

laser-plasma interactions and propagation of giga-ampere currents of megavolt electrons is required⁷. The efficiency of energy transfer from the short laser pulse to the hot spot in the compressed plasma is a crucial parameter, which has not yet been accurately measured or predicted, but must reach about 20% for the scheme to succeed.

The experiment by Kodama and colleagues is the first to combine production of compressed matter in a laser-driven implosion with picosecond heating by a laser pulse timed to coincide with peak compression. This is a small-scale test of the fast-ignition concept and uses a small spherical shell of deuterated polystyrene to simulate the D-T ice. Because the target has no tritium, it produces D-D fusion instead of D-T fusion. The shell is formed around a hollow gold cone to provide an access path for the ignitor beam to the fuel, which is compressed to a diameter of 40 micrometres at 50 g cm^{-3} (Fig. 1).

Their first results are encouraging. The thermonuclear yield of neutrons from D-D fusion is increased tenfold by irradiation at peak compression with a short 60-joule laser pulse. This means that 1% of the temperature rise needed for ignition was achieved using only 0.1% of the theoretically required ignitor beam energy. They also note that the longer, 1,200-joule laser pulse that drives fuel compression has to be increased to 2,800 joule to achieve the same increase in neutron yield without the 60-joule short-pulse heating — highlighting the efficiency of the fast-ignition approach. Preliminary analysis suggests greater than 20% energy transfer efficiency from the short pulse laser to heating of the compressed core, which is adequate for full-scale fast ignition.

If this heating efficiency were confirmed by experiments using 1-petawatt, 500-joule ignition pulses, planned by Kodama and co-workers for later this year, the longer-term prospects for full-scale fast ignition would be good. Stepping up to megajoule laser drivers, it might even lead to a 300-fold energy gain, and could initiate serious efforts worldwide to produce fusion energy by fast ignition. However, experience with other fusion energy projects should temper our enthusiasm for fast ignition. At such an early stage, this new approach to fusion energy should be viewed as promising, but speculative, until much more work has been done.

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Neurobiology

The many faces of adaptation

Pamela Reinagel

Sensory neurons constantly adapt to the changing environment. It seems they can do this surprisingly quickly, and without losing their absolute frame of reference.

Sensory nerve cells can produce only a small number of distinct outputs, so they cannot generate a unique response to every relevant stimulus. To solve this problem, neurons adapt to the prevailing conditions, so the same limited set of outputs can be reassigned to different stimuli in different contexts. It was already known that, after a sudden change in the strength of a stimulus, neurons abruptly change their average responses (firing rate). Then, as the cells adapt to the new conditions, the mean response gradually adapts back to a more moderate level. Fairhall and colleagues¹ (page 787 of this issue) now show that this change in average response is just part of the story: different aspects of a neuron's response adapt independently on different timescales. Uncoupling these aspects provides surprising insight into the functions of adaptation.

When you walk from bright daylight into a dimmed auditorium, you are initially almost blind, but after several minutes your eyes adjust and you can see quite clearly. Emerge from the auditorium an hour later and the sunlight is momentarily blinding. This familiar experience illustrates the importance of sensory adaptation: without it, we would be effectively blind except at one specific level of illumination. Instead, vision can operate over a 10^{11} -fold range of light levels (from about 10^{-6} candela per square metre in darkness to 10^5 in full sunlight), even though only 10 to 100 distinct values can be distinguished in any given context.

The level of light is just one of many features to which sensory systems adapt. For example, nerve cells that respond to a more complex feature, such as motion, can also adapt, in this case to the amount of motion in a scene. Neurons adapt not only to the average but also to the distribution (variance) of recent stimuli. Both kinds of adaptation help the cell to discriminate between typical stimuli in a given context (Fig. 1).

It can take several seconds for the average firing rate of a cell to adapt after a change in the variance of a stimulus. Is this just a result of the inefficiency of biological mechanisms? Perhaps not. Cells adapt more quickly when variance increases than when it decreases². This might be explained by a problem inherent to measuring distributions — how many stimuli would you need to observe before you were convinced that they came from a new distribution? Consider the situation

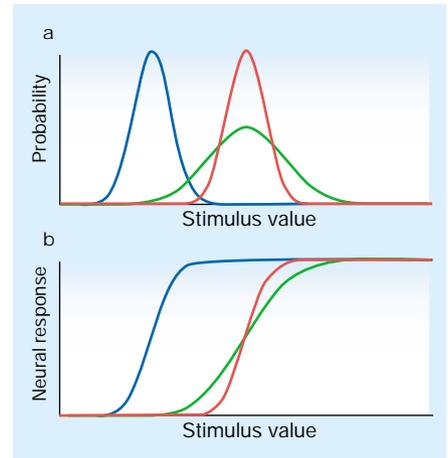


Figure 1 Natural stimuli change dramatically in different contexts; for example, light levels vary from day to night. Sensory neurons adapt to such changes. When average stimulus values (such as light intensity) are low (a, blue curve), a neuron uses its limited range of responses to represent the most likely values (b, blue curve), leaving it unable to distinguish among lower or higher values. If the average stimulus value suddenly increases (a, red), the neuron adapts by shifting its response function to the right (b, red). This optimizes encoding of the new stimuli. If the average value is held constant but the range suddenly becomes broader (a, green), the neuron becomes less sensitive to small differences (b, decreased slope of green curve), so the whole range of likely values can be represented. The neural response is shown as a continuous variable such as firing rate, but the same principles hold for more complex properties such as firing patterns. Fairhall *et al.*¹ reveal that adaptation involves many processes, occurring at different rates and with distinct functions.

in Fig. 1a. When variance has been low (red curve), just a few extreme values (from the green distribution) would quickly alert you to a change in the stimulus context. But when variance has been high (green curve), it would not be surprising to observe a few stimulus values from the red distribution; it takes a while before the lack of more extreme values becomes suspicious³. This raises the question of whether the speed of the change in firing rate (or of any other form of adaptation) is limited only by the time needed to measure the new distribution of signals.

Fairhall *et al.*¹ have now tested this by investigating how a motion-sensitive neuron

in the fly *Calliphora vicina* adapts its response when the variance of motion signals suddenly changes. Previous studies showed that after neurons have adapted to a change in variance, information transmission — that is, the ability to discriminate among stimuli — is optimized to the new conditions^{4,5}. Fairhall *et al.* find that the neuron adapts its input–output relationship extremely rapidly, achieving optimal information transfer within tens of milliseconds. The authors demonstrate that this is about as soon as any system could reliably know that the stimulus distribution has indeed changed.

On the other hand, as mentioned above, firing rate adapts much more slowly, over several seconds. So this cannot be the main mechanism by which information transfer is optimized. Instead, the authors show that the speed of firing-rate adaptation scales to match the frequency of context changes. That is, the dynamics of firing-rate adaptation depend not only on the variance of the preceding and following stimuli, as described above, but also on the ‘metastatic’ of how frequently the stimulus conditions change. This suggests that the brain could use the speed of firing-rate adaptation to predict how soon conditions are likely to change again.

Adaptation has a potential drawback, however: if a sensory neuron changes its input–output relationship without notifying the brain that it is operating in a new context, its messages will become ambiguous. In some systems this might not matter, because information about the context would be biologically useless⁶. But Fairhall *et al.* find that, in their system, information about context is not lost as a result of adap-

tation. Some firing statistics adapt to carry reliable information about the context (variance). These signals could be used to indicate which input–output relationship is operating, thereby removing any ambiguity arising from the shifting response properties of the neuron.

Fairhall *et al.*'s study¹ shows that many independent adaptation mechanisms occur, over a continuous range of timescales. Of course, this raises questions about the mechanisms underlying sensory adaptation. Different forms of adaptation could theoretically be implemented at different levels of organization, ranging from molecules to cells to neural networks. But the authors provocatively speculate that all the observed timescales might be mapped to different biophysical properties of sodium channels. Finally, it is often argued that the coding properties of sensory neurons are adapted to represent their natural stimuli efficiently. Such arguments need to consider that this adaptation may not be hard-wired but rather a dynamic process that occurs throughout the life of an organism. ■

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Earth science

Journey beneath southern Africa

Suzanne Y. O'Reilly

Seismic analyses of the lithosphere, undertaken as part of the Kaapvaal project, provide an unprecedented view of cratons — the earliest parts of continental landmasses.

How continents formed on the early Earth is one of the big questions in geoscience. One way to tackle it is by studying cratons. These are the nuclei of continents that formed during Archaean times, at least 2.5 billion years ago. Southern Africa is an especially rich area of study, so it was the setting for the Kaapvaal project. This international and multidisciplinary programme was designed to probe the architecture and age of the region's lithosphere (the upper mantle and crust that constitute the upper 200–300 km of the Earth). The result, as described in papers in *Geophysical Research Letters*^{1–7}, is the most detailed picture yet of cratons.

Southern Africa is made up of several terrains ranging in age from Archaean to very young. One of the main sources of information about what is happening deep in the lithosphere is xenoliths — fragments of mantle rock that were carried to the surface in molten rocks called kimberlite magmas. Analyses of xenoliths that erupted through the lithosphere from 1.2 billion to 80 million years ago have allowed measurement of the ages (using a system based on the ratio of rhenium and osmium isotopes)^{1,2} and physical properties³ of the deep Earth beneath southern Africa at the times of eruption.

The most remarkable results of the pro-



100 YEARS AGO

The very remarkable description of the “Fire Walk” collected by Mr. Andrew Lang and others had aroused a curiosity in me to witness the original ceremony, which I have lately been able to gratify in a visit to Tahiti. I had heard that it was performed in Tahiti in 1897, and several persons there assured me of their having seen it, and one of them of his having walked through the fire himself under the guidance of the priest, Papa-Ita... who had also performed the rite at the island of Hawaii some time in the present year, of which circumstantial newspaper accounts were given... According to these, a pit was dug in which large stones were heated *red hot* by a fire which had been burning many hours. The upper stones were pushed away just before the ceremony, so as to leave the lower stones to tread upon, and over these, “glowing red hot” (according to the newspaper accounts), Papa-Ita had walked with naked feet... I could not doubt that if all these were verified by my own observation, it would mean nothing less to me than a departure from the customary order of Nature, and something very well worth seeing indeed.

From *Nature* 22 August 1901.

50 YEARS AGO

Many of the small plankton animals in the sea which are important as the food of fish such as herring, sprat and mackerel swim upwards towards the surface in the evening and down again to deeper levels after dawn. It is of interest from a purely biological point of view to find out what are the factors which govern these movements, and may also be useful in reaching a better understanding of the shoaling of herring. The plankton consist of small animals of many different kinds, small jellyfish, worms and molluscs, hosts of small crustaceans and many others; they nearly all show this nightly vertical migration upwards. Since it has been developed in so many different groups of animals and must use up so much energy every day — some of them climbing more than a hundred feet — it must clearly be of profound significance in their lives. We do not yet understand its meaning and are still only in the stages of studying the actual movements of the animals in relation to different conditions of light, temperature, pressure, etc.

From *Nature* 25 August 1951.