My New Scientist

Thoughts: The inside story

19 September 2013 by **Tim Bayne**
Magazine issue 2935. **Subscribe and save**
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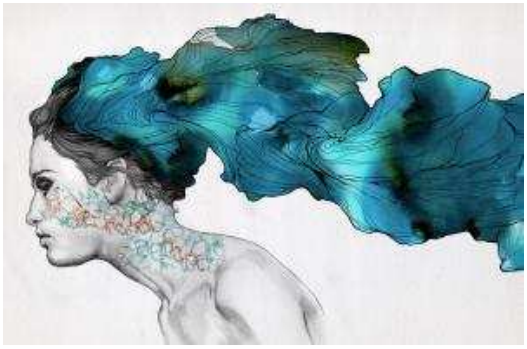
What are thoughts, and what exactly is thinking? Take a trip into the fantastic, ceaseless world our minds create



(Image: Gabriel Moreno)

TRY, if you can, to imagine a life without thought. For a human being it wouldn't be much of an existence. Thoughts fill our every waking moment, and whether they are insightful, banal, playful or bizarre, there is no denying that thinking comes naturally to us. We might say that thought is to human beings what flight is to eagles and swimming is to dolphins.

But it is one thing to think and quite another to understand the nature of thought. Just as eagles fly without any grasp of aerodynamics and dolphins swim without understanding fluid mechanics, so most of us think without having any insight into its nature. Thinking may be commonplace, but it is quite rare to think about thought itself.

So what is thought? That is a surprisingly difficult question to answer. Neuroscience, psychology, philosophy and other disciplines have approached it from their various perspectives, but thought has not received as much sustained attention as it deserves.

Perhaps part of the explanation for this is that thought is an extremely varied and complex phenomenon. We can think about an incredible variety of things: objects, people, places, relationships, abstract concepts, the past, the future, real things and imaginary things. We can think about nothing at all, and even think about thought itself.

The exercise of thought is also elusive, although there are some things we can say about it. We use thought to solve problems and invent things – but how much control do we have over it? And is there a limit to what we can think of?

To make some progress with these questions we first need to make some distinctions, for the term "thought" can refer to three quite different features of mental life.

In one sense, thought refers to a type of mental event. To think of something is to bring it to mind in some way. In another sense it refers to a certain kind of mental faculty. Just as there are faculties associated with perception and language, so too there is a mental faculty – or perhaps faculties – associated with the capacity to think. And in a third sense it refers to a certain kind of mental activity. Just as you can be engaged in the activity of looking for something or listening to something, so too you can be engaged in the activity of thinking about something.

Let's first consider thought as a mental event. What are thoughts, and what distinguishes them from other kinds of mental events, such as perceptual experiences and bodily sensations?

Suppose you are having a bonfire. You can see the flames and feel the heat. These are purely perceptual events. You may also find yourself wondering what would happen if the wind changed direction, or how combustion works. These events are prompted by your perceptual experience, but they are not themselves forms of perception. They are thoughts.

More than a feeling

Although the distinction between perception and thought is intuitive, no one has been able to characterise it unequivocally. One way is to argue that thoughts involve the deployment of concepts, whereas sensory states do not. It is possible to see a bonfire without possessing the concept of a bonfire, but impossible to think about it. However, this view is contentious. For one thing, some theorists argue that concepts are implicated in both thought and perception. And it has proved difficult to say precisely what concepts are.

Another way to distinguish thought from perception is by their conscious character: "what it's like" to think about a bonfire is very different from what it's like to perceive a bonfire. But here too we run into difficulties. Although everyone agrees that thinking about a bonfire is subjectively different from perceiving one, pinning down why is tricky.

The issue is further complicated by the fact that thoughts are often unconscious. Consider when you are trying to solve a problem, and something simply comes to mind, or you sleep on it and find that it is miraculously solved in the morning. So you can't just rely on their conscious character to distinguish thoughts from other mental events.

How about thought as a mental faculty? A useful starting point is René Descartes' description of thought as a "universal instrument which can be used in all kinds of situations." What did he mean?

Consider, again, the difference between perceiving and thinking. In order to perceive, say, an apple, there must be a causal connection between you and it. Light must be reflected from it and be processed by your visual system. No such connection is required to think about an apple. You can think about one whenever you want, whether or not it is there. This is what allows the faculty of thought to be used "in all kinds of situations".

Another feature of thought that Descartes points us to is its scope. Perception only provides access to a limited range of things. Vision can tell us that an apple is red or that it is falling, but only a creature with the power of thought is able to appreciate the fact that it originated in western Asia or that it has more genes than a human. We can think about objects that are far removed from us in space and time, about the concrete and the abstract, about the past and the future, and about what does and what does not exist. The reach of human thought may not be completely unlimited (more on this below), but there is no doubt that it vastly outstrips the reach of perception.

A final feature of the faculty of thought is its integrative nature. It enables us to relate one state of affairs to another and appreciate connections between them.

Consider a famous episode in the history of medicine. While working at a hospital in Vienna in the 1840s, physician Ignaz Semmelweis noticed that the incidence of childbed fever was much higher in one maternity ward than another. He also noticed that this ward was staffed by medical students who performed autopsies. This led him to wonder whether the students might be contaminating the women with "cadaverous material". He tested this hypothesis by requiring the students to wash their hands with calcium hypochlorite – known to remove the smell of corpses – before visiting the maternity ward. This led to a dramatic drop in deaths from childbed fever.

Semmelweis's discovery, which laid the foundations for the germ theory of disease, required two acts of integration: not only did he make a hitherto-unnoticed connection, he also thought of a way of testing the resulting hypothesis.

We make use of the problem-solving powers of thought on a daily basis. Whether planning a holiday, attempting to juggle work and children, or just trying to figure out the best way to get from A to B, we spend much of our lives thinking about the relationship between events.

Let us now turn to thought as a mental activity. In other words, let us consider thinking.

Although thoughts can occur in isolation, it is perhaps more common for them to come in trains. There are two types of trains of thought. Sometimes thoughts are related associatively: one thought naturally and effortlessly leads to another, like a game of word association. For example, thoughts of Switzerland might trigger thoughts of skiing which might lead to thoughts of snow which might lead to thoughts of Christmas... and so on. Associative thinking is familiar from daydreams and other forms of reverie.

Although there is a certain delight to be had in following this kind of train of thought, the power of thinking arguably resides in something more systematic: the fact that it enables us to use evidence

and logic. Indeed, the term "thinking" is sometimes reserved for this activity (see "Thought experiments").

Consider the chain of thought "Socrates is a human", "all humans are mortal" and "Socrates is mortal". The components are inferentially connected, for if the first two are true then so too is the third.

Much of the value of thinking comes from our ability to organise thoughts into coherent trains to "see" what follows from what. In other words, much of our interest in thinking concerns reasoning.

The nature of thought

Having distinguished various aspects of thought, we can now turn our attention to the nature of thought. What is it?

It used to be believed that thought required some kind of non-physical medium – a soul or an immaterial mind. Modern theorists typically reject this in favour of a materialist account, according to which thought involves only physical processes.

There are three main motivations for this. The first is because it can account for correlations between states of the brain and states of thought. From the mild changes that follow from drinking caffeine to the more radical ones that result from brain damage, it is clear that the state of the brain is intimately correlated with our capacity to think.

A second motivation is its ability to account for the causal role of thoughts in the world. Thoughts are both caused by physical events and are the cause of them. Seeing a train pull into the station might lead you to think "time to go", which leads you to pick up your luggage and board the train.

Thirdly, the materialist account of thought does justice to the continuity of nature. We assume that humans evolved from animals that lacked thought. Although we cannot rule out the possibility that this involved the emergence of some kind of non-physical medium, it is more plausible to assume that the evolution of thinking creatures can be fully explained by changes in the structure of physical systems.

None of these reasons is decisive alone, but taken together they provide a strong case for the physicalist conception of thought. So how might thoughts manifest as physical phenomena in the brain?

For most of human history thought has been essentially private, accessible only through speech and behaviour. There are various theories about how thoughts arise (see "Thinking like a computer"). But developments in "brain decoding" are starting to open up thought to more direct study.

Using fMRI, neuroscientists are starting to be able to use information about a person's brain states to determine what they are thinking. In one study, volunteers were asked to choose between two options – "add" or "subtract" – before being presented with two numbers upon which to perform their chosen operation. The researchers were able to tell with 70 per cent accuracy whether the subjects had decided to add or subtract, thereby reading their hidden intentions (*Current Biology*, vol 17, p 323). Other researchers have had similar success working out what people are looking at from their brain activity alone.

Although impressive first steps, it is worth emphasising the limitations of decoding studies. Firstly, the range of thoughts that participants are told to entertain is artificially restricted. In the add/subtract study, there were only two possibilities. In the real world the range of thoughts is not constrained like this, and thus the task of interpreting a person's brain activity in everyday life will be vastly more difficult.

Brain decoding also requires a lot of advance preparation, mapping correlations between peoples' thoughts and their brain activity. Researchers cannot read thoughts that are not already included in their database. Brain imaging is thus still a long way from decoding the language of thought, let alone designing a machine that can read people's thoughts.

Thoughts and words

One hotly contested question about the nature of thought is the role that language plays. There is a wide range of opinion. One end of the spectrum is that we think in language. At the other is the view that language has no role in thought other than to allow us to communicate our thoughts. The truth is likely to lie somewhere in the middle.

One way into this debate is to consider what kinds of thoughts non-human animals can entertain. Researching this is difficult, but there are at least three domains in which evidence of animal thought has been found: numbers, social relations and psychological states.

Many species have some capacity to track mathematical properties. In one study, rats were trained to press a lever when they heard two tones and a different lever when they heard four. They were trained to do the same in response to flashes of light. When presented with one tone and one flash, they pressed the first lever, indicating that they had understood the stimulus as "two events". In response to two tones and two flashes of light, they pressed the other lever.

A number of species can also compare quantities quite accurately. In one experiment chimpanzees were given a choice of two trays of chocolate chips. On each tray were two piles – a 3-chip pile and a 4-chip pile, say, or a 7-chip pile and a 2-chip pile. The chimps were thus faced with the problem of determining which tray had the most chips overall. Although they struggled when the quantities were very similar, they were generally good at choosing the right tray.

Chimps can also grasp simple fractions. When shown half a glass of milk, they are able to point to half an apple and ignore three-quarters of an apple in order to gain a treat.

Overall, the evidence suggests that a number of species can represent quantities up to three in exact ways and larger quantities in approximate terms. These representations are thought-like in so far as they are stimulus-independent and systematic.

A second domain in which there is evidence of animal thought concerns social rank. Some of the most intensive research on social cognition has been done on female baboons, whose complex social world involves a two-tiered hierarchy. Families are ranked relative to each other, and females within each family are too.

This ranking – which is fluid – plays a pivotal role in baboon society, and it is no surprise that baboons have complex representations of their social world. For example, a baboon may be more startled by a sequence of calls that represents a subordinate threatening a dominant baboon from a different family than it is by a sequence of calls that represents an equivalent conflict within a family, even when the difference in overall rank order is identical.

There are a number of ways in which a baboon's understanding of its social world has thought-like features. Firstly, social status is not directly obvious in the environment, and keeping track of it requires the deployment of a theory about it. Secondly, it appears to be somewhat open-ended: a baboon can represent a great number of possible relations between members of her troop including ones that are unexpected. These features provide good justification for describing the baboon's representation of its social world as a form of thought.

A third area in which thought-like representations have been found is in the understanding of psychological states. Primates, at least, seem to be able to determine what others can see – and thus, perhaps, what they know – on the basis of what they are looking at. They will follow the gaze of others to locate the object of their attention and will remove food items from the line of sight of other animals. In experiments, subordinate chimpanzees will only take food items that dominant chimps cannot see – dominant chimpanzees typically take all the food and punish subordinates that challenge them – suggesting they understand the connection between seeing and knowing.

State of mind

There is also evidence that primates can monitor their own states of mind. In a series of studies, monkeys learned to perform a test which required them to discriminate between two shapes. When they answered correctly they received food; when they got it wrong they got nothing, and were obliged to wait a while for the next trial, which they didn't like to do. The monkeys learned that by pressing a button they could opt out of a test and move immediately to the next. The monkeys' use of the opt-out suggested that they were assessing how difficult each test was, for they opted out only on difficult trials.

It seems clear that non-human species use thought-like processes in a number of situations. Even so, they do not come close to matching the range and sophistication of human thought. What accounts for the uniqueness of human thought? The answer appears to be related to language.

Consider the following experiment involving Sheba, a chimpanzee trained to use numerals to represent items. Sheba was offered two plates of food, one large and one small. To obtain the larger

plate, she had to point to the smaller one. Although she understood the rule she wasn't able to overcome her instinct to point towards the larger plate – until the plates were covered and numerals representing the number of treats were placed on top of them.

The use of symbols allowed Sheba to transcend her normal abilities and do something much smarter: disengage her thought from perception. This "decoupling" is a striking feature of human thought, and may be facilitated by (and perhaps even require) the use of symbols, especially language.

Another example of the transformative power of symbols is provided by a study of chimpanzees trained to use plastic tags to represent sameness and difference. A pair of cups might be associated with a red triangle (sameness) whereas a cup and a shoe might be associated with a blue circle (difference).

Once the chimps had grasped this idea they could then – and only then – go on to appreciate higher-order relations of sameness and difference. They understood that two pairs, such as cup-cup and cup-shoe, have the relation of difference. The researchers suggest that the tags enabled the chimps to perform this task because they could transform a higher-order task into a simpler one of determining whether the symbols associated with each pair were the same.

As the philosopher Andy Clark has remarked, "experience with external tags and labels thus enables the brain itself... to solve problems whose level of complexity and abstraction would otherwise leave us baffled."

Language facilitates thought in other important ways. It is a tool that allows us to augment our powers of thought. By putting thoughts into language we are able to take a step back and subject them to critical evaluation. There is good reason to suppose that much distinctively human thought involves, or is at least enabled by, language.

Another distinctive feature of human thought is that it occurs in a social environment. We are born into a community of thinkers, and we learn to think by being guided by those who are experts. Indeed, childhood is an extended apprenticeship in thinking. We learn both what to think and how to think.

Perhaps most importantly of all, cultural transmission allows the best thoughts of one generation to be passed on to the ones that follow. Unlike other species, whose cognitive breakthroughs usually have to be rediscovered anew by each generation, we are able build on the thoughts of our ancestors. We inherit not just the contents of their thoughts, but also methods for generating, evaluating and communicating thoughts.

What thinking involves

Another key question that arises from considering thought as an activity concerns the kind of control we have over it. Is thinking an intentional and controlled activity, or is it largely passive? Do we control it, or is it something that just happens to us?

Sometimes thought is controlled by the application of a rule. Mathematical and logical operations, for example, are rule-based, and philosophers have invented many other systematic "thinking tools" to help them think more clearly (see "Tools for thought"). But this is an unusual kind of activity, and most episodes of thinking involve no rule.

Suppose that I ask you why democracies tend not to wage war against other democracies. (It is often said that democracies have never waged war on one another but that is not true.) If you have not already considered this question, you may need to think about it.

What precisely does that involve? If your experience is anything like mine, you simply put the question to yourself... and wait for something to spring to mind. Sometimes nothing much happens; on other occasions, your unconscious comes up with something intelligible. Either way, there is no rule that you can consciously follow in order to generate the required thoughts.

On the whole, thinking often doesn't seem to extend much beyond putting questions to yourself and waiting for your unconscious to answer. The role of consciousness in such cases seems to be that of a minder whose job is to ensure that one's train of thought doesn't wander off topic.

We are, however, surprisingly poor at keeping our mind-wandering tendencies in check. In one study, people were asked to read a passage in their heads and monitor themselves for "zoning out". They

were interrupted at random to check whether they were still reading the passage. It turned out that the participants zoned out a lot and, what's more, were generally not even aware that they had.

In fact, a significant amount of thought is undirected – that is, not aimed at any specific goal or problem. This kind of thought takes many forms, ranging from simply wandering away from a task to the spontaneous, unbidden thoughts that pop into your head during rest or routine chores.

Until recently, undirected thought was seen as a useless and wasteful aspect of our internal mental lives. But research now suggests that it is a normal and even necessary aspect of thought. Brain activity during mind-wandering is reminiscent of that seen when people are deliberately engaged in creative thinking. It may be that, paradoxically, undirected thought is when we get our best thinking done.

There is also evidence that attempting to control the direction of a stream of thought can be counterproductive. In a famous study, psychologist Daniel Wegner asked participants not to think about white bears for a 5-minute period. He found that this group reported more thoughts about white bears than did a second who had been instructed to think about white bears.

The limits of thought

So although we have some conscious control over the direction of our thoughts, it is far from unlimited. And if we have relatively little control, perhaps we also have relatively little responsibility for what we think.

Nonetheless, the potential of human thought is clearly very great. It is not limited in the way our physical and perceptual abilities are. We cannot see or visit distant tracts of space and time, for example, but we can think about them.

Are there limits to what our minds can grasp? The idea that certain aspects of reality are beyond us might at first seem implausible. After all, there doesn't seem to be any aspect of the world that we cannot think about. Is there any reason to take the possibility of cognitive limits seriously?

There is. Given that the machinery of human thought is part of our biology, there is every reason to suspect that it suffers from the kinds of bugs and blind spots that constrain other biological systems. It is doubtful whether chimpanzees possess the ability to think about quantum mechanics, for example. Perhaps that is one of the limitations of lacking language. But if there are parts of reality that are inaccessible to other thinking species, why should we assume that no part is inaccessible to us?

It is one thing to grant that some aspects of reality lie beyond our grasp, but quite another to identify what they might be. Is it possible to demarcate the borders of human thought?

The question might seem absurd. You might argue that if a certain thought is unthinkable then we can't think about it, let alone know that it is unthinkable. But there is nothing paradoxical about attempting to determine where the limits lie. The key involves distinguishing thinking about a thought from actually thinking it. Just as we can know what we don't know – the known unknowns – so too we might be able to think about what we cannot think: the thinkable unthinkables, you might say.

Wherever the boundaries of human thought might lie, there is no doubt that we are very far from having reached them. There are thoughts – deep, important and profound thoughts – that no human being has yet entertained. Thought has taken us a long way; who knows where it will lead.

Thinking like a computer

There are many theories that try to explain how thought can arise from a material object such as a brain. One of the most successful is the computational theory of thought (CTT), which envisages thinking as being like the workings of a computer.

CTT concerns the nature of both thoughts and thinking. In a nutshell, it proposes that thoughts are sentences in a "language of thought", and that thinking involves transitions between these sentences governed purely by their "formal properties", not their meaning.

Let's unpack that a bit. A formal property is a property that something has by virtue of its physical form. The formal property of a word is its shape, not its meaning. The English word "monkey" and the French word "singe" differ in their formal properties but mean the same thing.

What does it mean to say that thoughts are sentences in a language of thought? Consider the thought "Marcel has a monkey". Just as the sentence itself is built up out of linguistic symbols that have meanings, CTT holds that the thought is built up out of "thought symbols" each of which carries a distinct meaning. One symbol will refer to Marcel, another to monkeys, and a third to the relation "having".

CTT explains thinking by appealing to the formal properties of these symbols. It posits a mechanism that is sensitive to the formal properties (whatever they are) and implements a set of rules about how to manipulate these symbols without knowing what they mean. Thought thus operates much like an automated address reader for letters. Although the machine doesn't know anything about Mr Smith or Mr Jones, it is able to ensure that their mail gets to them because it is sensitive to the formal differences between Smith and Jones.

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From issue 2935 of New Scientist magazine, page 32-39.

Feedback: Occam's razor blunted a bit

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How our wolf-dogs hounded out the Neanderthals

Back to article