revealing that theta changes linked to boundaries seem to be independent of such variables, and also of eye-movement measures.

Nonetheless, it is possible that some unspecified variables linked to walking might drive the results. Stangl *et al.* addressed this concern in their next experiment. The authors took neural recordings from people watching someone else perform the same task. This key experiment revealed that MTL theta oscillations also increase when someone views another person navigating close to a wall. So, whether you are approaching a cliff edge or watching your friend do so, you are likely to have enhanced theta oscillations in your MTL. Because this response is shared between watching and walking, it seems more likely that the theta oscillations are related to an internal representation of space than to purely visual inputs or self-motion.

The discovery that human MTL structures encode information about other people parallels evidence for rat and bat neurons that encode the location of another animal[8,9]. More broadly, the discovery chimes with the idea of 'mirror-like' codes for observing and acting in the world[10].

A key question is why theta oscillations increase near boundaries. Stangl *et al.* suggest that the change might originate from the greater demands for integrating information across brain networks when navigating. But it is unclear why network-integration demands would be higher near boundaries. Perhaps, when a person is close to a wall they are able to infer their location more precisely, and this increased precision leads to stronger theta oscillations. More research will be required to investigate this possibility and explore why researchers have not reported such results in rodents. Possible explanations are the experimental set-ups used to examine animals or the dominating influence of self-motion on theta in rodents[2].

A broader question raised by Stangl and colleagues' work is: how does the brain track the positions of other people in a space? Current models focus on how self-location is constructed[2], but how visual inputs are used to map the position of other agents is an exciting area for future exploration. Stangl *et al.* had participants sit still while watching the other person navigate. But the dictates of everyday life mean we are often watching and walking at the same time. How might the locations of multiple agents be integrated with that of our own? It seems plausible that the brain constructs multiple distinct maps for locating ourselves, friends and foes in physical space, and links these with more-abstract maps of social networks and knowledge hierarchies[11].

Several species, such as orcas, wolves and chimpanzees, are adapted for group hunting[12]. How their brains coordinate for this behaviour is unknown, but it now seems that the MTL theta rhythm might be involved. Thanks to Stangl and colleagues, who have climbed over a technical cliff-edge, we can now see new horizons where exciting discoveries await.

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Global health

Gaps in measles-vaccine coverage mapped

C. Edson Utazi & Andrew J. Tatem

Precise maps of routine first-dose measles vaccinations show slowing progress around the world between 2010 and 2019, and large gaps in coverage in many places. Many countries are unlikely to achieve global 2020 coverage targets. **See p.415**

Improved access to childhood vaccines has been one of the biggest breakthroughs in public health in recent decades, as evidenced by the eradication of smallpox in 1980 and this year's declaration of Africa as polio-free[1]. But for measles, the road towards elimination and eradication has been bumpy, despite the existence of a safe and cost-effective vaccine. Measles cases and deaths persist, particularly in low- and middle-income countries (LMICs; see go.nature.com/37ralbw), where many factors — from conflict to vaccine hesitancy and underfunding — continue to pose challenges to immunization. On page 415, a group called the Local Burden of Disease Vaccine Coverage Collaborators[2] provides evidence that targets for measles vaccination are in jeopardy, owing to major inequities in coverage, together with the slowdown, stagnation and regression of the coverage of routine first-dose measles vaccines between 2010 and 2019.

"The maps uncover remarkable inequities in vaccine coverage, both within and between countries."

The authors used a mapping approach that facilitates the estimation of population-health metrics in precise geographical areas — typically communities living in areas of 5 square kilometres. This approach to public health gained prominence following the launch of the United Nations Sustainable Development Goals in 2015, which call for improvements to a range of factors from health to education, leaving "no one behind". Precise mapping means that, instead of designating large areas for health interventions, policymakers have a basis for targeting resources better to improve equity and impact. High-resolution maps that estimate various health and demographic indicators (such as population density, vaccination coverage, educational attainment and child mortality) are becoming increasingly available at a range of geographical and temporal scales, from country-level to continental and global maps, and from specific years to annual estimates spanning multiple years[3–5].

This renaissance in mapping of health and demographic indicators is mostly being driven by an unprecedented increase in data availability and computing power over the past decade. Satellite images of Earth's surface conditions, along with gridded data on a wide range of socio-economic factors, are enhancing our understanding of living conditions in even the remotest places in the world. In turn, these data are helping researchers predict the coverage of essential health services.

The study authors made use of 354 household surveys that measure measles-vaccination coverage and other health indicators, some of which included precise information on the locations of the respondents. The surveys, conducted in 101 LMICs between 2000 and 2019, represented about 1.7 million children. The authors combined data from these surveys with existing information on other variables that can help to predict vaccination coverage, such as local environmental, socio-economic and health-related factors. The group then used a complex and computationally efficient statistical modelling approach to predict and map measles-vaccine coverage and associated uncertainties across the 101 countries. The model generates predictions by leveraging potential relationships between measles coverage and the predictors, along with other dependencies in the data in space and time.

The resulting maps are publicly available (see go.nature.com/36phfks). These maps reveal substantial improvements in measles-vaccine coverage globally from 2000 to 2010, but they also show that slower progress was made between 2010 and 2019.

In addition, the maps uncover remarkable inequities in vaccine coverage, both within and between countries, throughout the study period. This was particularly true in Africa and Asia. A higher percentage of the children living in rural areas were unvaccinated compared with those in urban areas, but the total number of unvaccinated children was higher in urban locations. The authors showed that, in 2019, coverage was most inequitable in Angola, Ethiopia, Madagascar, Nigeria and Pakistan.

Importantly, only 15 out of the 101 LMICs had a high probability of reaching targets set by the Global Vaccine Action Plan – a framework from the World Health Organization to improve vaccine access. The action plan aims for 80% coverage in all districts as of 2020 (Fig. 1). For measles, this target is lower than what is needed to achieve herd immunity – typically, 95% or more of children receiving two vaccine doses. These findings therefore raise concerns for measles control and elimination goals.

The collaborators' global, fine-grained estimation of measles-vaccine coverage builds on previous work by the same researchers[4] to map the coverage of diphtheria-pertussis-tetanus vaccines in Africa. The work is timely and crucial, particularly in the face of disruptions to vaccination services resulting from the ongoing COVID-19 pandemic and the subsequent need for data to inform and guide vaccination efforts globally. Areas that had poor vaccine coverage before the pandemic are likely to be worse off after it; hence, the current maps can be used to guide vaccination-programme planning in the coming years. The work also complements country-specific efforts to map measles coverage, such as our own work in Nigeria[5], which are often tailored to the specific needs of vaccination programmes.

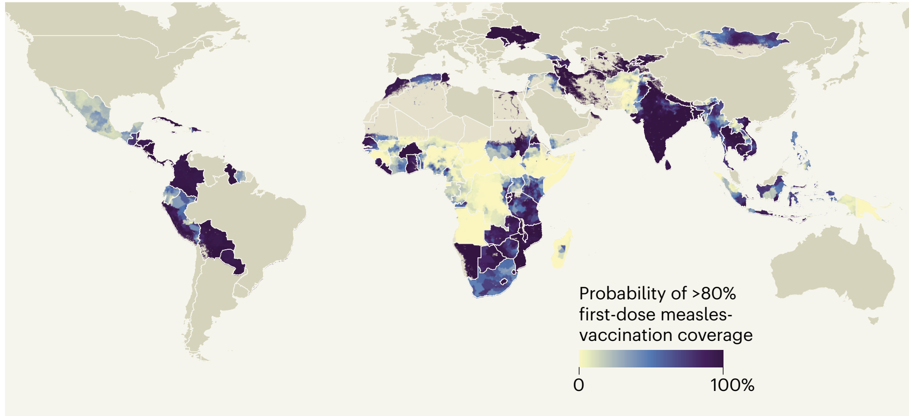

Figure 1 | Measles-vaccination target under pressure. The Local Burden of Disease Vaccine Coverage Collaborators[2] mapped measles coverage at high resolution (in 5-km^2 areas) across 101 low- and middle-income countries. This map shows the probability that each area in these countries had given 80% of its children a first dose of measles vaccine by the end of 2019 – a target set by the World Health Organization's Global Vaccine Action Plan. The regions shown in light brown were not included in the maps. (Adapted from ref. 2.) (Nature publications remain neutral with regard to contested jurisdictional claims in published maps.)

It is worth noting that the coverage estimates produced by the authors are 'best guesses' that depend on the data quality and modelling techniques used, and that the data often have wide uncertainty ranges. Their work aims to estimate the coverage of routine, first-dose measles vaccines, but it relies heavily on data from surveys, many of which do not distinguish between measles-vaccine doses received through routine immunization compared with supplementary immunization activities (SIAs) – an additional strategy used in many LMICs to fill immunity gaps in the population. The misclassification of SIA doses, especially for children who did not have card evidence of vaccination (card retention is often low in many LMICs), is likely to have resulted in overestimation of routine coverage in many places.

In addition, surveys might not be representative of key at-risk populations, such as people living in regions of conflict or in remote, rural or urban slum areas, simply because samples were not taken from these populations. Also, the estimates produced might be biased in areas where input data were scarce or unavailable at the required geographical precision. This highlights the need for more data in these areas and in other areas where, for some other reason, estimates were highly uncertain. Further validation using independent data sources should help to improve users' trust and confidence in the maps. Nonetheless, the trends and spatial inequalities found remain clear.

The Immunization Agenda 2030 is a global strategy for immunization set out by the World Health Organization this year (see go.nature.com/3luqcr7), which recognizes the need to make immunization coverage more equitable within countries, serving to renew the drive towards achieving a world without measles. We advocate greater commitments from governments, donors and other stakeholders, and call for vaccination programmes to use the valuable resource of the current paper and the modelling approaches it outlines to support the agenda. Opportunities exist for capacity strengthening within countries: map production and ownership can be shifted to governments, their vaccination programmes and local academic institutions, and these efforts should be a priority over the coming years.

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