lives in the basement, where bright yellow signs greet you with ominous warnings of strong magnetic fields. And they are strong magnetic fields indeed—the scanner creates a field strength of three teslas, nearly 50,000 times stronger than Earth's. The scanner, which occupies its own room, consists of a tube just big enough for a person to lie in. The subject lies down and a motor slides the person into the tube, where the magnetic field forces atomic nuclei in the body to align in one direction. Nuclei, which are positively charged, naturally spin on their axes, giving them magnetic poles. As a result, they act like tiny compass needles. The device then shoots radio-frequency waves to knock the nuclei off their alignment. When a nucleus returns to its resting state and realigns with the magnetic field, it emits

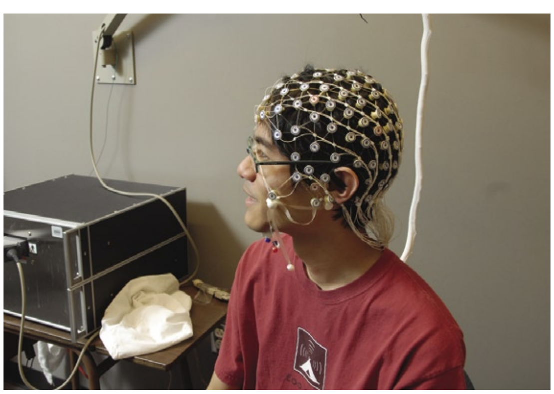
While technology has enabled scientists to observe the brain in action, Shimojo's lab is now trying to manipulate brain activity not with fancy machines, but with thinking.

another radio signal that betrays its location. Oxygen nuclei are susceptible to this phenomenon, and active brain regions use lots of oxygen. However, the technique is only a secondary way of measuring brain activity, and the several-second delay between neural activity and signal detection does not help.

A postdoc in O'Doherty's lab, Hackjin Kim also collaborates with Shimojo. Along with Bren Professor of Psychology and Neuroscience and professor of biology Ralph Adolphs, Kim, O'Doherty, and Shimojo have used fMRI to analyze the parts of the brain that light up when a person gets a reward. Kim, Shimojo, and O'Doherty recently found that avoiding a bad outcome activates the same brain area as receiving a reward. For example, saving an ice cream cone from falling on the ground and getting one for free may both lead to the same neurological response ("Woohoo!" says the brain). Knowing how the brain responds to rewards is crucial for understanding how people make decisions, since reward—or avoiding something bad—drives many choices.

Most recently, Kim, Adolphs, O'Doherty, and Shimojo applied fMRI to the problem of face preference. Instead of tracking eye movements, they tracked brain activity. By only flashing glimpses of each face, the researchers were able to limit the exposure time for the subjects, isolating the brain responses involved in decision making. For the first time, researchers were able to identify brain activity—in the nucleus accumbens and the orbital frontal cortex—at different stages of the preference decision-making process. They found that the nucleus accumbens, a region at the base of the brain known to be involved with rewards and addiction, was activated earlier. The orbital frontal cortex, which is responsible for emotions and decision making, was activated later in the decision-making process. This suggests that in preference decisions, at least, people use the nucleus accumbens for quick, intuitive decisions or making first impressions, while they use the orbital frontal cortex for more analytical or complex decisions, according to Kim. People also use the orbital frontal cortex to learn and store information relevant for future decisions, he says.

Additionally, the lab is conducting experiments with TMS and EEG. In one TMS experiment, researchers are stimulating the visual cortex to learn how the brain interprets what people see. With its ability to measure rapid changes in brain activity, EEG gives the scientists another tool to study the unconscious processes behind preference decision making. While technology has enabled scientists to observe the brain in action, Shimojo's lab is now trying to manipulate brain activity not with fancy machines, but with thinking.



Taking an EEG. Graduate student Neil Halelamien wears a cap of electrodes that measure electrical brain activity.

Make a quick buck without lifting a finger

The researchers are training people to focus their thoughts and manipulate their own brains. They are using the same techniques that animal trainers use to teach dolphins to jump through hoops. But you don't have to worry about mad scientists brainwashing subjects into becoming slaves. Called neural conditioning, the method is about activating or suppressing specific parts of the brain—not controlling them against the person's will. In fact, the process would not be possible without the subject's cooperation. The ultimate goal, Shimojo says, is to provide scientists with a powerful, noninvasive neurological tool. TMS, for instance, can activate some neurons, but cannot reach into deep places like the orbital frontal cortex, which resides behind the eyes. Right now, scientists do not have a way to noninvasively manipulate different parts of the human brain on demand, Shimojo says. "This neural conditioning technique may be the wild card in this regard," he says.

Graduate student Signe Bray, Shimojo, and O'Doherty have succeeded in conditioning some regions of the brain responsible for movement, such as wiggling fingers and toes. The researchers used fMRI to monitor brain activity and trained subjects with a reward. But instead of a tasty piece of fish, they gave them money. Subjects who successfully activated the relevant brain areas—without actually moving fingers or toes—were awarded a dollar. Scientists had tried other biological conditioning methods before, but those required that subjects have visual feedback; by watching a pulse monitor, for example, a person could slow or speed up heart rate. But in this experiment, subjects shaped their neural activity with only monetary motivation.

"What's exciting is the potential," Bray says. "What we've done is an initial demonstration. But we're really excited about the future applications." Now the researchers want to explore more sophisticated brain functions. For the next step, the researchers are applying the same conditioning techniques to the orbital frontal cortex, which Shimojo calls the core of emotional decision making. In the future, he hopes to conduct the following experiment: the subject would activate or suppress a part of the orbital frontal cortex while choosing the more attractive of two faces. From analyzing what happens, scientists could, in principle, figure out the neural mechanisms involved in the choice. "Of course, it may not be that easy," Shimojo says. "Not all areas of the brain can be conditioned—that's our suspicion now. But it might be possible."

In addition to providing insight into how the brain learns and a powerful research technique for neuroscience, neural conditioning could have numerous clinical applications. Direct manipulation of specific brain areas could help treat depression, people with nerve and spinal injuries, stroke patients, addiction, and pain. But at present, Shimojo still calls it a dream scenario, as he, Bray, and O'Doherty have only just begun this line of research. "No one has done this kind of conditioning experiment with fMRI before," he says.

A researcher inspects brain images taken with the MRI machine.

The brain vs. the mind

As a teenager in Japan, Shimojo would gaze into the sky, lost in thought over what he saw. He knew the sky was just empty air, thinning out as it extended deep into space. But at the same time, he could also interpret the image before his eyes as a smooth, blue surface at a finite distance, a sky he could reach up and touch. Shimojo was fascinated with how perception reflected reality, and how the mind works. "My original motivation—even as a teenager—was to solve the mystery of the mind," he says. But while he was captivated by the philosophy and psychology of the mind, he wanted as complete and rigorous an understanding as possible. "I decided that the religious approach is not satisfactory, and the classical psychology approach, which treats the brain as a black box, and you try not to open it, is also not satisfactory."

His lab brings together two traditionally separate ways of doing neuroscience: treating the brain purely as a biological organ, and studying it in the context of human consciousness and experience. Shimojo distinguishes the brain from the mind; the brain is where complex biochemical reactions take place, while the mind incorporates thought, consciousness, and emotion. The lab tries to investigate the brain without neglecting the mind, and vice versa, he says. "If you think about human minds, it's indeed the interaction between this hidden implicit part of the mind and the conscious part of the mind," he says. "If you understand the relationship between them, then that's the full understanding."

Many neuroscientists were originally interested in questions of the mind, Shimojo says. But to avoid the uncertainties and fuzziness of human thought, they sought more objective research by staying within the confines of the brain's biological mechanics. Studying brain chemistry or the rat's neural system was more cut-and-dried, possibly with more definitive results—even though these studies did not always address questions of the mind. Now, Shimojo says, the field has developed and is finally mature enough for scientists to rigorously answer the challenging questions of the mind. With the lab's diverse work as Exhibit A, research into preference decision making—and the mind in general—has taken off in many directions. "I really feel fortunate because it's such a rich and vivid field," he says.

You might even say the field is hot. □

PICTURE CREDITS: 27, 30, 31 — Bob Paz; 25, 29 — Doug Cummings; 30, 32 — Caltech Brain Imaging Center; 32 — NASA/JSC; 26, 27, 28, 29 — Shimojo lab