

A charcoal and pastel portrait of a person's face and hand. The person's hand is raised, with fingers spread, near their eye. The background is a mix of brown, tan, and blue washes. There are some abstract orange and red marks at the bottom. The overall style is expressive and somewhat abstract.

Your breath gently lilts,
your vision scans the world
in a seemingly smooth,
uninterrupted movement,
your heart chugs away –
sure and steady, and you
barely notice. The feeling
that you are you, that
the body you inhabit is
yours, that you can look
in a mirror and recognise
yourself, rarely changes.
Imagine, then, that this
sense of self could warp or
shift...

Shattering the self

Ella Rhodes on the contradictory nature of the self

Imagine suddenly seeing your double. You may even see several, and they move just as you do. Not only this but your sense of self may jump between the true 'you' and any of those doubles. This is the rare disorder heautoscopy. Conditions like this, schizophrenia, dissociative disorders and depression can dramatically and subtly affect our sense of self.

Once believed to be immune to scientific scrutiny, the sense of self is emerging from the philosophical domain and into the light of empirical study. Thanks to research with people with clinical conditions, and the rapid progress of technology such as virtual reality which can allow 'neurotypical' people to experience changes in the self, scientists are revealing one of the biggest mysteries of experience.

From lofty concept to baseline process?

'The self is everywhere and nowhere', says neuroscientist, philosopher and psychiatrist Professor Georg Northoff (University of Ottawa). 'Originally a philosophical concept, it has always been associated with higher-order cognitive functions and set apart from all other functions like emotions, cognitions, rationality, body, perception.' This way of thinking was also reflected in early neuroscientific work investigating the self and consciousness in attempts to find specific areas of the brain which corresponded to a feeling of self.

'You cannot say there are a specific set of regions just involved for the self, like the cortical midline structures which have been candidates for that, or that the self is an isolated function independent from others. No – the self impacts the memory, emotion and cognition. Maybe the self is not a very special higher-order cognitive function... maybe it's at the very bottom. It's not the flower in the vase on top of the table but maybe it's the ground upon which the table stands.'

How can we experience a seemingly stable self, despite our changing environment? Something which on the surface seems simple – the activity we observe in a brain which is at rest – may hold part of the answer. Northoff tells me the brain is an energy-ravenous



organ. It's only around 2 per cent of a body's total weight, yet the brain uses 20 per cent of our energy; and 90 per cent of that is used in 'resting state' activity.

'Of course, you ask, why does the brain use so much energy?' Northoff says. 'And one of the main reasons is there is continuous change and a dynamic pattern. Compare this to tennis playing; Andy Murray moved a lot when he was waiting for the service of his opponent. Prior to the service he was already moving back and forth. It looks arbitrary, but there's a certain pattern and organisation to it. That's what your brain does. In that change there's probably a certain continuity, and that's your sense of self.'

Northoff has noticed an overlap of active regions in studies which have investigated the self or the brain's resting state network. The variability in the activity of the cortical midline structures seems to link to the self, and in bipolar patients there's a striking pattern. 'In depression we saw too much change in the variability in these midline regions. That goes along with these patients' experience of rumination, these thoughts which are all about themselves: "I'm guilty, I'm a bad person, I don't deserve to live". It's an extreme focus on the self. In the manic patients, who are completely distracted by the environment, you see exactly the opposite pattern – no variability at all in the midline regions.' On asking about experiences of the self, those who were in the manic phase of their bipolar confirmed they do not have many self-related thoughts. 'Basically we infer from the variability on your neuronal level to the variability in your mental experience.'

I asked Northoff why studying the self really matters, and what the wider implications of findings such as his may be. 'First, as a psychiatrist, it matters for me because all psychiatric disorders involve changes to the self and everything else – emotion, mood, cognition and perception – builds on that. Your self matters for your psychological health: it's your baseline, your default. Because I have this peculiar combination of philosophy, psychiatry and neuroscience, for me it really matters... the self is a symbol of subjectivity and subjectivity is consciousness. If you want to understand how the brain brings forth the mind, you need to understand subjectivity and you need to understand self.'

The minimal self

So if the self is our 'baseline', our 'default', we'd surely expect it to leave a strong signature across the brain? 'The self is an elementary construct, it's probably the most important construct we have in our psychology', Dr Roy Salomon, a Cognitive Neuroscientist who runs a lab at Bar-Ilan University in Israel, tells me. 'The world can be divided into "me" and "everything else", in a way. So I thought there would be a very strong

robust representation of the self in the brain. That's where I was wrong.'

Salomon has been chasing these questions for more than a decade, working with typically-functioning people and those with schizophrenia and psychosis. 'Part of the difficulty in finding the neural correlates of the self is that the brain maintains many different kinds of self-models', he says. 'The most fundamental level of the self, the one that we never really think about, is what we call "minimal self-consciousness", or sometimes "bodily self-consciousness". This is what causes you to feel that this body is you, that there is a you in the world, there is an "I".'

During the earliest years of our development we gradually learn how it feels to inhabit a self – we experience the sensation of moving our own limbs, or proprioception, the steady rhythm of our heartbeat, giving us a stance from which to see the world through our own eyes. When these systems break down, as in disorders such as schizophrenia, the world can become a confusing and frightening place.

'Some people with schizophrenia feel they are not actually in control but that an external force is intervening and controlling their movements, implanting thoughts or stealing thoughts from their mind', Salomon tells me. 'In these situations, especially in psychosis, there is a barrier which defines me and my subjectivity. Then things which should be on the inside, sometimes they ooze out, and things from the outside sometimes come in. The barrier is not as strong as it should be, creating this confusing and disabling sense of the world. It's very difficult to actually act in the world without having some kind of strong sense of self.'

The typically-functioning brain has a way of predicting the consequences of our actions, whether this is the sound we make when we walk, or the expectation of how it will feel when we scratch an itch. 'If this connection is not robust, then things become confusing. Did I do that? Did that come from someone else? Was that my action? This leaves you in a vulnerable space. You're not really sure what you've done, what others have done, how your actions affect the world. And we think this is the main problem in schizophrenia.'

Salomon tests this idea in his lab using virtual reality. Participants see their own movements in VR, but the movements may be delayed by milliseconds. 'With healthy participants if they make a hand movement and you delay it by 200 to 300 milliseconds, they say "that wasn't me". But people with schizophrenia are very bad at making these discriminations. They often attribute a movement that's delayed by 300 to 400 milliseconds to themselves, which can be very confusing for them.'

Salomon has also begun looking at the impact

"Your self matters for
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on higher-level cognitive processes including memory. 'We know that there are strong associations between memory and sense of self. Surprisingly if you give someone a list of words, and you want them to remember them, what do you think the best instruction would be? We typically think the best instruction would be to tell this person "listen and memorise these words". Actually, the best instruction would be, "please think of what these words mean to you". When we relate to something and we actually bring it towards the self, we perceive it better, and we remember it better.'

The implications in an increasingly virtual world are clear. 'When you're disembodied, using a military drone from Pennsylvania and dropping bombs in Afghanistan, do you experience the same things? Do you have the same sense of morality? Of responsibility? Are the cognitive processes going on the same? Would you remember them in the same way?'

The internal self

Away from the virtual world, some psychologists take a decidedly low-tech route to studying the self – whacking a rubber hand with a hammer. In this body illusion, participants place their right hand on a table with a rubber hand in the position of their left. Stroking the real and fake hands in synchrony can create an illusion of ownership, and going on to strike the rubber hand can produce a startled response. Professor of Psychology Manos Tsakiris (Royal Holloway, University of London) has used this paradigm, but with the addition of an important source of information in our bodily sense of self.

'I can feel my heart from the inside, I can feel my guts from the inside, in a way that doesn't apply to when it comes to touch, or when it comes to looking at faces for example. So whenever there is this processing of your own body or your own self from the outside, this is also invested and tagged with information coming from your internal body. These resources jointly produce or underpin the awareness of your own self.'

In 2011 Tsakiris used the rubber hand illusion alongside the heartbeat counting task. He found that those people who are particularly accurate at this interoceptive task experienced a weaker response to the rubber hand illusion. 'When you have a pretty accurate representation of how it feels to be your body from within, you're less captivated and dominated by exteroceptive information about your body.' Tsakiris emphasises that one type of focus – environmental or internal – is not necessarily better than the other. Yet low interoceptive accuracy has been associated with some sub-clinical symptoms in terms of emotional regulation, and clinical symptoms in body image disorders such as anorexia nervosa.

Tsakiris has even investigated the effects of specific moments within the heart's rhythm: judgements made as the heart beats ('systole') in comparison with



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inbetween beats ('diastole'). While he admits 'the jury's still out' on what the results in such studies mean, he thinks 'there's more and more evidence suggesting that what the heart is doing to the brain is interesting: it's modulating our brain activity and eventually our cognitive processes'.

The world can be divided into 'me' and 'everything else'

The subjective space of self

'What if the brain is not just monitoring cardiac parameters, but is actually using just the fact the heart is beating to generate a kind of common space where you can have subjective experience?' So asks cognitive neuroscientist Dr Catherine Tallon-Baudry (Ecole Normale Supérieure), who is using measurements of the brain's response to heartbeats ('heartbeat-evoked responses') to investigate biology's role in forming the self.

In one study, Tallon-Baudry hypothesised that heartbeat-evoked responses could affect the ability to perceive visual stimuli presented to people at threshold level – just above conscious perception. Participants were simply asked whether they had seen a stimulus or not. Again she found heartbeat-evoked responses to be larger when participants correctly said they had seen something, even when compared with trials where they missed the stimulus or where nothing had been present. 'What we've shown is that the heartbeat-evoked response really behaves as if you had

more information on which to decide, not that you're changing the way you report your decision, which is still something quite puzzling.'

For Tallon-Baudry, the definition of the self must include the whole of an organism. 'The line of reasoning in my group is that any organ that continuously generates signals that are present throughout life and that are continuously sent to the brain should contribute.' Tallon-Baudry has recently moved to study the stomach, which has a slow rhythm of its own (oscillating around every 20 seconds). While she is yet to definitively link this rhythm to the subjective self space her work has uncovered some fascinating insights. 'The amplitude of the alpha rhythm, which is the dominant rhythm at rest in the brain, depends on the phase of the gastric cycle. Essentially you have slow waxing and waning and it seems to be that it's the stomach that sets the pace for the modulation and the amplitude of the alpha rhythm.'

More recently, using fMRI, Tallon-Baudry has looked into which regions of the brain covary with this rhythm in the stomach. 'We found a network of regions which are actually crossing over several resting state networks. It's more of a sequence of regions, beginning with those which are known to receive visceral input but also regions in the cingulate cortex. Then progressively it reaches regions where it was less expected, for instance in the occipital lobe.'

Tallon-Baudry returns to this idea of a common space for subjective experience – how you might experience a taste, a sound, pleasure, pain, and it all seems to be in the same 'space'.

'If I ask you a weird question like "would you rather go to the swimming pool or eat a cake?", you can answer – even though not all the information converges into one place. Those different frames of reference have to be coordinated. Because it seems that the representation of the visceral organs is actually pretty much distributed in the brain, it might be a way to create this common space so we can have those subjective experiences. Now the difficulty is how to test that experimentally.'

The virtual self

Virtual reality gives researchers the ability to manipulate the sense of self using these internal signals. Cognitive neuroscientist Dr Jane Aspell (Anglia Ruskin University) can often be found in her lab confusing the selves of her participants using full-body illusions. She's creating an approximation of out-of-body experiences, heautoscopy, and autoscopia – all of which interfere with our sense of self.

In these experiments, participants are filmed from behind and through VR headsets can see their own body in front of them. Aspell's work builds on the work of Olaf Blanke's lab which has found if participants

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are stroked on the back while being shown their own back through VR, and if the stroking on their own back and that of their virtual body is in synchrony, they will feel their sense of self moving toward their virtual self. Aspell found, in a similar set-up, when subjects are shown their virtual body standing in front of them and surrounded by a light which pulses in time to their own heartbeat, people feel as if the spatial location of their self becomes unstable and they identify more with their virtual self. This ties in with Tallon-Baudry's findings linking brain representations of the heart to the self.

Aspell's work broadly explores the role of bodily signals in constructing the self, but the question of how the brain combines all this information to create a stable feeling of 'I' remains a mystery. 'We know a bit about which areas of the brain are involved. There's an area the temporoparietal junction which we know is one key area for multisensory integration... Olaf Blanke found that's the area which is functioning abnormally when someone has an out-of-body experience. This area receives signals from multiple modalities and then, by integrating them, somehow gives rise to that coherent sense we have of being a single person, being located in our body.'

Aspell says it's 'quite a weird thing' that the brain localises touch according to the body part, but also maps where the body part is within space. 'We were shifting that part of the tactile localisation so it still feels like it's on your back but it feels like your back is over there. Using a reaction time task called the crossmodal congruency effect, we measured that in an objective way by looking at interactions between light flashes and reaction time to touches. We could show the touch really was experienced in a different location in space to the actual location of the body... which is bizarre.'

Intriguingly, in a study published earlier this year Aspell found that people with autism spectrum disorders (ASD) were less susceptible to full body illusions. They did not feel any self-identification with their virtual self, nor did they experience a shift in location of their self from real to virtual body. Aspell and her colleagues suggested these results may be due to differences in the integration of the senses among people with ASD, leading to a less flexible self representation. She's continuing to work on how sense of personal identity is linked to multisensory representations of our bodies. 'We think that identity somehow has its foundation in the multisensory representation of the body but we don't know much about the links between these two aspects of self at all. It's a challenge coming up with experimental designs which can test these kinds of questions.'

Another self

There's a hint of 'parlour trick' about some of these body illusions. But Dr Domna Banakou, a Postdoctoral Fellow at the University of Barcelona EVENT lab (Experimental Virtual Environments for Neuroscience and Technology), has been exploring how changing the self impacts our real-world behaviour.

In one VR experiment participants, particularly those with lower self-esteem, performed better on a cognitive task while inhabiting the body of virtual Einstein – regardless of their baseline IQ. Banakou also observed that participants' implicit bias against older people was reduced after their experience as Einstein. Similarly, her work has shown a reduction in racial bias, measured by the Implicit Association Task, after White participants virtually inhabited a Black body.

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Banakou's team, led by Research Professor Mel Slater, are also embarking on a fascinating project which will recreate famous concerts in VR so people can experience being in the crowd – or even part of the band. Projects like this will become more common as the technology improves, and many of the ways we will be able to investigate the sense of self in future may not have been invented yet. While the potential is massive, Banakou warns of ethical

considerations. 'There is no ethical code regarding the use of VR, that's an entire field of its own... Big companies care about entertainment, and that's alright, but this is where we come in with our research to show that the changes we can achieve in VR or augmented reality are so powerful. You can change yourself so easily, we don't know how long it lasts, but it's very important that we take on board the questions in this field and take them seriously.'

Reintegration

The self, as we know it, provides a world of contradictions; it is stable but moveable, individual and social, complex but potentially basic. For now, answers to the mysteries of the how, what and why of this feeling of self remain incomplete. But the potential and possibility offered by the technologies of tomorrow give hope that we will understand what gives you the 'me' of experience. Psychologists who have been at the forefront of disintegrating the self are likely to become increasingly involved in putting it back together again.

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