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Mandel and William Kessen noted that physicists, astronomers, and chemists don't need to take seriously commonsense ideas about nature because people's beliefs and attitudes about the stars, matter and energy, and chemical elements don't affect the subject under investigation. But psychologists do have to pay attention because people's beliefs about the mind influence their thoughts and actions in daily life and are thus an important part of what psychology is all about. For example, when biologists name a gene with a common language term like *hedgehog*, no one mistakes that for the animal of the same name. But when psychologists refer to a behaviour with a term derived from human introspection, like fear, the assumption is that the mental state of fear has some special relation to the behaviour, and also to the brain circuit that controls the behaviour. From time to time, we need to step back and evaluate the language of science. It's not that mental state words like fear are not useful. It's just that they should be used for mental states, and not be automatically assumed to be causes of behaviour in animals or humans just because the mental state is correlated with the behaviour in humans.

How do you feel about applied versus basic science? When I was just getting started as a scientist, I steered clear of applications. Having so little formal training in science I was trying to do my best to mimic the way a real scientist would think about basic versus applied research — that applied science lacked the beauty and purity of basic science. Then the more I got to know about research on emotions like fear and anxiety, the more I realized that the reason treatments for fear and anxiety disorders were not very good was because basic science notions about these states were wrong. The problem started with Darwin and his acolytes in the late 19th century. They viewed emotions as states of mind inherited from mammalian ancestors. In the early 20th century, behaviourists banned this kind of anthropomorphic talk about mental states. But they continued to use mental state terms like fear and anxiety to describe behaviours. Treatments for problems with fear and anxiety emerging in the mid 20th century were influenced by the behaviourist approach. Today, the focus remains on using behaviour as a marker for mental disorders, with little concern for the mental part of the problem. The assumption is that behaviour is a better readout of 'fear' than the feeling of fear. But so long as the mental part of mental disorders is marginalized, people will suffer mentally. In retrospect, I think that's what I understood in Freud but didn't know how to articulate.

Is there too much emphasis on big data-gathering collaborations as opposed to hypothesis-driven research by small groups? Big data and hypothesis driven research both have a place. But both could use more emphasis on the conceptual underpinnings of the research. Scientists are taught how to collect and analyse data. Philosophers are taught to think. It might be helpful if scientific education could include a bit of this kind of training as well.

If you would not have made it as a scientist, what would you have become? Well, I always wanted to be a musician as a kid. Decades later, being a scientist actually made that possible in ways I never expected. In 2005 or so we had a band composed of NYU researchers that played songs about mind and brain at holiday parties — Manic Depression, Mother's Little Helper, 19th Nervous Breakdown. We called ourselves 'The Amygdaloids', since a lot the work I and other band members were doing was on that part of the brain. Then I wrote a couple of these mind-brain songs myself for a gig that was written up in a local newspaper with the headline 'Heavy Mental'. We went on to record several heavy mental albums (see The Amygdaloids YouTube channel) and played countless gigs in NY and on the road. As an acoustic duo, two of us have travelled the world doing gigs in cities where I have lectured.

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Quick guide

Hoover the talking seal

Diandra Duengen[1], W. Tecumseh Fitch[2], and Andrea Ravignani[1,3]

Hoover, who? Hoover (1971–1985; Figure 1) was a male harbor seal (*Phoca vitulina*) famous for imitating human speech, who spent most of his life at the New England Aquarium in Boston, USA. Initially raised by a Maine fisherman, Hoover began imitating English phrases once he reached sexual maturity. The seal's repertoire included "hello there", "come over here", "hurry", "hey hey", and "Hoover". Hoover provides an unparalleled example of speech mimicry — a form of vocal learning — in seals.

How did a seal learn to parrot human speech? Hoover was an orphaned seal, found at Bethel Point, Maine, in 1971 and rescued a few weeks after his birth. George Swallow took the orphaned pup home, handfeeding and frequently speaking to him. Growing fast, Hoover was donated to the New England Aquarium at about three months. He started producing speech-like sounds much later, around his fifth birthday. Hoover produced his speech-like vocalizations typically in the water, from a vertical position, followed by bubble blowing. These vocal displays were especially frequent during breeding season, and often appeared directed at female seals, suggesting that these vocalizations may have acted as 'breeding songs' like those produced by male harbor seals. Importantly, the aquarium staff did not train Hoover to produce these displays.

Did Hoover faithfully copy speech, or simply trick us into thinking he does? One might think that Hoover was no different from some 'YouTube stars', like Siamese cats or Huskies that say 'Mama' or 'I love you'. Human perception is so attuned to finding (speech) patterns that some animals may trick our brains into hearing speech sounds where no such similarity exists. However, in the case of Hoover there is solid evidence for speech mimicry: spectrograms of his sounds (tools to visualize and compare animal or human voices) show that Hoover's vocalizations were indeed very 'human-like', containing the typical formant modulations that we use to produce vowels and consonants. Ongoing quantitative and statistical analyses of Hoover's vowel sounds also suggest that indeed this seal produced human-like English vowels. Thus, Hoover is one of the best-documented examples of vocal production learning of human speech available in a mammal.

What is vocal production learning? Vocal production learning is a form of social learning. Rare among mammals, it is the ability to produce new sounds or alter existing ones based on experience with others, such as humans learning new languages, or parrots mimicking speech. Vocal production learning and mimicry require mapping perceived sounds to movements of the vocal production system and rely on specialized brain circuits connecting auditory and motor cortices. The vast majority of species known to have vocal production learning are birds, and only a small fraction of mammals — humans, pinnipeds, cetaceans, bats and elephants — show vocal production learning.

Is seal vocal production learning closer to birdsong, or to human babies talking? Understanding or intending meaning is not relevant for vocal production learning, and neither Hoover nor most other animals exhibiting vocal production learning seem to 'understand' spoken language or the meaning of words. Nonetheless, vocal mimicry is impressive *per se* and represents a key building block of speech.The timeline of Hoover's vocal displays suggests that he 'imprinted' on George Swallow's vocalizations at a very young age. Hoover, like many birds, didn't actually begin producing these learned sounds until he approached sexual maturity, suggesting that there may be a sensitive period for vocal learning in seals, as for many bird species. Although it is possible that only males learn sounds in harbor seals, the issue is too little researched for a definitive statement. Hoover's example suggests that seals may learn their displays early in life, but only deploy this ability later, when sexually mature, to attract potential mates.

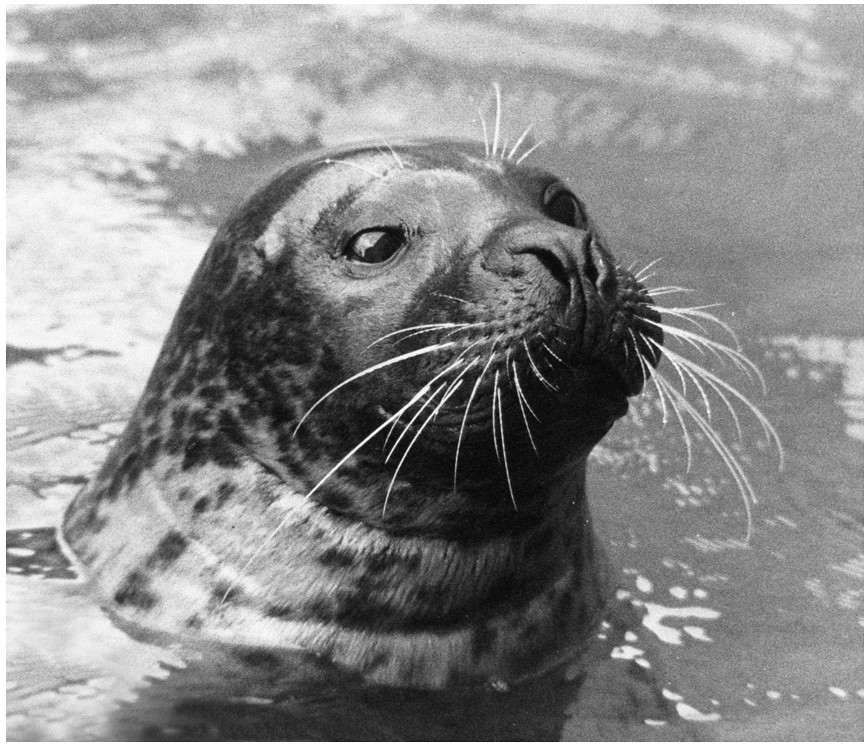

Figure 1. Hoover the talking seal.
Hoover at the New England Aquarium, where he lived from 1971 until his death in 1985 (photo © New England Aquarium).

Was Hoover a freak of nature or does he tell us something special about seals? Hoover was certainly unusual, but the basic machinery for vocal learning may be present in other harbor seals and pinnipeds. Three-week-old harbor seal pups can modulate the pitch of their voice without training, as we do when speaking or singing. Pitch plasticity requires laryngeal and breathing control — a key component of vocal production learning. Furthermore, seals and walruses can easily be trained to vocalize on command and can learn to roughly imitate both melodies and vowels. Finally, grey seals can be trained to configure their vocal tract to modulate formants, the building blocks of speech sounds, and mimic human vowels. Vocal production learning may thus be widespread in pinnipeds, making them both vocally gifted mammals and promising animal models for understanding human speech.

Why are Hoover and other pinnipeds key to understanding vocal learning and human speech? Vocal production learning is a prerequisite for spoken language: humans use it from birth to learn the sounds and words of their language, and vocal production learning thus may have played an important role in the origins of human speech. Understanding the evolution of speech requires a comparative approach, probing for presence or absence of the trait across species in the context of phylogeny. Mammalian vocalizations and human speech are based on three interacting anatomical components: lungs (which control intensity and duration of sound), larynx (which affects the pitch), and vocal tract (for timbre and vowels distinction). Fine-tuned neural control over all three components is required for human speech. At present, harbor seals are one of the few other mammals known to finely control all three components. Apes, our closest relatives, appear to lack key neural connections enabling fine control of their larynx and vocal tract, despite the anatomy of the vocal tract itself being adequate for speech. Pinnipeds use a similar vocal tract to ours and are more closely related to humans than most other species with vocal production learning. Hoover's case prompted a small scientific revolution in the comparative study of vocal learning by showing that harbor seals are clearly capable of vocal production learning, including formant modification, but much further research and more controlled experiments will be necessary to fully understand these capabilities. But, Hoover may eventually be immortalized as one of the godfathers of mammalian vocal production learning research.

SUPPLEMENTAL INFORMATION

Supplemental audio files of Hoover 'talking' can be found with this article online at https://doi.org/10.1016/j.cub.2022.12.023.

Where can I find out more?

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Primer

Sauropods

P. Martin Sander[1,2]

This article begins as many others on sauropods before it: "Sauropod dinosaurs were the largest animals to ever walk the Earth, by far". The largest sauropods were easily four times heavier than the largest land mammals (and the largest other dinosaur species, for that matter). The iconic body plan of sauropods is dominated by their very long neck, in some species exceeding 14 meters in length, provided with a relatively small head (Figure 1). The neck was mostly held horizontally or at a low angle. The massive but relatively short trunk was supported by four columnar legs, much like in an elephant. The bones in the fore foot of sauropods are oriented vertically, and some late forms even lost their finger bones, walking on their metacarpals (middle bones of the hand). The hind leg, which bore most of the weight, has a half-upright foot. The femur (thigh bone) was the largest bone in the skeleton, like in most other true land vertebrates (amniotes). The long neck was counterbalanced by the long tail, the base of which also functioned as the anchoring region of the giant muscles that pulled back the hind leg during walking.

Whereas in popular culture sauropods are often depicted as the ultimate failure in evolution, exactly the opposite is the case. No other herbivore in the history of land animals was equally successful, by a wide margin and by any measure. Sauropods existed for a minimum of 135 million years, from the beginning of the Jurassic 201 million years ago to the end of the Cretaceous, 66 million years ago. Sauropods where the dominant herbivores on all continents for most of this time, only being rivalled during the Late Cretaceous on some landmasses by hadrosaurs.

Despite their large body size, which inversely correlates with diversity in mammals today, sauropods are the most diverse of any extinct dinosaur group (with the exception of non-avian theropods), with hundreds of species known. Size itself arguably is a measure of evolutionary success. Although there is no official size classification, a 'large' sauropod would begin at 20 tonnes, a 'giant' sauropod at 50 tonnes and a 'super-giant' would have reached over 80 tonnes, the mass of a large baleen whale. Strikingly, giant body size evolved independently in virtually all lineages of sauropods and was an attribute from early on in their evolutionary history. The 20-ton barrier, larger than any other land animal, was already broken by some of the earliest sauropods. Most sauropods were large to super-giant, the exceptions being mainly dwarf forms on islands.

Sauropod diversity through time and space

Dinosaurs consist of two major groups, the bird-hipped dinosaurs, or Ornithischia, and the lizard-hipped dinosaurs, or Saurischia. Sauropods belong to the sauropodomorphs, the major bifurcation together with theropods at the base of the saurischians. Theropods, or meat-eating dinosaurs, include the birds. Birds thus are living dinosaurs, but they are not descended from bird-hipped dinosaurs (Figure 2).

Sauropodomorphs show up in the fossil record together with theropods at least by the beginning of the Late Triassic, about 237 million years ago. From then on, these initially bipedal, deer- to rhino-sized animals (such as *Plateosaurus*) diversified and spread around the globe. As recorded by their fossil bones, true sauropods only evolved in the Early Jurassic, after the end-Triassic mass extinction, 201 million years ago. Tracks and trackways from the Late Triassic of Greenland, however, suggest an earlier appearance. Among the best known early sauropods is *Vulcanodon* from the Early Jurassic of southern Africa that clearly shows the typical features of the group, most notable the fully upright legs, indicating quadrupedal locomotion. Early-branching sauropodomorphs disappeared near the end of the Early Jurassic, 180 million years ago, probably because

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