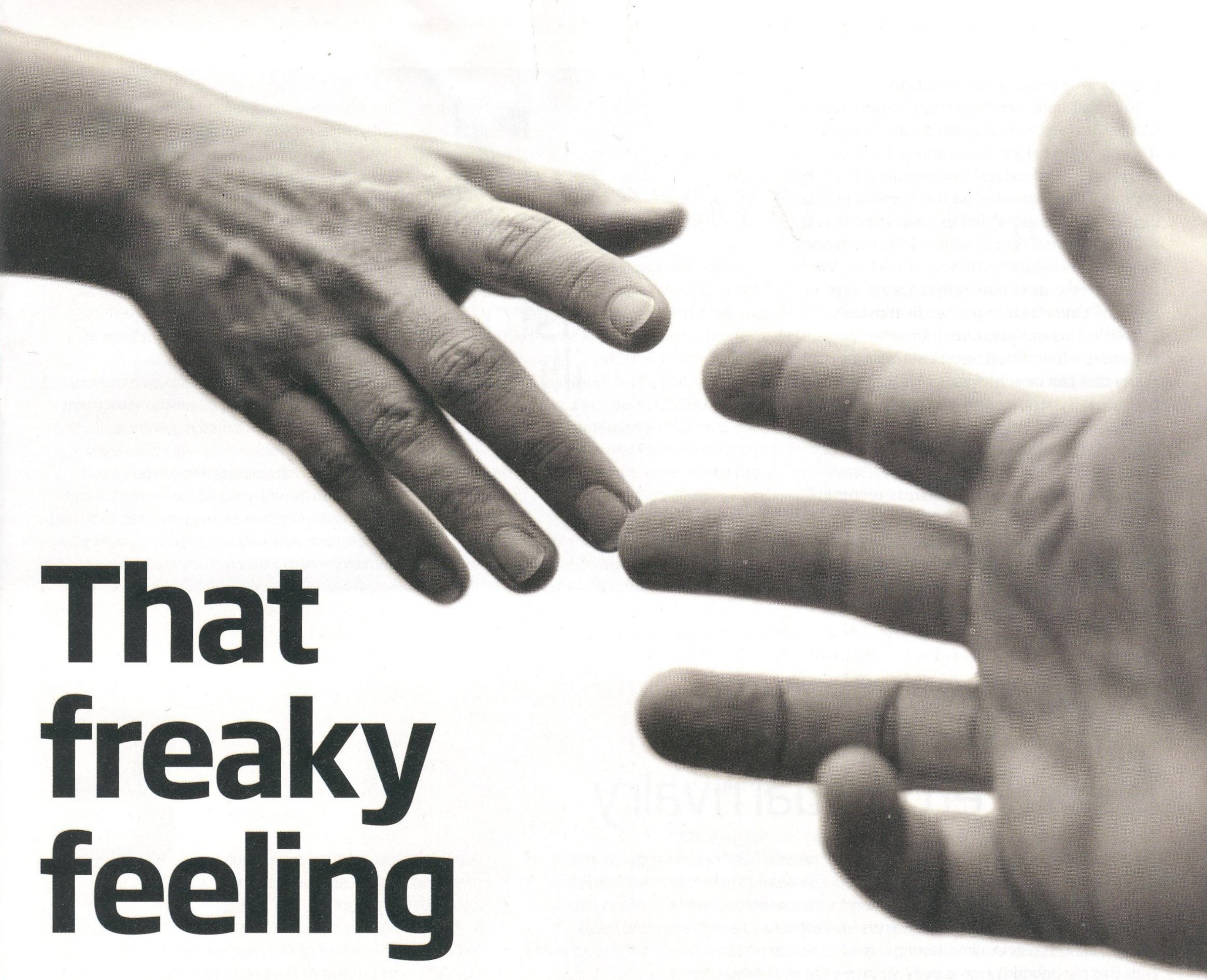


That freaky feeling

It's surprisingly easy for your body to fool your brain. **Graham Lawton** puts his sense of touch to the test

RIC KALLAHER/SOLUS-VEER/CORBIS

IMAGINE you are lying in the bath with your toes poking out of the water. A drip starts to form on the tap; you watch as it grows, then drops onto your big toe. Ooh! Not pleasant – but was the drip boiling hot or icy cold? It's impossible to tell.

What you just experienced was a tactile illusion – something psychologists are increasingly interested in. For at least 200 years, they have used visual and auditory illusions to uncover the inner workings of sensory perception. Now it is the turn of touch.

"There's a lot of interest in tactile illusions," says Vincent Hayward, an electrical engineer and haptics researcher at the Pierre and Marie Curie University in Paris, France. "Many people think of perception as vision, but clearly perception is a lot more. You have a very diverse sensory machine."

Some tactile illusions have been known for a long time – one is named after Aristotle – but in general they have been harder to discover and demonstrate than visual illusions. "Optical effects are easily probed. You can study vision with a piece of paper or make fundamental discoveries using a slide projector," says Hayward. "Tactile effects are not so easy."

Now that researchers have started to develop new ways to probe the sense of touch, however, tactile illusions are enjoying a golden age. "There has been a surge in the past few years as it has become easier to manipulate and present stimuli," says Charles Spence, an experimental psychologist at the University of Oxford. As a result, in recent years we have seen the discovery of numerous tactile illusions that are no less mind-boggling than their visual counterparts.

Another reason for the interest is the drive to add tactile or "haptic" interfaces to phones and other consumer devices. This has already been done to some extent. When you switch your phone to vibrate or play a video game with a rumbling controller, you are using haptic technology. The plan is to go beyond those elementary applications: for example, adding interfaces so that you can feel who is calling without taking your phone out of your pocket, or an MP3 player you can search by touch alone. There is also interest in designing interfaces that make it easy for › blind people to access information.

To make haptics work you need to understand tactile illusions, says Hayward. For one thing, if you want to deliver information by touch, you need to understand the limitations of the system. There's also the possibility that tactile illusions can be exploited to make haptics more effective. "There's a lot of interest in how much tactile information you can deliver via touch screens or vibrating interfaces," says Spence. "One way is to use tactile illusions."

Tactile illusions are often harder to experience that visual ones, but there are many that can be achieved with a little bit of care, perseverance and a few ordinary household items (*Brain Research Bulletin*, vol 75, p 742). "If you push perception into a corner it behaves in interesting ways," says Hayward. "There are many more to discover."

Graham Lawton is the deputy editor of *New Scientist*. Read about the freaky world of whole body illusions in next week's issue, on sale from Thursday 19 March

1 Aristotle illusion

One of the oldest tactile illusions is the Aristotle illusion. It is easy to perform. Cross your fingers, then touch a small spherical object such as a dried pea, and it feels like you are touching two peas. This also works if you touch your nose.

This is an example of what is called "perceptual disjunction". It arises because your brain has failed to take into account that you have crossed your fingers. Because the pea (or nose) touches the outside of both fingers at the same time - something that rarely happens - your brain interprets it as two separate objects.

A variation on the Aristotle illusion is to cross your fingers, close your eyes and then touch two different objects simultaneously - a piece of Blu Tack and a dried pea, say - one with each fingertip. You will need someone to guide your fingers onto the objects, and the illusion doesn't always work, but if you're lucky your sense of touch will tell you that the objects are the opposite way round from where they actually are. This is because

2 Perceptual rivalry

One of the newly discovered tactile illusions is called "tactile rivalry", a haptic version of a wider class of illusion called perceptual rivalry.

The best example of perceptual rivalry is the Necker cube, a simple line drawing of a 3D cube that can be interpreted as being viewed from slightly above or slightly below (see diagram, below). Stare at a Necker cube and the two interpretations spontaneously swap around in your mind's eye. This is visual rivalry, and it is thought to exist to allow your brain to make sense of ambiguous inputs: when there is no correct answer to the question "what am I looking at?" your brain tries one interpretation, then switches to the other.

Visual rivalry has been used to study vision for more than 200 years, but only recently has it become apparent that other senses do similar things. In 2006 French researchers discovered auditory rivalry, where a stream of electronic beeps can be interpreted in two different ways (listen at www.tinyurl.com/amaqux).

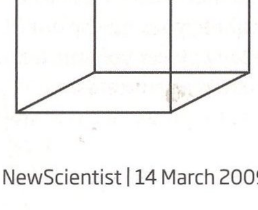
Now a touch equivalent has been discovered too. There is no tactile equivalent of the Necker cube, but there is for a similar illusion called visual apparent motion.

Imagine four dots arranged in a square, in which the dots in opposite corners flash on and off alternately (see diagram, or animation at www.tinyurl.com/659xcf). This creates the illusion of two dots moving either horizontally or vertically, or perhaps rotating around the corners of the square. As with the Necker cube, if you stare at it for long enough the motion spontaneously flips from one interpretation to another.

A team led by Christopher Moore at the McGovern Institute for Brain Research at the Massachusetts Institute of Technology recently discovered that the same thing happens with touch. Using a grid of tactile stimulators, they delivered a tactile equivalent of the four flashing dots onto volunteers' fingertips. Sure enough, the volunteers perceived the dots as moving either horizontally or vertically, and their perceptions spontaneously switched after a minute or so. In touch too, if the brain isn't sure what it is sensing, it avoids committing you to one interpretation or another (*Current Biology*, vol 18, p 1050).

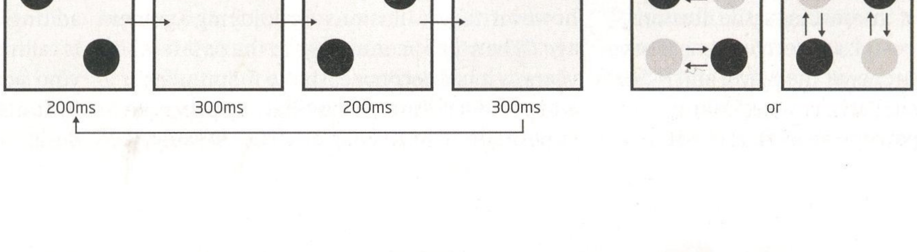
Necker cube

This classic visual illusion demonstrates "perceptual rivalry"



Visual apparent motion

When displayed on a screen, this illusion creates the impression of motion that doesn't exist. A direct tactile equivalent was recently discovered



your brain fails to correct for the fact that your fingers are crossed over.

There's also the reverse Aristotle illusion: cross your fingers and touch the inside of a corner of a room or a box. This time, because the wall is contacting the insides of your fingertips, you should feel one surface, not two. Some people even experience three.

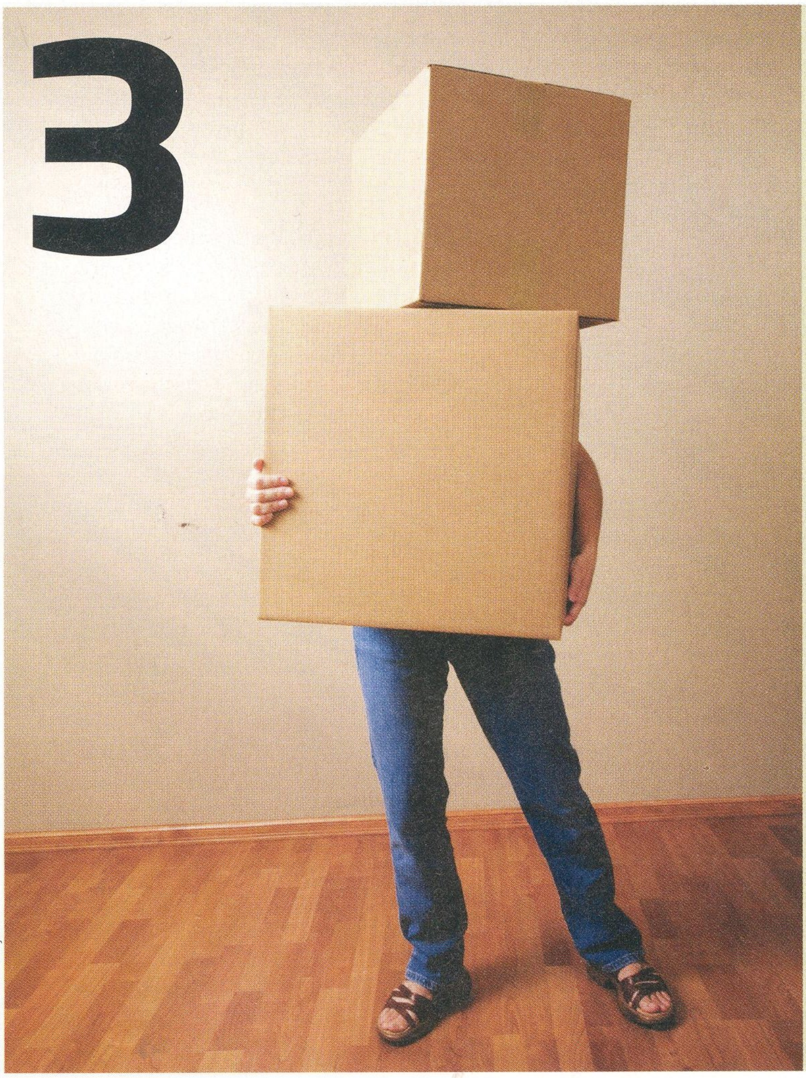
A similar effect can be achieved by holding your hands in front of you with palms down. Close your eyes and get somebody to lightly tap the back of both hands once, one after the other, with as short an interval as possible between the taps. Open your eyes and wave the hand that was tapped first. You'll get it right every time. Now do it again with crossed arms. If the taps are sufficiently close together - less than 300 milliseconds or so - you'll get it wrong a lot of the time.

This clearly has something to do with a failure to "remap" your body schema to take your crossed hands into account, but that can't be the whole story as single taps are easy to get right even with crossed hands. Neuroscientists think it happens because your brain is trying to do too many things at once: remap your body schema and also work out the order of the taps. The second task sometimes interferes with the remapping and causes it to fail (*Nature Neuroscience*, vol 4, p 759).

Amazingly, the illusion can also be made to work with sticks. Hold two wooden spoons out in front of you, one in each hand, with arms uncrossed, and get somebody to tap the ends of the spoons in quick succession. Again, you automatically know which stick was tapped first. But cross the spoons (not your arms) over and you'll get it wrong. Even more weirdly, if you cross your arms and the spoons, the two crossings-over cancel each other out and it again becomes obvious which one was tapped first (*Journal of Neurophysiology*, vol 93, p 2856).

Last year, Marc Egeth of the Children's Hospital of Philadelphia, Pennsylvania, reported a variant on this illusion. Stick your tongue out and turn it upside down (not everyone can do this), then run a finger along its top and bottom. It will feel as if your finger is touching a numb part of your tongue, while your tongue will register the touch on the opposite side from where it is being touched. Again, this is down to a failure to remap your body schema to take your unfamiliar tongue position into account (*Perception*, vol 37, p 1305).

Another simple tactile illusion relies on fooling your perception of distance. Take a paper clip, straighten it out, then bend it so that the tips are about a centimetre apart. Now close your eyes and run it from the tip of your index finger to your forearm via your palm and wrist. As you move the tips of the paper clip from an area of high acuity - your fingertip - to lower-acuity areas, it feels as if they are getting closer together, or even that only one end of the paper clip is touching your skin. This is because your forearms are less well set up for discerning fine structure than the tips of your fingers.



STEVEN RANISZEWSKI/JUPITER

3 Boxing clever

Here's one to try out on your family and friends. Get hold of two cardboard boxes of different sizes and put a brick in each one. Check they weigh the same, then get somebody to lift them and tell you which is the heavier. The vast majority of people will say that the smaller box is heavier, even though it isn't, and will continue to maintain that it is even after looking inside both boxes and lifting them several times.

This "perceptual size-weight illusion" is very robust. So much so that it works even if the smaller box is slightly lighter (*Journal of Neurophysiology*, vol 95, p 887). Even labelling two identical boxes "heavy" and "light" can pull the same trick.

The exact reason for these illusions remains a mystery. Curiously, experiments show that even though people initially use greater force to lift the larger box than the smaller one, on subsequent lifts they unconsciously equalise the amount of force they use to lift them. Despite their bodies apparently "knowing" that the boxes weigh the same, their minds still perceive the smaller box as being heavier.

Last year, J. Randall Flanagan of Queen's University in Kingston, Ontario, Canada, complicated matters further when he showed that we can unlearn the size-weight illusion. He got volunteers to spend several days manipulating boxes that became lighter the larger they were. At the end of the process he found that their size-weight illusion was reversed. They consistently judged the larger of two objects to be heavier even though they weighed the same (*Current Biology*, vol 18, p 1742). This is good evidence that the illusion arises out of experience of the world, where larger objects tend to weigh more than smaller objects of the same kind.

4 I feel it in my fingers

Your fingertips are among the most sensitive parts of your body, and this makes them surprisingly easy to fool. Take an ordinary comb and pencil and lay your index finger along the top of the comb, then run the pencil back and forth along the side of the teeth. Even though the teeth are moving from side to side in a wave-like motion, your finger will feel as if a raised dot is travelling up and down the comb.

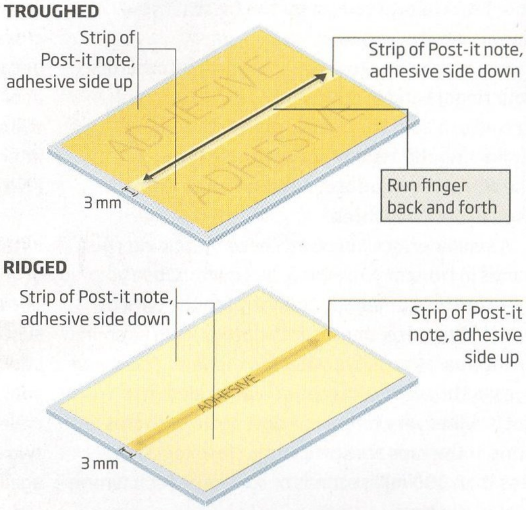
According to Hayward, this works because the unfamiliar motion of the teeth causes similar skin deformation to the more usual action of running your finger over a raised bump, so your brain interprets it that way.

Another way to fool your fingertips is to cut up a Post-it note and glue parts of it to the back of a card as shown in the diagrams (right). Now close your eyes and run your fingertip along the thin central strips. You will probably feel a raised ridge or depressed trough, even though the surface of the reassembled Post-it notes is perfectly flush. This illusion relies on the fact that your finger slides more freely along the non-sticky area, causing skin deformations that are exactly like those when touching a ridge or trough.

Your tongue is also very sensitive, and it can be fooled in a similar way. Take a fork and press the tip of your tongue between the prongs. You will feel as though the middle two prongs are bent out of shape. This is because the skin on your tongue is distorted in a way that doesn't normally happen, so your brain assumes that the prongs, not your tongue, are bent.

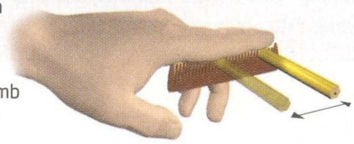
Ridge/trough illusion

By manipulating texture, a perfectly flush surface can be made to feel ridged or troughed



Comb illusion

The teeth move from side to side, but your finger interprets this as a small bump moving along the comb



5 Change numbness

One of the most striking visual illusions is change blindness – complete failure to spot changes to a scene that ought to be obvious. Show somebody two scenes that are identical in all but one feature – an airliner with and without its engines, for example – interspersed with a brief blank screen, and they will almost certainly fail to notice any change (see www.tinyurl.com/2f8p2a). We are also very bad at detecting gradual but major changes to static scenes, such as an imposingly large building fading into a cityscape (see www.tinyurl.com/aen625).

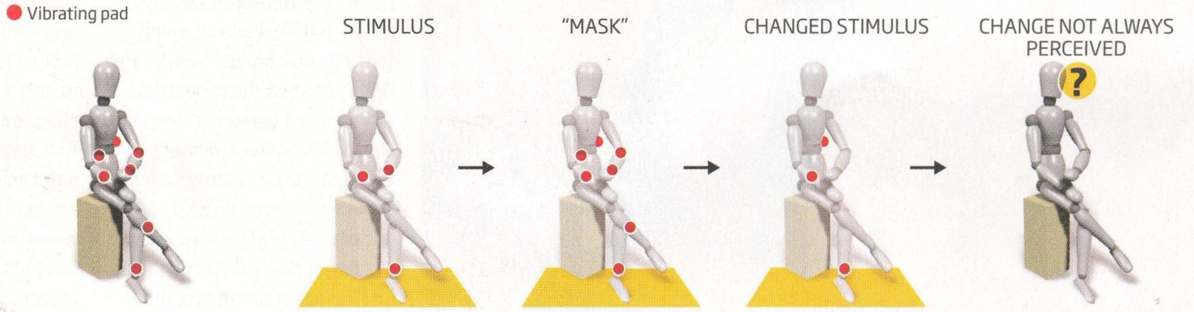
Change blindness happens because you have to be paying attention to a change to notice it. The brief blank screen acts as a mask that prevents the change from attracting your attention. Because gradual changes don't grab your attention, they too can go completely unnoticed.

If change blindness is hard to believe without experiencing it, the recently discovered tactile equivalent – change numbness – is even more so. Demonstrating it requires special equipment but, according to Hayward, it is "astonishing to those who experience it".

In 2006, Charles Spence of the University of Oxford and colleagues took a group of volunteers and attached vibrating resonators to seven widely spaced locations on their bodies (see diagram, below). They then buzzed two or three of the resonators simultaneously for 200 milliseconds, followed by a brief "mask" with all seven buzzing at once. Then they buzzed two or three again, sometimes changing the location of one of the stimuli. Around 30 per cent of the time volunteers failed to notice that the stimulus had changed.

Change numbness

People reliably notice when the location of a tactile stimlus changes – but a masking stimulus can hide the change



6 Motion after-effects

Another classic visual illusion is the waterfall illusion, which relies on a phenomenon called motion after-effect. After staring at a waterfall – or a similar moving-yet-static object such as a rotating spiral – anything you look at afterwards will appear to be in motion in the opposite direction. This is particularly spooky if you look at the back of your hand (see www.tinyurl.com/kb5de, for example).

It works because the visual neurons that fire in response to the motion get fatigued. When you look at something else, these neurons fail to fire – and your brain interprets that as movement in the opposite direction.

In 2000, Charles Dong of the University of British Columbia in Vancouver, Canada, reported an auditory equivalent. He found that after repeatedly listening to a sound source moving to the right, an identical but stationary sound appeared to be moving to the left (*Perception & Psychophysics*, vol 62, p 1099).

There is now a tactile version too. A team at the University of Tokyo in Japan devised a fingertip stimulator that repeatedly delivered a series of three brief buzzes, first near the tip of the finger then moving downwards towards the first joint. When they retested with an ambiguous sequence – the middle buzzer first, followed by both outer ones – the subjects reported feeling upward motion.

The tactile after-effect also happens when you get used to the feel of an object of one shape and then touch something of a different shape. You can experience this by either squeezing a basketball or pushing your palm into a large, shallow salad bowl for 20 seconds or so. If you then lay your hand on a flat surface, it will feel curved in the opposite direction.

Parchment skin 7

If you happen to have a chalkboard and some earplugs handy, try this out. Write something on the board, then rub it out and write it again wearing earplugs (or, better still, noise-cancelling headphones). The board will feel much smoother when you can't hear the chalk squeaking across its surface, even though it is the same board and the same chalk.

This is an example of a "cross-modal interaction": what you feel is strongly affected by what you hear. Another way of demonstrating this is to tap somebody's skin once while at the same time playing two or three closely spaced electronic beeps. They will feel two or three taps.

Other sensory domains also interact to create illusions. One of the best known is the McGurk effect, where listening to a string of identical syllables such as "ba ba ba ba" while watching someone mouth "ba da la va" makes you hear sounds that are not there (www.tinyurl.com/yprld7). Visual-auditory interaction works the other way too. If you show somebody a single flash on a computer screen accompanied by two beeps, they will usually report seeing two flashes (see www.tinyurl.com/yoo5qe).

In recent years, psychologists have discovered that the cross-modal interaction is particularly powerful between hearing and touch, perhaps because both senses perceive mechanical energy (*Behavioural Brain Research*, vol 196, p 145). One version discovered only recently is the parchment skin illusion, described by Veikko Jousmäki of Helsinki University of Technology in Finland.

He rigged up a microphone and got volunteers to rub the palms of their hands together next to it while feeding the sound of their rubbing into their ears via headphones. If he accentuated the high frequencies, people reported that their hands felt smooth and dry, like parchment. Damping down the high frequencies led to them feeling rougher and more moist. If you don't have the technology to dampen different frequencies at home, try rubbing your hands together while wearing earplugs. They should feel smoother (*Current Biology*, vol 8, p R190).

Something very similar was reported in 2005, when Charles Spence of the University of Oxford found that the perceived crispness of potato chips depends on how they sound when you bite them. Damp down the sound of crunching, or muffle the higher frequencies, and people report that the chips feel stale. You can experience this illusion with a bag of potato chips and some earplugs (*Journal of Sensory Studies*, vol 19, p 347).

Spence also found that the same rule applies to sparkling water and electric toothbrushes. Place a microphone in front of a glass of sparkling water, then pump up the volume or accentuate the high frequencies, and the water feels fizzier on your tongue. Electric toothbrushes can be made to feel smoother by damping down high-frequency sounds (*Journal of Dental Research*, vol 82, p 929).

BLEND/GETTY