ISSN 1754-3657 (Print)
ISSN 1754-3665 (Online)

CS4FN

Computer Science for Fun

Issue 5

Special Issue on

The Perception Deception

Computer Science Illusions

Face Off – Changing Faces the Computer Science Way

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How do I know you're telling the truth?

In this edition of cs4fn we look at illusions, how they work and their links to computer science. This area of science, like all of science, doesn't have all the correct answers. What science does is to give good answers that fit the current evidence. Of course how you put the evidence together and the conclusions you draw from them may change over time.

The coal and carrot mystery

Suppose you find, in a field, two small pieces of coal and a carrot close together. What happened here? From the evidence you might claim that in fact there had been a snowman in the field, with coal eyes and a carrot nose. The snowman had melted and this was all that was left. Your evidence supports the 'snowman hypothesis', a hypothesis being a posh Greek word for a suggested explanation. Now suppose someone else comes along, they look at the evidence and they come up with the 'two vans hypothesis' that it was caused by a coal truck passing the field and loosing two bits of coal, then a vegetable truck passing by and dropping a carrot. Which hypothesis is correct?

My hypothesis is better than yours!

Suppose now that you check the recent weather and find it was recently snowing there. That could give more clout to the 'snowman hypothesis', but equally well in the winter people need more coal for heat and carrots to make hot soup, so there would be more vans. That means the 'two van hypothesis' could still easily be correct. What's needed is an experiment to find some new evidence to separate the two hypotheses, and see which is better. An experiment is proposed: build a time machine (or create your own Primeval style anomaly) and go back and see what actually happened. That will settle things once and for all. But no! That's rejected: you can't find a police box big enough on the inside. So what next?

Sorry no can do, but how about....

Because of reasons like limitations in technology we can't do exactly the experiment we want so we have to come up with experiments we can do. Back in our field the 'find a truck track' experiment is proposed. If the 'two van hypothesis' is correct then it follows there should be evidence of van tyre tracks near by. An expedition is sent, but to ensure fair play they aren't told what to look for. If they did know they were after tyre tracks that could prejudice them. They might be trying so hard they mistake some other muddy pattern for tyre tracks. The team return with their new evidence. They found tyre tracks on the road just at the side of the field, over the hedge where no one had bothered to look before, and what's more there were bits of coal and carrots all over the place, and a 'beware rough road surface' sign. **Result!**

In this issue:

Victory is mine, or is it?

The ‘two van hypothesis’ works. It explains everything. Oh says the ‘snowman hypothesis’ camp, that’s not right. The kids who built the snowman came in a truck to the fields, and they had extra coal and carrots in their pockets and that fell out when they were getting out of the van shaking because they had been bounced by the bumpy road. At this point you’re probably thinking that sounds a bit silly.
Of course it could be true that there are untidy, traumatised, snowman building kids in vans, but probably it’s more likely that the ‘two van hypothesis’ is correct. You can’t be 100 per cent certain, though. Okay, so let\s try a new experiment why don’t we ….

We leave the field at this stage. It’s getting late and the two camps are still arguing away, coming up with more experiments, accumulating more data and evidence, following the scientific method.

Every illusion explanation in this edition needs to be considered in the light of the scientific method, as does every scientific result. What’s the evidence to support the claim? It is because science is built on an ever-increasing foundation of evidence that it is so powerful and is able to give us our understanding of the world around us today. It may have its limitations, and can never give answers with 100 per cent certainty. After all there may be some missing piece of the puzzle, but it has achieved some wonderful triumphs. But science never rests. You can (and probably do) apply the scientific process constantly in your day to day life; you have a view on things (hypothesis) and are constantly testing these with new evidence from new experiences (experiments). You don’t always take things for granted, you ask questions, like scientists do. We can always expect the unexpected.

PS: I never thought that my snowman building would cause such problems! Perhaps I should mention it to someone?

True or falsification?

Science can never say never. That’s why it’s such a dynamic and exciting field. Theories have to fit the existing evidence, but the ideas change as new evidence comes to light. New discoveries change the world and the people in it. There are also sociologists and philosophers who study the way that science works on a personal level. After all science is done by people and scientists have all the usual human characteristics. One philosopher of science, Karl Popper, argued that good scientific theories need to be able to be proved wrong. For example, my theory is ‘all cats are grey’. Someone can falsify this by showing me Eddy a lovely tabby cat, cute but certainly not grey! Until a non-grey cat turns up though (if ever) the theory is fine.

Viva the scientific revolution

Thomas Kuhn, who studied the history of science, argues that science moves forward through political revolutions. At any one time there are theories that everyone believes. This is called the normal science phase and scientists work day to day with the current theories. However scientists who don’t agree, don’t get published so easily, and find it hard to get any money to do research. All the effort goes into the current way of thinking (or paradigm). Slowly over a period of time the current theories make wrong predictions, errors turn up, they are ignored, till eventually there are too many to ignore. A crisis ensues, and a paradigm shift occurs. Everyone starts to believe the new theory, and the normal science phase begins again… till the next big jump.

Cover Illusion: The cover illusion is called the Scintillating grid illusion. Stare at one point on the grid – other points will flash!

Wake Up! Fix It!

She owns a chain of very posh hotels. She is not happy. You are going to fix it though aren't you. Well aren't you?

The problem is nothing is actually broken. Everything works just as intended. So what's the problem? The guests keep complaining. They can’t work the hotel alarm clocks. One was late for a meeting. Another was woken in the middle of the night…
The complaints keep coming. It is not that anything is broken, just too hard to use.

That is why you've been called in. You are a Usability Expert and she has had enough. She founded the hotel chain on ‘total customer care’ - everything perfect. Stress-free. No hassle. The gadgets were supposed to help not hinder. She wants a new design.

Go to the cs4fn webzine’s (**www.cs4fn.org**) online usability workshop to find out more and try your hand as a usability expert, learn about science based techniques like Walkthroughs and Wizard-of-Oz studies.

Pepper's Ghost

When Pepper's Ghost first appeared on the stage as part of one of Professor Pepper's shows on Christmas Eve, 1862 it stunned the audiences. This was more than just magic: it was miraculous. It was so amazing that some spiritualists were convinced Pepper had discovered a way of really summoning spirits. A ghostly figure appeared on the stage out of thin air, interacted with the other characters on the stage and then disappeared in an instant. This was no dark séance where ghostly effects happen in a darkened room: who knows what tricks are then being pulled in the dark to cause the effects. Neither was it modern day special effects where it is all done on film or in the virtual world of a computer. This was on a brightly lit stage in front of everyone's eyes…

Switch to the modern day and similar ghostly magic is now being used by fighter pilots. Has the military been funding X-files research? Well maybe, but there is nothing supernatural about Pepper's Ghost. It is just an illusion. The show it first appeared in was a Science show, though it went on to amaze audiences as part of magic shows for years to come, and can still be found, for example in Disney Theme Parks, and to make Virtual band Gorillaz come to life onstage and perform with Madonna.

With Pepper's ghost, 19th century magic has in fact become enormously useful 21st century hi-tech

Today's 'supernatural' often becomes tomorrow's reality, thanks to technology. With Pepper's ghost, 19th century magic has in fact become enormously useful in 21st century hi-tech. 19th century magicians were more than just showmen, they were inventors, precision engineers and scientists, making use of the latest scientific results, frequently pushing technology forward themselves. People often think of magicians as being secretive, but they were also businessmen, often patenting the inventions behind their tricks, making them available for all to see but also ensuring their rivals could not use them without permission. The magic behind Pepper's ghost was patented by Henry Dircks, a Liverpudlian engineer, in 1863 as a theatrical effect though it was probably originally invented much earlier – it was described in an Italian book back in 1558 by Baptista Porta.

So what was Pepper's ghost? It's a cliché to say that "it's all done with mirrors", but it is quite amazing what you can do with them if you both understand their physics and are innovative enough to think up extraordinary ways to use old ideas. Pepper's ghost worked in a completely different way to the normal way mirrors are used in tricks though. It was done using a normal sheet of glass, not a silvered mirror at all. If you have ever looked at your image reflected in a window on a dark night you have seen a weak version of Pepper's Ghost. The trick was to place a large, spotlessly clean sheet of glass at an angle in front of the stage between the actors and the audience. By using the stage lights in just the right way, it becomes a half mirror. Not only can the stage be seen through the glass, but so can anything placed at the right position off the stage where the glass is pointing. Better still, because of the Physics of reflection, the reflected images don't seem to be on the surface of the glass at all, but the same distance behind as the objects are in front. The actor playing the ghost would perform in a hidden black area so that he or she was the only thing that reflected light from that area. When the ghost was to appear a very strong light was shone on the actor. Suddenly the reflection would appear – and as long as they were standing the right distance from the mirror, they could appear anywhere desired on the stage. To make them disappear in an instant the light was just switched off.

Jump to the 21st century and a similar technique has reappeared. Now the ghosts are instrument panels. A problem with controlling a fighter plane is you don't have time to look down. You really want the data you need to keep control of your plane wherever you are looking outside the plane. It needs not just to be in the right position on the screen but at the right depth so you don't need to refocus your eyes. Most importantly you must also be able to see out of the plane in an unrestricted way…You need the Peppers Ghost effect. That is all 'Head-up' displays do, though the precise technology used varies.

Satnav systems in cars are very dangerous if you have to keep looking down to see where the thing actually means you to turn. "What? This left turn or the next one?" Use a Head-up display and the instructions can hover in front of you. Better still you can project a yellow line (say) as though it was on the road, showing you the way off into the distance: Follow the Yellow Brick Road … Oh and wasn't the Wizard of Oz another great magician who used science and engineering rather than magic dust?

Go to the cs4fn webzine to see how to make your own Pepper's Ghost magic box.

The Virtual Savannah

Some 'big game hunters' think the greatest hunting thrill is to hunt a lion. Much more exciting surely would by to hunt **with** a pack of lions... out on the school playing field.

Mobile technology is now everywhere but what kind of new experiences are now possible? How can mobile technology best be used to make school more fun? What matters most to make learning engaging: Complicated graphics? Authentic challenges? Precise location awareness?

A team from Futurelab, the BBC's Natural History Unit, Hewlett Packard, the University of Bristol and the Mixed Reality Lab at the University of Nottingham decided to explore these issues with a novel way to learn. They realised that the BBC's huge amounts of wildlife footage, when combined with state-of-the-art mobile phone technology, could be used as the basics of lessons in animal behaviour that were as much a game as they were a class. Enter the lions.

The way the Virtual Savannah works is that the class spend the day acting out being lionesses, trying to live on the Savannah. To survive they must behave like real lions, marking out territory (done by spraying ... guess what!), hunting as a pack (the ultimate in team-work challenges) needed to eat that day, and surviving the dry season. All this is done on the playing fields. As the trainee 'lions' move around the playing field, their mobiles keep track of where they are on the Savannah, showing them pictures of their surroundings including other nearby animals. The lions signal to each other using the handset (so don't worry 'spraying' for the virtual lions is done at the touch of a button!) To survive the challenges the participants can spend as much time back in the classroom as they wish learning how they must behave to survive. Lots of resources are available but which ones they use is up to them. If the virtual lionesses struggle over a challenge, such as hunting as a pack, then they can, if they like, go back inside and learn more to improve.

Not the way a lion learns maybe, but still effective!

The Savannah experience was trialled on a class of year 7 pupils who thought it was way better than normal lessons. The class had fun and learnt. The researchers, meanwhile, found that engaging learning experiences don't actually need lots of fancy graphics or hardware like virtual reality headsets. A minimal amount of video and audio can transport people to a virtual world outside their normal experience. Our imaginations are enough to fill in the rest of the illusion. What matters most is that the challenge itself is a real and engaging one.

So in future, rather than watching a David Attenborough film about your favourite animals you could actually be out there being one – though if you are an antelope: **watch out for those lions – they are pretty good at it now.**

The illusion of super powers – X-ray specs

Often given away free in comics, X-ray specs supposedly give you Superman's power of seeing through solid objects. They were a trick of course but the reality is actually far more interesting than the myth.

Making a spectacle of yourself

The glasses are normally a big colourful cardboard spectacle frame, the 'lenses' of which are made with two layers of cardboard with a small hole in the middle. You look at the world through these holes, but unknown to you embedded in between the cardboard layers of the lenses, covering the holes is a bit of bird feather. It's the feather, with a bit of physics and the help of your brain that makes them 'work'!

Going feather into X-ray specs

The veins of a feather are semi transparent and grow very tightly together. This ribbed structure is so dense that light coming in through the holes is diffracted. That is, it's bent slightly by the structure of the feather veins. This causes the wearer to see two slightly displaced and blurry images of the world. Looking at a pencil for example you see two offset images. When your brain combines these together you get a darker image in the overlap. You interpret this as being able to see the graphite in the pencil or the bones in your hand. Well sort of.

Invisible fish anyone?

It was American mail order marketer Harold Nathan Braunhut who invented X-ray specs. He also 'invented' and sold invisible goldfish. These were non-existent fish that were guaranteed to remain invisible permanently, which was a fairly transparent marketing ploy that you can see right through!

Getting an angle on the brain

Your brain is doing some amazing calculations as you read these words. Not only are you recognising the letters, the upright and top cross of the 'T', but you are also understanding what those letters mean when put together. Computer Scientists are looking at how our brains work to build better machines with the same kinds of skills. One area where people are far better than current technology is in seeing. Around half your brain is estimated to be involved in processing some type of information from your eyes. It takes a lot of computing power for us to see and understand what we see, whether it's faces, letters or even a café wall (but more of that wall later).

Bits of Brains

Scientists have recently started to get a better understanding of the early stages of vision, but seeing is a complex process and there is much more to discover. Your visual cortex at the back of your brain takes the nerve signals from your eyes and starts to calculate with them. From this calculation some of the basic 'building blocks' of seeing are created. We see things moving and in colour, and we also know very accurately how the parts of the scene we are looking at slope. Slopes, or spatial orientations, are a very important part of the early visual calculations. Slopes tell us something about an object, a rectangular table for example has straight edges, and slopes also tell us something about how far an object is away and how it's positioned in the scene. Think of the table again. If you are looking straight down on it all the sides are parallel. If you are looking from a distance the sides seam to slope. It's called perspective and was one of the key discoveries that made Renaissance art in the middle ages so realistic.

New Directions

We can start to build computer models of how humans perceive a whole range of properties of the scene like movement, colour, or slopes (orientations). When it comes to slopes we know that in your brain you measure the orientation at each point in the scene at several different angles, rather than just at one or two. This brain structure is called an orientation column, and is probably there to help our computation be more robust. Modelling these orientation columns, and building a computer model as close to the biology as possible allows two things.

First we can see if our model performs like a human would. We can predict from our model how a human would see a particular pattern, then test with a real human to see if we were right. If we were, then our model got something right, and we have a better understanding of how our brains compute. Secondly since the model is mathematical it doesn't matter if it's run on biological 'stuff' like your brain, or on electronics 'stuff' in a computer, so we can build computer vision systems with human-like abilities.

Around half your brain is involved in processing information from your eyes

Useful illusions

So where does the café wall come into this? If you look at a brick wall you can sometimes get a strange effect. The straight lines of the mortar can sometimes look sloped. It's an optical illusion. Your brain is making a 'mistake' in its slope calculations.

A mathematical model developed by researchers at Queen Mary suffers the same sorts of mistakes. It miscalculates like a human does, and in effect it is 'seeing' the illusion too... and because an optical illusion is an unusual miscalculation for our brains to make, the fact that the model makes the same mistakes is useful evidence for us to say that the model somehow has caught the essence of the human brain calculations. Now we have built part of a brain we can use it for many different computer vision applications.

Biology has found some great solutions to hard engineering and computing problems. Now we can use them in our machines too.

Say have you heard the one about the McGurk effect?

We normally think about sight and sound as being different senses. What we hear and what we see are independent of each other. So it was something of a surprise when researchers discovered that what we see can actually change what we hear.

The McGurk Effect, named after Harry McGurk, one of the researchers who first discovered this strange reality, shows that what you see is what you hear. The experiments involved taking videos of people saying various different syllables. Syllables such as Ba and Ga are sounds that are the building blocks of all spoken words. The videos were edited to replace the recorded sound with another prerecorded syllable sound. The new edited video was then played to an observer and they were asked what the person in the video was saying. What the researchers found was that observers always go for the syllable they see being spoken on the video rather than the actual sound being heard.

This effect is very general, it works with people from all language backgrounds, young children, or even when you mix male and female faces and voices. What this strange McGurk illusion shows is that our brain is using the visual information to work with even when it's in direct contradiction to the actual sound. Your eyes help you hear. Stranger still the effect has also been shown to work when observers touch rather than look at the face, so it's not just about sight.

Understanding how our brain works in going from measurements of physical things like light wavelength, which is the starting point for vision, or changes in air pressure, the starting point for sound, to create the perceptions of seeing and hearing is a fascinating fundamental problem. All this information comes into our brain and somehow it turns into our perception of the world, but how on earth does it do it? At present we have some clever ideas, and some intriguing clues, but the problem has not been solved yet.

To try and unravel this human mystery will take many more years of hard work, and it will need a range of different skills; from the psychologists doing experiments to the mathematicians and computer scientists trying to build and test computer simulations of the process, but clever clues like the illusion of the McGurk effect can help us along the way. It is also important if we are to build computers and robots that we find more naturally easy to talk with. It suggests they need to get more than just the sounds right, but the lips too!

The face base rap experiment

Try this one at home

You and two friends can experiment with the McGurk effect yourself. One of your friends is the OBSERVER. Have them look directly at your face, and have your other friend, let's call them the HIDDEN SPEAKER, stand behind the OBSERVER so the OBSERVER can't see their face.

Now start to silently and repeatedly mouth the monosyllabic word (that is one syllable word) 'face'. At the same time your HIDDEN SPEAKER friend behind the OBSERVER says the word 'base' over and over again (you might want to use hand signals to synchronise the actions, so the hidden speaker wags their finger to set the beat). After about ten repetitions stop and ask your OBSERVER what they 'hear' – they should 'hear' face (even though base is the word being spoken!). Now try it again, but this time have your OBSERVER close their eyes. As they can't be confused by what they see they should just hear 'base'.

Experiment with what happens if you ask your observer to open and close their eyes while you and the hidden speaker are doing your 'base', 'face' rap. The theory predicts that when the observer can see the word 'face' being mouthed that's what they will hear. Try using different monosyllabic words, or syllables like Ba and Pa, or even try having the observer close their eyes and feel the person's face. Perhaps you can come up with your own idea to test… that's how research works.

Who knows? You might find a new clue to help unlock the secrets of the brain!

How to fake a super brain

Fun with Fibonacci sequences

Would you like to be able to impress your friends and family with your amazing mathematical skills? Now is your chance. Here is a rather cunning maths magic trick that uses the power of something called a *Fibonacci sequence* to do all the hard work for you.

Performing the amazing mathematical brain trick

First select a person to impress. Ask them to write down any two numbers (say both less than 30) one under the other. Suppose they chose the numbers 16 and 21. They write these two numbers under each other:

16
21

Now ask them to add these two numbers together and write the total under the first two numbers. After a bit of mental arithmetic they write:

16
21
37

Now you ask them, having just added the first and second, to add the second number to the third number in the list: that is 21+37 for our example. They must write that new total under the numbers in the list. So they now have:

16
21
37
58

Now we step up a gear. Have them do this same thing again and again, adding the last two numbers each time until there are ten numbers in the list. They may need to resort to button pressing on a calculator. That's fine, and all the better to show your maths super powers if they are finding it hard. Look away while they are doing the later numbers, so they don't think you are up to anything. When they have ten numbers in the list you turn back and prepare to impress.

The final list of 10 for our example looks like this:

16
21
37
58
95
153
248
401
649
1050

You are going to instantly find the sum of these ten numbers. They can start to add them on their calculator, but you will beat them to the answer, "It's 2728," you say, and what's more, after the buttons are pressed and the additions done on their machine they see you are right!

I'd like to thank...

But how has this illusion of super maths power been possible? Well it's all down to the genius of the sixth century Indian mathematician Virahanka and the thirteenth century Italian mathematician Leonardo Pisano. Leonardo Pisano is better known by his nickname Fibonacci, and that is where the term 'Fibonacci sequence' comes from.

Adding the first and second numbers to get the third number in the sequence then adding the second and third numbers to get the fourth number, and so on creates a Fibonacci sequence, and these number sequences have some very special properties. Let's look at the trick. How can you do the sum so quickly? Well the sum of all ten numbers every time is just eleven times the fourth number from the bottom, and multiplying by 11 is easy even without a calculator – you just multiply by ten and add the number back again! So 11x248 is 2480+248 … 2728 and that's the trick! But of course what's important with any trick is that you really know for sure it will always work and I'm not just making it up. You wouldn't want it to go wrong in front of an audience, would you?

Prove it then!

Okay, so I'll prove it! What could possibly go wrong? Well the only free choices are the starting numbers (16 and 21 here), so you can check that my claim of 11 times the fourth number from the bottom of a list of ten is correct, but we've seen that's true for those numbers. What happens if the person picks other numbers? Well we could try checking all possible number combinations, but hey, you have a life, so lets use some computational thinking here.

Rather than use specific numbers let's get all abstract and mathematical. Lets call the first two numbers A and B. That way they can be anything! So lets see how the sequence builds up with these. It's simply a case of adding the A's and B's, so for example the third term is the sum of A and B. That's easy it's A+B. The fourth is B+ (A+B) = A+2B, and so on, writing it out in full we have:

A
B
A + B
A + 2B
2A + 3B
3A + 5B
5A + 8B
8A + 13B
13A + 21B
21A + 34B

55A + 88B

So we now know that the sum of 10 terms, starting with A and B (whatever they actually are) is 55A+88B, but look at the value of the fourth number up from the bottom. It's 5A + 8B, and what do we get if we multiply 5A + 8B by 11? That's right it is 55A + 88B, the total sum! So the trick works because there is something mathematically special about adding up exactly ten numbers from a Fibonacci sequence and we now know for sure that it will work for any two starting values A and B. Sorted!

She Loves Me... She Loves Me Not

Pure Fibonacci numbers (the sequence starting: 1,1,2,3,5,8,13,...) crop up in nature a lot – count the number of petals on a flower: "She loves, me. She loves, me not, She loves me..."
Whether she loves you or not, the chances are the count of petals was a Fibonacci number (Daisies usually have 34, 55 or 89 petals, for example – all Fibonacci numbers). It isn't magic, but due to the structure of the natural process that leads to their formation. The sequence crops up in the family trees of bees too, because of the way male and female bees breed – a fact that is used in the book *The Da Vinci Code*. Unfortunately author Dan Brown got the details wrong, as computer scientist, Harold Thimbleby of Swansea has pointed out (see the webzine).

Computer scientists like the Fibonacci sequence because it is a good example of something that can be programmed easily using what is known as recursion. Recursion just means you define something using a simpler version of itself: If we write the fifth Fibonacci number (which is actually 8) as fib(5), the fourth as fib(4) and so on then we can calculate it as:

Define fib(5) = fib(4) + fib(3)

That tells a computer to calculate fib(5) by calculating fib(4) and fib(3) first and add them together. fib(4) and fib(3) are worked out in the same way. We can write this to work for any number (lets call it n) as:

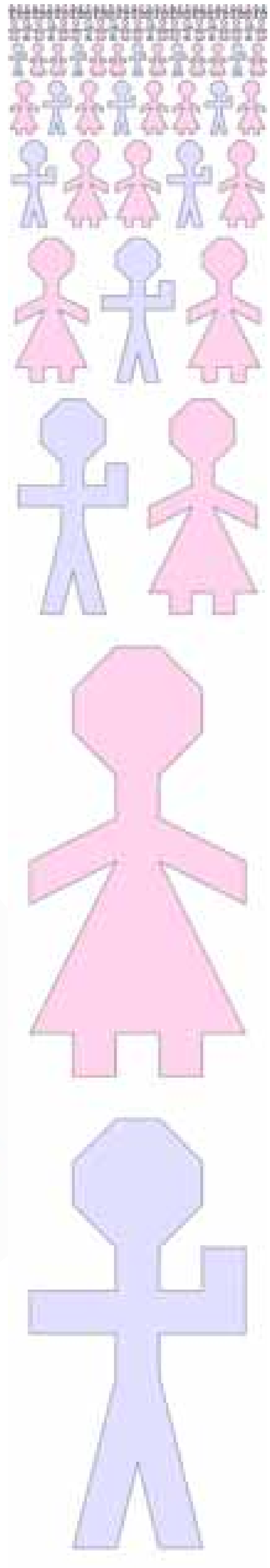
Define fib(n)=fib(n-1)+fib(n-2)

We then just have to say how to do the simple cases:

Define fib(1)=1

Define fib(0)=1

You can write your own recursive programs that draw pictures based on recursive patterns. In fact the man-woman picture (right) is drawn by a program using a Fibonacci recursion, just drawing men or women instead of adding numbers...and the picture shows what happens when bees breed too. See the webzine for more detail and for how to use the free GeomLab software from Oxford University to write programs that draw like this using recursion.



Face off

The computer science of changing faces

The gory plot line of the 1997 movie *Face/Off* staring John Travolta and Nicolas Cage, involves what was then the science fiction medical process of a face transplant. Government agent Sean Archer must find a ticking bomb planted by terrorist Caster Troy. To do this he takes on the identity of Troy by having Caster's face surgically transferred onto him so he can infiltrate the terrorist's group in prison. Just to complicate things the real Troy (the baddy) later manages to get hold of Archer's (the goody) face and pretending to be Archer helps his twin brother, Pollox Troy escape from prison. The real Archer is left in prison, looking like the baddy, while Caster, looking like the goody, goes off to destroy all the documents that would prove that the swap ever took place. If he's successful Archer will be left with Caster's Identity to rot in jail. Typical John Woo (the director) action follows with lots of two-handed gun shooting and chases. Eventually it all gets sorted, but it all goes to prove that faces are a key part of our personal identity and that shifting them around can be very confusing.

Meanwhile medical science has progressed to the stage where we can actually successfully transplant a face to help people whose own faces have been disfigured. Computer Scientists are also developing a way to digitally create and transfer faces, (in a less gruesome way) which could open up some fascinating new applications.

The psychology of faces

Humans seem to have a special part of the brain to process faces. Since we are social animals it's obviously important that we are able to recognise friends and family, and to be able to tell from their expressions what kind of mood they are in. Psychologists have studied how we use facial information for years, and have discovered that it's far from easy. Your brain is doing a lot of difficult calculations and using lots of assumptions to make the job easier. For example, when looking at faces we tend to think of them as convex, that is bulging outwards towards us, which of course they normally do. The brain is so convinced that faces are convex that even when we look at the inside of a mask we see a solid face – the hollow face illusion. See page 12 for more on this. The way our faces move is also very important. It's been found that if you use motion tracking (see page 12) to transfer the movements from an individual onto a computer generated face, even though that computerised face is genderless (looking as much female as male), observers can tell the gender of the original person from the pattern of movements alone; women and men have different ways of moving their faces.

Identikit faces

This idea that we can build faces from component parts is at the heart of the identikit process used to try to reconstruct the face of a criminal in a police investigation. In the original system the witness was given a book filled with different eyes, ears, noses, mouth, hairlines and so on, and from this they selected the parts that they believed were like those of the criminal. It had some success. The problem though is that we tend not to see faces like that. We don't see them as a combination of bits. We see them as whole faces, and so often the identikit pictures created bit by bit didn't really look like the criminal at all. The computer-based E-Fit system tries to overcome this by taking account of some of the psychology of face recognition. By running the process electronically the face building elements stored in the database can be blended together to form a realistic looking face. One problem is that the witness building the face needs to say what isn't quite right with it. That can be difficult. A software system called Evo-Fit, developed in the Psychology Department at the University of Stirling, overcomes this by creating a range of similar faces rather than a single face. The witness selects the ones that are closest to the criminal. That is often easier to do. The system then uses genetic algorithms; simple computer models for biological evolution, to breed more similar faces, and step-by-step, the system lets the witness focus in on the best likeness.

The principle of Principle Components

The Evo-Fit system works by having, not a database full of different ears, noses, eyes and so on, but a database containing something more cunning. It contains 'Principle Components' of faces.

Principle Components are produced by a statistical technique that helps us represent lots of complicated data in a simplified form. We can think of pictures of faces as being represented as a collection of numbers (after all that's how they are stored as the pixels of a computer screen). A single good-quality image can contain many thousands of numbers. If we combine a set of many different face images, the amount of data becomes gigantic, and each new face added will add more muddle to this big set of numbers; all faces are still in there it's just that they are all mixed up. We need some way to reduce this muddle so that we have just a few images that capture as much of the useful 'face stuff' in the full set as possible. That's where statistics comes in.

You may already have come across the idea of standard deviation or variance in maths lessons. These values are calculated from the data you are analysing and indicate how spread out the numbers are. A large variance shows that most of the numbers are spread out. A small variance shows that they are close together. We can use similar mathematical tricks on our set of face images. What we want to do is find a few images that will account for the most variation in the data; after all it is the variations in the data that makes the faces different from each other.

Once we turn the handle on the Principle Component Calculating Machine what we get out is a set of images. The first image (the first 'Principle Component') accounts for most of the variation in the data, the second Principle Component accounts for the next highest level of variation and so on. So rather than having to store all the images in the original set we can just store as many Principle Component images as we need (this is called data reduction). What's more we can add and subtract these Principle Component images to let us recreate a good approximation to any of the original faces that we mangled together in the first place (this is called data reconstruction).

Face painting

If all this maths is a little confusing, think of it this way. You know from art class that you can make any colour by mixing together amounts of red, green and blue paint (the primary colours). Think of the Principle Component images as computer calculated 'primary colours', which you can mix together to 'paint any colour' – or in this case make any face. The fact that the Principle Component images are all faces (of a sort) rather than colours means that they have the standard overall arrangement of the face. That means the Evo-Fit software doesn't have a problem of mistakenly adding in a nose where it shouldn't belong. The system just moves through painting new faces with the Principle combinations of the Component images until the best match to the criminal is found.

Let's get moving

We can also apply the Principle Component trick to sets of videos of faces, because videos are just a series of still frames all stacked together. Of course this means the amount of data involved is even bigger, but it can be done. What comes out of the Principle Component Calculating Machine here is not static images but video images. The first Principle Component video accounts for most of the variation in the original set of videos, the second Principle Component video accounts for... and you know the rest. So we can now 'paint' with these videos to create new video sequences, by combining the appropriate Principle Component videos – and that's exactly what computer science researchers at Queen Mary and psychologists at UCL did!

The Digital Face/Off illusion

Suppose we take lots of video of one person, say Caster Troy, talking and laughing in typical baddy style and put this set of videos thorough the Principle Component Calculating Machine. What we have are videos that will let us paint new videos of Caster Troy by combining the components. If we can combine the right set of components we can make his face do whatever we want, even give us a cheery smile.

Now suppose we do the same with goody agent Sean Archer: take lots of videos of him and put this set of videos thorough the Principle Component Calculating Machine. We could now paint new Archer videos. Suppose instead we take a video of Archer pulling a particularly silly face. We can take this single video and work out the mix of Archer Principle Component videos that he uses to do this. In effect we have an instruction list of how to add and subtract the Archer components to make Archer look silly.

Now we take this instruction list from Archer but apply it to combine Caster Troy's' video components instead. The result: a new video where the baddy pulls exactly the same funny face – a face he never pulled in reality! We have taken Archer's facial movements and transplanted them onto Troy's face without a scalpel. The illusion is complete: Archer's face can work Troy's face like a puppet, and there is nothing he can do about it.

Facing up to the future

Apart from applications in espionage, these techniques could be used to allow, for example, actors to impersonate other possibly dead actors, of even let you pretend to be someone else on you mobile video phone. You would download the components for your new face, and then just send the instructions on how to build it. You could even create a face 'graphics equaliser' where rather than mixing music together by a set of sliders you mix facial expressions to create subtle performances for computer generated actors.

With computer science, virtually nothing can be taken at face value.

A mathematical model of the mind

How does the physical world influence the mind? It's a profound question central to human experience that has troubled philosophers through the centuries. We sense the physical world around us, through, for example, measuring light intensity in the eye, detecting changes in air pressure in the ear, detecting changes in pressure on our skin, detecting chemicals in the air in our nose or chemicals in our food with our tongue; but how does this physical stimulation become a feeling of weight, or of hearing words or of tasting delicious food? How does the measurement of the stimulus by the body become the experience of perception in the mind?

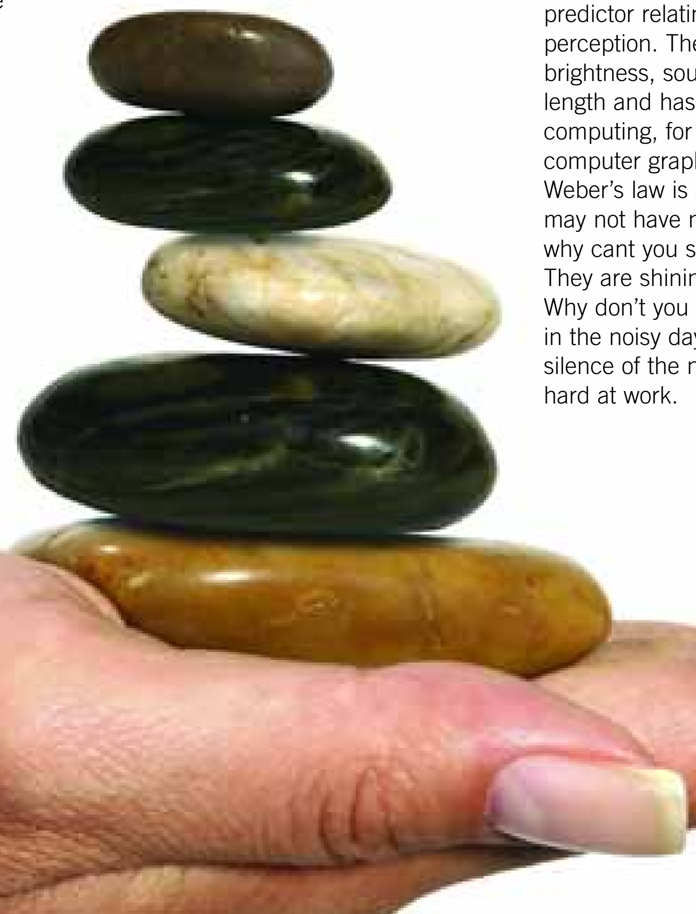
We still don't know the full answer, but back in 1860 a German doctor called Ernst Heinrich Weber, working with a colleague Gustav Fechner, discovered something rather fascinating. There is a simple mathematical rule (equation) relating the strength of stimulation to the strength of the perception, and it works across a whole range of our senses. This rule is called Weber's Law, and it's one of the first examples of a mathematical model relating body to mind. It's also interesting that while it was actually Fechner who did the maths, he gave the law as a 'gift' to Weber whose name it still carries today.

A weighty psychophysics experiment

Weber carried out several classic experiments to help him devise the rule. He blindfolded a man and gave him a weight to hold. Slowly Weber added more weight to the man's hand, until the man indicated he could first feel a difference. The weight was the stimulus strength, and the ability of the man to notice the difference in weight was the measure of a change in his perception. What Weber found was that the amount of extra weight he could add until the man could just notice the difference depended on how much weight there was in the hand at the start. If the weight was say only 10g to start with, adding 1g more was noticeable, if the starting weight was say 1kg, then an extra 1g added wasn't perceived. This type of experiment where you manipulate something in the real physical world and measure the perception caused in a person's mind is called psychophysics, and it was Weber and Fechner who started this whole field of research.

Say it with maths

In words, Weber's law says the stronger the original stimulus, the larger the change you need to make to notice that any thing has changed. Words are always useful and Weber could describe his findings, but looking at the experimental data Fechner was able to find a wonderfully simple mathematic description as well. If we call the stimulus strength S, (for example here this would be the original weight in the hand), and we can just notice the change if we increase the strength by amount dS, (remember dS is the amount of extra weight we add when we notice it), then (dS/S) = k where k is a constant, a number you can work out from the experimental data.



I predict that...

If we measure the constant k for one particular weight (by taking the measurements and doing the division), we can then test if it is really the same for other weights. Better still we can make predictions to test. Suppose we do it for a low initial weight of 10g where we can just notice when 1g extra is added. Weber's law says 1g/10g is a constant - here 0.1. Using this experimental constant, 0.1, we can predict how much we should be able to add to the hand (dS) if we started with 1kg (1000g). The law says (dS/1000) must equal 0.1, so changing the subject of the formula dS = 0.1x1000 = 100g. Our mathematics has made a specific mind/body prediction we can now go and test. Just using descriptive words we couldn't achieve this useful ability.

Useful all round rule

Experimentally, psychophysics researchers have found that, if you don't go to extremes, then Weber's law is a good predictor relating stimulus strength to perception. The law holds for weight, light brightness, sound loudness and even line length and has many applications in computing, for example in image displays, computer graphics and audio processing. Weber's law is all around us, though you may not have noticed. Ask yourself this, why cant you see the stars in the daytime? They are shining just as brightly as at night. Why don't you notice the ticking of a clock in the noisy daytime when it's there in the silence of the night? It's all just Weber's law hard at work.

Intelligence Testing Party Games

Party games are just for fun – nothing serious about them at all. A party game certainly wouldn't be behind one of the most important research papers of the twentieth century would it?

Err, actually yes. A Victorian parlour game called the Imitation Game lies at the heart of research on Artificial Intelligence and the quest to make machines think.

Back in the 1940s and 1950s, Alan Turing, one of the most influential computer scientists ever, was interested in giving computers intelligence. Intelligence is a tricky thing though that is very hard to tie down even in humans, never mind animals or computers. Turing started to wonder if ever a computer deserved to be called intelligent, how could we test it? He turned to the Imitation Game for inspiration.

The Imitation Game involves two people, a man and a woman, both trying to convince the rest of the party that they are the woman. They go into a different room and are asked questions. Their answers are read out by a neutral referee. The woman must answer truthfully. The man answers in any way he believes will convince everyone else he is really the woman.

The Imitation game tests for femaleness, but a similar test could be used to test for other things too, and in particular, Turing suggested it could be used as a test for intelligence in a machine. If on questioning a hidden machine at length it can convince you that it is a person, then given you accept that a person is intelligent, the computer must be too. Turing's version of the imitation game therefore, replaced the man by a computer and the aim of both person and computer was to convince everyone that they were the human and so intelligent.

The paper helped launch the field of Artificial Intelligence (AI). It pulls together biologists, computer scientists and psychologists in a quest to understand and replicate intelligence. Turing thought machines would pass his test before the twentieth century was out, but Intelligence has proved more elusive than that. AI techniques have delivered some stunning results though – computers that can beat the best human at chess, diagnose disease, and invest in stocks more successfully than humans, for example. Not bad for a Victorian parlour game.

So next time you find yourself playing a game of Musical Chairs, don't just sit on your backside. Do some serious thinking about it and you too might launch a new research area.

The Illusion of Intelligence?

Not everyone agrees that the Turing test is really about intelligence. Many researchers believe it is just about the illusion of intelligence. They claim it will be possible for machines to pass the Turing test without being able to do anything remotely like thinking at all – just like chess computers can beat humans without thinking like a grandmaster. After all, just because a man passed himself off as a woman in the original game that wouldn't mean he was a woman.

There is in fact a competition run every year based on the Turing Test. The Loebner Prize for artificial intelligence will award $100,000 and a Gold Medal for the first computer "whose responses are indistinguishable from a human's". Many of the entrants each year are created by people with no intention of building intelligent machines: just ones able to pass the test. Just like students sometimes "learn to a test" which they then pass without gaining any real understanding of the subject, so it is argued chatbots will eventually win the Loebner prize without any understanding of what they are talking about. So far no chatbot has come close to winning the prize though – so maybe it's a difficult illusion to pull off after all.

Sensational – the try 'em at home guide to illusions

Here is a try-it-at-home *Blue Peter* type guide to some easy-to-do illusions with your senses and other body bits. It uses things you can find around your home or school, and we guarantee no need for any sticky-backed plastic.

Making sense of your senses

We have five senses: hearing, smell, taste, touch and vision. It's your senses' job to let you know what's happening in the environment around you. We can distinguish millions of shades of colours, ten thousand different smells, we can feel a feather touch our skin or hear a faint rustle of a leaf. Our senses are fantastic. Having to process all that information in real time means that your brain is taking some short cuts in the calculations though. It's making assumptions all along, and when those assumptions don't apply then illusions happen!

The sweetness illusion

The way we perceive the sweetness of sugar depends on its temperature. So try this. Take some sugar and water and mix in a bowl, then pour half the liquid into one glass and pop this glass in the fridge to cool. Take the remainder and pour it into another glass and leave it near a radiator to warm up. The science says that the perceived sweetness of sucrose (sugar) increase by 40 per cent as the temperature increases from 4°C (about fridge temperature) to 36°C (about body temperature). Take the two glasses of liquid and ask a friend which tastes sweeter (of course they both have the same amount of sugar in them). If your friend says the warm glass is sweeter then you have your illusion.

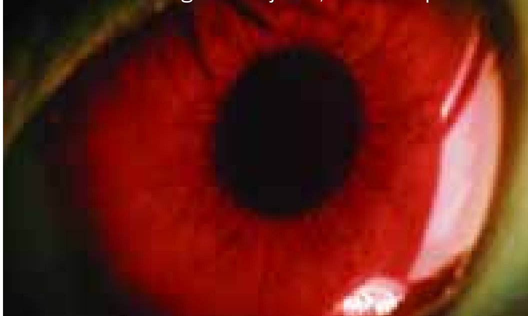
If you want to be really scientific about it, make more liquid in the bowl and put it equally into four glasses. Put one in the fridge, one by the radiator and leave the other two in the room. The two in the room are called the experimental control. Ask your friend first to taste the sweetness of the two room temperature glasses. Because they have the same amount of sugar and the same temperature they should taste the same sweetness, so our control will show that it is in fact the temperature that's causing the effect and not, for example, that the first glass drunk always tastes sweeter.

It's also a good idea to have your friend swoosh their mouth out with normal water between tastes of the sugary water so you don't contaminate your samples.

Your adaptable senses: Looking at your eyes' wiring

Scientists often work out a theory in one area and find it also applies in another. Our senses are a good example of this. They all have the same sorts of characteristics and adaptation is one of the ones that is common across the senses.

In vision, for example, it's been shown that if you use special contact lenses that cause an image to fall on exactly the same part of the retina (the light sensitive part at the back of your eye) as you move your eye, that image will vanish. The light sensitive cells in the retina adapt to the image on them. In effect it's there for too long and the vision system ends up ignoring it, waiting for something interesting to come along. That is why your eyes make thousands of tiny involuntary movements called saccades every second, so that the image on the retina is always changing. This kind of eye movement can also be used in computer vision systems to help improve their accuracy, by building up the information needed to recognise objects, for example.



Perhaps one of the most "Gee, I'm a biological machine," moments you could have is when you see your wiring. The retina needs lots of energy to measure the light in your eye. To do this it needs blood, biology's way of carrying nutrients. The surface of your retina is covered with a web of blood capillaries, but you don't see them. Why? Because they are static on your retina, so your visual system adapts them away. From time to time, when you wake up and the early morning sunlight comes in at an angle you can briefly see a dense tree of these capillaries, as the light at an angle casts a shadow that the visual system wasn't expecting and didn't adapt to. If you're very careful you can use a torch (do not of course use anything powerful that could damage your eyes – no laser pointers!) at an angle to create this effect. When you get it right it's amazing. You can see the wiring on your retina, albeit briefly. It's quite a sensational experience.

The floating arms illusion

Adaptation also happens in your muscles, and can cause some strange effects. Stand in a doorway and press the back of each hand hard against the doorframe for a minute or so. Then walk forward. Your arms will feel like they want to float up. In fact they might actually do it. The reason is that all the muscles in your body work in pairs. These are called antagonistic pairs and they are needed as muscle fibre can only contract. You need one muscle on one side of a joint to pull the bone one way and another muscle on the other side to pull it back in the opposite direction. When you stand in the doorframe and push, you fatigue one of the sets of muscles. The muscle adapts to being under pressure. When you walk forward the antagonistic muscle is ready to go. It hasn't had to adapt. The two sets are now out of balance so the antagonistic muscle starts to contract and up go your arms. Understanding how the muscles in the body work so cleverly together gives robot builders some clever engineering models to hep them build walking machines.

The size-weight illusion

This illusion, first described over 100 years ago, shows that if you lift two objects of equal weight, you will tend to perceive the smaller object as heavier. You can test this out at home. Take two empty plastic bottles of different sizes and, using scales, fill each with water or sand so they both weigh the same. Ask a friend to lift them up and ask which they think is heavier. If they say the smaller bottle then the 'size-weight' illusion is at work. You can even tell them the objects are the same weight. The illusion will still persist.

But things get even stranger! Researchers have found that when people alternately lift objects of the same weight but different size they apply the same fingertip force to both objects even though they still experience the size-weight illusion. One part of their brain is being fooled but another part of their brain isn't, and the two parts aren't communicating with each other.

The Temperature Illusion

Take three glasses of water, put one in the fridge, fill the other with warm water from the hot tap (just warm NOT hot water) and fill the third with normal cold tap water.

Put the three glasses in a row in the order: warm, normal and cold. Pop a finger into the warm water and, with your other hand, pop a finger in the fridge-cold water. Leave for a short time, and then put both fingers into the middle glass. You will feel that the finger that was in the warm water feels cold and the finger originally in the fridge-cold water now feels warm, even though they are both now in the same temperature water. What's happened here is that when your finger was, say, in the warm water it adapted to that temperature. Your body is really only interested in things that change in the environment, as it is the changes that you need to be able to react to. So, after your finger has adapted to the warm water, when it goes into the middle glass it's 'expecting' it to be warm. When it's not, your brain reasons, "this isn't warm so it must be cold". Similarly, the finger in the fridge water adapts to coldness, and when it moves into the centre glass, "that's not cold, so it must be hot". So one finger is saying hot, the other is saying cold, and both are actually at the same temperature.

The Touch Illusion

If you raid a DIY toolbox you can try the similar sandpaper touch Illusion. Carefully rub one hand on fine sandpaper, the other on coarse sandpaper. Now take both hands and rub some medium sandpaper. It feels different to each hand. Why? Because the hand rubbing the fine sandpaper first adapts to feeling fine roughness, whereas the hand on the course sandpaper adapts to lots of roughness. So like the temperature illusion when your two hands have had their touch sensors adapted to different roughness, the medium paper will feel different to each. Try to predict, from the Temperature Illusion explanation, which hand will feel the medium paper as more rough, then try the experiment and see if you are right.

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The remote control brain experiment

Here is an experiment that looks at the power of the human mind to control distant events.

Experimental Equipment required

- **Deck of playing cards**
- **Brain**

Method

Get a deck of cards and give them a good shuffle. Spread the cards on the table face down. Now think of the colour **RED** and select any eight cards, then think of the colour **BLACK** and select another seven cards at random. Now think of **RED** again, select another six random cards, then finally **BLACK** again and select five cards.

Shuffle the cards you chose, and then turn the pile face-up. Take the remaining cards, shuffle them and spread them face-down.

Now Concentrate

Now the remote control starts. Concentrate. You are going to separate the cards you selected (and that are now in your face-up pile) into two piles, a **RED** pile and a **BLACK** pile, in the following way.

Go through your face-up cards one at a time. If the next card is **RED** put it in the **RED** pile. For each **RED** card you put in your **RED** pile think **RED** and select a random card from the face-down cards on the table without looking at it. Put this random card in a pile face-down in front of your **RED** pile.

Similarly if the next card is a **BLACK** card put it face up on your **BLACK** pile, think **BLACK** and select a random face down card. Put this face-down card in a pile in front of your **BLACK** pile.

Go through this procedure until you run out of face-up cards.

The experiment so far

You now have the following: a **RED** pile and in front of that a pile containing the same number of face-down cards you selected while thinking **RED**. You also have a **BLACK** pile in front of which is a pile of random cards you selected while thinking **BLACK**.

Did your thought control work?

Interestingly your thoughts have influenced your choice of random cards! Don't believe me? Look at the pile of random cards you chose and put in front of your **RED** pile. Count the number of **RED** cards in this pile. Now look at the random cards in front of your **BLACK** pile, and count the number of **BLACK** cards you selected. They are the same! You selected the same number of **RED** and **BLACK** cards totally at random!

It's a final proof that your sub-conscience mind can make you choose random cards to balance those numbers! ... Or is it? See Magazine+ in the webzine for an explanation of what is REALLY going on!

Back (page) to reality

This issue has been about illusions and reality, so it's only right to finish with some word tricks. Understanding how we turn the written word into understanding is a real challenge for computer scientists. Get it right and you can build computers that understand the writing, a really useful thing to do. First off when we look at a written sentence there are two parts to it, the syntax and the semantics.

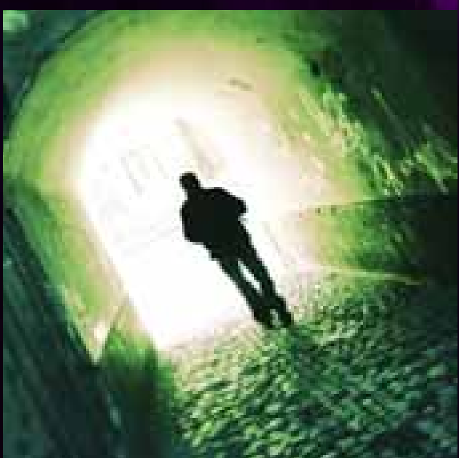
A word spell

Syntax is about the structure of language – what is allowed to follow what, ignoring what it means. Turns out the order of letters matters very little to humans. How do we read words? Do we pay attention to every single letter to be able to extract the information? Perhaps not! Perhaps we recognise words and give them meaning with a lot less information. Try and read the paragraph below.

'Aoccdrnig to rscheearch, 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. Tihs is bcuseae the huamn mnid deos not raed ervey lteter by istlef, but the wrod as a wlohe'

We humans can get the gist of it even though the data is very messy, but imagine how a poor computer would do, trying to match each letter to a set of stored words. The typos would floor it! So that's why examining how humans read and understand is an important area of research.

The trick is: Perfect the start and finish



Its not what you say it's the way that you say it

Semantics is trickier. It's about the meaning of words. Put the stress when you speak a sentence in a different place and you can change the reality!

'**I** didn't steal Granny's chocolate cake' – Wasn't me, was someone else!

'I **didn't** steal Granny's chocolate cake' – It really wasn't me!

'I didn't **steal** Granny's chocolate cake' – I planed to give it back, honest!

'I didn't steal **Granny's** chocolate cake '– It was actually Uncle John's I stole!

'I didn't steal Granny's **chocolate** cake' – It was her vanilla sponge cake I nicked!

'I didn't steal Granny's chocolate **cake**' – It was her bar of chocolate!

How does a computer work that out from the words alone?

The trick is: say it like you mean it

The computer is better than you! (well sometimes)

Quickly count the number of letter 'F's in the following:

FINISHED FILES ARE THE RESULT OF YEARS OF SCIENTIFIC STUDY COMBINED WITH THE EXPERIENCE OF YEARS

How many did you get? Three or four? In fact there are six F's. During a quick read, your eyes and brain fix on the meaningful (lexical) words, and tend to ignore the grammatical syntactic words (like the three 'of's). Young children aged six tend not to make this mistake. They take each word in turn slowly so can count the number of 'F"s correctly, as would a current computer program. When you get older your brain starts to learn to take shortcuts in reading to make it more fluid.

The trick is: fast and fluid usually gets you there

Colouring your perception

Say the colour of the following words out loud quickly

Blue	Red	Green	Yellow	Red
Yellow	Green	Blue	Yellow	Red
Red	Blue	Yellow	Red	Green
Blue	Yellow	Red	Green	Green

I bet you read the word rather than the colour! This is a really powerful illusion called the Stroop effect, named after its discoverer John Ridley Stroop in 1935. He found that if you have to say colours quickly then **Green** will normally cause less of an error than **Green**, as the word and it's colour are conflicting information that your brain can't cope with. It shows again that your brain uses shortcuts to deal with all the information you're throwing at it. It makes assumptions and when those assumptions are wrong, your brain makes a mistake and an illusion happens.

The trick is: don't always trust your brain

Studying how the brain makes mistakes give us a valuable insight into how it works, and since most of the time it does a really good job of things, building computers that follow the same processes, even if they suffer the same illusions, is a very useful thing to do.

You can trust your brain most of the time, but when its assumptions are wrong, illusions follow...

cs4fn is produced by Paul Curzon and Peter McOwan of the Department of Computer Science, Queen Mary, University of London. Support provided by Sue White.

The Wake Up! Fix it! Web pages were developed for Science Week 2007 with funding from RCUK

Selected for the Royal Society's SUMMER SCIENCE EXHIBITION 07

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cs4fn is supported by EPSRC and the BCS

Microsoft, ARM and Intel provide support for printing.

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