experimentalists have announced the state's discovery before. In 2002, one collaboration claimed to have found a bound tetraneutron[2] in an experiment based on the detection of neutron clusters formed by fragmentation of beryllium-14 projectiles. But the result remains unconfirmed, and theorists quickly showed that, based on the best knowledge of the nucleon–nucleon interactions and other arguments[3,4], the existence of a bound tetraneutron was nearly impossible.

However, theorists could not rule out the existence of a tetraneutron as a short-lived 'resonant' state on the basis of a dineutron–dineutron structure[3,4]. The dineutron state is formed by two neutrons, and is not stable. It is known as a virtual state: if its energy were reduced by 66 keV, then the dineutron system would become bound. Decades earlier, it had been proposed[5] that dineutrons can become bound in the presence of additional nucleons; this mechanism is responsible for the properties of some bound nuclei that have a neutron excess, such as lithium-11, in which a pair of external neutrons forms a remote halo around the core of lithium-9.

The tetraneutron cannot form an atomic nucleus because it is charge neutral and therefore cannot hold electrons. But there is an intimate relationship between the tetraneutron structure and theoretical studies of neutron stars (Fig. 1), in which neutrons are compressed to densities more than 10^{14} times that of water[6]. They are prevented from imploding by an outward pressure that is generated by the nucleon–nucleon interaction and other quantum-mechanical effects.

Nuclear physicists hope to develop a full understanding of how quarks and gluons inside nucleons generate nucleon–nucleon forces, and how many-body objects evolve to form complex structures such as the uranium nucleus and neutron stars. This is a formidable task, with well-understood parts but also many missing links. If Kisamori and co-workers' report of the tetraneutron state is confirmed, even as a short-lived resonance, it will add another structure to the nuclear chart that will help to improve our understanding of the nuclear interaction. ■

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NEUROSCIENCE

Fault tolerance in the brain

If stored information is erased from neural circuits in one brain hemisphere in mice, the lost data can be recovered from the other. This finding highlights a safeguarding mechanism at work in the brain. SEE ARTICLE P.459

BYRON M. YU

When we send an e-mail or save a file on our hard drives, information can be lost, owing to dropped data packets or corrupted bits. We typically do not notice such failures because systems are designed with built-in mechanisms to restore the lost data. Dropped packets are retransmitted, and multiple copies of data are saved. The brain also stores and transmits information — is it, too, fault-tolerant? In this issue, Li *et al.*[1] (page 459) report the perturbation of brain activity to erase stored information in mice. They discover that the lost information can be rapidly restored by an unperturbed brain region.

The brain can reorganize itself to restore function after certain types of injury[2], but this type of fault tolerance typically takes place over weeks. By contrast, many everyday brain functions, such as putting a name to the face of an acquaintance or hitting a tennis ball, take place on a timescale of seconds or less. Does a fault-tolerance mechanism also operate in neural circuits over these shorter timescales?

Li *et al.* investigated whether regions present in each of the brain's two hemispheres might act together to produce a rapid back-up system for stored information — a mechanism

50 Years Ago

Hypnotic Susceptibility. By Ernest R. Hilgard — A large number of studies designed to investigate various hypnotic phenomena have been carried out by Ernest Hilgard and his co-workers on a considerable number of college students during the past eight years. Individual differences in 'hypnotizability' have been a major area of interest and in the course of their investigations several scales were developed for the quantitative assessment of hypnotic susceptibility … There are three general purpose scales and a scale for yielding profiles of hypnotic ability. Convincing statistical evidence is given concerning their validity and reliability … The latter part of the book is concerned with the relation of hypnotic susceptibility to a number of personality variables … Although some significant correlations do emerge, they are insufficient to characterize the hypnotizable person clearly.
From *Nature* 30 April 1966

100 Years Ago

The large meteors which passed over Northern America on February 9, 1913, presented some unique features. The length of their observed flight was about 2600 miles, and they must have been moving in paths concentric, or nearly concentric, with the earth's surface, so that they temporarily formed new terrestrial satellites … The meteors were last seen from the Bermuda Islands … I have since made efforts to obtain further observations from seafaring men through the medium of the *Nautical Magazine*, and have succeeded in procuring data which prove that the meteors were observed during a course of 5500 miles from about lat. 51° N., long. 107° W., to lat. 5½° S., long. 32½° W.
From *Nature* 27 April 1916

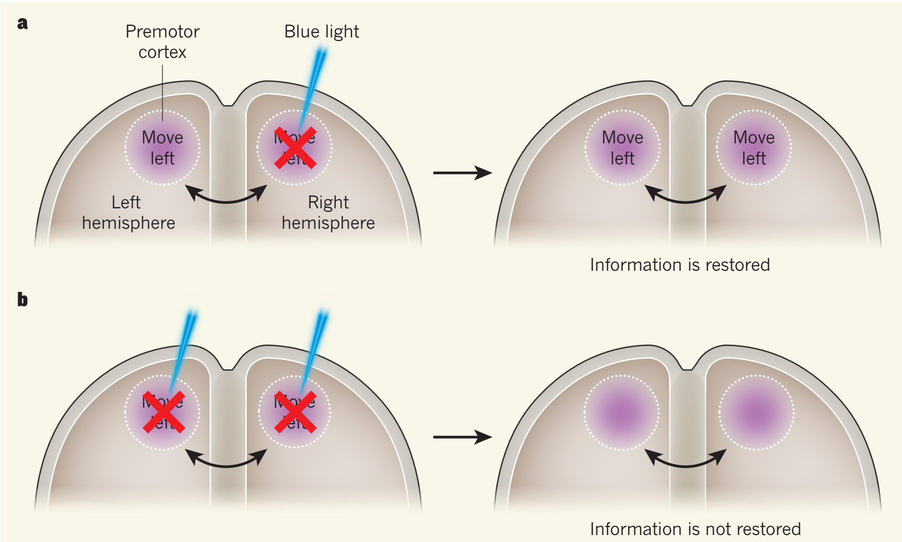

Figure 1 | A mechanism of redundancy. **a**, The premotor cortex regions in each hemisphere of the mouse brain, which are connected by neurons (double-headed arrows), produce activity that prepares the animal to move its tongue left or right. Li *et al.*[1] genetically engineered mice such that blue light could temporarily block neuronal activity in these regions, erasing information about the intended direction of movement. If information is erased in one hemisphere, it is quickly restored. **b**, By contrast, if information is erased in both hemispheres, it is not restored.

known as redundancy. Specifically, they tested whether the two premotor cortices of the mouse brain act redundantly to prepare the animal to lick with its tongue in a particular direction, which it has been taught will lead to a reward of water. The authors briefly blocked the activity of premotor neurons in one hemisphere and observed that information about intended licking direction was quickly restored (Fig. 1a). However, if they silenced neurons in both hemispheres in this way, the information was not restored, and so the animal licked left or right at random (Fig. 1b).

These results indicate that, during single-hemisphere silencing, fault tolerance is provided by the unmodified hemisphere. To test this back-up system more directly, the researchers severed the connections between the two hemispheres. When neurons in one hemisphere were silenced in this setting, the information about intended licking direction was not restored.

Next, Li *et al.* constructed computational network models of neurons in two interacting hemispheres to study how connectivity between the two brain regions enables fault tolerance. In these models, as in the experimental setting, information about movement direction was restored after neuronal silencing in one hemisphere. Together with the experimental evidence, these data suggest that each hemisphere helps the other to restore information about planned movement direction.

Perhaps the most interesting finding in this study is that, after silencing neurons in one hemisphere, not all aspects (called dimensions) of the perturbed neural activity recovered equally. Li and colleagues found that the neural activity that enabled maximal differentiation between left and right licks recovered rapidly. By contrast, other dimensions of neural activity that were not relevant to the task did not always recover. Thus, there was preferential recovery of the dimension that was needed for the animal to succeed at the licking task.

The current study involved both hemispheres controlling a single effector, the tongue. An open question is how these findings apply to brain functions that predominantly involve a single hemisphere, such as control over reaching with one arm. As the authors point out, one possibility is that there are redundant subcircuits within a hemisphere, perhaps spread across multiple brain areas, working together to provide fault tolerance.

Li *et al.* perturbed neural activity using an optogenetic technique, in which the activity of neurons that harbour light-sensitive ion channels can be modulated using light. This approach allows the silencing or activation of many neurons in unison. To further understand the fault-tolerant properties of neural circuits, more-flexible methods that allow selective activation and silencing of different groups of neurons at different times are needed. Such methods would permit testing of the robustness of a neural circuit to different patterns of perturbation, including those that mimic the random signal disturbances, known as noise, that are a part of normal neuronal signalling[3].

The current work demonstrates the power of perturbing neural activity in combination with multidimensional analysis of the activity of a neural population[4]. By perturbing neural activity in different ways and observing how it recovers, we should be able to gain further insights into fundamental network-level mechanisms that support brain functions[5]. Advances in methods for perturbing and recording neural activity, for analysing population-wide neural activity and for network modelling are rapidly making such studies possible. ■

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MATHEMATICAL PHYSICS

Glitches in time

A mathematical technique has now been developed that reveals the underlying dynamics of time-dependent data collected with extreme temporal uncertainty, without using additional, costly instrumentation. SEE LETTER P.471

CHARLOTTE A. L. HALEY

Many of today's scientific questions require the reconstruction of accurate histories from data collected with uncertainty in the temporal or spatial measurement process. Examples include the systematic errors in timing or spacing seen in measurements of astronomical time series collected at uneven intervals[1,2]; in determinations of global climate history from concentrations of gas extracted from bubbles in ice cores drilled in the Antarctic[3]; and in deductions of the proximity of far-away galaxies when the observed light is bent by gravitational lensing[4]. On page 471 of this issue, Fung *et al.*[5] report a mathematical method that allowed them to analyse data with uneven temporal