



# 2023 Award Winners

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## **Modeling temporal variation of driver supply in an electrified ride sourcing market considering drivers' charging and resting behavior**

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Electric vehicles (EVs) are now being introduced to the ride-sourcing market (e.g. Didi, Uber, etc.) to promote sustainable transportation. Given their demand for charging, ride-sourcing EV drivers may have distinct work schedules from gasoline vehicle (GV) drivers, yielding significant impacts on the market supply when their penetration becomes high. Driving fatigue is another factor affecting ride-sourcing drivers' working hours and work schedules, but has received little attention. In this research, we develop an analytical model to capture how the driver supply in an electrified ride-sourcing market varies over a day considering drivers' resting and charging behavior. In our model, drivers earn and manage to maximize their payoff by choosing a schedule (i.e., deciding when to work, rest and recharge). Each driver's payoff is calculated by quantifying the losses and gains associated with different decisions (i.e., work, rest or recharge) at each time period and reflecting context-dependent factors (e.g., time-varying passenger demand and traffic conditions), driver characteristics (e.g., GV/EV and full/part-time) and driver interactions (e.g., their competition for passengers and limited chargers). Due to the interaction, every driver's payoff is affected by not only their own but also peer drivers' schedule choices. The system outcome (i.e., all drivers' schedule choices) is stable when every driver achieves their maximum payoff given other drivers' schedule choices. Such an outcome (or equilibrium) can be efficiently obtained using a novel algorithm we designed. Numerical examples reveal that the temporal equilibrium of the electrified ride sourcing market is moderated by the charging capacity, EV penetration as well as the competition among drivers. Moreover, our model can evaluate not only driver supply but also platform revenue and passengers' expected waiting time. More importantly, it can be applied to conduct various of prescriptive analyses such as assessing the policy effect of changing the charging facility deployment plan and/or varying the EV penetration.

## How the brain processes auditory and visual temporal structures of the world

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Our brain automatically cuts sequential information into pieces and then groups these pieces into new patterns. For example, during music listening, musical beats are grouped into meters and phrases, and during visual perception, individual movements can be grouped into superordinate patterns such as walking and dancing. The brain's ability to integrate smaller sensory events into larger structures is termed chunking, which is a fundamental function of the brain that can effectively reduce the cost for sequence processing and memorization. The chunking process occurs in multiple sensory modalities, such as auditory and visual domains. Is there a domain-general center in the brain for sequence chunking or is the chunking function separately implemented for each sensory modality? Here, we recorded brain waves using magnetoencephalography (MEG) when human participants broke up auditory and visual sequences into chunks based on a simple rule. We demonstrate that brain activity can track the rhythms of both individual sensory events and chunks. Critically, chunk-tracking of auditory and visual information are over the left and right sides of the brain, respectively. Additionally, magnetic resonance imaging (MRI) reveals that the strength of neural fibers in the left and right hemispheres, which connects frontal and temporal cortices, are also separately associated with auditory and visual chunking. These results suggest a temporal frontal network for chunking and that the left- and right-lateralized networks are specialized for auditory and visual chunking, respectively. We provide mechanistic insight into multi-modal sequence encoding, revealing how the human brain constructs the sequence structures of auditory and visual percepts.

## Identification of Aneuploidy Sensing Genes in Cells

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One of the biggest mysteries in biology is: how does cancer arise? Molecular biologists define cancer as the uncontrollable division of abnormal cells, and the majority of abnormal cells are aneuploid. Diving into the microscopic cell world, we see thread-like structures called chromosomes primarily made of DNA. Zooming in, we find 20000 genes spread out on DNA, each carrying specific instructions to regulate cell behavior. A normally dividing cell should precisely copy its own chromosomes and evenly distribute them to make two genetically identical daughter cells. However, mistakes occur on rare occasions to generate abnormal aneuploid cells, that is, cells with extra or missing chromosomes. Aneuploid cells are unhealthy and should be destroyed. Luckily, cells have a series of internal sensing machinery to detect aneuploidy, which then triggers their own programmed suicide. If the sensing ability is lost, aneuploid cells will continue to divide and eventually become cancer. In fact, aneuploidy is a hallmark of cancer, but the genetic background of its sensing machinery is poorly understood. My research studies how cells detect aneuploidy. Specifically, I aim to identify the genes involved in sensing from 20000 genes in the cell. We used a powerful gene editing tool called Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR) for this purpose. CRISPR has two key components: a molecular GPS which locates the exact position of each gene on DNA; and a molecular scissor which cuts and deletes this particular gene. We created 20000 sets of cells simultaneously, each of which has a unique gene deleted by CRISPR. Our rationale was: deleting a sensing gene in aneuploid cells allows them to divide fast, whereas deleting an irrelevant gene triggers cell suicide. By monitoring differential cell growth, we identified 3 genes, named UVRAG, TRPC4AP, and ATPAF1, as potential aneuploidy sensors. Next, we plan to examine these sensors individually to find out their exact regulatory mechanisms. Overall, this research reveals several therapeutic targets for cancer. It will lead to a better understanding of the molecular link between aneuploidy and cancer onset.

**Localized and degenerate controls for the incompressible Navier–Stokes system**

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This research concerns the mathematical question of controllability for incompressible Newtonian fluids driven by a localized and degenerate force. Fluids of this type (e.g., water) are mathematically modeled by the Navier–Stokes equations (NSE), which comprise physical laws representing the balance of momentum and the conservation of mass. The NSE are not only useful for numerous applications such as weather forecasting, power generation, airfoil design, visual effect production, and biomedical engineering, but they also constitute an attractive object of study from an abstract mathematical point of view. Some of the most prestigious mathematics prizes, including the Fields Medal and the Abel Prize, have been awarded to mathematicians who worked intensively on theoretical aspects of the NSE. Motivated by real-world problems that involve the regulation of fluids (e.g., drag reduction), the controllability of the NSE has been actively investigated in recent decades. Our present objective is the explicit description of a localized oscillating force (the control) which guides a fluid toward an imposed target profile. With the help of novel geometric arguments, meanwhile introducing the notion of "transported Fourier modes", suitable building blocks for the control are characterized. We subsequently employ these basic blocks in order to act on the local circulations (vortices) of the fluid. Our results partially solve a challenging problem posed by A. A. Agrachev, who is a highly respected mathematician known for his achievements in various areas, including control theory, differential geometry, and nonlinear analysis. In addition, we provide a new approach for the mathematical investigation of controllability problems in fluid mechanics.

**Total internal reflection of a vortex ring at a water-air interface**

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Vortex ring is a structure in fluids that we can frequently see in nature, such as bubble rings made by dolphins, smoke rings blown by skilled smokers or even volcanoes. It is actually a structure of fundamental importance in fluids that can also be observed in other physical fields, including plasmas and electromagnetics. The interactions of a vortex ring with a solid boundary, as well as with other vortex rings have been widely studied. The intriguing phenomenon of a vortex ring interacting with a water-air interface, however, has not drawn enough attention. We have conducted experimental investigations on this problem and observed a phenomenon similar to the total internal reflection of light at the water-air interface. Using flow visualization and a high-speed camera, we were able to capture the motion of a vortex ring reflecting at the interface. Then it was analyzed by an object tracking algorithm to generate data such as the gesture and velocity of the vortex ring. Based on these data, we have built a fluid dynamical model that can explain this phenomenon properly. Links between this phenomenon with similar electromagnetic phenomena are still to be studied which might provide more insights into the links between these two fields.

## **My child and I: Self- and child-reference effects among parents with self-worth contingent on children's performance**

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How individuals feel about themselves is often linked to their success in specific domains of their lives. For parents, their children often represent a central domain of their lives. Research shows that parents vary in their tendency to base their self-worth on their children's performance. Such a tendency, also known as parents' child-based worth, has implications for parents' interactions with children. But little is known regarding the cognitive representations associated with parents' child-based worth. This study examined whether such child-based worth is manifested in parents' recognition memory. Participants were 527 parents of school age children in China who reported on their child-based worth in a survey and completed a recognition memory task which started with an encoding phase, followed by a 15-min short break, and ended with a recognition phase. In the encoding phase, parents viewed three lists, each with 28 evaluative trait adjectives, and were asked to indicate whether each adjective described themselves (self reference condition), described their child (child-reference condition), or was positive or negative (semantic processing condition). In the unannounced recognition phase, parents viewed 168 adjectives and were asked to indicate whether they had seen each adjective in the encoding phase. We found that the more parents based their self-worth on their children's performance, the more they exhibited a memory advantage for evaluative trait adjectives encoded with reference to the child compared to those encoded semantically. But parents with high child-based worth did not show the classic self-reference effect (i.e., better recognition memory for adjectives encoded with reference to the self than those encoded semantically). This study provides the first evidence that evaluative information about children may be an elaborate structure in memory among parents with heightened child-based worth. Cognitive representations may explain why parents with heightened child-based worth tend to use negative parenting practices such as control. Our findings have important implications for the design of interventions targeting parents' child-based worth.



## **Does self-containment of urban function and urban scale promote sustainable development in new towns? Lessons from the urban heat island dynamics in Shanghai**

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The blueprint of Garden City has spurred the ambitious new town (NT) movement in the municipalities. The urban scale (US) expansion of NTs to build self-containment communities is considered as sustainable development (SD) of NT. However, record climate extremes and the heavy ecological footprint caused by NT construction bring heightened risks to urban well-being, thus, proposing climate adaptation strategies has emerged as the foremost challenge for SD in the coming decades. In response, this study used urban heat islands (UHIs), which show the closest connection between urbanization and climate change, as indicators to examine the SD, for Shanghai's five NTs from 2005 to 2020. Our study revolved around the issue that how urban function (UF) and US influence UHI. We interpreted the spatial pattern of UHI using a Hotspot analysis. UF indicators include single and composite function intensity, and functional diversity (FD); the US was measured by population density (PD), gross domestic product (GDP), and nighttime light (NL) by Shannon index and Density analysis. Finally, we used the Optimal Parameter Geodetector to quantitatively analyze the influence of the above factors on the UHI. Findings indicate that the NT movement decreased the UHI intensity (UHII) during the day by 0.153-1.33, however, taking the cost of UHI footprint expansion; the UHII at night increased by 0.423-1.193. Low FD is an important constraint to the SD of NTs, when it ranges from 2.52-3.00 contributes to a pleasant thermal environment. Large community projects aim at population suburbanization, however, the UHI was aggravated by its total increment. Industrial suburbanization and mixed-use (horizontal and vertical) with other functions contribute to the SD. Optimizing the NT's blue-greenspace by creating an urban-rural park system that connects the suburbs and the center is recommended. The growth of the GDP is favorable for SD, but the PD and NL display an inverted U-shaped curve. Furthermore, the UF of all towns, except for an eco-town, had a higher influence on UHI than the US. This study enriches the connotation of self-containment from UF and US perspectives in the SD of contemporary Asian NTs and provides practical experience and theoretical guidance for urban planners and policymakers.



## **How does support from others protects us from depression? A network perspective.**

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Higher instrumental or emotional support from one's social network, as known as social support, is known to protect people from developing mental disorders such as depression. However, limited evidence is available on the mechanism through which social support plays this protective role. The current study investigated the stress-buffering process of social support on depressive symptoms using a novel longitudinal dynamic symptom network approach, incorporating loneliness and gender as potential mediating and moderating mechanisms, respectively. A total of 4,242 adult participants who completed the first two waves (from May to Oct 2020) of the international Covid Mental Health Survey from 13 countries were included in the study. We applied cross-lagged panel network (CLPN) modeling to estimate a longitudinal network of self-reported social support, loneliness, and nine depressive symptoms. The network showed good stability and replicability when tested by resampling-based methods. The resulting network supported a unidirectional protective effect of social support on key depressive symptoms, partly mediated through loneliness: A higher number of close confidants and accessible practical help would lead to lower anhedonia and negative self appraisal symptoms. Support from others was also negatively associated with loneliness level, which in turn led to lower depressed mood and negative self appraisal. Indicted by its high bridge centrality index, improved negative self appraisal could be the key bridge symptom and amplifier of the protective effect of social support. This identified mechanism supports the self-esteem theory of social support. By comparing the networks generated from male and females subjects, we found that while more direct effects from social support with higher weight on depression were identified among males, the effect in females was less weighted, and more dependent on mediation of decreased loneliness. This finding suggests that males tend to benefit more from social support than females and partly explains the gender difference in depression risks. Our study reinvestigated the psychosocial correlates of depression among a large international sample at the early phase of the COVID-19 pandemic. It contributes novel evidence about the mechanism through which social-cultural factors affects people's mental health and well-being, from a novel longitudinal network perspective.

## **Wedging during crisis: great power and multilateral institution competition during the Sri Lankan crisis**

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Analysis of geopolitical competition tends to focus on relations between the great power countries. However, recent scholarship has highlighted the relationship between and impact of, so called, tertiary actors whether those are third party states or multilateral institutions. In April 2022, Sri Lanka preemptively defaulted on all loan repayments. It had a total of USD 51 billion in foreign debt to be paid, of which USD 4 billion needed to be paid in 2022. It needed the assistance of the international community to restructure its loans, obtain an economic bailout and material assistance for essential items. In this context, we pose three questions: how did great powers respond to Sri Lanka's crisis?; What was Sri Lanka's response to the actions taken by these countries? How is Sri Lanka leveraging these opportunities? Qualitative in nature, this study uses economic data from the governments of Sri Lanka, India, China, Japan and the US alongside data from the four multilateral institutions that are being examined. Further, secondary sources like journal articles, scholarly publications, newspaper reports too are being used in this research. In this study, we argue that a domestic crisis prompts great power competition particularly in the context of seeking to drive a wedge in existing relations. When the Sri Lankan crisis began, several great powers (India, China, Japan and the US) and relevant multilateral banking institutions (Asian Infrastructure Investment Bank (AIIB), Asian Development Bank (ADB), World Bank (IBRD), and the International Monetary Fund (IMF) took a wide array of actions. We find that the crisis revealed limited Chinese engagement in the Sri Lankan crisis despite close relations via the Belt and Road Initiative (BRI) etc. Moreover, India, Japan and the United States that had difficulties engaging with Sri Lanka prior to the crisis, leveraged the crisis to make inroads into Sri Lanka by increasing their economic assistance. Examining the relationship between great powers and their impact on a tertiary state like Sri Lanka during a crisis sheds light on whether great powers use economic turmoil for their benefit and if so, how they do engage in it. It also illuminates the role of tertiary actors in the international system.