There is one caveat, however: clear skies are required to see and measure the pulsating-aurora signals, so Earth's terrestrial weather needs to cooperate. Furthermore, the chorus waves contain components of different frequency that interact with magnetospheric electrons in different ways depending on the energy of the particles. This affects which particles end up travelling down to Earth's atmosphere. These details are directly related to geomagnetic activity and have not yet been fully quantified. There is still a rich body of research to be carried out regarding the mysterious pulsating auroras. ■

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ANIMAL BEHAVIOUR

Brainpower boost for birds in large groups

Whether intelligence is selected for in species that have a complex social life is debated and hard to test. Cognitive performance and associated reproductive success are now linked to group size in wild magpies. SEE LETTER P.364

ANDREW WHITEN

Observations of primates' everyday lives led the psychologist Nicholas Humphrey to make a revolutionary proposal[1] in 1976 to explain primate intelligence. Before then, it had been commonly assumed that these animals' cleverness was an adaptation to their physical niches, reflected in their need for sophisticated skills in realms such as foraging, navigation or avoiding predators. Humphrey suggested instead that the complex social dynamics experienced when such animals live in a group become the main selective force driving the evolution of primate intelligence. On page 364, Ashton *et al.*[2] offer support for Humphrey's social-intelligence hypothesis, in a study of wild Australian magpies (*Cracticus tibicen dorsalis,* also known as *Gymnorhina tibicen dorsalis*).

The causal relationships between social complexity, intelligence and reproductive success proposed by Humphrey inspired a generation of primatologists, who uncovered unexpected sophistication in monkeys' and apes' social knowledge and political manoeuvrings[3–5]. However, these discoveries arguably made it difficult to test Humphrey's hypothesis directly, because intelligence — both in social interactions and in non-social realms, such as foraging or tool use — and social complexity were revealed to be composed of many components[4,5]. Primate social complexity, like intelligence itself, was found to be extraordinarily complex.

In 1995, primatologist Robin Dunbar suggested[6] that focusing on the typical group size of a species as a proxy for social complexity, and on its brain size instead of intelligence, might resolve the dilemma of how to test Humphrey's ideas. Both measurements were available for a range of primates — and, as predicted, a positive relationship was found between these factors. Multiple teams replicated the finding, using a range of related variables — for example, measuring the relative sizes of the neocortex region rather than overall brain size — for primates[7] and other taxa[8]. Yet, as Ashton and colleagues acknowledge, analyses of large databases often provide conflicting results. When many variables differ between species, cross-species comparisons can lack robustness, because compensating for the differences can make a study so unwieldy that it undermines reliable testing of a hypothesis[9].

Ashton and colleagues turned instead to intraspecies comparisons. They studied 56 magpies, which were ringed to enable identification, from 14 different territorial groups that ranged in size from 3 to 12 birds (Fig. 1). Rather than measuring brain size, the authors conducted cognitive-performance tests in which the birds encountered wooden or plastic devices that tested problem-solving skills; successful birds received a mozzarella-cheese treat. Four different devices each tested a specific skill, including spatial memory and the ability to learn new associations between stimuli and rewards.

The authors report that group size is linked to cognitive performance. Birds living in a larger group displayed better performance at the population level on each of the tests than did birds living in smaller groups. At the individual level, exceptions to this trend could be found — some birds from smaller groups outperformed birds from larger groups, and vice versa.

The authors recorded the reproductive success of individuals by counting the average number of hatched clutches of eggs per year, and found that birds that performed well on the tests had greater reproductive success than

BEN ASHTON

Figure 1 | Australian magpies in Guildford, Western Australia. Wild Australian magpies (*Cracticus tibicen dorsalis*, also known as *Gymnorhina tibicen dorsalis*) are territorial and live in groups. Ashton *et al.*[2] analysed the relationship between the birds' group size and cognitive performance to test the long-debated idea[1] that life in complex social groups can select for intelligence. At the population level, larger groups of birds performed better than smaller groups in cognitive-performance tests, and cognitive performance was also linked to reproductive success.

birds that performed poorly. Evidence for a connection between test performance and biological fitness could not have been assessed by the earlier approaches based on interspecies comparisons.

For any given individual, the bird's performance on each of the four skill tests was correlated. A principal-components statistical analysis, which identifies the number of factors accounting for variance in an array of scores, showed that a single unknown factor accounted for 65% of the variance in test scores. The authors refer to this factor as 'general intelligence', analogous to the '*g* factor' used to assess general intelligence in humans. However, it is worth noting that the magpie tests assess learning abilities rather than testing the capacity to invent creative solutions to problems — a talent sometimes considered to be a defining characteristic of animal or human intelligence.

Humphrey proposed that intelligence evolved in response to the pressures of social complexity. Ashton and colleagues, however, did not directly address this evolutionary hypothesis; instead, they investigated the relationship between social-group size and the development of cognition in the birds' early life, a linkage that was observed to emerge by the time the birds were 200 days old. Nevertheless, the link between cognitive prowess and fitness identified by Ashton and colleagues has major implications for connecting the social-intellect hypothesis to an underlying evolutionary mechanism, and it suggests that selection is acting on a relationship between sociality and cognition.

Group size is, of course, a crude index of social complexity, just as brain size is a crude indicator for the complexities of cognition being selected for. Indeed, group size itself cannot be the key causal factor — the immensity of a wildebeest herd, for example, is unlikely to select strongly for intellect. And even three individuals can suffice to create a high level of social complexity, as demonstrated in the humorous account provided by Jerome K. Jerome's 1889 book *Three Men in a Boat*, or documented in an analysis[3] of three adult chimpanzees that repeatedly shifted alliances in a way that allowed each to be supreme for a while in their 'game of thrones'. Ashton and colleagues can only speculate on how magpies' cognitive powers relate to social-group size and number of offspring, and suggest that some kind of political skill, such as the ability to successfully handle or avoid conflicts, might be involved.

Which types of intelligence deserve closer attention in future studies of the social-intelligence hypothesis? Some substantially different ideas exist regarding which form of intelligence might be selected for[4]. One such contrast is between whether social complexity selects for overall intelligence across many different contexts (also known as domain-general intelligence), or for specialized forms of intelligence, such as the social skill of understanding what others might be thinking. This might sound like a tall order for a magpie. But there is evidence[10] for such sophisticated behaviour in the crow family — a western scrub-jay (*Aphelocoma californica*) might make a theft-prevention manoeuvre by relocating hidden food elsewhere if it spots that another bird observed where the food was hidden. Social cognition has numerous other manifestations[11,12]. Yet, what Ashton *et al.*[2] tested was essentially non-social cognition. What now begs to be fleshed out is the nature of both the social and non-social intelligence skills that may have been at work in the phenomena these authors observed. ■

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NEUROSCIENCE

Burst firing sets the stage for depression

Salvos of neuronal activity in the brain's lateral habenula, regulated by astrocyte cells, drive depression-like behaviours in rodents. The finding might help us to understand one antidepressant and to develop more. **SEE ARTICLES P.317 & P.323**

WILLIAM M. HOWE & PAUL J. KENNY

Opposing forces shape our everyday lives — for instance, stimuli can encourage us to move or stop, and events can make us happy or sad. Accordingly, our brains are designed with 'yin–yang' systems that guide our actions and influence our feelings. Neurons in the brain's mesolimbic system promote reward-seeking behaviour and help to process information about actions that result in pleasurable outcomes[1–3]. By contrast, neurons in the lateral habenula (LHb) encode information related to noxious outcomes and suppress reward-seeking[4–6]. Unbalancing these opposing systems might therefore affect our behaviour. Indeed, emerging evidence[7] suggests that LHb hyperactivity contributes to mood disorders such as major depression. Two papers[8,9] in *Nature* now shed light on the mechanisms that underlie LHb hyperactivity, and on how the antidepressant drug ketamine modulates this state.

In the first paper, Yang and colleagues[8] (page 317) assessed the firing activity of LHb neurons in two rat models of depression. Neuronal firing involves depolarization of the electrical potential across the cell membrane (in a resting state, the inside of the cell is negatively charged relative to the extracellular space around it). Hyperpolarization, in which the cell interior becomes more negative than normal, is typically associated with neuronal inhibition.

By studying brain slices *ex vivo*, Yang and co-workers showed that LHb neurons were more likely to fire in a pattern of rapid bursts in the 'depressed' rats than in control animals. They also observed that, when the LHb neurons were hyperpolarized, this increased the likelihood that these cells would fire in bursts rather than steady volleys. The researchers went on to show that they could increase depression-like behaviours in rats using a genetic manipulation to drive hyperpolarization, and so burst firing, in LHb neurons.

Next, the group investigated the signals that regulate this burst firing. In other brain regions[10], burst firing is controlled by *N*-methyl-D-aspartate receptors (NMDARs) — membrane-spanning channel proteins whose activation leads to an influx of positively charged calcium ions into neurons, resulting in depolarization and neuronal firing. Yang