

DISPATCH

Animal behavior: innovation in the City

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Behavioral innovations may help animals cope with new environments, but how such behaviors start is hard to capture. A new study reports the innovation and transmission of a new foraging culture in an urban parrot.

British tits opening milk bottles¹, dolphins foraging from prawn trawlers² or crows making use of vehicles to crack walnuts³ — these are just a few examples of the many behavioral innovations that animals use to profit from human civilization. Innovation — that is a new or modified learned behavior not previously known in a population⁴ — allows animals to exploit new resources and to cope with environmental change⁴. Such new behaviors can spread through a population by social transmission from informed individuals to uninformed individuals via social learning⁵ and potentially lead to adaptive cultures⁶. In recent decades, studies of animal social learning, information spread and arising culture have increased rapidly, spanning a great variety of behavioral domains and species^{7,8}. Nevertheless, the identification of cultures in wild populations remains difficult. This is because behavioral innovations often arise unpredictably, are usually difficult to track across space and time and alternative explanations for local variation in the novel behavior, such as genetic or ecological factors, can be difficult to eliminate^{8,9}. In a new study⁶, Barbara Klump, Lucy Aplin and colleagues report in detail the development of a novel cultural adaptation to an anthropogenic resource by Sulphur-crested cockatoos (*Cacatua galerita*).

Sulphur-crested cockatoos are long-lived and highly social parrots, native to eastern Australia. These curious and intelligent birds increasingly inhabit urban environments and adapt well to city life. Klump and colleagues⁶ document the social spread of a new foraging behavior of these parrots in Sydney, Australia: the opening of household-waste bins (Figure 1). The new study maps the diffusion of this novel behavior across suburbs of Sydney by collecting reports of 'bin-opening' through a large-scale citizen-science survey and combines this with detailed observations of the behavior by specific cockatoos of known identities within specific sites. Researchers used a web-based survey to collect 1396 reports across 478 suburbs in the Sydney and Wollongong regions about whether residents had witnessed

birds opening household bins. By the end of the study, 338 reports from 44 suburbs had reported the behavior, despite being observed in just three suburbs initially.

If a behavior is socially transmitted, we would expect its spread to follow the social network, with individuals being more likely to gain the new information from their informed close associates, and then subsequently pass it on to their uninformed close associates¹⁰. However, collecting information about individual cockatoos' social connections across such a large geographical scale (over 150km in diameter) is difficult to achieve. Therefore, a spatial 'network' of geographic distance between suburbs was created and fed with information about the cockatoo dispersal ranges, which are usually under 25km. The assumption was made that if bin-opening is socially learned, new occurrences should be more likely in suburbs close to the area where the behavior originated, and subsequently spread from the new areas that the behavior was observed within.

Using spatial network-based diffusion analysis¹¹, Klump and colleagues⁶ tracked the geographical spread of this new behavior and showed that transmission was strongly linked to the spatial proximity of suburbs, suggesting that the behavior was passed on through social learning as informed individuals dispersed into naive areas and took the behavior with them. Interestingly, as cockatoos appeared to avoid movement through forested areas and preferred other routes⁶, this additionally suggests that it would now be beneficial for future work to examine how the distribution of habitat types across a landscape shapes the spread of new innovations.

In addition, the large-scale citizen-science approach utilized by Klump and colleagues⁶ demonstrates how public engagement in scientific work increasingly makes important contributions to ecological research, and is at the same time a fantastic tool to engage the public¹². Indeed, citizen science data are incorporated in many diverse research fields ranging from biodiversity to astronomy^{13,14}. While Klump and colleagues⁶ demonstrate here how direct citizen science can also be used to study animal behavior, other examples are beginning to emerge in other areas of behavioral ecology, such as using passively generated data from internet activity by individuals (termed 'iEcology'¹⁵) to provide insights into ecology. The internet holds a vast amount of accessible digital data, such as pictures from social media posts, and now this kind of passively generated data may perhaps provide another useful tool for researchers¹⁵, especially when studying rare phenomena such as behavioral innovations.

Klump and colleagues⁶ also combine their findings from the citizen-science data (which documents behavioral spread across the landscape) with direct observations of individually-identified birds at multiple suburbs to identify the finer-scale mechanics of this socially learnt behavior. At three hotspots, video recordings of bin-opening revealed a complex, multi-step behavior involving five stages with various options: pry, open, hold, walk and flip. Several components of the behavioral sequence were location-specific, and dissimilarity in behavioral sequences increased with increasing geographic distance between sites. Site-specific differences in behavior indicate the formation of local cultures within sites, similar to as reported in foraging behavior of chimpanzees¹⁶. Finally, at one focal site, the authors measured various traits of 90% of birds to examine the effect of different characteristics in bin-opening behavior (Figure 2). Out of 114 individuals, nine opened a bin successfully and 27 attempted unsuccessfully. Successful bin-openers were mostly males ranking high in the dominance hierarchy. Social network analysis revealed that successful individuals had more extended social connections and occupied more central social network positions, which follows the common assumption that socially connected individuals may be the most likely to gain new information^{10,11}. Furthermore, among males, bin openers were more closely associated to one another, as expected from social learning. These insights into how individual characteristics may shape innovation and behavioral spread within sites (Figure 2) now provide a foundation of examining this across sites too. Specifically, if future developments allow researchers to track individuals' social connections across suburbs, this will provide a bridge between the two components of this work, and will further knowledge about the transmission pathways, the role of dispersal, and the emergence of local behavioral variants.

Urban environments provide a whole range of novel resources for wildlife and may promote innovation¹⁷. A major attraction luring wildlife into cities is often considered as the availability of waste. Leftover food in bins or just a few breadcrumbs on the street make a great meal for the many city animals living among us. Just like the milk-drinking tits, prawn-trawling dolphins and the crows using cars as nut-crackers, the cockatoos of Sydney have taken urban scavenging behavior to the next level by learning to access anthropogenic resources in an entirely new way, and spreading this across their social networks. Once a waste bin has been successfully opened, birds will explore the content and — to the annoyance of the bin owners — leave a mess behind. In fact, the cockatoos' novel foraging technique, bothers humans so much that they have started developing anti-cockatoo devices to thwart their access to bins. Humans are excellent innovators and social learners. The usage of bin protection, and particularly what type of protection, may also spread socially within and across suburbs. This interaction between humans and cockatoos hence has the

potential to be a case of human–animal cultural co-evolution, where cultural adaptations in one species lead to the cultural adaptations in another species. As such, the conflict between humans and cockatoos may provide an interesting case of a cultural arms-race. Although time will show whether humans are continually outsmarted or if they manage to put an end to this novel cockatoo foraging behavior, we can continue to expect to see new innovations arising and spreading through various urban animal social networks as many different urban-dwelling species attempt to profit from our activities.

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Figure 1. Urban innovators.[OK? Yes]

Sulphur Crested Cockatoo opening a household-waste bin while surrounded by flock members (photo: Barbara Klump [OK? Yes]).

Figure 2. Cockatoo Social Network.

Each point represents an individual sulphur-crested cockatoo in Stanwell Park, with point shape denoting bin-opening activity (white circle = successfully opened, grey circle = attempted opening, grey square = no attempt at opening), point size showing social network centrality (larger = higher eigenvector centrality), point color showing sex (blue = female, red = male, grey = unknown) and shading indicating the dominance of males (darker = more dominant), and letters showing age (A = adult, J = Juvenile). The edges between points

184 show the social associations between individuals, and social associations with successful
185 bin openers are highlighted in white.

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