NEWS & VIEWS

SOCIAL NEUROSCIENCE

Stress and the city

Many of us were raised or currently live in an urban environment. A neuroimaging study now reveals how this affects brain function when an individual is faced with a stressful situation. SEE LETTER P.498

DANIEL P. KENNEDY & RALPH ADOLPHS

The landscape of human society is changing drastically. In 1950, only 30% of the world's population lived in urban regions; today, more than 50% of us do so; by 2050, this figure is expected[1] to have climbed to almost 70% (Fig. 1). And, just as social isolation is well known to have harmful effects[2], so does the opposite extreme: overcrowding can induce stress and illness in species ranging from insects to rodents[3] to primates, including humans[4]. In particular, mental illness in humans has been linked to the urban environment: living in a city increases the risk of depression and anxiety, and the rate of schizophrenia is markedly higher in people born and brought up in cities[5]. Writing on page 498 of this issue, Lederbogen *et al.*[6] use functional magnetic resonance imaging to investigate for the first time the specific human brain structures that are affected by urban living.

The study's participants lived or had lived in locations ranging from rural areas to large cities (Fig. 2). The authors measured regional brain activation while participants performed a social-stress test — solving hard arithmetic problems under time pressure and with negative feedback from the experimenter. This task not only increased the participants' heart rate, blood pressure and salivary levels of the stress-associated hormone cortisol, but also resulted in significant activity in brain structures known to be involved in emotion and stress.

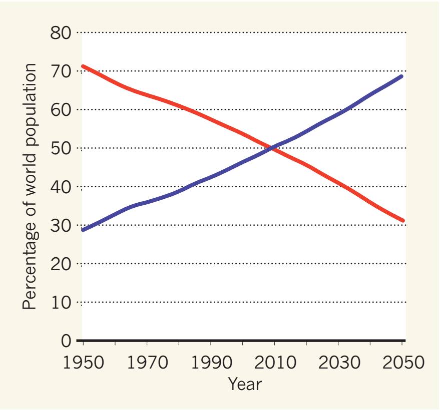

Figure 1 | The city allure. The percentage of the global population living in urban (blue) and rural (red) regions since 1950, with projected[1] figures up to 2050.

Of the activated brain regions, two were of particular interest: activation in the amygdala correlated with the size of the city in which an individual currently resided, and activation of the perigenual anterior cingulate cortex (pACC) correlated with how long a participant had lived in a large city during their childhood. Urban upbringing also affected the strength of the functional coupling between the amygdala and the pACC: those who had spent more time growing up in large cities had reduced functional connectivity between these two regions.

Intriguingly, a similar pattern of reduced amygdala–pACC coupling has previously been associated[7] with genetic risk for psychiatric disorders, and the amygdala has recently been linked both to social-network size[8] and to the sense of personal-space violation[9]. Taken together, the findings suggest that the cingulate–amygdala circuit is one on which genetic and environmental risks for mental illness may converge.

The sheer number and complexity of the factors involved in studies of real-world society raise concerns about both the reliability of effects and the possibility of confounding explanations. To address the first of these concerns, Lederbogen *et al.*[6] replicated their findings in several separate samples, used two different stress-inducing tasks, and demonstrated that there were no effects of urbanicity on brain activation when participants performed a non-stressful cognitive task.

The second concern — that urbanicity may be confounded by other variables associated with but causally separable from it — is difficult to address, given the enormous

PHOTOLIBRARY.COM; a, R. TOMLINSON; b, S. GRANDADAM; c, EYE UBIQUITOUS

Figure 2 | Regional categories. In their study[6], Lederbogen *et al.* categorized living conditions as those asssociated with rural areas (**a**), towns with more than 10,000 inhabitants (**b**) and cities with more than 100,000 inhabitants (**c**). Their data suggest that city living affects the brain's response to stress.

number of such variables. To probe some of the possibilities, the authors examined participants' age, education, income, marital and family status, as well as aspects of their health, mood, personality and the amount of social support they had. None of these factors significantly influenced the effects of urbanicity, suggesting that living in a city environment changes brain response during a social stressor by a distinct, although mysterious, mechanism.

Given that Lederbogen and colleagues' study is purely correlational, an obvious next step will be to conduct larger-scale, longitudinal studies that measure more variables and that attempt to trace a causal factor linking brain activity to more fine-grained and individualized aspects of city living. Such studies could, for example, measure individuals' perceived position in a social hierarchy and frequency of encounter with strangers, as well as population density, amount of space and type of housing.

There are wide variations in individuals' preferences for, and ability to cope with, city life: some thrive in New York City; others would happily swap it for a desert island. Psychologists have found[10] that a substantial factor accounting for this variability is the perceived degree of control that people have over their daily lives. Social threat, lack of control and subordination are all likely candidates for mediating the stressful effects of city life, and probably account for much of the individual differences seen.

But although the negative aspects of city living have been highlighted extensively, city life is by no means always bad. In many countries, for example, studies on the complex relationship between urbanicity and suicide show higher rates of suicide in rural areas than in cities[11]. Although there are a number of possible explanations for this observation, it could relate to cities' provision of a richer, more stimulating and more interactive social environment, a larger social-support network and easier access to medical care.

Future work complementary to Lederbogen and co-workers' study[6] could investigate the positive effects of city living in more detail and begin to make recommendations for urban planning and architecture. Given the world's increasing population (estimated to hit 7 billion this autumn), the fact that we will be living mostly in cities seems inescapable. This highlights the importance of understanding the effects that such living conditions will have on human mental health. ■

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MATERIALS SCIENCE

Graphene moiré mystery solved?

In systems consisting of just a few layers of graphene, the relative orientation of adjacent layers depends on the material's preparation method. Light has now been shed on the relationship between stacking arrangement and electronic properties.

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Moiré patterns appear whenever two regular templates are overlaid at an angle — commonly as artful designs in textiles, and unfortunately also as annoying distractions in digital images. More than 20 years ago, periodic modulations (superlattices) were discovered[1] in scanning tunnelling microscopy (STM) studies of graphite surfaces and correctly interpreted as moiré patterns caused by misorientations between subsurface graphene layers. (Graphene is a two-dimensional, pure carbon material that forms three-dimensional graphite when stacked in layers.)

The graphitic moiré pattern phenomenon has recently reappeared in studies of materials consisting of only a few layers of graphene, especially in systems prepared by the technique of epitaxial growth on a silicon carbide (SiC) substrate[2] or by the process of chemical-vapour-decomposition growth on metallic substrates. But as in the graphite case[3], the relationship between stacking rotations and electronic properties has been difficult to sort out. Writing in *Physical Review Letters*, Luican *et al.*[4] provide insight into this relationship by combining advanced microscopy and spectroscopy techniques.

The problem of identifying the relationship between stacking rotations and electronic properties is particularly intriguing in the few-layer case, both because it should be tractable and because it is known[5] that stacking arrangements can radically alter a material's electronic properties. For few-layer graphene systems, the main sticking point has been that studies[6–8] of epitaxial graphene layers grown on SiC have given the impression that adjacent layers that are misoriented by only a few degrees could, in stark contradiction to theory[9], be very weakly coupled electronically.

By combining high-magnetic-field STM and Landau-level spectroscopy on samples consisting of a few layers of graphene grown by chemical-vapour deposition, Luican and colleagues[4] now convincingly establish that electronic decoupling occurs between layers misoriented by more than about 20° and that strong coupling occurs between layers rotated by less than about 2°. Moreover, the authors point to hints in previous epitaxial graphene data[8] which suggest that the layer pairs identified as weakly coupled may not have been adjacent. If confirmed by additional STM studies, this conjecture would allow for a consistent interpretation of all current data.

The authors' findings[4] provide an attractive jumping-off point for systematic studies of interlayer coupling in misoriented few-layer graphene systems. Many important and subtle mysteries remain, both at large and small rotation angles. For example, what does effective decoupling at rotation angles larger than about 20° mean quantitatively? Complete decoupling at the typical separation between adjacent graphene sheets of only approximately 0.3 nanometres would be truly unexpected.

When two graphene sheets, each with a honeycomb lattice structure, are overlaid at an angle (Fig. 1), the result is almost always not a crystal. A crystal forms only at a discrete set of commensurate rotation angles[9–12]. In graphene, most observable properties depend on electrons close to the Dirac point, the point at which the gap between the material's conduction and valence energy bands vanishes. These electrons have an unusual ultrarelativistic, massless behaviour, which is characterized by a velocity that does not vanish with momentum. And in the presence of a magnetic field they show a characteristic pattern of discrete energy states, known as Landau levels, that is disturbed when layers couple.