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Handedness: What Kangaroos Tell Us about Our Lopsided Brains

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Brain asymmetry is widespread, but the presence of handedness in non-human animals is debated. A new study now provides evidence for handedness in bipedal — but not quadrupedal — marsupials.

A persistent myth in neuroscience has been the idea that brain asymmetry — the different functions of the left and right sides of the nervous system — is a uniquely human trait. Of course, there could be uniquely human biological traits that also show asymmetry (e.g. language), but brain asymmetry in itself is so widespread in the animal kingdom that it can be very plausibly considered a fundamental principle of organization of their nervous systems. In recent years, besides having been shown in vertebrates [1], laterality has been found to occur also in invertebrates, such as *Caenorhabditis elegans* [2] and the honeybee [3], thus revealing that brain size or number of neurons is certainly not a key factor in the emergence of cerebral asymmetry. However, in spite of the huge amount of evidence for brain asymmetry in different animal groups, there is still debate on one particular manifestation of cerebral and functional asymmetry in behaviour in the form of handedness. A recent study in *Current Biology* by Giljov *et al.* [4] now provides for the first time evidence for true handedness in some species of marsupials.

The term ‘handedness’ describes manual asymmetries at the population level, whereas ‘hand preference’ refers usually to the individual level. Though

there might be some geographical variation [5], around 90% of humans are right-handed. In non-human primates, whereas there is little doubt that individuals may show hand preferences, differences in the methods used to study manual asymmetries (tasks, sample size, etc.) have sometimes produced discrepant findings [6]. Nonetheless, some striking evidence for handedness has emerged, particularly in great apes. Bill Hopkins and his collaborators [7] have collected data for more than 700 chimpanzees from four different populations who have been tested for hand use on a task requiring coordinated bimanual actions, revealing a significant right-hand bias in each sampled population. The captive chimp colonies that Hopkins studied are 60–70 percent right-handed, regardless of the proportion of individuals in each colony that were human-reared. Thus, it has been suggested that, whereas there might be a genetic basis for handedness in chimpanzees, it must be expressed less strongly than in humans. This may be due to the fact that right-handedness in humans is associated with the left hemisphere’s specialization for language and speech production. Yet, the association is far from straightforward, because handedness in humans is only

weakly correlated with cerebral dominance for either praxis or language [8]. Besides, the argument based on the strength of handedness between human and non-human animals is problematic. First, because the measures of handedness in humans (largely based on questionnaires) rarely compare with those carried out in non-human animals (for exceptions, see [9]). Second, if we look at other animals, the idea that handedness is present with maximal strength only in our species is untenable. Parrots, for instance, show preferred use of a foot, the left foot in most species, to hold food objects with percentages of bias at the population level that parallel or exceed those of human handedness [10].

Even among non-human primates the presence or absence of handedness should be not taken as a cue of the presence of other biases that indicate the presence of functional asymmetry in the brain. Common marmosets (*Callithrix jacchus*), for instance, have a preferred hand in simple reaching tasks which develops by the time they are 8–12 months old and each individual uses the same preferred hand across its lifetime [11], but no population bias is apparent. However, the same group of marmosets has been shown to display a striking group bias in a completely

different behavioural measure: they use the left eye preferentially to view pieces of food through a peephole [12]. Thus, brains can be lateralized at the population level without that lateralization being manifested as a paw or hand preference in the population. Besides, a lateralized brain can make left- and right-preferring individuals different, even if handedness in itself is only 50:50 in the population. Cameron and Rogers [13] found, for instance, that the right-handed marmosets began to explore a new environment sooner than did the left-handed marmosets. The difference in behaviour between these two groups may depend on emotional aspects like the level of fear [14]. Why then can population-level handedness be so variable in spite of the fact that other manifestations of functional asymmetries are ubiquitous in all vertebrate taxa studied so far?

The findings of Giljov *et al.* [4] may provide some insight. These authors showed for the first time that bipedal macropod marsupials show a left-forelimb bias at the population level in a variety of ordinary behaviours in the wild (Figure 1). In two species, in particular, the Eastern grey kangaroo and the red kangaroo, the pattern of handedness is striking and holds across a wide range of behaviours, thus paralleling so-called ‘true’ handedness of humans.

The most interesting part of the Giljov *et al.* [4] paper is, however, not related to evidence for true handedness in some species of marsupials but to the plausible reason why some other species of marsupials do not show any evidence of handedness. Interspecies differences seem to be not associated with phylogenetic relatedness, as members of different families may have similar levels of handedness whereas within the same family different species may show different levels of handedness. Posture and preferred gait rather than relatedness seem to account better for the presence or absence of handedness. Basically, marsupials using bipedal locomotion as a preferred gait show higher levels of handedness than marsupials that are mainly quadrupeds. Again, it does not matter whether bipedality or quadrupedality was primarily or secondarily evolved; tree-kangaroos, for



Figure 1. Left hand up.

A red-necked (Bennett's) wallaby (*Macropus rufogriseus*) in a bipedal body position, using the left forelimb to manipulate a food item in the wild in Tasmania. Photo: Andrey Giljov.

instance, evolved from bipedal terrestrial macropods and only secondarily adapted to an arboreal lifestyle and quadrupedal locomotion. Nonetheless they do not show pronounced handedness. Only the species with bipedal locomotion display consistent handedness across multiple behaviours.

The idea of a postural origin for handedness was raised originally by Peter MacNeilage for primates [15], and although in kangaroos no evidence was apparent for a role of arboreal life style for the emergence of functional specialization, it seems clear that for both placentals and marsupials pressures associated with postural and ecological factors may be the main determinants of the emergence of a differential role for the two fore-limbs.

Brain asymmetry, with its multifaceted expression, poses unique challenges because of its relatively stable polymorphism. Most human individuals prefer to use the right hand in a variety of tasks (right handedness) but a minority of about 10–13% of individuals show the opposite pattern (left handedness). There are different hypotheses to account for the persistence of this polymorphism, for instance that genes associated with handedness may show some form of heterozygote advantage [16] or that left-handedness is maintained by frequency-selection mechanisms [17,18].

Marsupials lack a *corpus callosum* but have instead a large anterior commissure connecting the two hemispheres. With their clear-cut association between handedness and bipedalism, they may represent an important model to test our hypotheses on the evolutionary origins, neurobiology and genetics of brain asymmetry. Future research in particular should investigate other forms of behavioural and, possibly, cerebral asymmetries in order to clarify whether marsupials conform to the general pattern observed so far in vertebrates — the left hemisphere originally focused on controlling well-established patterns of behavior and the right specialized in detecting and responding to unexpected stimuli [19]. This should reveal whether demands associated with ecological factors can account for differences in direction of some asymmetries, such as their predominant left-handedness.

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Autism Spectrum Disorder: Sniffing Out a New Biomarker

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Early intervention improves prognosis in autism spectrum disorder, yet diagnosis is very difficult in preverbal children. A new study demonstrates that the automatic adjustments in sniffing patterns to pleasant and unpleasant odors may provide a window into early diagnosis.

Autism spectrum disorder (ASD) is widely recognized as a neurodevelopmental condition characterized by early emerging and persistent deficits in social communication and social interaction, often combined with restricted, repetitive patterns of behaviors, interests, and activities [1]. Despite extensive research and clinical efforts, ASD remains exceedingly difficult to diagnose before age two —most children are diagnosed at 5–6 years of age. This is a critical limitation because early treatment is associated with a better prognosis [2]. As such, there is a profound need for more sophisticated and quantifiable biological markers that

appear early in development and that could help detect autism in the first six months. Ideally, such measures will not rely upon emerging linguistic abilities or complex social behaviors. In a recent study in *Current Biology*, Rozenkrantz and colleagues [3] now describe a possible marker, based on link between olfaction and ASD.

Intriguingly, another core aspect of ASD are altered sensory and motor behaviors. For example, children with ASD may exhibit indifference to pain or temperature, adverse response to specific sounds or textures, excessive smelling or touching of objects or visual

fascination with lights or movement. Of central importance in the quest for early diagnosis is the fact that these alterations in sensory and motor behaviors are the earliest behavioral indications of ASD [4]. Measurement of these behaviors may therefore provide a window into early diagnosis.

The olfactory system is a particularly well-suited candidate for assessing sensory and affective behavior in very young children. A unique aspect of olfaction is its relative separation from linguistic processing [5,6]. Aromas are notoriously difficult to identify and name [7]. Think of trying to name a spice in a