

# RESEARCH FEATURE



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Rhythmic structures appear to govern our 24-hour body clock

People may be more likely to choose partners of the same blood type

Earbud-like devices that could help read your mind

A fresh look at indoor air pollution in China

# FOREWORD

At the forefront of global research, Tsinghua University stands as a hub of cutting-edge work, with its researchers leading the way in creating new knowledge. Known for its strong academic culture and innovative discoveries, the university takes on complex projects that tackle urgent health issues and environmental concerns, as well as delve deep into the secrets of human genes and behavior. In a world that's constantly changing, Tsinghua's dedication to learning guides us toward a smarter and stronger global community.

In the sphere of biological research, the team led by Yi Lin has made significant strides in elucidating the role of two proteins, Ataxin-2 and Ataxin-2L, in regulating the circadian rhythm. Their work, precise and methodical, promises to open new avenues in the treatment of disorders associated with our internal biological clock, marking a step forward in clinical therapeutics.

On a social science front, researchers at Tsinghua University have conducted an extensive study on matrimonial selection, correlating the choice of life partners with blood type compatibility. This intriguing research, encompassing nearly one million Chinese couples, suggests a genetic and social interplay in marital decisions, potentially offering new insights into the nature of human relationships.

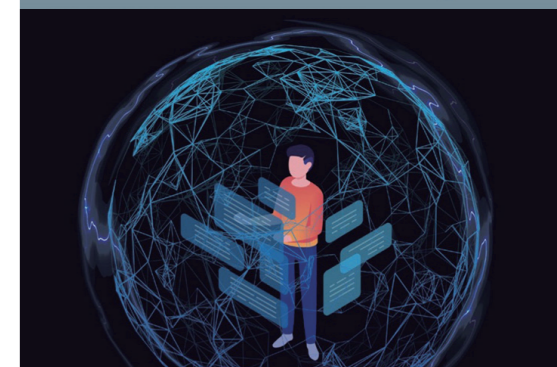
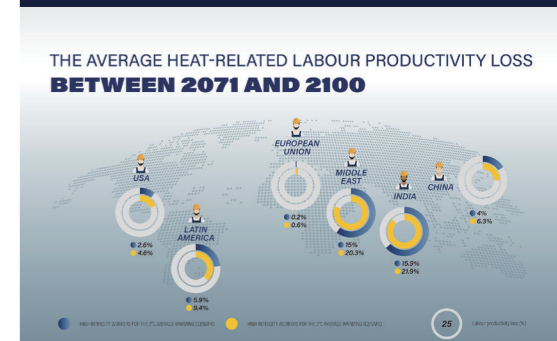
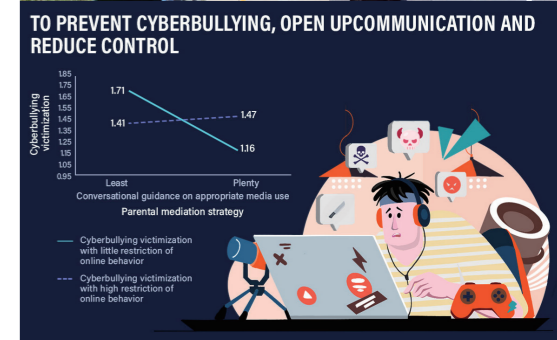
In the arena of technological innovation, 'SpiralE' stands out as a notable development from Tsinghua University. This brain-computer interface, akin to an earbud, combines ergonomic design with meticulous signal accuracy. As documented in 'Nature Communications', it seamlessly integrates into everyday use, enhancing medical monitoring and supporting the rehabilitation of neurological disorders in a non-intrusive manner.

Addressing environmental concerns, Bin Zhao's team has been actively engaged in the study of indoor air pollution. They bring into focus the impact of household activities on air quality, advocating for advanced ventilation systems and air purification solutions. Their work underscores the importance of improving indoor air standards with simple solutions, thereby contributing to public health and well-being.

The 2024 Research Feature is designed to showcase the remarkable research achievements at Tsinghua University. It celebrates the dynamic and supportive research community that makes these advancements possible — a place where innovation is encouraged and new ideas in technology are cultivated. As you read on, you will discover the latest in research and development from Tsinghua, reflecting the university's commitment to setting high standards in academia and beyond.

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# Rhythmic structures appear to govern our 24-hour body clock

Two proteins in the brain enrich the ingredients for gene translation every 24-hours, leading to rhythmic changes in the bodies of mice – and perhaps people.

The physiological and biological activity of many living things follows a roughly 24-hour cycle. This so-called circadian rhythm explains why we get sleepy at night and feel more alert in the morning.

Now scientists have discovered special switches that may control the process: proteins that assemble to form ‘liquid-like condensates’ and then disassemble in the brain every 24 hours, following a rhythmic pattern.

It turns out that the condensation of these proteins plays an important role in controlling various rhythmic physiological processes in the body, including the switch between sleep and wakefulness, as well as the release of hormones, explains Yi Lin, the lead author of a new paper on the find,

published in the journal *Cell* in July 2023.

While the study was carried out on mice, the results could help scientists understand the disruption of circadian rhythms in people with conditions such as diabetes, cancer and depression.

## Timed translation

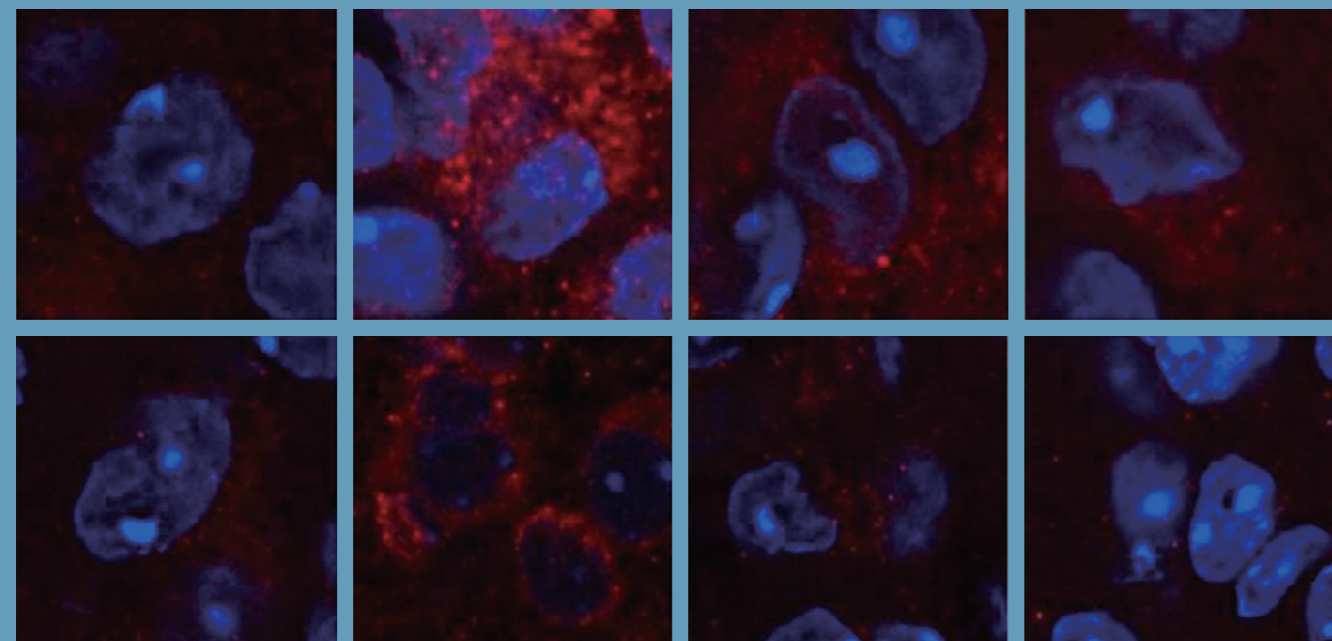
Researchers have long been fascinated by how the body’s circadian rhythm tracks the cycle of day and night. They have already unlocked some of the mechanisms, including transcription, translation and modification of the ‘clock genes’ that influence bodily activities such as the release of hormones.

However, a major question has been

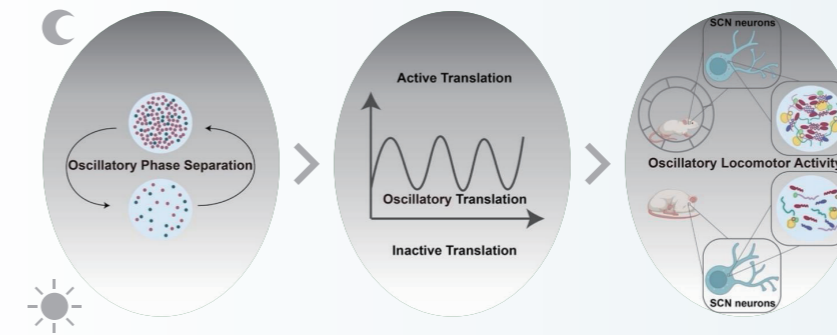
how these biological processes are controlled on a 24-hour schedule that, for example, makes levels of protein synthesis ebb and flow across a day.

To investigate, a Tsinghua University team looked at the action of proteins called Ataxin-2 and Ataxin-2L in the brain’s suprachiasmatic nucleus, a region of the brain’s hypothalamus that helps manage body temperature, hunger, thirst, mood, sex drive, blood pressure and desire to sleep.

They found that every 24 hours the Ataxin-2 protein formed condensates that locally enrich the ribosomes, translation initiation machinery, and specific RNAs, all of which cells need for gene translation – the process through which proteins are made.



It turns out these structures in the brain assemble and disassemble following a daily pattern.



Lin says that inside the suprachiasmatic nucleus, the regular enrichment of gene translation machinery by the Ataxin-2 protein boosts the expression of the clock genes *Per2* and *Cry1*, on a 24-hour cycle.

*Per2* and *Cry1* are associated with processes such as sleep and the release of neurotransmitters, including dopamine. Changes to these genes have also been linked to sleep disorders, neurodegenerative disorders, drug addiction and depression, among other things.

## Treatment takeaway

Lab work on human cells has shown similar activity in the two clock genes

observed in mice, suggesting that the findings could be highly relevant to humans.

“The major circadian clock regulation mechanisms are conserved from mice to humans, including the two genes we studied,” says Lin. “Therefore we believe our research might point to physiological or clinical relevance in humans.”

Ataxin-2 has been found to be associated with multiple neurodegenerative diseases. For example, Ataxin-2 antisense oligonucleotides (ASO), which target RNA and modulate protein expression, have been suggested as a therapy for amyotrophic lateral sclerosis (ALS), a rare neurological disease that affects motor neurons. Considering the Ataxin-2 condensates oscillate along

*Liquid-like protein condensates in the brain assemble and disassemble following a rhythmic pattern that likely facilitates daily protein synthesis in the human body, among other physiological processes.*

the circadian cycle, the results raise questions about when it is effective to administer such treatments, which should be the basis of further research, says Lin. “The timing of diagnosis and therapeutic interventions should be carefully considered in the future,” she points out.

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Yi Lin (at center, front row) an Assistant Professor in Tsinghua University’s School of Life Science, and her team.



# People may be more likely to choose partners of the same blood type

Researchers have found that people of the same blood group have been more likely to pair up.

How we choose a spouse is probably not random. Studies already suggest that spouses often share phenotypes — a person's observable traits, such as body mass index, weight, height and intelligence<sup>1-7</sup>. Now, a new examination of 931,964 couples in China suggests that romantic pairs are also more likely to share a blood type<sup>8</sup>.

The results were slightly different for each blood group, ranging from 5.2% to roughly 18.1% more likely than expected, if randomly selected, to share

the same blood type. And the findings stood up even when multiple other population and locality factors were considered, notes one of the authors, Danxia Xie, from Tsinghua's Institute of Economics. This, he says, suggests that it is not just opportunity, but partner choice that drives the pattern.

## Sameness attracts

The sample population for the study was drawn from a group that participated in a free pre-pregnancy

check-up targeting low-income married Chinese couples in urban areas and married couples in rural areas, all of whom planned to conceive in the next six months.

Another Tsinghua author, Ke Tang, also from the Institute of Economics, says: "One possible explanation is that blood type may act as a proxy for other phenotypes." To look more deeply at this, the researchers examined phenotypic variables available in their data, such as education, job type, height, weight, pressure, and drinking

Table 1.

Observed mating pairs and ratios over expected mating pairs

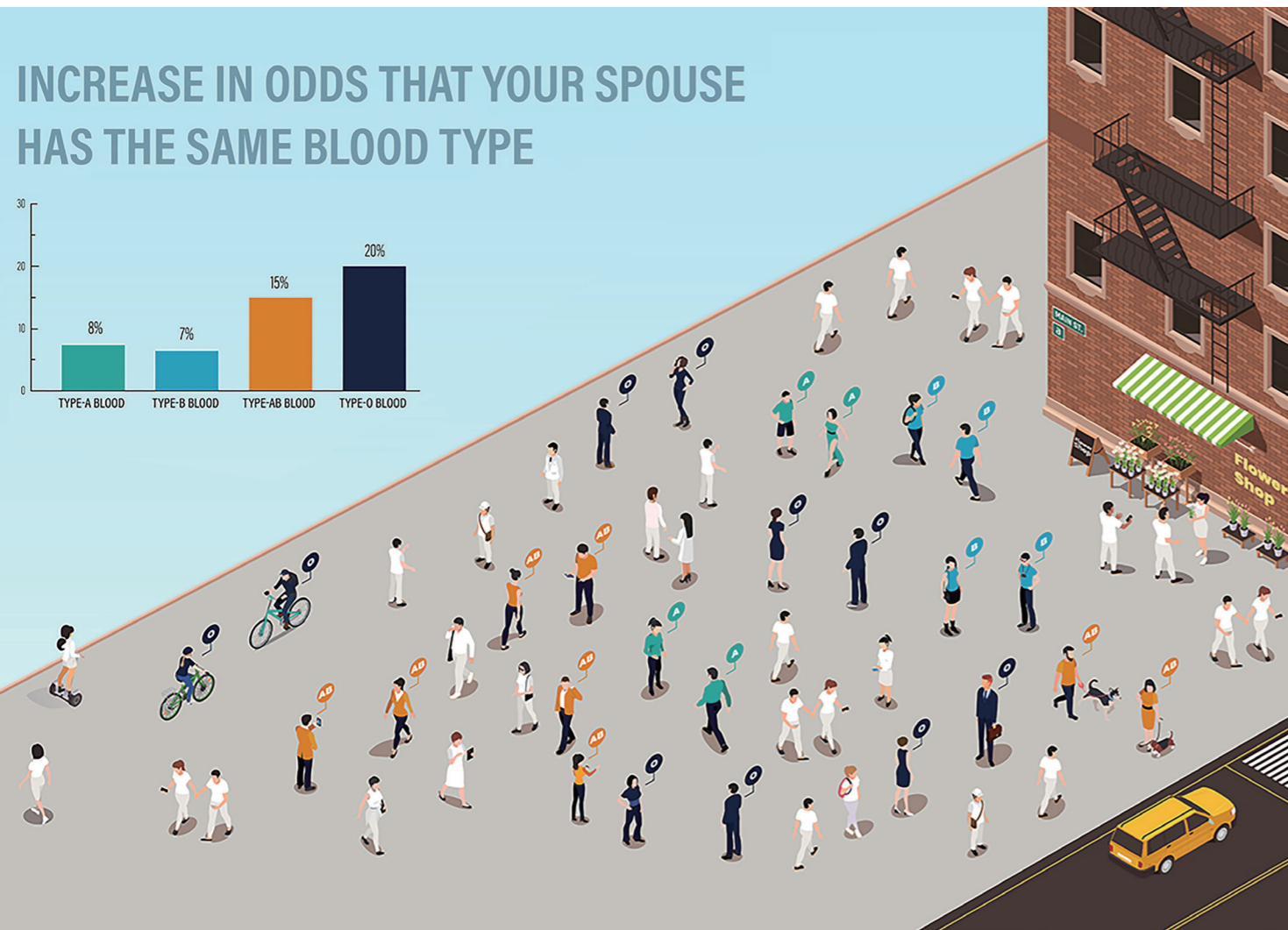
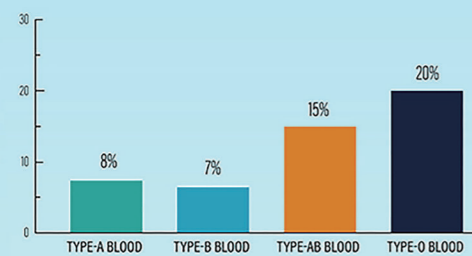
		Female			
		A	B	AB	O
Male	A	88,168 <u>+5.2%</u>	77,223 <u>+0.1%</u>	24,426 <u>+0.1%</u>	86,224 <u>-4.9%</u>
	B	79,506 <u>+2.2%</u>	75,959 <u>+6.1%</u>	22,842 <u>+0.9%</u>	77,904 <u>-7.4%</u>
	AB	24,277 <u>-1.8%</u>	24,033 <u>+5.7%</u>	8,492 <u>+18.1%</u>	24,564 <u>-8.1%</u>
	O	91,135 <u>-5.8%</u>	83,310 <u>-6.4%</u>	26,584 <u>-5.5%</u>	117,317 <u>+12.2%</u>

COLLAPSE ^

Note: Percentages of observed mating pairs above the expected mating pairs are underlined.

It appears that in this sample, 5.2% of people in the A type blood group, 6.1% in the B type blood group, 18.1% of people in the AB type blood group and 12.2% of people in the O type blood group were more likely than expected, if randomly selected, to share the same blood type.

## INCREASE IN ODDS THAT YOUR SPOUSE HAS THE SAME BLOOD TYPE



habits, and found some statistical links to blood types. However, when the statisticians controlled for these variables, they still found strong evidence for separate blood-type mating tendencies.

Another potential reason for their finding, the authors suggested, might be the ease of living with a partner with the same blood type. Some studies indicate couples with similar phenotypes, such as alcohol consumption, may be more likely to remain in a relationship and thus make up a greater portion of couples in the sample, for example<sup>9-11</sup>. However, the researchers didn't find strong evidence to support the argument that the similarity of spousal pairs' blood types is associated with the length of marriage, and so ruled this out as a main driver.

Blood type, they say, is mostly explained by the distribution of blood types in the population of birthplace. Local population structure and the individual's ethnicity also explain a considerable fraction, they note. Then, if a partner has a given blood

type, the odds of their partner having the same blood type will increase by approximately 8% for those with type-A blood, 7% for those with type-B blood, 15% for those with type-AB blood, and 20% for those with type-O blood.

"These findings suggest that there is an unknown mechanism for this pattern," says Tang. And this is a fascinating topic for future research, he says.

## Disease consequences

Increases in pairings of those of the same blood type could have important genetic consequences, says Xie. Some blood types appear to have elevated disease risks, such as predispositions to dementia or cardiovascular disease. So, having a baby with someone with the same blood type can inflate their offspring's chances of inheriting some traits, such as depression, which has been shown to be significantly higher in the type A and O blood types.

Blood type has, in fact, been linked with a variety of mental disorders: children

with type O blood may be at a greater risk of attention-deficit disorder; people with A blood type may be more prone to obsessive-compulsive disorder, and children may be at a greater risk of attention-deficit disorder; and children with type B blood may have a lower risk of attention-deficit disorder. However, the associations are weak and many other factors may be more important in determining illness outcomes. Disorders such as these, without a clear pattern of inheritance in families and with multiple genetic links, may be affected in complex ways by reduced genetic diversity.

to administer such treatments, which should be the basis of further research, says Lin. "The timing of diagnosis and therapeutic interventions should be carefully considered in the future," she points out.

Nonetheless, those with similar traits who choose to have children entrench those traits further, says Xie, by reducing the frequency of people that have two different alleles, one from each parent, of a particular gene

or genes, and are thus able to pass on varying characteristics in their offspring.

For this reason, procreation between non-similar phenotypes is often considered favorable, since it reduces the chances of producing less fit phenotypic extremes. Abundant research has shown that inbreeding may decrease the fitness of offspring<sup>12</sup>, as it increases the frequency of individuals who have two of the same alleles of a particular gene or genes, which enhances the risk of the unmasking of deleterious recessive alleles. This may be why the rarest AB blood group showed the most likelihood of choosing a spouse with the same blood type in this study.

## Population modelling

Producing offspring with a person of the same blood type should also intensify trait divergence between the different blood groups, says Xie. And this will likely heighten natural selection directions<sup>13</sup>, since there are fewer individuals with two different alleles and the frequency of less fit homozygotes — people inheriting the same gene from each parent — could be reduced via natural selection<sup>14</sup>.

However, we should be cautious when extrapolating findings in Chinese populations to other populations, says Tang. Different contexts may encourage different outcomes. Other studies have shown, for example, that differences in immune function may encourage mate selection to give offspring a greater chance of survival.

Nonetheless, if blood type pairings are shown to be consistent across a population, it could have implications for modelling of future disease burden and should be explored further, say the researchers. "As far as we know, few studies focus on assortative mating on blood type," Tang says. "It is therefore an open-ended result and there is endless potential to explore theories and look for evidence of mechanisms."



Tsinghua University authors (left to right) Ke Tang, Yao Hou and Danxia Xie have looked at the likelihood of spouses having the same blood type alongside colleagues from Beihang University in China and Michigan State University in the United States.

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# Earbud-like devices that could help read your mind

A compact electronic device worn discreetly behind or slipped into the ear could soon help monitor the wearer's brain activity or even deliver brain stimulation. This new type of brain-computer interface (BCI) is far more comfortable and less conspicuous than the traditional electrode arrays placed across, or even inserted in the scalp.

Brain-computer interfaces are progressing rapidly, says Xiaorong Gao of Tsinghua University's School of Medicine, China, a lead author of a paper published in *Nature Communications* describing the 'SpiralE' in-ear BCI.<sup>1</sup> In the field of medical rehabilitation, for example, BCIs have already allowed those with paralysis to regain partial motor function with the help of robotic prosthetics.

But new developments that allow for the interpretation of increasingly intricate brain activity are rapidly expanding BCI's potential, Gao says. For example, in people with diseases affecting motor nerve cell function, such as amyotrophic lateral sclerosis (ALS), BCIs are increasingly able to decode motor intentions involved in writing or speech so that they can be mimicked by computer aids. Another development is the design of comfortable interfaces that are non-invasive and painless to wear, such as Gao's work.

## Discreet design

Gao was inspired to develop his in-ear BCI device following a foundational 2015 study he led demonstrating the rapidly evolving power of the brain

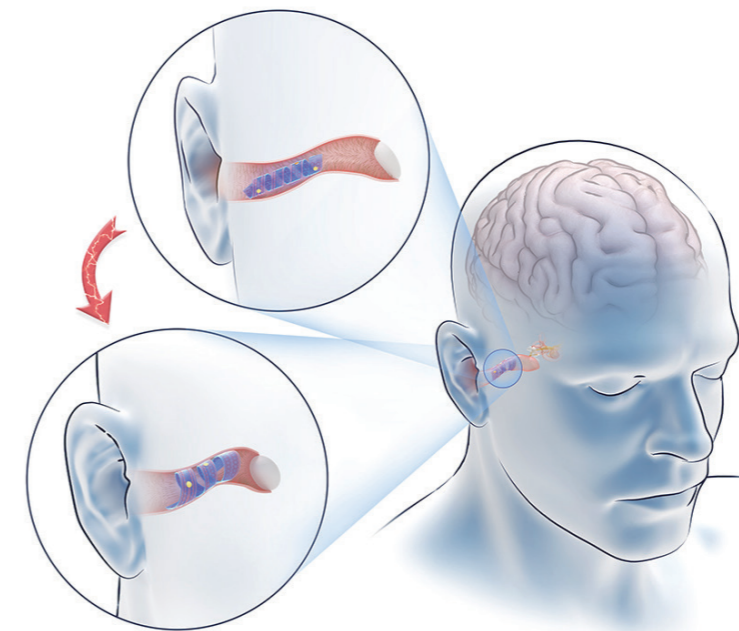
A non-invasive piece of tech placed into the ear brings wearable brain-computer interface technology closer to everyday use.

activity tracking technology.<sup>2</sup> The study pioneered a high-speed BCI, called a state visual evoked potential (SSVEP) BCI, in which participants would 'type' words by directing their gaze in different directions to select characters of the alphabet.

The BCI detected and understood gaze so fast that it allowed subjects to communicate in real-time, at the speed of a person typing on a keyboard. This result markedly surpassed the speed of other options at the time, setting a new standard for non-invasive BCIs. "This motivated us to take this technology from a lab setting and to use it in real-life settings," says Gao.

Conventional BCIs designed to monitor electrical activity in the brain via technology called electroencephalography (EEG) have typically followed one of two designs. They either featured electrodes surgically implanted under the scalp, or — as with Gao's visual typing study — electrodes worn across the outside of the scalp as an 'EEG cap'. Gao's in-ear BCIs are designed to be far more comfortable, convenient and discreet for use outside of the lab. "Our in-ear BCIs are the result of refining the interface to strike a balance between recording quality and comfort," says Gao.

But as the shape of the ear canal is unique to each person, Gao faced significant challenges in designing devices that fit comfortably, while maintaining good contact with the inner wall of the ear canal for EEG recording. "Designing SpiralE was tricky because seldom have in-ear devices achieved a balance between comfort and signal quality," he says.



A Tsinghua-designed brain-computer interface inserted into the ear could soon help monitor a wearer's brain activity.

## Valuable tool

Using soft electronics, the team designed SpiralE to fit in anyone's ear by creating a flexible, narrow corkscrew EEG reader; once inserted into the ear canal, gentle heating expands the device, helping form a tight contact with the ear canal's inner wall. Because the inside is hollow, SpiralE lets sound through to maintain normal hearing.

"We consulted medical experts and repeated rigorous tests to ensure that it was safe to insert the device," Gao adds. The team has demonstrated that the device worked well for recording brain activity including responses to visual and auditory stimuli.

These advances, coupled with electronic brain stimulation techniques, could also transform BCIs from passive recording devices of neural signals to potentially active players in tracking and addressing the symptoms of neurological and psychological disorders, including severe depression, Gao says.



*Caption: A Tsinghua-designed device called SpiralE expands and deforms to maintain contact with ear canal walls to enable less invasive readings of electrical impulses from the brain.*

*Credit: Tsinghua University/Ref 1. <https://creativecommons.org/licenses/by/4.0/>*

"BCIs may also soon become valuable day-to-day tools, for example, with helping users monitor sleep quality and attention levels, or detecting drowsiness," he adds. "BCIs in the ear have shown promise in areas like seizure detection and sleep monitoring, and SpiralE holds the potential to significantly enhance these applications."

He is now working with several other research teams developing BCIs placed in or around the ear in innovative ways, particularly for BCIs that involve vision.<sup>3</sup> In a 2023 study led by collaborators from the University of Chinese Academy of Sciences, Gao and his colleagues reported their creation of an earpiece made of hydrogel.

The new earpiece eliminated the need for wet electrodes, which required extensive participant preparation before use, including removing hair and grinding the outermost skin layer. They also showed that placing devices in the region behind the ear canal is better for visual information decoding, compared to ear canal placement.

The hydrogel earpiece adds to a 2021 study led by Liyan Liang of Tsinghua University's School of Medicine, in which Gao participated, which explored different ways of stimulating the brain's vision centres.<sup>4</sup> The team showed that optimizing brain stimulation for electrode placement in the hairless area behind the ear made the BCI faster and more accurate. The combination of these insights may inspire vision-related BCI that is wearable, comfortable, and discreet.

## Commercial potential

Gao's ultimate BCI vision is to integrate brain activity recording and stimulation into a single device, culminating in the development of what he calls a bi-directional closed-loop BCI system. This would also allow two-way communication between the brain and external devices. It would also capture real-time brain data and provide

feedback to the user, so that a person with a prosthetic hand, for example, could not only pick up a glass, but 'feel' the glass in their hand. "This could help restore brain functions that were compromised, or even augment certain capabilities," Gao says.

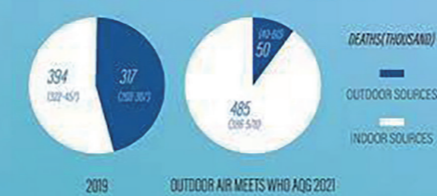
In addition to the technological improvements, Gao believes BCIs placed in or around the ear have vast commercial potential.

"Their commercial viability is evident through the tremendous investment that start-up companies delving into this technology are receiving," says Gao. "Tech giants like Apple and Samsung have also ventured into this space, filing patents for EEG sensor technology to use in their earbuds. These circumstances indicate that BCIs in or around the ear may be the technology that finally makes BCI technology commonplace."

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## PREMATURE DEATHS ATTRIBUTABLE TO LONG-TERM EXPOSURE TO PM<sub>2.5</sub> AND NO<sub>2</sub> IN CHINESE URBAN AREAS



*The World Health Organization reduced their recommended level of annual mean PM<sub>2.5</sub> (as well as other air pollutants, such as NO<sub>2</sub> and O<sub>3</sub>) concentrations specified in their air quality guidelines (AQG) in 2021. However, even if China urban areas meet these guidelines, Tsinghua modeling suggests that there would still be 485 thousand annual deaths attributable to indoor PM<sub>2.5</sub> sources.*

## A fresh look at indoor air pollution in China

According to the World Health Organization, air pollution is the largest environmental risk to human health. Given that most people spend more than 80% of their time inside, indoor air pollution is an increasing area of concern, with numerous studies linking it to cardiovascular, pulmonary and neurological conditions, such as cancer and stroke. In 2020, indoor air pollution killed an estimated 3.2 million people worldwide, including more than 237,000 young children.

The problem is particularly pressing in China. "The rates of indoor air pollution here are generally higher compared to many parts of the world", says Bin Zhao,

a professor at Tsinghua University's School of Architecture. "However, it's a problem that affects many countries around the world, especially low-income and developing nations, where access to both clean energy and proper ventilation systems may be limited."

In rural areas, burning solid fuels such as wood, crop waste and charcoal is a major source of indoor air pollution and generates large quantities of fine particulate matter (PM<sub>2.5</sub> — particulate matter with aerodynamic diameter of 2.5 micrometers or less). In less wealthy areas, these materials provide fuel for heating and cooking as they are readily accessible and inexpensive, says Zhao.

Indoor air pollution kills millions of people globally each year. Tsinghua University researchers are documenting the problem and coming up with simple solutions to save lives.

## Cooking and cigarettes

In urban areas, cooking is a major cause of indoor air pollution. Chinese cooking often involves frying in oil, which generates PM<sub>2.5</sub>. Additionally, gas is a common cooking fuel in urban households, but it emits nitrogen dioxide (NO<sub>2</sub>). Research has shown that levels of PM<sub>2.5</sub>, which are tiny enough to penetrate deep into the lungs, can triple during cooking.

In 2022, Zhao and his PhD student, Ying Hu, created a model that allowed them to estimate the level of exposure to PM<sub>2.5</sub> and NO<sub>2</sub> for people in 333 Chinese



Bin Zhao is a full professor at Tsinghua's School of Architecture.

cities, and from what sources it came from<sup>1</sup>. "We discovered that gas cooking is the most important indoor source of these pollutants to urban Chinese households," says Zhao.

In addition to burning solid fuels and gas cooking, cigarette smoke is another major factor contributing to China's indoor air pollution problem. As of 2018, there were 300 million smokers in China, with 44.9% of adults and 63.2% of adolescents exposed to second-hand smoke at home.

## A deadly problem

Levels of pollution vary across the vast country, with the indoor concentrations of PM<sub>2.5</sub>, for example, highest in the north. "Colder climates can lead to more time spent indoors and less window ventilation, thus increasing exposure to indoor air pollutants," explains Zhao. Industrial development is also denser in the north, which "leads to more severe outdoor pollution that can also affect indoor air quality."

The impact of indoor air pollution can be severe. Gas cooking, for instance, accounted for 25% of total NO<sub>2</sub>-linked cases of asthma in children in 2019 in the urban areas, as Zhao's team revealed in a modelling study published last year in *The Lancet Regional Health-Western Pacific*<sup>2</sup>. In a separate study, they determined that indoor PM<sub>2.5</sub> contributed to 394,000 deaths and 1.53 trillion Chinese yuan (roughly US\$222 billion) of economic losses due to premature deaths in 2019 in China's urban areas<sup>3</sup>.

The Chinese government has taken steps to address the problem. In 2013, the Air Pollution Prevention and Control Action Plan helped improve outdoor air quality through restrictions on emissions from coal mining, transportation and other industries. In 2022 this was followed by a revision of government Standards for Indoor Air Quality, aligning it with the WHO's new standards for a lower recommended mean annual PM<sub>2.5</sub> concentration.

The Chinese government's Poverty Alleviation Resettlement (PAR) program, which saw nearly 10 million rural residents being moved to urban centers between 2016 and 2020 has also helped reduce impacts of indoor air pollution as people adopted cleaner fuels for cooking and heating. Zhao's team estimated that the move helped avoid 5,400 deaths due to the reduction of indoor PM<sub>2.5</sub> levels<sup>4</sup>.

People have become better aware of the health hazards associated with air pollution and have begun to take measures to protect themselves, for example using air purifiers<sup>5</sup>, says Zhao. These changes have helped reduce the problem over the years, but there is "still a long way to go as indoor levels of pollutants are still far from meeting the WHO standards."

## Towards cleaner air

There are many simple ways to further improve the situation, he says. For a start, ventilation can be enhanced by designing living and kitchen spaces to improve airflow. Optimizing the exhaust efficiency of cooker hoods — which currently average just 60% — could also help tremendously. His team also found that switching from gas to electric stoves can prevent nearly 300,000 new asthma cases in children every year due to a reduction in NO<sub>2</sub> emissions.

Installing more air purifiers in homes could also help. Zhao suggests that government subsidies for purchasing and maintaining purifiers could help relieve economic pressure for lower income groups, particularly in less economically developed cities

where high outdoor PM<sub>2.5</sub> levels may be infiltrating homes and adding to indoor pollution<sup>5</sup>. Tighter regulations around smoking and the availability of cigarettes, as well as public education campaigns could help reduce indoor air pollution even further.

Zhao and his team are now looking to take their extensive research on indoor air pollution even further: they plan to conduct an interdisciplinary study alongside environmental epidemiologists, engineers and material scientists to look for new cost-effective solutions. "Overall, my hope is to build healthy indoor and built environments, and to raise everybody's awareness of indoor air pollution," he says.

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# Are sugary drinks linked to hair loss?

A surprising survey result supports evidence from mice that a metabolic pathway involving glucose can damage the roots of hair follicles.

A recent survey study from scientists at Tsinghua University suggests that drinking large volumes of sugary drinks increased the likelihood of male pattern hair loss<sup>1</sup> more than threefold, but this finding requires more investigation.

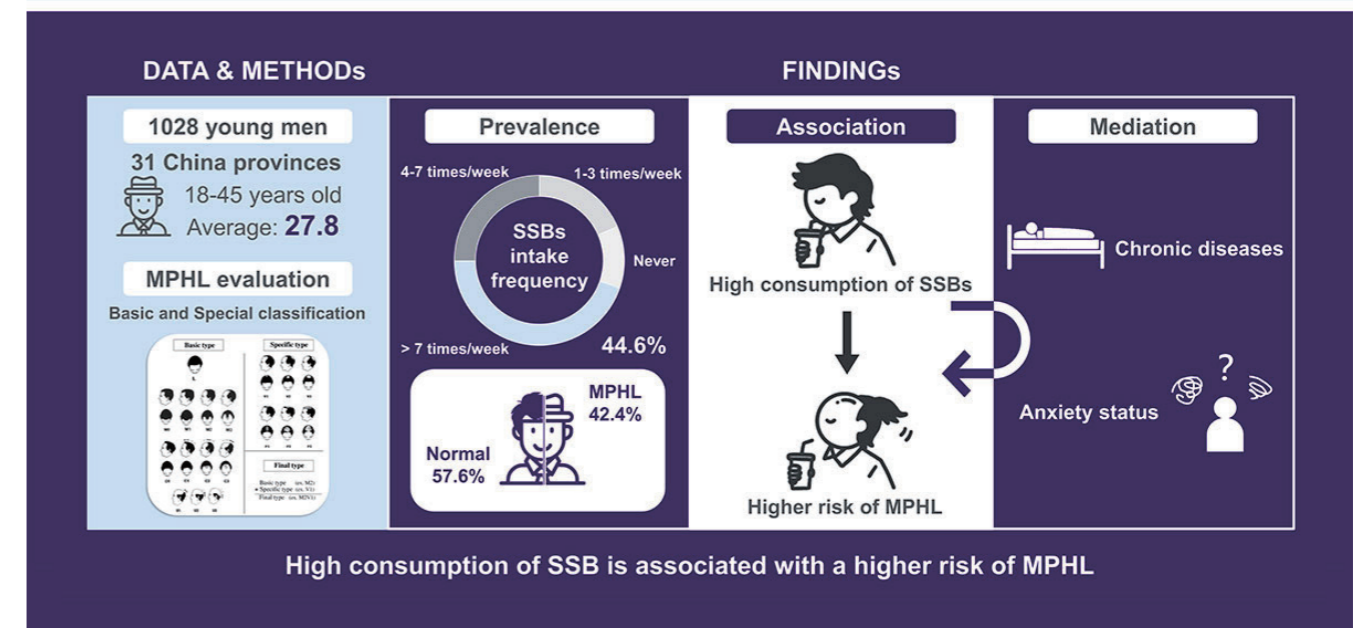
Male pattern hair loss is a common, progressive form of hair loss that affects up to 15% of men aged 18-29 and up to 50% of men aged 40-49. It has been linked to numerous factors,

including hormones, genetics and diet. The study, led by Ai Zhao, an expert in nutrition epidemiology at the Vanke School of Public Health, surveyed 1,028 respondents. It found that men aged 18-45 years old who consumed beverages such as juice with added sugar, energy drinks, sweet milk, and sweet tea or coffee more than seven times a week were 3.36 times more likely to have male pattern hair loss than men who didn't consume them.

The findings were recently published in the journal *Nutrients*.

Zhao says that while her team controlled for socio-economic status, diet, lifestyle and other factors, it is still hard to draw firm conclusions from the results. The study also relied on self-reported data, rather than clinical examinations in a controlled environment, which opens the possibility of misreporting by respondents, and other biases, says Zhao.

## The Association Between Sugar-Sweetened Beverage (SSB) and Male Pattern Hair Loss (MPHL) in Young Men



A survey of 1028 men aged 18-45 suggests that those who drank sugary drinks more than seven times were 3.36 times more likely to suffer from male pattern hair loss.



A recent Tsinghua University survey study suggests that a high level of sugary drink consumption is associated with a more than tripled risk of male pattern hair loss.

## Young people and sugar

Her team now plans to explore the association between sugar and hair loss in a much larger population using cohort studies and randomized controlled trials.

Zhao adds that research in China has already reported that sugary drink consumption is highest in the 13-29-year-old age group, with more than 22% drinking sugar-sweetened beverages.

“Chronic diseases and deaths seem so vague and distant for young people that they may be unwilling to give up sugary drinks for the sake of long-term health goals,” says Zhao, who hopes her research will have an impact.

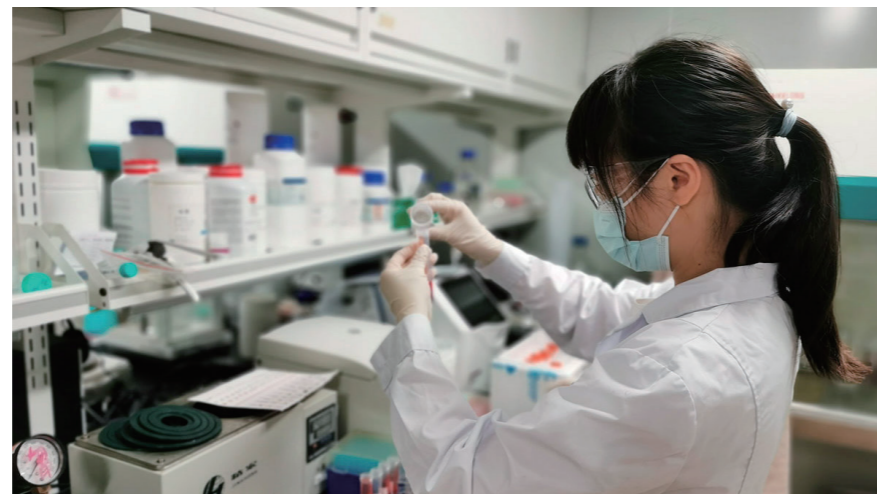
As studies build to show the many different ways in which a high-sugar diet can negatively impact health, Zhao hopes people will avoid excessively sweetened beverages. “Reducing sweet drink consumption has become a thorny problem, puzzling governments and health institutions around the world,” write Zhao and her co-authors.

## Mouse mechanism

Nonetheless, a potential mechanism between sugar consumption and hair loss has previously been identified in mice<sup>2,3,4,5</sup>. “Several animal studies provided evidence that excessive sugar beverage intake might impair sugar metabolism at the root of the hair,” Zhao explains.

The process involved is the polyol pathway, a metabolic route for converting excess glucose into fructose, and finally fatty acids. This inhibits the energy supply to keratinocyte cells on the outer hair root, which are essential to hair follicle repair.

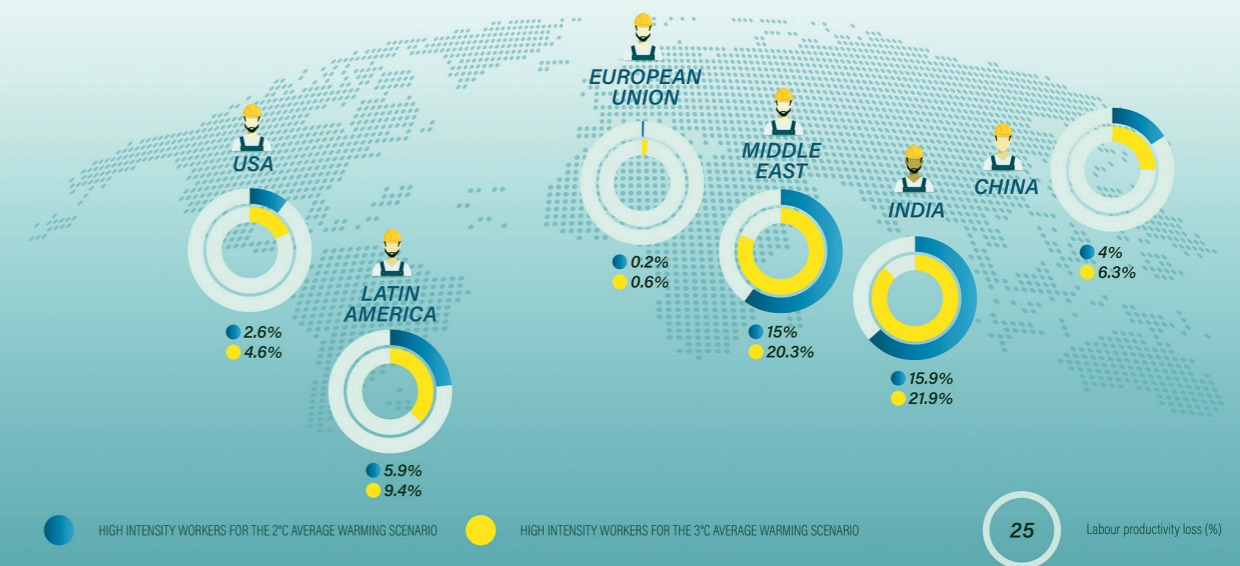
As yet, this biological mechanism is just a hypothesis taken from the results of several animal experiments<sup>2,3,4,5</sup>, and the exact molecular mechanism needs further study to confirm, says Zhao.



Ai Zhao leads a team at the Vanke School of Public Health at Tsinghua University that study how diet is related to health and disease.

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## THE AVERAGE HEAT-RELATED LABOUR PRODUCTIVITY LOSS BETWEEN 2071 AND 2100

Caption: Large economic benefits could be gained if global temperature rise is limited to 2°C through avoiding heat-related labor productivity loss.

# How rising temperatures will hit worker productivity

Climate change is already reducing labor productivity. Researchers are now revealing the potential costs and exploring the best mitigation tactics.

As climate change continues to cause temperatures to rise around the world, employees working outdoors or with little access to air conditioning, are likely to suffer a significant hit to productivity, a problem that has received very little attention.

“The impacts of lower-level heat on labor productivity can be imperceptible as it rarely causes direct physical harm,” explains Wenjia Cai, a professor in global change economics at Tsinghua University in Beijing, China. “While more extreme heat conditions are still considered an anomaly.”

The problem with lower-level heat is that many workers, such as manual construction or agricultural laborers, must slow down, or heat-related sicknesses and injuries increase, which also slows production.

Though necessary, this loss of productivity can be expensive. In China, for example, Cai and her colleagues estimated<sup>1</sup> that high heat cost the country US\$33 billion due to labor productivity loss in 2021. That represented 1.4% of China’s total national work hours.

Climate change will only exacerbate this issue, says Cai. Her team has surmised from current literature<sup>2</sup> that by 2100 the impact of increased heat on worker productivity globally will be 0.31–2.6%.

The variation in these figures is partly due to the uncertainty of climate data projections, she explains, which can differ widely across climate models and scenarios. Despite this, “all scenarios in our study show that climate change would pose a significant threat to the world economy through reducing labor productivity,” says Cai.

## The first hot spots

The effects on workers are more evident in regions that are being exposed to dangerously high ambient temperatures.

“South and Southeast Asia, Sub-Saharan Africa, and Central America are located at low latitudes, nearer to the equator, and already experience high heat exposure, so even modest rises in temperature can push heat into a dangerous zone for laborers in these regions,” Cai says. In a recent study<sup>3</sup> of 2,900 workers in India, Cai and her colleagues found that 84% of workers suffered from heat-related illnesses, such as heat cramps and heat stroke.

The socioeconomic situation of some regions also exacerbates this problem, she says, especially in areas that “rely heavily on agriculture and construction”.





Caption: Wenjia Cai is a professor in global change economics at Tsinghua University.

Due to poor economic development, workers in these regions may work in conditions that lack heat protection, such as shade coverings and air conditioning; affected workers may also find it harder to access public health systems; and, employers may lack the funds for adaptation technologies.

In extreme conditions, deaths due to heat stress are also not uncommon. High heat days can lead people to experience accelerated heart rates, vasodilation, water and electrolyte loss, and increased blood viscosity, ultimately resulting in a higher risk of death among patients with cardiovascular disease, for example. A 2022 meta-analysis by a different Chinese team suggested that non-accidental deaths increase by almost 20% during Chinese heatwave days due to heat stress complications.

Cai also points out that very hot days appear to be increasing in China. "In 2021, compared with the 1986–2005 average, people in China had an average of 7.85 (113%) more heatwave days." Indeed, in 2022 China experienced the longest and hottest heatwave since national records began in 1961. In that same year, Cai and her colleagues published a paper suggesting<sup>4</sup> that heatwaves could cause more than 20,000 deaths a year in China by 2090, even under the modest warming scenario of aiming for an only 2°C average global temperature rise by 2100.

## Building resilience

One solution is better heat stress awareness and management by employers, Cai says. This is reflected

in the Chinese government's *Administrative Measures on Heatstroke Prevention* plan, which was released in 2012, is designed to help address temperature-related productivity issues. In part, it requires employers to provide measures to protect their workers, including reducing intensity and cutting down working hours when outdoor temperatures reach 35°C, and indoor temperatures reach 33°C.

In a study of insurance claims before and after the plan was adopted, Cai and her colleagues showed<sup>5</sup> that the plan has been effective — in reducing heat-related injury claims by workers by 13% in Guangzhou in southern China across a two-year period. Nonetheless, she points out that the measures "often go ignored, especially by private companies employing large informal workforces with little incentive for compliance".

Governments should also address rising temperatures through carbon mitigation, says Cai. Recently, one of her students, Mengzhen Zhao, led a study<sup>6</sup> on labor productivity and carbon mitigation. "The results showed that by 2100 about 51.8% of global climate change mitigation costs could be offset by economic benefits from reduced labor productivity losses," says Zhao. By including other benefits, such as cleaner air, the cost-benefit ratio is even better, she argues.

"Overall, framing climate change mitigation primarily as a burden or sacrifice ignores the vast opportunities and advantages of building more resilient societies and economies," says Zhao.

Cai also pinpoints several other ways that governments can help build resilience against temperature-related productivity losses. "Firstly, countries can establish a robust early warning system that provides alerts on impending heat risks. This can help protect vulnerable populations and facilitate coordination among relevant agencies and stakeholders," she says.

"Secondly, strong occupational heat stress standards must be established and enforced — compliance incentives and monitoring are needed."

Thirdly, Cai recommends adjusting work schedules and tasks during

hot weather. "Options like shifting schedules earlier or later, and taking more frequent breaks can reduce heat risks," she says.

Further measures protect workers from the heat with air conditioning, fans, shades, or ventilation — or improve workers' knowledge of how to stay safe through education and regular training on the risks of heat-related illness.

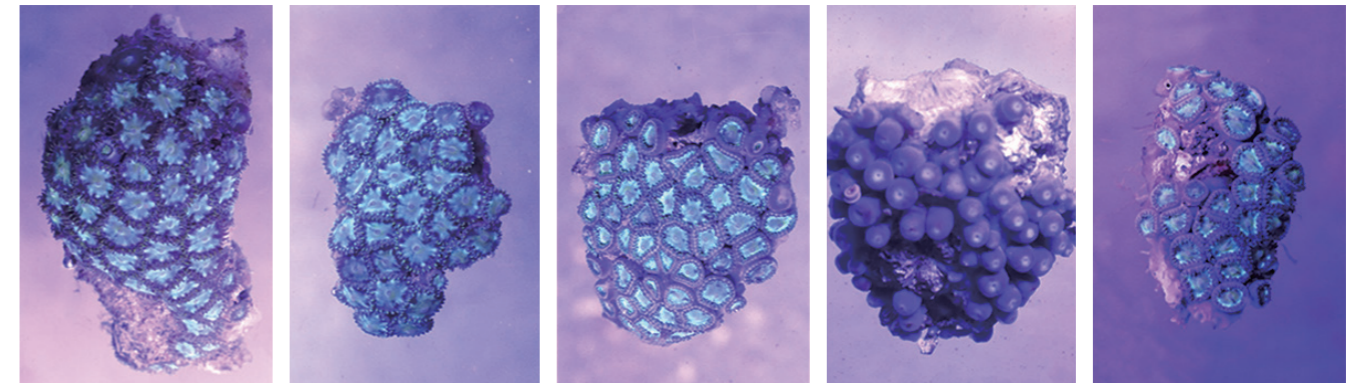
"Transitioning more global economies to greener, sustainable models can mitigate future heat risks," adds Cai. "But the shift requires policy, technology, and financial adaptations at levels from individual businesses right up to industrial sectors and city governments."

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# Sunscreens that bring color to coral not your skin

A new polymer sunscreen creates a physical barrier to UV light without the chalky look.



The effect of the presence of UV filters – P3, oxybenzone and avobenzone – on *Palythoa* sp. after two weeks of exposure.

Skin cancers are linked to tens of thousands of deaths each year. Sunscreen saves lives by protecting the skin from harmful ultra-violet (UV) rays. But there are nagging doubts about their safety because of evidence, albeit limited, that sunscreen may disrupt hormones, cause lymphatic and blood cancers<sup>1</sup> and bleach coral.<sup>2</sup> A new polymer-based sunscreen that remains on the skin surface developed by Tsinghua University researchers may provide a route to sidestepping those concerns.

Today's chemical sunscreens depend on small organic molecules that absorb UV, such as oxybenzone, avobenzone and octinoxate. That's a potential problem because the molecules are absorbed by the top skin layer, explains Lei Tao, lead author of the study and an associate professor at Tsinghua's Department of Chemistry.

Once inside the body, these small molecules may lead to endocrine disruptions<sup>2</sup> that harm fertility and reproductive organs<sup>3</sup> and increase

the risk of cancer,<sup>1</sup> although various international government agencies, including the Australian Therapeutic Goods Administration (TGA), have declared them safe for human use.

What's more, an estimated 14,000 tons of sunscreen enter waterways each year globally. *In situ* and laboratory research suggests that the small organic molecules in sunscreen could be toxic to,<sup>4</sup> or promote viral infection<sup>5</sup> in, corals. This results in bleaching. "We need new sunscreens that protect both humans and the environment," says Tao.

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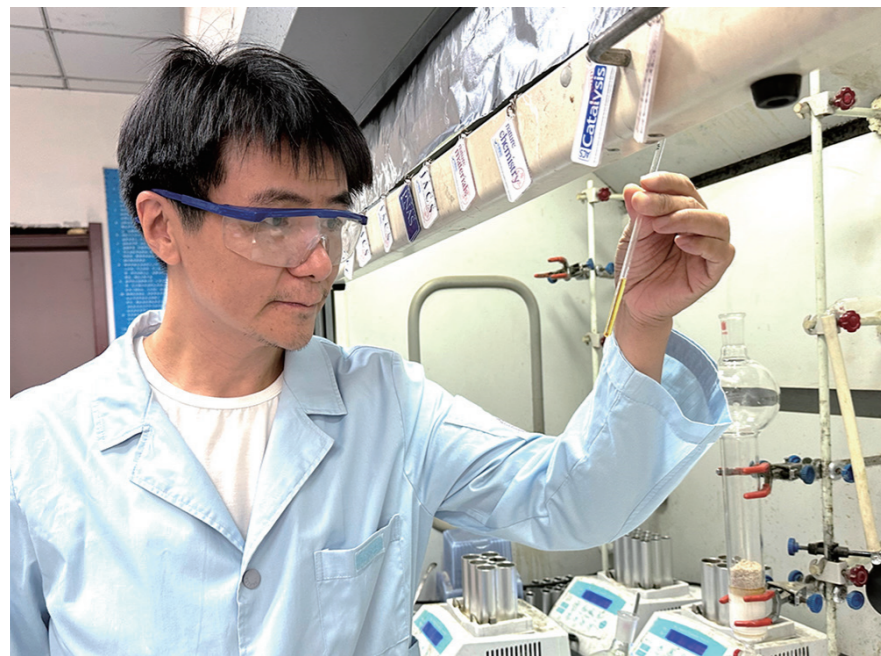
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"We need new sunscreens that protect both humans and the environment," says Tao.

## Surface sunscreen

At the moment, the only alternative to chemical sunscreens based on small organic molecules are sunscreens containing minerals like zinc oxide that sit on the skin and physically block rays. These aren't absorbed into the body, but



Associate professor Lei Tao is from Tsinghua's Department of Chemistry.

leave a white caste that puts people off using them.

To solve the problem, Tao and his team developed a polymer sunscreen made up of large molecules that don't penetrate the skin.<sup>6</sup> This polymer sunscreen sits on the skin like physical sunscreen, but without the white caste, says Tao.

In mouse experiments, the new polymer sunscreen blocked UV more effectively than SPF 50+ commercial sunscreens. Mice wearing Tao's new 'polymeric' sunscreen had significantly less sun damage after being directly exposed to very strong UV light for six minutes, roughly equivalent to the exposure one might expect in Australia across the course of 5–10 years, compared to mice wearing commercial SPF 50+ sunscreens.

When the team exposed corals to the new polymer sunscreen, the corals retained their colors for more than 20 days. Corals exposed to the active ingredients in commercial chemical sunscreens were completely bleached within six days.

## A colorful future

But there are still hurdles to overcome, says Tao. For example, the sunscreen polymer is water soluble so it may not be practical at the beach, he says.

The researchers also need to address concerns about the environmental impact due to the new sunscreen's lack of biodegradability. Tao and his colleagues are now exploring different polymerization methods that combine biodegradable molecules with UV-shielding molecules in an attempt to enhance biodegradability.

The mechanism behind why the corals react to other sunscreen ingredients, but not to the new polymeric filter, also needs to be explored, Tao says.

Nonetheless, he is excited about the potential impact of his new polymeric sunscreen on human and coral health. "Such sunscreen could have been invented already if more chemists had travelled to the beautiful Great Barrier Reef!" he says.

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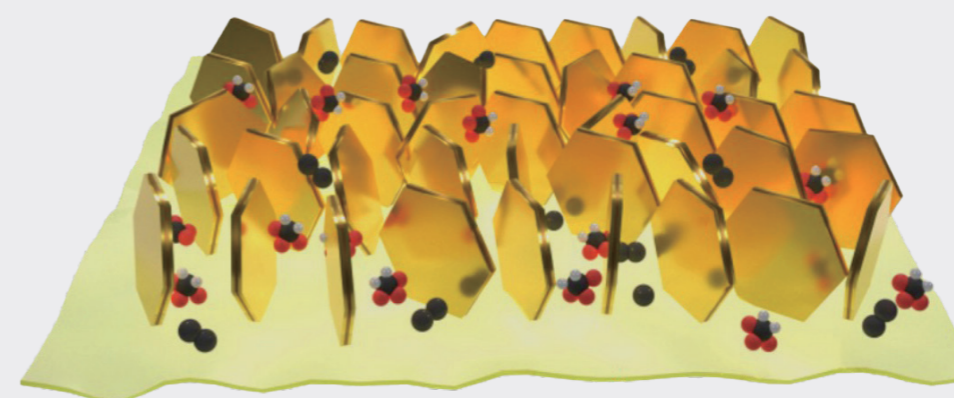
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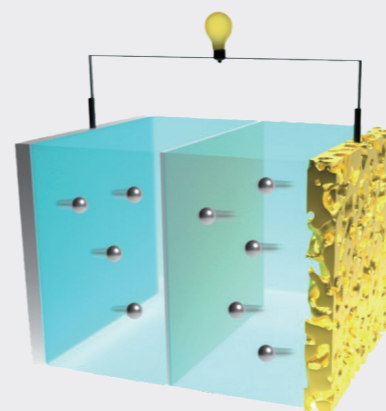
# Lithium-carbon dioxide batteries get a boost

A new cathode design brings energy-dense and environmentally friendly lithium-carbon dioxide batteries closer to reality



The team's new catalyst, composed of MoS<sub>2</sub> (hexagons) growing vertically on Co<sub>9</sub>S<sub>8</sub> (yellow base), has a large number of exposed, active edge sites.

A novel bidirectional catalyst, designed at Tsinghua University, has overcome a key issue hindering the development of rechargeable lithium-carbon dioxide (Li-CO<sub>2</sub>) batteries. Still in the early stages of development, potential uses for these unusual batteries range from powering rovers under the harsh conditions of Mars, to utilizing waste carbon dioxide here on Earth.



The new two-dimensional, called V-MoS<sub>2</sub>/Co<sub>9</sub>S<sub>8</sub>@CP (in yellow), has been designed for use in rechargeable lithium-carbon dioxide batteries (pictured).

Li-CO<sub>2</sub> batteries, by design, use up carbon dioxide. As the batteries discharge, lithium and carbon dioxide are converted into the solids lithium carbonate and carbon, potentially locking away the greenhouse gas.

This also makes them suitable for use in environments with high proportions of carbon dioxide, such as the atmosphere of Mars or on Earth-bound submarines.

These batteries could also be used in conjunction with the carbon capture and storage technologies increasingly being installed at power plants and other industrial sites — where they would turn waste carbon dioxide into green electricity.

## Green power

"The use of Li-CO<sub>2</sub> batteries is a win-win situation, providing a new method for CO<sub>2</sub> fixation and also opportunities in CO<sub>2</sub>-rich environments," says lead researcher, Guangmin Zhou, a chemical engineer at the Tsinghua-Berkeley

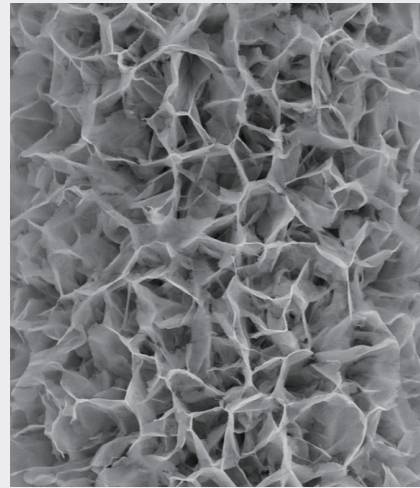
Shenzhen Institute and Tsinghua Shenzhen International Graduate School.

It is anticipated that Li-CO<sub>2</sub> batteries could eventually offer energy densities five to 10 times greater than traditional lithium-ion batteries. Researchers hope that Li-CO<sub>2</sub> batteries will find uses in the aviation and aerospace industries, which are continually searching for smaller and lighter batteries.

A typical Li-CO<sub>2</sub> battery design has a lithium-metal anode, a non-aqueous electrolyte, and a porous cathode. The cathode is the site where carbon dioxide is reduced to form lithium carbonate and carbon during battery discharge, and also the site of the reverse reaction during recharge.

But both these reactions are sluggish with current cathode designs, explains Zhou, leading to poor reaction reversibility and low energy efficiency of the battery.

Zhou's team recently detailed an improved porous cathode design in the journal *PNAS (Proceedings of the National Academy of Sciences)*.



A scanning electron microscope of V-MoS<sub>2</sub>/Co<sub>9</sub>S<sub>8</sub>@CP at a micrometre scale.

The scientists' cathode is comprised of ultra-small molybdenum disulfide (MoS<sub>2</sub>) crystals grown vertically on sheets of cobaltpentlandite (Co<sub>9</sub>S<sub>8</sub>), supported by carbon paper.

## Impressive efficiency

There are locations, called active sites, on both the MoS<sub>2</sub> and Co<sub>9</sub>S<sub>8</sub> where the reactions take place. "We designed a two-dimensional material with a large number of exposed dual active sites — MoS<sub>2</sub> edge sites and Co<sub>9</sub>S<sub>8</sub> active sites — which show obviously synergistic effects to facilitate the reaction kinetics," says Zhou.

As well as providing numerous active sites of both types, the pores in the sheets were designed to facilitate diffusion of carbon dioxide and electrolyte through the materials. The pores also provide ample storage space for the solid discharge products.

The team's experimental measurements and density functional theory calculations suggest that the new

cathode design has an impressive energy efficiency of more than 81%.

However, there is still work to be done before Li-CO<sub>2</sub> batteries can reach their full potential, says Zhou. This includes finding suitable electrolytes and perfecting the anode design. Stable lithium 'plating/stripping' at the anode to prevent unwanted build-ups of the metal is "essential for long-life and safe Li-CO<sub>2</sub> batteries," Zhou adds.

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Guangmin Zhou (at center), an associate professor at the Tsinghua-Berkeley Shenzhen Institute and Tsinghua Shenzhen International Graduate School, is creating highly efficient cathode materials for use in rechargeable lithium-carbon dioxide batteries.



The researchers tested their enhanced autonomous-vehicle safety testing AI in an augmented-reality environment that included simulated background vehicles and a real car and test track.

## Accelerated crash tests for autonomous vehicles

A new road safety testing simulation multiplies adverse events, so commercially available driverless vehicles can get on the road faster.

One of the major roadblocks for fully autonomous vehicles is effective safety testing software. Testing autonomous cars on actual roads is incredibly time-consuming, expensive and potentially hazardous to other drivers.

Because of the limits to obtaining real-world data, the accuracy of artificial

intelligence (AI) simulation testing — which is less dangerous but relies on the input of real-world data for accuracy — is also constrained, explains Shuo Feng, an alumnus from Tsinghua University's Department of Automation.

To get enough data on real-world hazards for AI simulations, each physical test vehicle needs to drive

for hundreds of millions to hundreds of billions of kilometres, which isn't practical.

But now, in a paper published in the journal *Nature*<sup>1</sup> in March 2023, Feng and a team from the University of Michigan in Ann Arbor, US, report on a method to boost the speed of autonomous vehicle safety testing by up to 100,000-fold.

## Calling in reinforcements

Their new system addresses the issue of the rarity of ‘safety-critical incidents’ – such as near misses, pre-collision events or crashes. It does this by reinforcing real-world driving data with ‘densified data’, a modelling technique that plots highly likely outcomes to increase the number of observations in a dataset, explains Feng. These tweaks ultimately led to faster and more accurate decision-making by their test vehicle in augmented-reality driving scenarios.

The researchers tested their AI on a real mid-size luxury saloon or sedan car called a Lincoln MKZ hybrid, produced by American car manufacturer Ford. The vehicle was modified into a ‘level 4 autonomous vehicle’ – which means it doesn’t require human attention or input – using a popular open-source driving system called Autoware.

“We demonstrated the effectiveness of our approach by testing on both a 4km highway and urban test tracks in

the United States. The tests used an augmented-reality environment that included simulated background vehicles, alongside the actual physical road infrastructure and a real autonomous test vehicle,” explains Feng.

## AI’s assessing other AI’s?

In that environment, they simulated safety-critical events using their AI and evaluated crash types and crash severities in addition to crash rates.

Their results showed that their ‘densified data’ AI testing system can accelerate the simulated safety evaluation process by many orders of magnitude – landing at between 1,000 and 100,000 times faster than real-world driving tests. But it remains to be seen how much national testing authorities will accept this in place of real-world tests.

The study could have implications for more than just cars, providing a means to improve safety simulations for

everything from autonomous drones and planes to more android-type robots. “The study is advancing AI-based methods to validate AI-based systems. It’s essentially AI against AI,” Feng points out.

But for cars, he hopes this advance will provide a potentially affordable and timely path forward for safety testing.

“This type of research will be critical for manufacturers, governments, and third-party agencies, such as insurance agencies, who will ultimately decide whether AVs are ready for large-scale deployment,” explains Feng. “It will also be important for customers, who will need to have more confidence in the autonomous vehicles.”

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The new AI was tested using a real mid-size luxury saloon or sedan car fitted with a popular open-source driving system called Autoware.

# Parents can help curb cyberbullying in teens

Snooping through a teenager’s social media isn’t the best way to prevent cyberbullying – here’s what works instead.

At some point, cyberbullying – the use of technology to repeatedly harass, threaten, anger, or shame someone – will affect nearly 80% of Chinese teenagers<sup>1</sup>. Similar numbers may be facing such abuse in other countries too. Victims are more likely to smoke, abuse alcohol or drugs, commit crimes and even hurt themselves<sup>2,3</sup>.

Fortunately, a recent study has determined a trifecta of parental approaches that can help lower the risk of their teenagers being bullied online. These include maintaining open

communication about online threats, not overly restricting social media usage, and refraining from snooping around a teen’s profiles<sup>4</sup>.

The individual impacts of each of these measures have previously been studied, explains Associate Professor Liang Chen, an expert in computational communication at Tsinghua University who led the study – but this is the first-time the combined impacts have been examined.

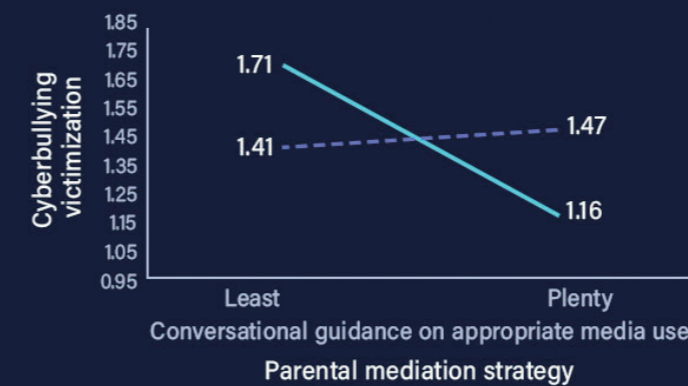
“Parents actually employ multiple mediation strategies simultaneously,

so we wanted to investigate how the interactive effects of these strategies can influence the outcomes of cyberbullying experiences for young individuals,” he says.

## Cyber-smart teens

In a 2017 study, which has been cited more than 360 times, Chen and then his co-authors found that children who interacted more frequently with their parents were less likely to be perpetrators of cyberbullying<sup>5</sup>.

## TO PREVENT CYBERBULLYING, OPEN UP COMMUNICATION AND REDUCE CONTROL



Moreover, Chen determined in a separate study published the same year<sup>6</sup>, this risk was further reduced when parents practiced ‘active mediation’, which involves discussing media content and offering guidance on appropriate media use, as well as ‘restrictive mediation’, such as limiting children’s time and activities on social media.

To investigate the combined effects of such strategies on the likelihood of being cyberbullied, Chen and his co-authors — postgraduate students Xiaoming Liu and Hongjie Tang — surveyed 642 parents across China to find out the types of mediation techniques they most commonly practiced. They also included ‘non-intrusive inspection,’ which involves befriending their children on social media to browse their friend lists, interactions, and comments.

The researchers examined the issue by asking the parents to rate how often they did certain things, such as reminding their teenager not to reveal personal information online, restricting the type of platforms they can visit, and check their child’s social media profile.

They then interviewed the respondents’ teenagers aged 13–18, to determine how frequently they made or received comments that were rude, nasty, threatening, or aggressive.

They also asked the teens how often they spread or were targeted by online rumors, in order to assess the likelihood of them being cyberbullies or victims, respectively.

In their analysis, Chen and his team found that parents who practiced active mediation were less likely to have teens who were bullied or who were bullies. “Actively engaging with teenagers and creating an open and trusting relationship where they feel comfortable discussing their online experiences, while providing guidance on responsible and respectful online behavior is very effective at reducing cyberbullying,” Chen says.

A similar effect was observed when parents weren’t overly-controlling and didn’t spy on their kids’ social media accounts. “Restrictive meditation shows teens they aren’t trusted, which leads to them resisting parental management,” Chen notes, “And high non-intrusive inspection may give rise to a sense of oppression.”

But the most effective way to minimize cyberbullying involves attention to all of these elements Chen adds. “This integrated approach provides support, guidance, and monitoring while allowing teenagers to develop autonomy and self-protection skills.”

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Associate Professor Liang Chen has been studying cyberbullying to identify real interventions that can be used to help prevent victimization.

# Moderate-intensity exercise has significant brain-boosting effect, study says

Working out can improve cognitive abilities such as problem-solving in young adults, and some forms of exercise offer greater benefits than others, according to new Tsinghua research.

A study of two popular types of workout has suggested that for young adults, a smarter regime is better than a harder one when it comes to boosting executive function through exercise.

The research led by Xindong Ma, a professor at Tsinghua University’s Division of Sports Science and Physical Education, compared two groups following a 12-week physical activity programme, as well as a control group that didn’t participate in exercise training.

Ma’s team found that those doing regular moderate-intensity continuous training (MICT) performed better in executive function tests than those doing high-intensity interval training (HIIT) when both compared to the control group. This was corroborated by measurements of blood flow in the brain.<sup>1</sup>

MICT is consistent, moderate aerobic exercise sustained over time, such as brisk walking, cycling, swimming, and jogging. It boosts cardiovascular fitness without excessive strain. HIIT involves

alternating between intense exercises and periods of rest or lower intensity. Examples include sprints, jump squats and burpees.

HIIT has the advantage of achieving similar physiological adaptations as MICT, but within a shorter time frame. However, prolonged HIIT was reported to lead to fatigue and decrease cerebral oxygenation in the brain compared to MICT, which may explain the results, speculates Ma. “Maintaining a relatively constant cerebral blood flow is

Regular moderate exercise — such as brisk walking, cycling, swimming, and jogging — appears to boost executive function in young adults more than high-intensity interval training.





The Tsinghua team used transcranial Doppler flow analysis to assess speed and direction of blood flow in the brains of study participants.

fundamental to preserving normal brain function,” he says.

Conversely, in previous studies on sedentary elderly individuals, HIIT has been shown to enhance memory performance to a greater extent than MICT. Several studies have also indicated that HIIT leads to greater improvements in cardio-respiratory fitness and overall vascular function compared to MICT.

Those studies have tended to focus on children, adolescents and the elderly, while studies on young adults are rarer, says Ma, which is what makes this finding more interesting.

## Results focused

The study design comprised 93 healthy adults aged between 20 and 30, who were randomly assigned to a HIIT, MICT, or control group. Each exercise group performed 40 minutes of HIIT

or MICT three times a week, while the control group received only health information.

The researchers then sought to measure executive function – which involves skills like problem-solving, planning, and organizing. To do this, they applied the Trail Making Test (TMT), a widely used cognitive task that assesses skills such as problem-solving and attention by asking participants to order and connect disordered numbers and letters.

Both exercise groups showed significant improvements in TMT completion time compared to the control group, but the MICT group showed better results than the HIIT group.

Then, to better understand the mechanisms, the researchers employed transcranial Doppler flow analysis, a non-invasive method that uses ultrasound technology to assess the speed and direction of blood flow in the brain in real time. The results

showed that the MICT group had more significant improvements in cerebral blood flow than the HIIT group.

Given the subtle differences seen between MICT and HIIT in this study group, future research would do well to explore longer intervention periods and different exercises to gain a fuller picture and understanding of the mechanism, says Ma.

The more we know, the better we can be at preventing cognitive decline across a lifetime, he explains.

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# Traffic pollution policy saves lives

China’s city roads are among the most congested on the planet as rapid economic growth has seen the number of vehicles rise more than 40-fold in the last 20 years. People in China owned 240 million vehicles in 2018, up from about 27 million in 2004. Cars and trucks have mobilised Chinese society, but have brought a terrible health burden.

Internal combustion engines spew fine particulate matter (known as PM<sub>2.5</sub>) and nitrogen oxides (NO<sub>x</sub>), which form ground-level ozone and smog. Once inhaled, this toxic pollution triggers heart disease, respiratory problems, and other illnesses.

In 2015 alone, PM<sub>2.5</sub> contributed to 810,000 deaths in China. Ozone exposure added a further 170,000 deaths.

Now, a team led by Shaojun Zhang from Tsinghua University’s School of Environment is looking at what has worked to reduce pollution to drive new air quality policies, and refine old ones.

## Strict pollution policies

China, which first introduced policies to reduce traffic pollution at the end of the 1990s, has pushed ahead with strict regulations, leapfrogging other countries in scope, notes Zhang. Now, “China’s regulation system is one of the most stringent in the world.” For instance, in many regions of China, controls such as on-board monitoring of NO<sub>x</sub> emissions for some diesel vehicles, are standard.

Electric vehicles, and tight regulation of car and truck emissions, are improving the health of millions in China.

After years of investigating how effective China’s policies are, Zhang and his colleagues are optimistic. They have shown that deaths due to PM<sub>2.5</sub> and ozone would have been roughly 50% greater in China without pollution control measures, because vehicle emissions from 1998 to 2015 would have been 2–3 times larger<sup>1</sup>.

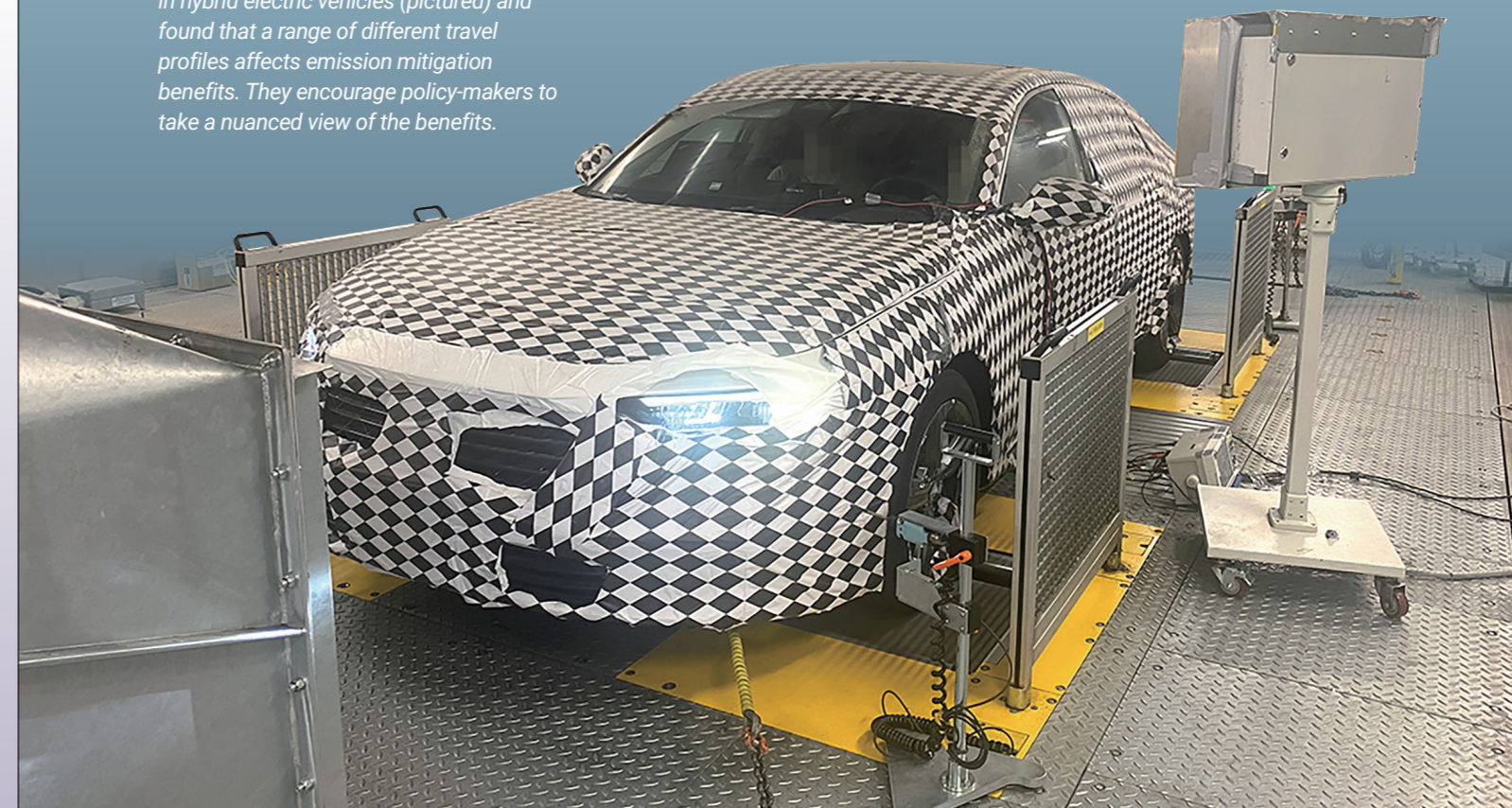
The benefits were most significant in urban areas that see the highest levels of pollution, he adds.

## Electric avenue

China’s transition to electric vehicles is also playing a vital role in improving health, as well as the economy, says Zhang.

Again, China leads this global development. About half of all new

A Tsinghua team has tested various plug-in hybrid electric vehicles (pictured) and found that a range of different travel profiles affects emission mitigation benefits. They encourage policy-makers to take a nuanced view of the benefits.





Researchers have been using real-time diagnostics platforms to track carbon dioxide and nitrogen oxides emissions in Beijing city.

electric vehicles sold globally are purchased in China. In 2018, annual sales across the country exceeded one million, and those numbers will soon increase exponentially.

China's New Energy Vehicle Industrial Development Plan (2021-2035) plans to put roughly 80 million electric vehicles on China's roads by 2030, including battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs). BEVs alone could account for 30-40% of passenger car sales by 2030.

Electric vehicles are usually promoted as a way to reduce CO<sub>2</sub> emissions and tackle climate change. But Zhang's team shows that this transition promises significant health benefits, too.

The researchers used an atmospheric chemistry model to estimate the impact of achieving 27% electrification of private vehicles, and a larger proportion of commercial vehicles (e.g., more than

80% for urban transit buses), by 2030<sup>2</sup>. They estimate that meeting this target would reduce PM<sub>2.5</sub> levels in urban areas by up to 3%, and reduce NO<sub>x</sub> levels by up to 19%, reducing urban ozone levels. This, in turn, would avoid about 17,000 premature deaths per year, with the most significant health benefits seen in large cities.

There is also an economic benefit of electrification, points out Zhang. Health gains, together with the reduction in greenhouse gas emissions, deliver an economic benefit of US\$10 billion in just three urban regions in the south and east of the country by 2030<sup>2</sup>, the team estimates. These regions were the Beijing-Tianjin-Hebei region, which contains cities such as Beijing; the Yangtze River Delta region, which includes Shanghai; and the Pearl River Delta, which includes cities such as Guangzhou and Shenzhen.

Vehicle electrification also reduces CO<sub>2</sub> emissions, including when increased emissions from the power stations that generate electricity, and the factories that produce components, are taken into account.

Zhang's team used a technique called life-cycle assessment to calculate how the shift to electric vehicles changed CO<sub>2</sub> emissions, including emissions released at every stage of electric car manufacture.

The results showed that in 2015, electric models reduced the average lifetime CO<sub>2</sub> emissions of a vehicle by 23%, compared with an internal combustion engine vehicle. By 2020, that reduction had grown to about 40% due to factors such as better battery performance, more efficient use of materials, and China's growing deployment of renewable power, a trend Zhang expects to continue.<sup>3</sup>

The benefits even held good in northern China, which is most dependent on coal-fired power plants. Switching a petrol or diesel car for a BEV in 2020 reduced the lifetime CO<sub>2</sub> emissions of the vehicle by roughly 30%. In areas with cleaner electricity grids, that reduction was as high as 62%.

## Diesel and data

Another key policy that is helping tackle traffic pollution is the mandated use of sensors in heavy diesel vehicles that monitor NO<sub>x</sub> emissions in real-time. When the monitor detects levels above a set threshold it triggers catalytic converter in the exhaust system to reduce emissions. It also alerts the environmental authorities in each of the regions run by China's Ministry of Ecology and Environment.

In Beijing, vehicle manufacturers have had to fit these monitoring systems into new vehicles since 2018. Soon, older vehicles may need to retrofit monitoring systems.

The Zhang team has found that data from sensors in new vehicles show that they work well, retrofitted units were not always reliable<sup>4</sup>.

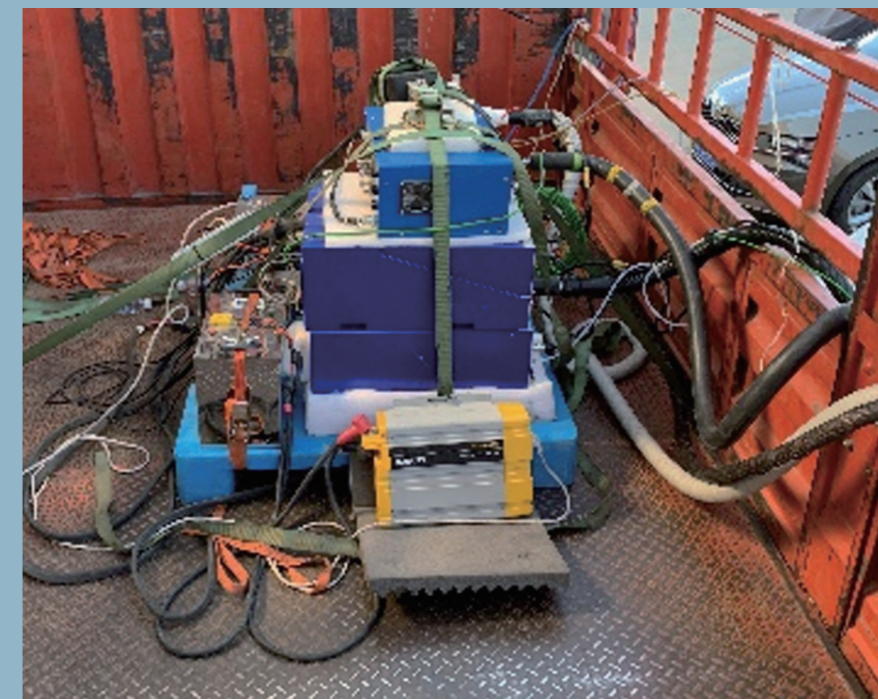
For Zhang, there is a clear path towards even greater reductions in traffic pollution and improvements in health. He proposes government subsidies for electric vehicles should continue, and municipal governments should focus their electrification incentives on urban areas, for example by creating low-emission zones. Rigorous inspections of vehicles and their emissions are also a must, he says.

Lessons learned in China about effective pollution control could also help improve health in other developing countries such as India, he says.

"Our results show that the declines of various pollutants will continue, and electrification will be one of the most important factors to achieve deeper emission reductions due to the increase in renewable energy systems," says Zhang.

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On board emission measurement platforms (pictured) are fitted to vehicles and can be used to collect second-by-second profiles of carbon dioxide and other air pollutant emissions.

# Why your job status helps predict work resilience

At one Chinese manufacturing company, workers who considered themselves to have lower-status jobs showed surprising tenacity in the aftermath of COVID-19, often exceeding pre-pandemic productivity expectations.

To unravel the effects of 'job stigma' during major upheavals, researchers from Tsinghua University's China Business Case Center looked at the

performance records of 708 employees at a company that manufactures lithium battery components in southern China.

The great majority of employees were assembly workers, while a small minority worked in accounting, auditing, human resourcing, cost-control, purchasing and sales.

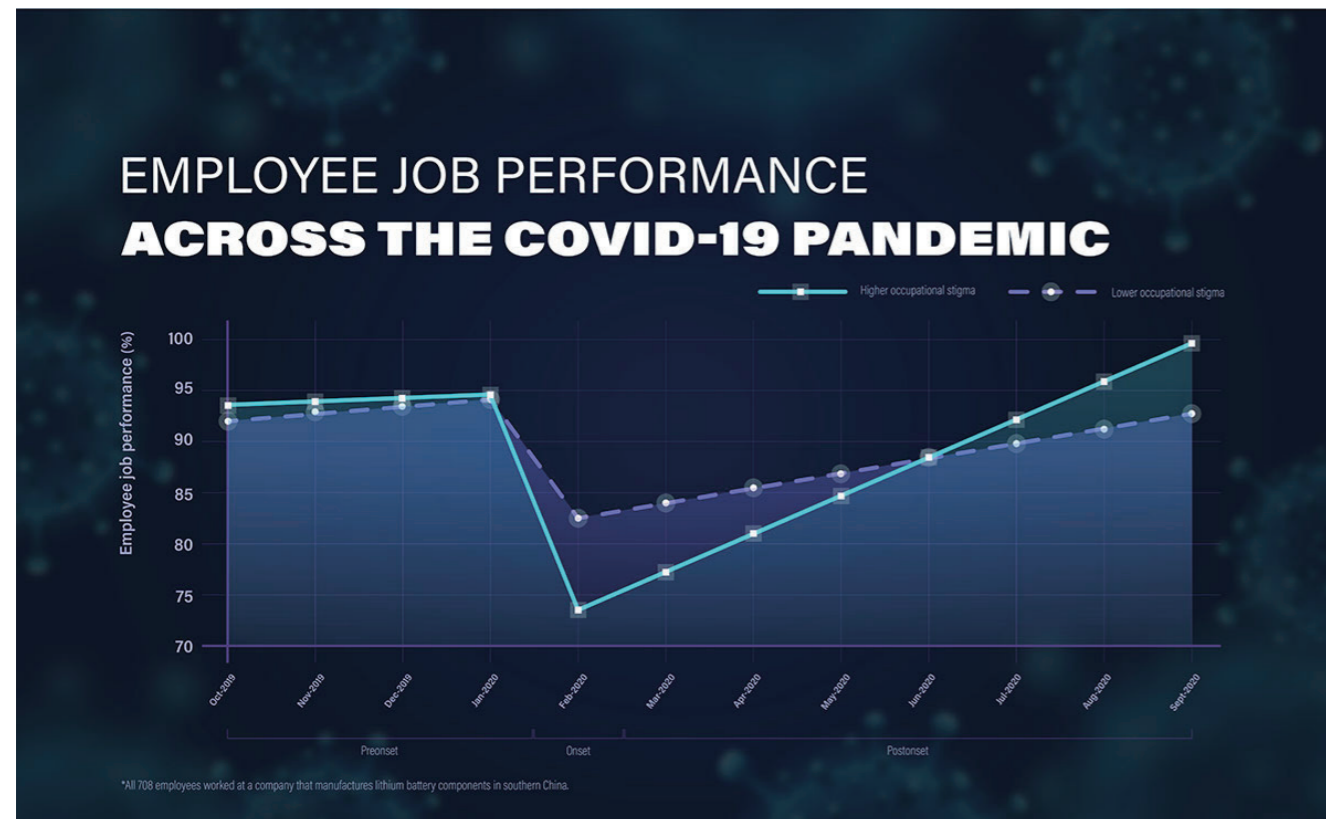
Questionnaires provided insights into how these employees viewed their jobs, says lead author, Xiaoming Zheng,

A case study looking at the COVID-19 pandemic showed that the productivity of those who consider themselves to be in 'low-status' jobs rebounded better than others.

director of the center. "Respondents were asked to rate how proud they were of their job. For example, one option was 'Few people would be proud to have my job'."

## COVID-19 crisis

The researchers then compared monthly employee work performance records across 21 months — a period



During the onset of the COVID-19 pandemic, the performance of self-identified 'lower status' employees at a Chinese lithium battery component manufacturing company underwent a sharper decline than their self-identified 'higher status' co-workers. But those with self-identified 'lower status' jobs also bounced back more strongly as the pandemic wore on.



A Tsinghua University group studied roughly 700 employees — ranging from assembly workers (pictured) to accounting, human resourcing, purchasing and sales — at a company that manufactures lithium battery components in southern China.

that included the onset of the epidemic in February 2020, as well as the seven months of adaptation that followed.

The researchers found that the work performance of all employees underwent a sharp decline during the month-long onset period of the epidemic. This is probably because attention was directed away from work tasks and towards adjusting to new routines and procedures, and to dealing with the anxieties about an employee's own health and the health of their loved ones, explains Zheng. The decline in performance, however, was also less pronounced for employees who considered themselves to be in higher status jobs.

During the subsequent post-onset period performance recovered as workers adapted, until overall performance reached its pre-epidemic levels. But the job performance of employees who felt the most job stigma not only bounced back more strongly than other employees, it eventually significantly exceeded the levels forecast for that period in the pre-COVID-19 era<sup>1</sup>.

"Stigmatized occupations were often targets for the company downsizings that the pandemic caused," Zheng speculates. "So, it's possible that pushed people of low occupational status into making an extra effort."

## Leadership lessons

Status has a fairly intangible nature, adds Zheng, so it is understudied compared to management issues related to material resources or interpersonal support. But it appeared to be a trend-driving factor during the crisis for this company. When the researchers divided employees by socio-economic status, or standard job hierarchies, they found no real difference in performance trajectories.

The lesson is that some companies should consider how they foster respect for workers with lower job statuses, says Zheng. Small changes could help to reduce large fluctuations in productivity during a crisis. Zheng points to one of his previous studies that found significant psychological and

productivity benefits when expressions of gratitude were directed at workers during the pandemic<sup>2</sup>.

There is still much work to be done on this topic, Zheng says. The long-term effects of a possible feeling of job insecurity have not yet been examined, he adds. "Will this productivity drop off? Will these employees burn out? We don't know."

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# Scientists reveal how plants warn others about pest attacks

The mechanism behind airborne signals that plants use to alert each other to aphid attacks has been uncovered by Tsinghua University researchers – and the findings hint at new ways to engineer crops to defend them against pests.

The biomolecular processes involved have puzzled scientists since the airborne defence was observed more than 40 years ago.

“Our study lays the ground-breaking work to develop novel bioinspired tools to defend plants against insect infestation and virus epidemics,” says Yule Liu, a plant scientist at Tsinghua University.

## Messages on the breeze

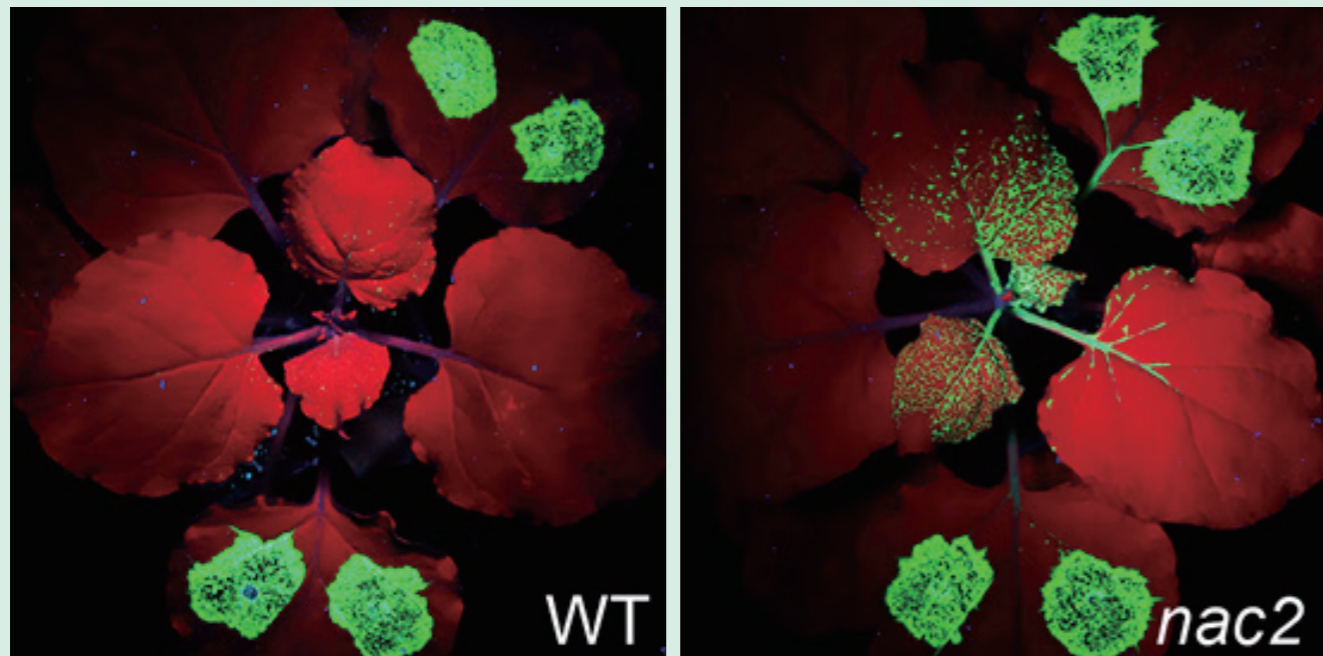
The research, recently published in *Nature*, focuses on how some plants attacked by aphids release methyl salicylate gas, and how other plants sense and mount their own pre-emptive defences.

Liu’s team looked at a relative of tobacco, called *Nicotiana benthamiana*. They traced the production of methyl salicylate in *N. benthamiana* to a gene called *NAC2* and showed that plants that lack this gene are more attractive to aphids.

A study reveals how plants send out alarm signals in response to insect infestations – a finding that might help research into pest-proof crops.

The scientists also identified a receptor in the plants called salicylic-acid-binding protein-2 (SABP2). It binds to and converts airborne methyl salicylate into salicylic acid, an important plant hormone that can regulate resistance to environmental stress.

The researchers found that salicylic acid can trigger a defence against aphids, even before plants are attacked by aphids themselves. They speculate that upon contact with methyl salicylate from neighbouring plants under attack, plants are able to raise a pre-emptive defence via this salicylic acid pathway.



A Tsinghua team traced the production of a gas warning other plants of aphid attack to a gene called *NAC2*. They also showed that plants that lack this gene are more susceptible to viruses. Here the scientists examined the green fluorescent protein (GFP) levels (green) in wild type (WT) plants and plants that lack *NAC2*, both of which were infected with GFP-tagged tobacco mosaic virus.

## Aphid attacks

In addition to sucking the nutrition from plants, aphids can also spread viruses that wreck crops. The researchers found that some aphid-transmitted viruses, such as cucumber mosaic virus and potato virus Y, have evolved a way to combat plant airborne defence. They do this by producing proteins that interfere with the *NAC2* pathway, which reduces the synthesis and release of methyl salicylate.

Liu suggests that breeding plants that are resistant to these virus proteins, or using methyl salicylate in some other way, could help protect crops against

aphids and aphid-transmitted diseases.

He adds that “methyl salicylate-mediated airborne defence is an environmentally friendly strategy to resist aphids,” making it an even more appealing approach.

The findings on *N. benthamiana* could also have broader implications for agricultural research, adds Liu.

The researchers believe similar mechanisms could be found that help crops defend against fungi, bacteria, nematodes, whiteflies, leafhoppers and other pests. Once these signalling pathways are identified, they could be used to breed resistance against pests and pathogens.

Airborne signalling might even help plants coordinate their response to other environmental stresses, such as drought or excess heat, or even to normal growth conditions, adds Liu. This recent finding, he argues, could open a host of interesting possibilities.

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Emitter and receiver tobacco plants were placed on trays at a distance of 30 cm apart. Aphids that were either virus-free or infected were added to some of the emitter plants. After three days, the receiver plants were taken out for further experiments.

# Digging the dirt on contaminated soils

With many agricultural soils at risk of degradation, the world's food supply might soon depend on the success of remediation science.

It can take hundreds of years for microbes and animals, such as worms, to break down organic matter and create just a few centimetres of fertile surface soil — also known as topsoil. But, according to the Food and Agriculture Organization of the United Nations, 90% of agricultural topsoil is at risk of degradation and erosion<sup>1</sup> by 2050.

Given that almost all of the world's food is grown in soil,<sup>2</sup> it's alarming that the United Nations estimates that as much as 40% of the Earth's land is degraded, says Deyi Hou, director of the division of soil and groundwater environment at the School of Environment at Tsinghua University in Beijing. This effect poses a threat to roughly half of the global GDP<sup>3</sup>, he points out.

China is a major agricultural producer, and Hou is working to protect its valuable agricultural soils using sustainable approaches. "Black soil is generally considered richer in nutrient content, and is suitable for most agricultural purposes," explains Hou.

Northeast China is also one of the world's largest areas of black soil. But

between 1996 and 2019, an additional 116,000 square kilometres was planted with crops.<sup>4</sup> Unsustainable agricultural practices can lead to pesticide and heavy metal pollution, which accelerates erosion, says Hou.

"A national soil survey in China in 2014 revealed that more than 16% of our soil is contaminated," says Hou. "This led the government to establish legislation for soil remediation. In 2019, for example, China enacted a law that requires state agencies to supervise and control soil contamination."<sup>5</sup> An ongoing soil survey — planned for completion in 2025 — should provide insight into the impact of such laws.<sup>6</sup>

## Protecting microbes

"Soil degradation is the result of many factors, including soil pollution, increases in salt or acid concentrations, and mechanical water and wind erosion," Hou explains. These all reduce the amount of life in the soil, while water and wind erosion leach essential nutrients and damage the soil structure.

A huge problem is that many businesses

— from petrol stations to factories — abandon polluted industrial sites rather than remediating them, which results in vast swaths of unhealthy soil, or 'brownfields'. These can contain toxic heavy metals and volatile organic compounds released from waste, leaking pipelines, broken storage tanks and wastewater ponds. There are more than five million potentially contaminated brownfield sites globally, notes Hou.

His experience working with brownfields began early in his career. Before joining the faculty at Tsinghua University, Hou had been working as a consultant on soil remediation in the United States and the United Kingdom, including at locations that had formerly been rubbish tips.

Hou notes that "achieving long-term and sustainable remediation of contaminants at such sites is exceptionally challenging" due to difficult geophysical conditions and complex pollutants.

Today, Hou's team is working on another type of brownfield that is contaminated by multiple heavy-metal pollutants — including arsenic, cadmium, and mercury. These can be caused by everything from coal-burning power plants and oil refineries, to chemical and pesticide-producing facilities.<sup>7</sup>

"Heavy metal pollution is widespread and they are often evident on sites that have mixed and complicated contamination issues. These are challenging to remediate when compared to soils contaminated by single elements," Hou says.

## From the ashes

One solution Hou is working on involves adding biochar to soils. Biochar is a form of charcoal made by breaking down biomass at high temperatures (typically above 300 °C) in the absence of oxygen.

One of the things biochar does is increase the microbial content of soil, which helps break down organic contaminants in soil, Hou explains. Studies have shown that this is due to biochar's high porosity, which provides a higher density of living space in the soil for bacteria and fungi.<sup>8</sup>

Biochar's porosity can also draw in large amounts of organic and inorganic contaminants, says Hou.<sup>9</sup> "Additionally, biochar can be engineered to possess certain surface properties, allowing it to be customized for specific types of contaminants, such as heavy metals or organic pollutants."

Adding biochar can help improve soil nutrient content and the amount of water it can hold, protecting it from erosion. Hou's team is leveraging engineered biochars and clay-based additions, such as layered double hydroxides, to remediate soils that contain multiple contaminants.

Biochar composites and modified layered double hydroxides have been shown to capture both heavy metals and organic contaminants, including herbicides, Hou explains.<sup>10,11</sup> Field-scale trials of this type of remediation are underway in many regions from southwest to northeast China, says Hou. If successful, these amendments will be potentially developed for use by industry, he adds.

## The benefits of black soil

In the end, we must not forget that black soil is also a sustainable resource, says Hou. It retains moisture well, which helps the uptake of water by plants and reduces wind erosion. It is also full of nutrients, reducing the need for chemical fertilizers. Black soil also holds its shape, providing a stable and fertile base for crops, contributing to long-term crop production, "which is crucial for global food security", says Hou.

Beyond agricultural benefits, black soil can store large amounts of organic carbon, making it a significant global carbon sink. "Protecting this soil type is critical for carbon sequestration and mitigating climate change," Hou



Deyi Hou (fourth from left) and his team are working on solutions for remediating soil contaminated by multiple heavy-metal and organic pollutants.

says. "When black soil erodes or degrades, the stored carbon is released into the atmosphere, contributing to greenhouse-gas emissions."

Environmentally sound approaches to remediating brownfields can reduce greenhouse gas emissions by as much as 80%.<sup>12</sup> These can range from 'sustainable immobilization' — which involves adding low-impact binders to the soil (like biochar) — to bioremediation, which is when plants, bacteria, fungi or animals are used to extract, stabilize, degrade or move contaminants in the soil or groundwater.

But these remediation systems are also challenged by climate change, says Hou. Inundation at contaminated sites related to flooding or sea-level rise can cause the spread of pollutants, for example. We must pick remediation strategies that are resilient to these changes, says Hou.

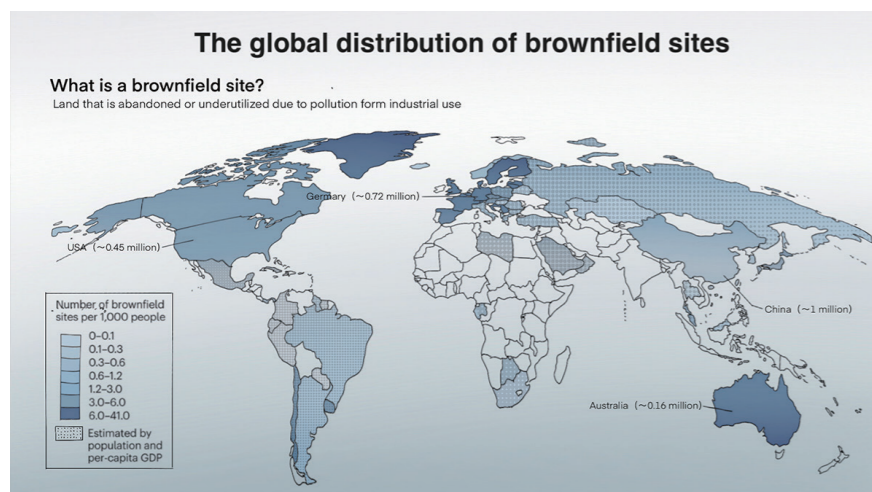
He also points out that the UN estimates that the speed of global land take for settlement will double by 2050.

So, ideally, brownfields are able to be reused and revitalized. This raises ethical and equality considerations, says Hou. For instance, low-income communities should not be forced to live on or near brownfields or poorly remediated brownfields, he says.

And to really address soil issues, nations must also work together, he says. "It's essential to adopt a holistic perspective that transcends the site boundaries and considers a broader remit and time horizon."

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Deyi Hou at Tsinghua University is working on ways to remediate a growing number of brownfield sites so that they can be used as productive land.

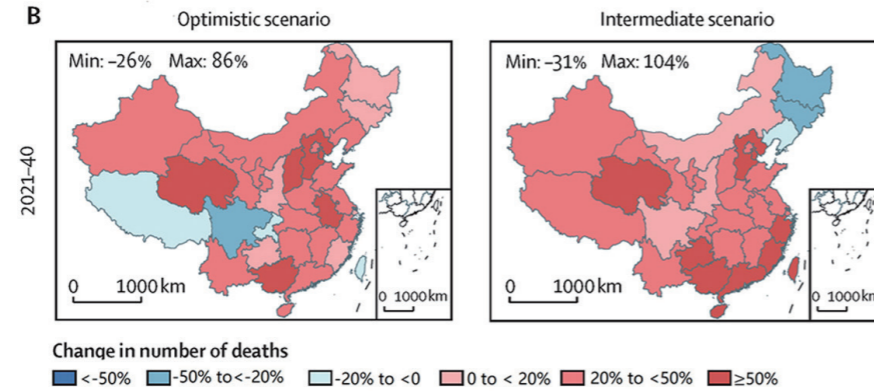
# Deaths in China due to wildfire smoke could be higher than expected

A sophisticated model predicts that Chinese deaths linked to wildfire smoke will be higher than previous estimates.

A significant growth in the Chinese population's exposure to wildfire smoke was tracked by researchers at Tsinghua University in 2021.<sup>1</sup> Led by Yuqi Bai, the team found a 24.5% increase in the average annual exposure of people to wildfire air pollution in China for the period 2016–2020 compared to 2001–2005.

Bai's team followed up in 2022 with detailed models that predict future wildfire-related deaths in China, both across time and by region. These models predict that the growth in wildfire mortality will peak in the near future. But they also predict that mortality linked to short-term exposure (i.e., a few days) to wildfire pollution in China is likely to exceed estimates by global models.

If low levels of carbon-emission control are implemented, China's annual mean all-cause death attributable to fine particulate matter (PM<sub>2.5</sub>) pollution



Map B shows the projected changes in all-cause deaths in China between 2021–2040 due to landscape fire-related PM<sub>2.5</sub>.

from wildfires is projected to increase by 37.38% in the period 2021–2040, compared to the period 1986–2005 period (see map).<sup>2</sup>

This is more deaths than predicted by previous models. The difference: Bai's models employed 11 fire models

instead of one. "Using multiple models helps cover more possibilities and uncertainties, making our projections more reliable," Bai explains.

The models also used specialized equations designed specifically for fine particulate matter from wildfires rather than formulas for more general air pollution. PM<sub>2.5</sub> particles from wildfires are often more harmful than PM<sub>2.5</sub> from urban sources such as car exhaust, Bai explains. Being smaller, these particles more readily infiltrate the depths of the lungs and enter the bloodstream. This can trigger systemic inflammation and heighten the overall risk of death from multiple causes (most notably heart attacks, strokes and severe respiratory problems).

Yuqi Bai (in blue) and his team use drones to map wildfire risk in China.



## Projections for protection

Bai's work is part of a Lancet Countdown Asia Center's initiative, which aims to understand the multidimensional health risks China faces due to climate change.

To help drive wildfire policy, his team's study published in 2023 made predictions under different global-warming scenarios about wildfire related mortality up to 2100<sup>3</sup>.

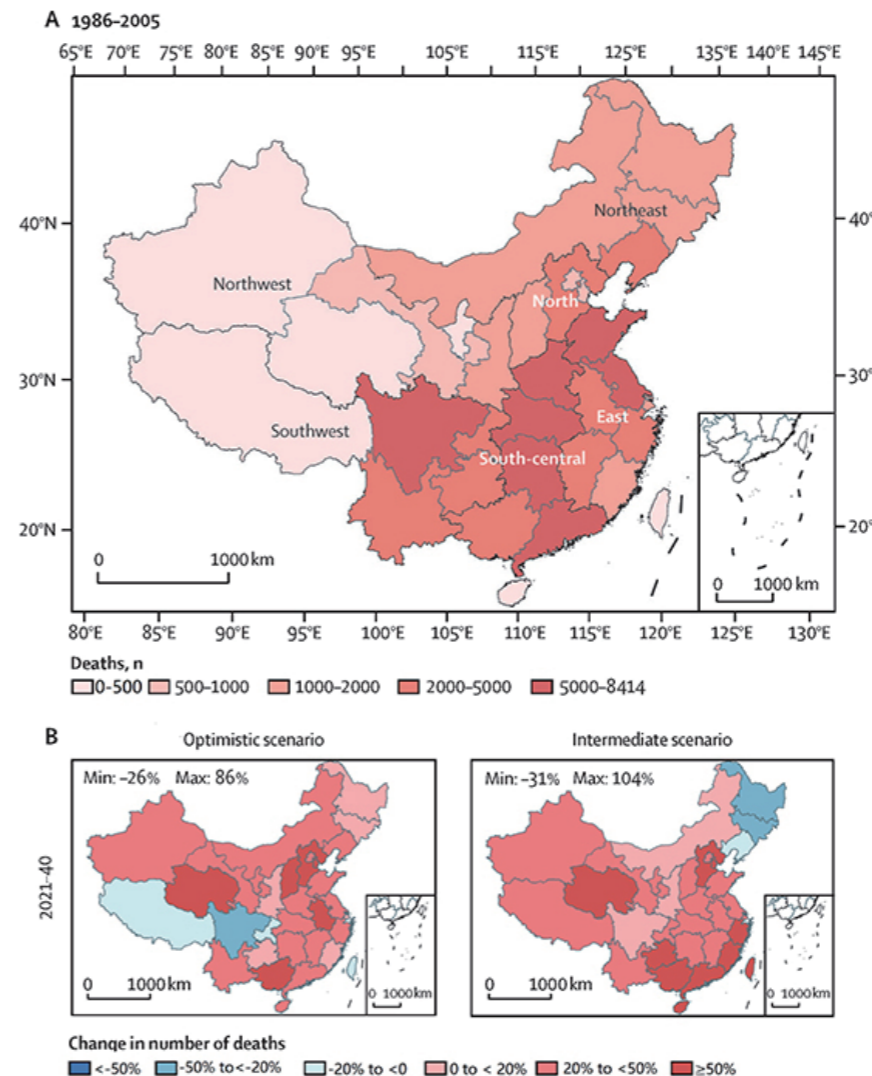
"Looking towards the future, the frequency of wildfires in China will probably increase as a consequence of climate change," explains Bai. Capping

the global temperature rise to within 2°C will significantly reduce the health burden caused by wildfires.

However, continuous implementation of rigorous policies to prevent and address wildfire smoke is also imperative, says Bai. The focus must shift from fire suppression to holistic fire management, he says. This approach involves fuel-reduction treatments to lessen wildfire size and intensity, along with reinforcing policies against risky practices, such as crop burning. Special attention, he adds, is needed in vulnerable regions like south-central China, east China, and the North China Plain, where the highest increases in fire-related mortality are anticipated (see map).

It will also mean updating and extending national plans, such as China's National Forest Fire Prevention Plan and the National Grassland Fire Prevention Plan, says Bai.

"The nation's substantial population renders it particularly vulnerable to wildfires, leading to the currently high annual deaths attributed to fire-related PM<sub>2.5</sub>," says Bai. "A comprehensive strategy combining global climate action, targeted local policies, systematic planning, and a shift towards holistic fire management is vital to mitigate the risks."



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Map A shows the projected all-cause deaths due to landscape fire-related PM<sub>2.5</sub> at a provincial level in China (1986–2005). Map B shows the projected changes in deaths (2021–2040) due to the same factors.

# Take a page from nature, and fold it to create exciting new technologies

A technique for designing two-dimensional films that can fold into three-dimensional microspheres could be used in new tech, such as artificial retinas.

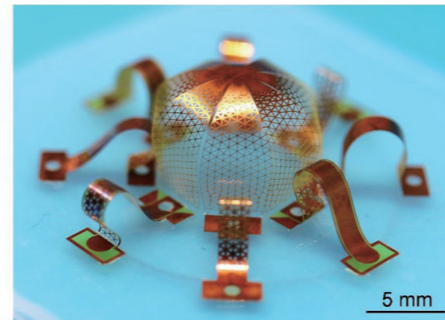
The art of folding two-dimensional paper into beautiful three-dimensional shapes is more than a thousand years old. And while its exact place of origin in eastern Asia is unclear, today it's most readily associated with the Japanese word origami. One modern challenge is how to make these kinds of folds at the microscale, which would enable the construction of tiny devices for use in biomedical technology, batteries, and catalysis.

Yihui Zhang from Tsinghua University and his colleagues have developed innovative new microlattice design models for transforming two-dimensional thin films into three-dimensional curved surfaces.

Their findings were recently published in the prestigious journal *Science*.<sup>1</sup> In the equally impactful journal *Nature*, which reported on the study, a writer points



Tsinghua researchers used microlattice designs to create a 2D template that could be folded into this millimeter-scale octopus.



out that the bioinspired microlattice strategy "could be harnessed to build structures out of materials ranging from silicon to polymers to graphene".<sup>2</sup>

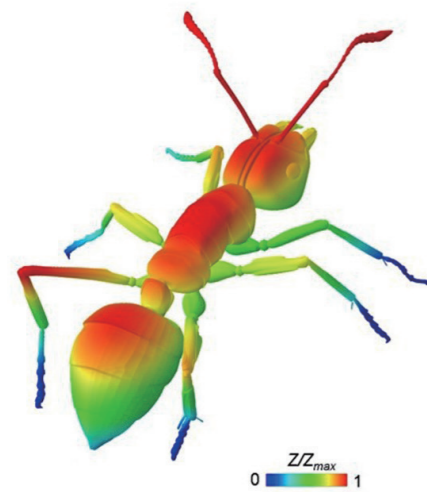
Some types of silicon have been particularly difficult to shape due to their brittleness, Zhang points out. His

work will be particularly useful when applied to these difficult materials.

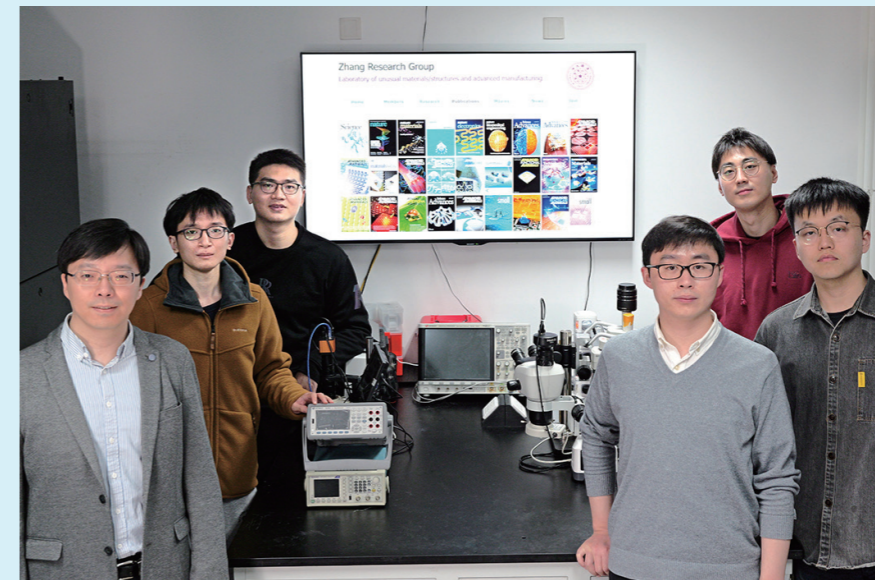
In 2016, Zhang was recognized by the *MIT Technology Review* as one of the world's leading innovators under the age of 35 for his work on mechanically-guided assembly of 3D nanoscale structures.

## Inspirations from natural geometry

It's sometimes difficult to flatten a curved surface into a plane without stretching or tearing parts, says Zhang. A globe of the world, for example, cannot be transformed into a two-dimensional map without serious distortions of its shape and the relative sizes of many countries. In the case of materials, such nonuniform stretching would cause changes in the atomic structure, altering the substance's mechanical and electronic properties. These are called 'undevelopable' curved surfaces.



A Tsinghua team designed this ant, which is formed from more than 4,000 microtriangles and almost 8,000 microribbons.



Yihui Zhang (at left) and his team from Tsinghua University's Applied Mechanics Laboratory and Laboratory of Flexible Electronics Technology.

A solution is to divide the curved shape into a lattice of flat discrete elements, a concept known as 'discretization'. This idea can be seen in geometric glass domes made from lattices of triangular panes. But as the three-dimensional shape becomes more complicated, the two-dimensional discretized lattice must also become more elaborate.

So, the problem then becomes how to design a two-dimensional lattice for complex curved, three-dimensional microstructures. By taking inspiration from microlattices found in nature, Zhang and his co-workers used analytical and computational modeling methods to design both artificial and natural 3D shapes or 'mesosurfaces' starting from a flat surface.

"Learning from nature is important for materials science, because nature has evolved over millions of years to create materials that are optimized for their specific functions," explains Zhang. The natural world is full of examples of microlattices with complex 3D layouts, he says. To give just one example, lattices made up of vascular networks in cabbage leaves locally shrink and thicken at low temperatures to form a cabbage's multilayer spherical shape.

## Shaping new devices

The team applied their microlattice design strategy to a wide range of materials, including metals, laser-induced graphene, chitosan (a material found in the exoskeletons of insects and crustaceans) and even a brittle form of monocrystalline silicon, which had previously thought to be impossible to shape owing to its fragility.

They were able to create more than thirty different structures with different shapes with lateral lengths ranging from ~ 0.25 to 30 millimeters.

"The octopus-shaped and the ant-shaped microspheres are my favorite 3D structures from this work," Zhang says. "They truly look like the real objects, while their complex shapes demonstrate the powerful capabilities of our microlattice-based shape programming methods."

The next possible step in this research is to combine biocompatible materials (e.g. the chitosan) with a high density of sensing electrodes. The ultimate goal, says Zhang, is to develop biomimetic robotics and biocompatible devices, such as implantable artificial retinas "that are capable of providing

high-resolution imaging by detecting and processing signals from living retinal cells".

Zhang's study was done with colleagues from Tsinghua University's Applied Mechanics Laboratory and Laboratory of Flexible Electronics Technology, along with researchers from Hunan University and the University of Science and Technology Beijing, in China, and Northwestern University in the United States.

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# How do we get stuck in dead ends on online information platforms?

New research shows how people get trapped in cocoons of troublingly similar online content – and how a thumbs-down can help break the cycle.



Through large-scale empirical research and information dynamics modelling from the perspective of statistical physics, a Tsinghua team has provided some key insights into how human-AI interactions can lead to the emergence of information cocoons in online media.

New recommendation algorithms mean information platforms are becoming more and more tailored to users. However, the precision of content recommendations has given rise to the phenomenon of ‘information cocoons’, where users are isolated from diverse information and eventually become trapped in a single topic or viewpoint.

“Information cocoons not only deprive humans of the diversity of information available for informed decision-making and innovation, but also exacerbate social polarization and reinforce biases,” says Yong Li, an information science and technology researcher at Tsinghua University, who led the new study, which was published in *Nature Machine Intelligence*.

Even worse, most online users have no idea when they get trapped in such a cocoon and are therefore being exposed to only a fraction of available information, he says.

## Deep information cocoons

Helping people to realise they are stuck in information cocoons, and offering ways to help them escape, requires a deeper understanding of how these states form in the first place. The new study addresses that question: investigating information cocoons in the real world using two large datasets involving more than 500 million records – one drawn from video content and the other from Microsoft News.

The analysis suggests the information cocoon state is different from what people call an ‘echo chamber’ – a situation where like-minded peers gather on social media. In contrast, information cocoons form because of a multi-layered feedback loop between people and AI-driven recommendation algorithms.



Professor Yong Li is an information science and technology researcher at Tsinghua University.

Based on the way information cocoons seem to form in the real world, the study worked out a mechanistic model that can recreate the steps involved. This model can predict critical transitions between three states: diversification, partial information cocoons, and deep information cocoons.

## The mechanisms behind information cocoons

Two mechanisms drive the system away from diversification and towards an information cocoon. The first is similarity-based matching, which is the way that an algorithm tracks what people see and offers them more of the same. Algorithms that use positive feedback amplify this effect and reinforce the cocoons that restrict information diversity.

So, how can someone tell if they have become trapped in an information cocoon? The most observable phenomenon is the increasing homogeneity of the information accessible to them, Li explains.

“For example, initially, users have access to a diverse range of topics such as celebrities, sports,

animals, and more. However, as the interactions between users and the recommendation algorithm increase, their access is gradually limited to only a few of these topics.”

To escape from a cocoon, online users must reverse the steps, by giving the algorithm negative feedback on its choices – such as a thumbs down on content that a user would typically thumbs up – and by randomly exploring other options. Even then, individuals can struggle to break out on their own, says Li. “Government-level regulations are urgently required,” he says.

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