

Dispatches

Conscious intention: New data on where and how in the brain

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How do we decide to act, and how do those decisions relate to conscious choice? A new study helps dissociate the neuronal mechanisms that choose, prepare, and trigger movement from our explicit reports of conscious intention.

In the 1980s, the scientist Benjamin Libet published an experiment that caused a sensation¹. The results have been debated fiercely ever since^{2–4}. He asked people to sit at a table and press a button. They could press whenever they chose. At the same time, they watched the moving hand on a clock, and reported the exact time at which, as far as they could tell, they had consciously decided to press the button. In a surprise result, the brain's activity, measured through electrodes placed on the scalp, showed that the cerebral cortex was preparing to trigger the button press more than a second before the person claimed to have made the decision. How could the conscious intention to act have come after the brain began to plan the act? What does that finding tell us about consciousness and choice? Are people simply bad at judging the exact time of their own decisions? Is conscious realization the end stage, rather than the beginning, of a decision? Or should we think of movement planning and of self theory-of-mind as two different tasks that rely on two different systems within the brain? Many studies have tried to tackle the mystery, but none have looked in such granular detail at the human machinery for movement planning as a new study by Aflalo *et al.*⁵, reported in this issue of *Current Biology*. The study used the Libet task while tracking the activity of populations of individual neurons in the human posterior parietal cortex, an area known to be centrally involved in planning and initiating movements.

The reason why Libet's result is so disturbing to most people is probably because it contradicts a common,

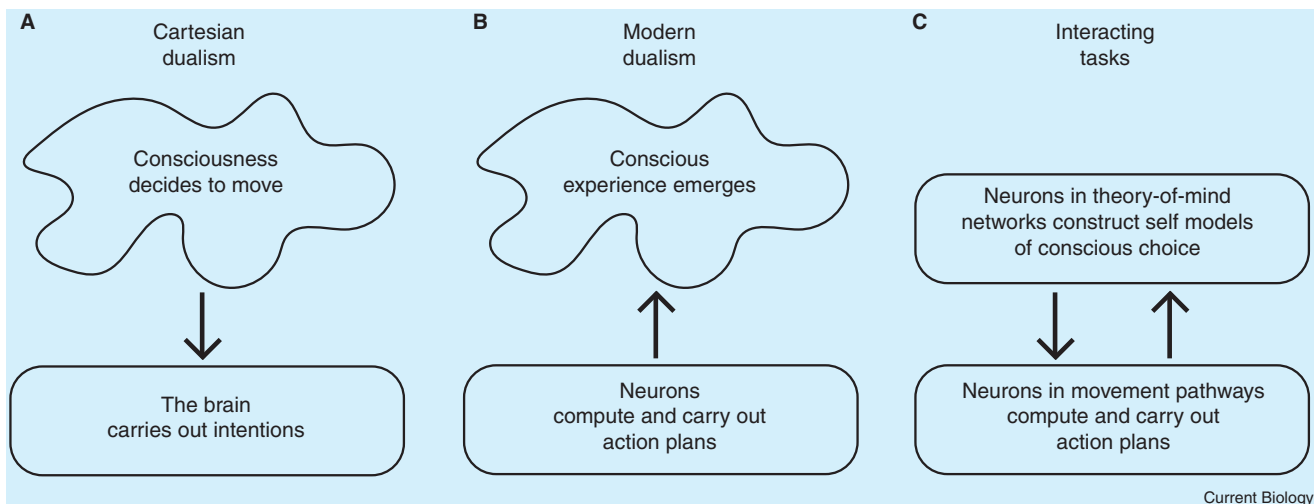
intuitive view of the mind called dualism. In that view, your consciousness is a non-physical essence that makes decisions, and then, somehow, induces your physical brain to become active in the correct manner to carry out those decisions (Figure 1A). The view was made famous by the French philosopher Descartes four hundred years ago⁶. If the neurons in your brain make a decision to act before your conscious mind does, then something is wrong with dualism.

No serious modern neuroscientist believes in Cartesian dualism. Yet a common interpretation of conscious intention, in philosophy and neuroscience, may suffer from its own, more subtle version of dualism. In that interpretation, consciousness, or subjective experience arises from the activity of neurons as they process information (Figure 1B). Consciousness is *what it feels like* to process information, at least some information, in at least some parts of the brain^{7,8}. In that view, if we become conscious of making a decision to press the button, it must be because the neuronal machinery that prepares the movement has become active, and a conscious experience has emerged out of that activity, like heat rising from electronic circuitry. In that view, again, the Libet result makes little sense. The conscious experience of deciding to move should occur simultaneous with the neuronal activity that plans and initiates the movement.

A third interpretation is more grounded in information processing, and may be able to make more sense of the Libet result while avoiding dualistic ideas (Figure 1C). Though the Libet paradigm is

usually considered to be one task, it actually combines two simultaneous and very different tasks. One is a motor preparation and execution task that could be handled by a movement control network. The second is what might be called a self theory-of-mind task, in which people make claims about their own internal processes. That second task almost certainly depends on a different network of areas in the brain. When computing information to do with minds, intentions, decisions, or experience, the relevant brain network that handles that domain of information is probably the well-studied social cognition network^{9,10}. If you ask someone, "When did you make a decision?" presumably no other networks in the brain can even understand the question. The two networks — the motor control network that performs the button press task, and the social cognition network that performs the mental self-report task — must interact to some degree. One must feed information to the other, or we would not be able to make theory-of-mind reports about our own motor planning. But there is no reason to suppose that the computations and responses in one task share any specific or tight temporal relationship to the computations and responses in the other task. This third interpretation follows a growing new perspective on consciousness^{11–13}. In that perspective, consciousness is definitely not a non-physical essence that controls the brain; but it is also not a non-physical, adjunctive feeling that is generated by the brain. Instead, people believe and claim that they have a subjective





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Figure 1. Three perspectives on the conscious choice to perform an action.

(A) In Cartesian dualism, a conscious mind makes a decision and instructs the physical brain to carry out the decision. (B) In a common modern interpretation, with similarities to dualism, the brain computes and carries out decisions and actions, and a conscious experience of intention and choice emerges from the activity of the neurons. (C) In a perspective that emphasizes information processing, two different brain systems participate. One constructs and carries out movement intentions. Another builds models of conscious intentions and choices. The two presumably interact.

conscious experience because the brain constructs a schematic model that depicts the self in that way. To ask people about their conscious decisions is to query a schematic, imperfect model of the self.

The three views outlined above could make for endless philosophical debates. To answer the question, we need more data, and that is where the new study by Aflalo *et al.*⁵ enters the debate. Two people who suffered from partial paralysis were fitted with electrode arrays in the posterior parietal cortex, to measure the activity of individual neurons. The original, clinical purpose was to translate that activity into the movement of mechanical, prosthetic devices. A scientific benefit of the procedure was the unique window it provided on neuronal activity in the movement preparation parts of the brain. Aflalo *et al.* asked their two subjects to perform several versions of the Libet task while measuring the activity of parietal neurons.

The results showed that the neurons were associated with the movement task. When the participants were asked to shrug a shoulder or clench a hand, the neurons became active in ways tightly coupled to movement choice, preparation, planning, and initiation. However, the neuronal activity was not well aligned to the time of the conscious decision that was reported by the

participants. Not only did the neuronal activity precede the indicated time of conscious decision by about a second, but the timing between the two was inconsistent. It was not as if the neurons ultimately triggered the conscious experience at a consistent delay. Instead, the data suggested that the neuronal activity measured in the parietal cortex was unrelated to the task of judging the time of conscious decision. The results point to the third interpretation outlined above, in which the Libet paradigm includes two different tasks that are performed by different networks. The movement task is carried out by the known movement control network. The self theory-of-mind task must be carried out by a different network of neurons, not measured by the electrode arrays implanted in the parietal cortex.

The findings imply that the most common interpretation of conscious intention is probably wrong. When neurons in the main motor-planning pathway in the brain become active as they plan and initiate a movement, there is no evidence that those neurons generate a reportable conscious experience of deciding to move. Conscious experience is not simply what it feels like for neurons to process information. The report of a conscious choice may come from some other pathway in the brain with expertise

on processing information about mind states.

It remains for future studies to test electrodes in brain areas known for social cognition, such as the right temporoparietal junction, or the dorsomedial prefrontal cortex, if such an electrode placement ever becomes clinically necessary. Researchers might then be able to measure neuronal activity related to the self theory-of-mind component of the Libet paradigm, finally completing the neuroscientific picture of how movement planning and the self-report of conscious choice relate to each other.

DECLARATION OF INTERESTS

The author declares no competing interests.

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Evolution: Various routes to sex determination

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Combining empirical data and theoretical analyses, a new study reconstructs the series of evolutionary changes that have led the African pygmy mouse, *Mus minutoides*, to its elaborate sex chromosome system.

Sex chromosomes are not required for sexual reproduction or sexual differentiation. Plenty of organisms get along fine without them. For example — most plants don’t opt for being one sex or the other and instead develop both female and male organs on the same body; some fish spend the early part of their lives as one sex and then the latter part as another; some homosporous ferns choose their sex by relying on chemical signals from near neighbors; and crocodiles use the temperature at which they’re reared to guide them to develop as one sex or the other¹. All of this raises the question — why, if they aren’t necessary for sex determination or differentiation, are there sex chromosomes at all? Sex chromosomes have arisen repeatedly, which suggests there must be an advantage to them, but why would natural selection favor them? A new study published in this issue of *Current Biology* by Saunders *et al.*² takes on these questions in the elaborate sex chromosome system of the African pygmy mouse, *Mus minutoides*, and finds an explanation rooted in violations of Mendelian laws.

The sex chromosome system in *M. minutoides* is much like the X/Y system that is common to most mammals, such as our own, but for a few interesting wrinkles. The first of which is that there are two kinds of X chromosome: the familiar X chromosome, which is recessive to the Y; and the so-called X*, a feminizing X chromosome that is dominant to the Y. This gives three female genotypes (XX, X*X, and X*Y) and one male genotype (XY). At first glance, the system seems poised for difficulties. For starters, with so many genotypes for making a female, one expects the population to become female-biased. Additionally, one expects reproductive difficulty for the X*Y females, both because of complications from harboring a Y chromosome in a female body and also because mating with XY males should see them producing inviable YY offspring 25% of the time. This leads to another interesting wrinkle — Mendel’s law of segregation is completely flouted for the sex chromosomes. The transmission of X and Y chromosomes through males is not 50:50, as expected, but is instead biased. Further — and for the final wrinkle — their transmission is

conditional on the genotype of the female to which they’re mated.

Saunders *et al.*² first provide some new empirical findings on this latter wrinkle. They find that the male Y is transmitted to 79% of offspring in crosses with XX females and 76% of offspring in crosses with X*X females. But with X*Y females they find the male Y transmitted to only 36% of offspring, with no apparent drive taking place through female meiosis (Figure 1). This leads to an overall greater number of male offspring in all three crosses than would be expected by chance alone. With these numbers in hand, they then attempt to map out theoretically the plausible historical steps by which this species might have come by its sex chromosome system.

Previous work^{3–5} has sought a connection between the various wrinkles of the X/X*/Y system, which is not limited to just *M. minutoides* but has evolved independently in several other rodents⁶. As with many evolutionary genetic phenomena relating to the sex chromosomes, one can make sense of why various features tend to co-occur. In a sense, sex chromosomes are habitats