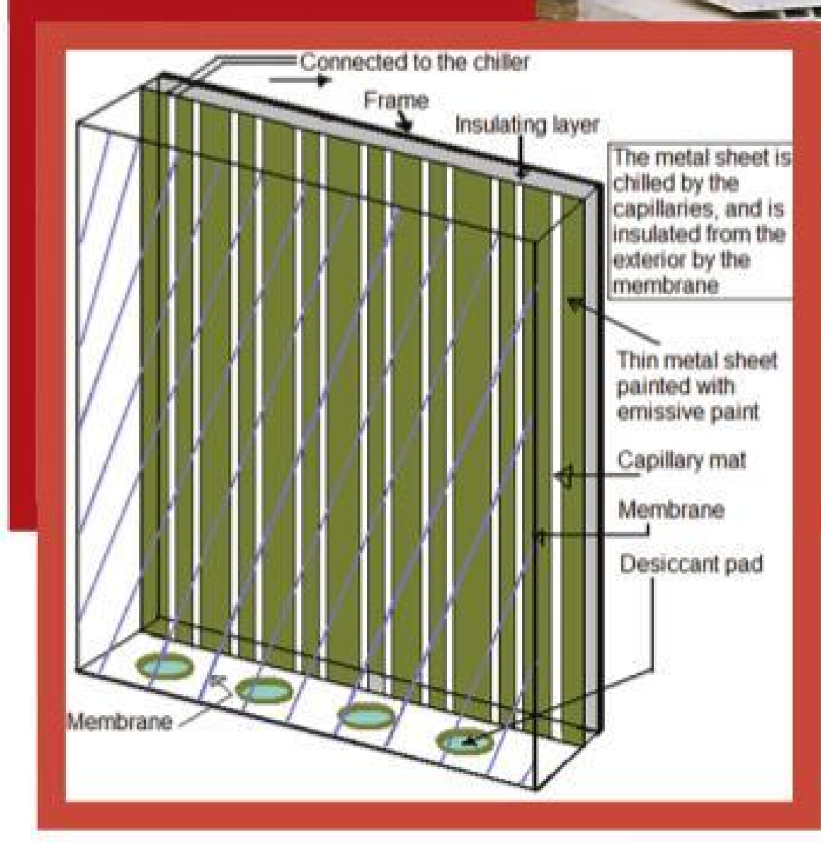
Who needs an AC for cooling?

It is people, and not the surroundings, that feel the heat



S ANANTHANARAYANAN

In our approach to beating the heat by creating bubbles of coolness, we expend resources in cooling things that do not appreciate the effort. The heat capacity of things in a room that air conditioners cool is many times more than the cooling people need.

Eric Teitelbaum, Kian Wee Chen, Dorit Aviv Kipp, Bradford, Lea Ruefenacht, Denon Sheppard, Megan Teitelbaum, Forrest Meggers, Jovan Pantelic and Adam Rysanek, from the Singapore campuses of ETH, Zurich and Berkley Education Alliance, Princeton University and the universities of Pennsylvania, British Columbia and California, report in the journal, *Proceedings of the National Academy of Sciences*, an experiment with "radiative cooling" – a method to allow the body to throw out heat, but without spending energy in cooling the surroundings.

Just as we can throw coloured light on an object, but we cannot "shine darkness" on it, only warm bodies radiate heat – cool things do not "radiate coolness". But cool things absorb more heat than they emit, and their presence helps warm things lose their heat and cool down -- the question is only of limiting the cooling to things that need to be cooled.

The common method we use to help people stay cool in warm weather is air conditioning, which is to blow refrigerated air into the spaces that people occupy. To help them stay warm in the winter, we do use "radiators", or warm objects that warm the air in the room, but people can also directly sense the warmth of radiators. For cooling, however, the only practical way is to chill air by passing it through a refrigerator, and then blow it into the room (apart from just blowing air, which causes a little cooling by evaporation of moisture on human bodies). And the cool air blown into the room needs to chill the walls, furniture and floor, before people begin to be comfortable.

The human body stays at an almost constant temperature of 37°C or 98.6°F. As the surroundings are usually cooler, there is a balance of heat production within the body and heat loss to the surroundings. The heat loss is mainly by radiation, where a warm body loses more heat than the radiation that it absorbs from its surroundings. And there is some heat lost to the surrounding air, by contact, but this is not much, as the air has little heat capacity. The problem, however, starts when the surroundings get warm, as on a summer day, and the body does not lose enough heat. The body needs to sweat, to lose heat by evaporation, but if it is humid, this is not effective and discomfort increases.

The method the PNAS group have used is to position in the room a specially fashioned, substantial "cool" surface, which would absorb heat radiated by human bodies but not return much radiant heat to the surroundings – a kind of one-way window, through which radiation can escape. The reason why just any cold surface in the room cannot do the same thing is that an ordinary surface would rapidly warm by the heat from the surrounding air, which would blow over it in convection currents. And then, the moisture in the air would condense on the cool surface. Condensation releases a great deal of heat. In the case of air conditioning, in fact, the power used in drying the air that is circulated is greater than the energy needed for cooling it. The arrangement that the PNAS group has created takes care of these two effects and allows the cool surface to receive heat only by radiation that falls on it.

The arrangement, which was tried out in an outdoor pavilion in Singapore, where the temperature was almost 30°C, was a wall, with a metal surface that was kept cool, at 17°C, by circulating refrigerated water. Normally, currents of air would have warmed the sheet. But this was prevented by an insulating, low density, polyethylene film, a membrane that was placed before the metal sheet. "...we eliminate this unwanted convection as a mechanism of heat transfer," the paper says. The film, however, was transparent to thermal radiation, and the heat from warm human bodies in the pavilion could pass through, to be absorbed by the cool surface.

As for condensation – the insulating film kept the surface exposed to air from getting much cooler. Trials showed that even with 66.5 per cent humidity, and a "dew point", or the temperature at which condensation starts, of 23.7°C, there was no condensation on the wall surface. The chilled water circulating inside the wall could go down to 12.7°C below the dew point, the paper says, before condensation set in.

And for human comfort? There was a study of how 55 persons, who participated in a trial, perceived cooling, during the days between 8 and 27 January, the summer in Singapore. Of the 55 persons, 37 entered the pavilion when the cooling system was on and the remaining when the system was switched off. The group which entered when the system was on, reported a "satisfactory" ambient temperature in the pavilion 79 per cent of the time, in those hot days, the study says. It was seen that warm objects in the area lost heat to the absorbent wall, and the humans, the warmest objects, were the main losers. The air temperature, however, was hardly affected, falling from 31°C to just 30°C. This last observation shows that very little energy is being spent in cooling the air – which is the sole vehicle of low temperatures in conventional cooling systems.

The technology reported is thus an effective stand-in for air conditioning. The reduction of energy consumption can be 50 per cent, using only what it takes for chilled water to circulate in the heat absorbent walls, an author of the paper says. This is significant, as air conditioning forms a major part of the world's energy budget, and by the end of this year, the demand is projected to surpass the demand for heating.

Another advantage of the new system is that the cooled spaces can be well ventilated. In air conditioning, economy demands that much of the cooled air be recirculated. One person with a cold (or worse) in an enclosed office is hence sure to give it to all the others.

The technology of radiant cooling works because the heat from human bodies is not absorbed by the surrounding air, to be radiated back, but can reach the cool surface. At the scale of the Earth, however, the atmosphere does not allow heat to escape, which is why the Earth does not cool deep below freezing at night (and why changes in the atmosphere are causing global warming).

There is, however, a narrow band of wavelengths, eight to 13 micrometres, to which the atmosphere is transparent. Emission of heat in this wavelength window goes straight out into space. This has been made use of by covering objects with films that convert heat into the required wavelength range. The result is that the objects can cool, through "radiative cooling", four to five °C below the ambient, while they are out in the sun. A useful thing, for "green" cold stores, and solar energy panels, which become less efficient when they get warmer.

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INITIATION OF TRANSLATION

Here is the process by which ribosomes synthesise proteins in the cell's nucleus

TAPAN KUMAR MAITRA

The initiation of translation in prokaryotes reveals that initiation can be subdivided into three distinct steps. In step (1), three initiation factors – called IF1, IF2, and IF3 – bind to the small (30S) ribosomal subunit, with GTP attaching to IF2.

In step (2) mRNA and the tRNA carrying the first amino acid bind to the 30S ribosomal subunit. The mRNA is bound to the 30S subunit in its proper orientation by means of a special nucleotide sequence called the mRNA's *ribosome-binding site* (also known as the Shine-Dalgamo sequence, after its discoverers). This sequence consists of a stretch of three to nine purine nucleotides located slightly upstream of the initiation codon. These purines in the mRNA form complementary base pairs with a pyrimidine-rich sequence at the 3' end of 16S rRNA, which forms the ribosome's mRNA-binding site

The importance of the mRNA-binding site has been shown by studies involving colicins, which are proteins produced by certain strains of *Escherichia coli* that can kill other types of bacteria. One such protein, colicin E3, kills bacteria by destroying their ability to synthesise proteins. Upon entrance into the cytoplasm of susceptible bacteria, colicin E3 catalyses the removal of a 49-nucleotide fragment from the 3' end of 16S rRNA, destroying the mRNA-binding site and thereby creating ribosomes that can no longer initiate polypeptide synthesis.

The binding of mRNA to the mRNA-binding site of the small ribosomal subunit places the mRNA's AUG start codon at the ribosome's P site, where it can then bind to the anticodon of the appropriate tRNA. The first clue that a special kind of tRNA is involved in this step emerged when it was discovered that roughly half the proteins in *E coli* contain methionine at their N-terminal ends. This was surprising because methionine is a relatively uncommon amino acid, accounting for no more than a few percent of the amino acids in bacterial proteins.

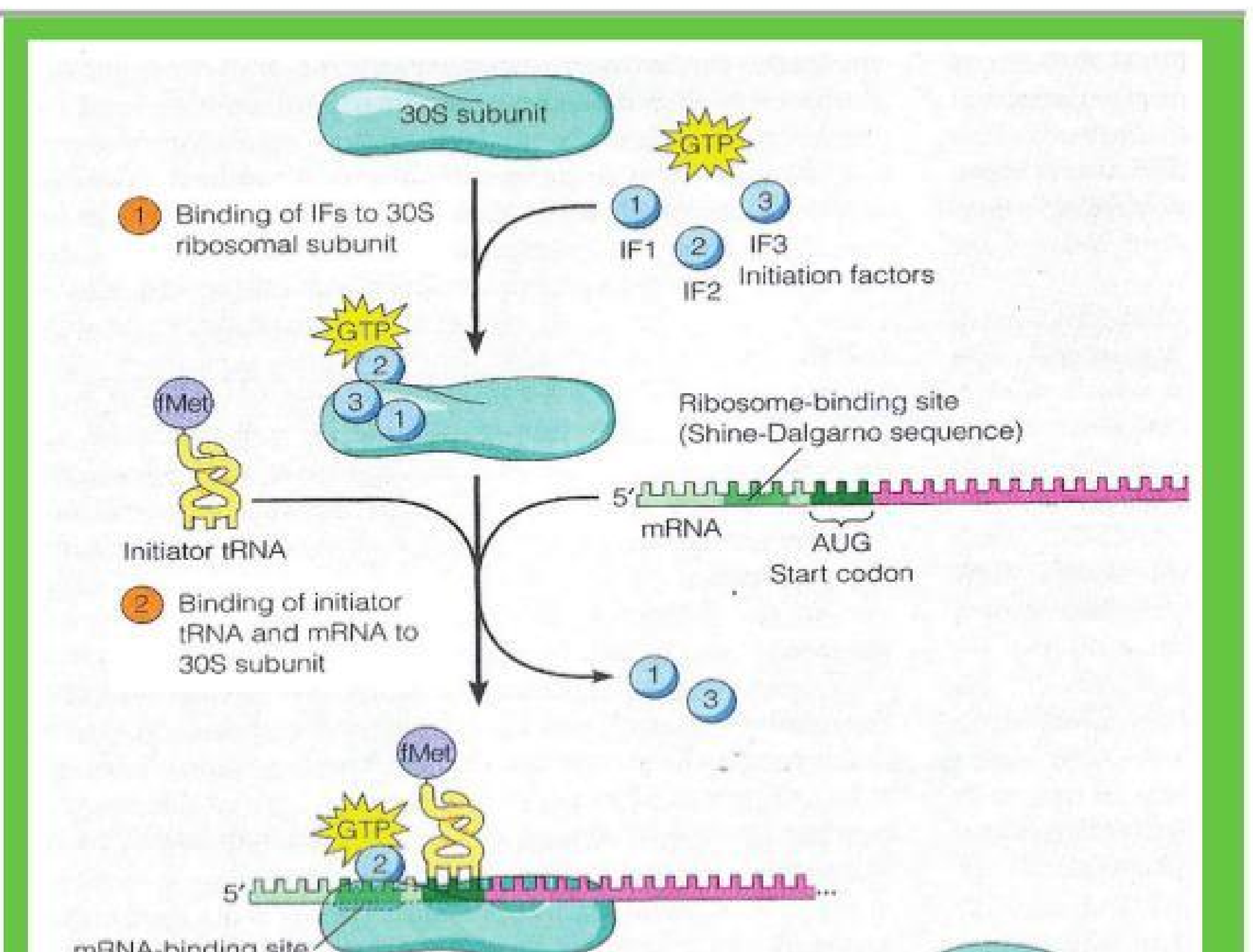
The explanation for such a pattern became apparent when it was discovered that bacterial cells contain two different methionine-specific tRNAs. One, designated $tRNA^{Met}$, carries a normal methio-nine destined for insertion into the internal regions of polypeptide chains. The other, called $tRNAf^{Met}$,, carries a methionine that is converted to the derivative N-formylmethionine (fMet) after linkage to the tRNA. In N-formylmethionine, the amino group of methionine is blocked by the addition of a formyl group and so cannot form a peptide bond with another amino acid; only the carboxyl group is available for bonding to another amino acid. Hence N-formylmethionine can be situated only at the N-terminal end of a polypeptide chain, suggesting that $tRNAf^{Met}$ functions as an initiator tRNA that starts the process of translation.

The idea was soon confirmed by the discovery that bacterial polypeptide chains in the early stages of synthesis always contain N-formylmethionine at their N-terminus. Following completion of the polypeptide chain (and in some cases while it is still being synthesised), the formyl group, and often the methionine itself, is enzymatically removed.

During initiation, the initiator tRNA with its attached N-formylmethionine is bound to the P site of the 30S ribosomal subunit by the action of initiation factor IF2 (bound to GTP), which can distinguish initiator tRNA^61 from other kinds of tRNA. This attribute of IF2 helps to explain why AUG start codons bind to the initiator tRNA0461, whereas AUG codons located elsewhere in mRNA bind to the non-initiating $tRNA^{Met}$. Once $tRNAt^{Met}$ enters the P site, its anticodon base-pairs with the AUG start codon in the mRNA, and IF1 and IF3 are released. At this point, the 30S subunit with its associated IF2-GTP, mRNA, and N-formylmethionyl tRNA0461 is referred to the 30S initiation complex.

Finally, in step (3), the 30S initiate complex is joined by a free 50S ribosomal subunit, generating the 70S initiation complex. Binding of the 50S subunit is driven by hydrolysis of the GTP associated with IF2, which occurs as IF2 leaves the ribosome. At this stage, all three initiation factors have been released.

The initiation process in eukaryotes involves a different set of initiation factors (called *elFs*), a somewhat different pathway for assembling the initiation complex, and a special initiator $tRNA^{Met}$ that – like the normal tRNA for methionine but unlike the initiator tRNA of prokaryotes – carries methionine that does not become formylated. The initiation factor *eIF2*, with GTP already attached, binds to the initiator methionyl $tRNA^{Met}$ *before* the tRNA then binds to the small ribosomal subunit along with other initiation factors. The resulting complex next binds to the 5' end of an mRNA, recognising the 5' cap (in some situations the complex may instead bind to an internal ribosome entry sequence or IRES, which lies directly upstream of the start codon of certain types of mRNA, including viral mRNAs).



After binding to an mRNA, the small ribosomal subunit, with the initiator tRNA in tow, scans along the mRNA and usually begins translation at the first AUG triplet it encounters. The nucleotides on either side of the eukaryotic start codon seem to be involved in its recognition; ACCAUGG (also called a Kozak sequence) is a common start sequence, where the underlined triplet is the actual start codon. When the initiator $tRNA^{Met}$ base-pairs with the start codon, the large ribosomal subunit joins the complex.

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PLUS POINTS

Measuring brainwaves

Researchers at the Indian Institute of Technology-Madras have shown that electroencephalogram can be used to measure brainwaves in workers, to assess their mental sharpness, especially during times of crisis.

EEG involves placing sensors on the scalp of the subject and measuring brain wave activity. Such measurements will help in assessing the capability of the worker to respond to an emergency in real-time, which, in turn, could prevent accidents and mishaps on a factory floor.

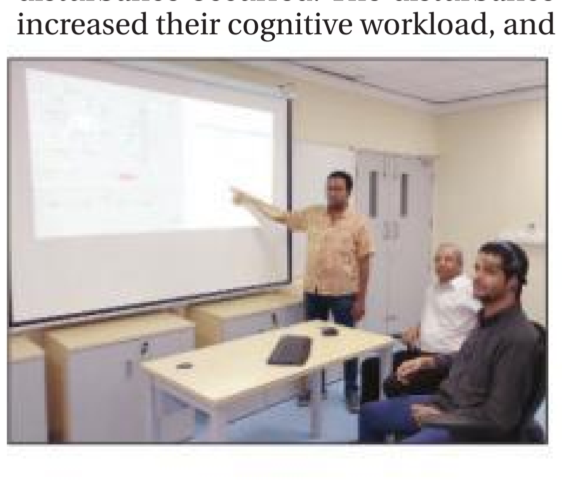
The IIT-Madras team has shown the potential of EEG, a technique that measures brain activity, to assess the cognitive workload of human operators in a chemical plant control room. The cognitive workload is the level of measurable mental effort that is expended by an individual to perform a task. High cognitive workload state of workers makes them prone to commit errors that can lead to accidents.

The research was undertaken by a team led by Rajagopalan Srinivasan, department of chemical engineering, IIT-Madras. The results have been published recently in the peer-reviewed *Journal of Computers and Computer Engineering* in a paper co-authored by Srinivasan, Mohd Umair Iqbal and Babji Srinivasan.

Elaborating about the need for this research, Rajagopalan Srinivasan said, "Human errors are the cause of nearly 70 per cent of industrial accidents, the world over. Human errors, whether at the planning or execution stage, depend not only on the skill of the worker but also on his/her mental state and sharpness at that time. Anybody's performance will become error-prone if there is a mismatch between the demands of the task which the person is responsible for and their ability at that moment to handle it. Such a mismatch leads to high cognitive workload in human operators, often a precursor to poor performance.

"All our thoughts and activities are driven by electrical signals between the cells in our brain called brainwaves, which occur at different frequencies and are called alpha, beta, gamma, theta and delta. The relative magnitudes of these waves along with their variation are a signature of our thought process and current mental state."

The research team affixed sensors to the heads of six participants and had them perform eight tasks each. The nature of the tasks was to monitor a typical industrial section for any disturbances, which if not controlled by the participant in a given time frame, can lead to accidents. Thus, the nature of the job required them to understand the plant (industrial section) behaviour, take appropriate decisions and actions if any disturbance occurred. The disturbance increased their cognitive workload, and



only if the correct decision was made, did the cognitive workload reduce.

Their results showed that the amount of theta waves could identify any mismatch between the worker's mental model of the process and the actual plant behaviour during abnormal situations. This makes sense because the "theta band" of brainwaves has been thought to be responsible for the control process of working memory functions.

The determination of the varying cognitive workload, in turn, influences human performance, and indeed, the IIT-Madras researchers found that the power spectral density in the theta band, correlated well with participants' successes and failures during the task. "We intend to study the potential of these EEG methods to improve human performance in various high-risk industries, thus opening a new paradigm to industrial safety and its relation to the real-time mental state of the worker," Rajagopalan Srinivasan said.

The EEG-based approach can provide information about the cognitive workload of operators during training, which in turn can be used to fine-tune the training process itself. It can also provide targeted cues during learning, to improve the overall effectiveness of training.