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Behavioral neuroscience: Dominance in the absence of competition

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https://doi.org/10.1016/j.cub.2025.05.058

Mice infer dominance rank using chemosensory cues rather than physical competition. This sensory-based inference reshapes how we think about hierarchy learning, stability, and behavioral flexibility in social animals.

In the saloons of the old American West, a seasoned cowboy did not need a fight to know where he stood. Stepping inside, he would scan the room with practiced eyes — registering who sat confidently at the bar, who avoided his gaze, who held the quiet authority of someone not to be crossed. Without a word, subtle cues like body language, posture, positioning revealed an unspoken hierarchy that kept uneasy peace in a volatile setting. In a strikingly parallel fashion, in work recently published in *Current Biology*, Borak *et al.*[1] demonstrate that male mice too can navigate unfamiliar social terrain, using chemosensory cues to infer dominance and adjust their behavior accordingly.

The formation of social hierarchies is a defining feature of many species[2]. These hierarchies, once established, are relatively stable and serve to reduce in-fighting, enhance protection, optimize resources, and facilitate reproductive fitness. An individual's relative rank within a linear hierarchy, the 'pecking order'[3,4], defines their access to fitness-relevant resources — food, territory, mates — and can be established by either conflict-based or competence-based means depending on the species and their social ecosystem[5].

Whether in chickens or chimps, an individual's relative position, or rank, determines access to vital resources. In an evolutionarily conserved manner, rank is typically detected using either sensory cues — facial features, body posture, scent, vocalizations — or the memory of previous encounters between pairs of individuals which gives rise to transitive inference (if A>B and B>C, then A>C). Hierarchy stability requires each individual to accurately encode, recall, and adhere to their own and others rank. Understanding the neural correlates of these phenomena serves to further our knowledge of social pathology development (repeated aggression or social withdrawal), representations of self *versus* others, and social communication[6].

Consequently, in humans, the neural basis of learning and maintenance of social hierarchies remain relatively unknown. However, key hub regions like the medial prefrontal cortex may selectively mediate knowledge about one's own hierarchy while the amygdala and hippocampus encode information related to other's social rank[7]. In mice, a social species that also forms linear hierarchies, social rank is thought to be derived as a statistic of past social outcomes with animals relying on transitive inference to assume the rank of familiar conspecifics.

The neural basis of this competition-based computation has been heavily investigated in mice. Repeated optogenetic stimulation of the mediodorsal thalamic input to the prefrontal cortex mediates long-lasting changes in the social dominance status that are affected by history of winning[8]. Similarly, projections from the prefrontal cortex to the nucleus accumbens (a key reward node) signal learned hierarchical relationships and are required for the adaptive regulation of social interaction behavior based on prior hierarchical interactions[9]. The prefrontal cortex may bidirectionally regulate physical conflict win-related and lose-related behaviors through anatomically segregated projections to the periaqueductal gray/dorsal raphe nucleus and basolateral amygdala, respectively[10]. All this is to say,

when push comes to shove, the neural computation of physically entrained social hierarchy is slowly coming into focus.

But how is rank perceived, particularly outside direct physical conflict? Can animals assess another's position in a social structure without ever interacting with them? Borak *et al.*[1] addressed this question in male mice, and found that they can infer the dominance rank of unfamiliar individuals using scent cues — specifically chemosensory information— rather than relying solely on memory or repeated physical conflict. These findings shift the focus from behavior to biology: social rank is not just earned but detected.

Borak *et al.*[1] employed the well-established tube test, where a narrow passage forces two mice to confront one another to probe dominance[11]. Generally, the mouse that retreats is considered subordinate, while the mouse that pushes forward and through the other is considered dominant. First, the authors confirmed that mice flexibly change their behavior depending on the opponent, even when that opponent is familiar. Next, they tested whether this behavioral flexibility extended to unfamiliar mice. Strikingly, mice altered their strategy even when facing strangers, as long as they could detect the strangers 'in-group' rank via scent. Mice generalized their own social position and adjusted behavior accordingly, suggesting that dominance signals are not just internally computed but externally sensed.

Prior research had established that major urinary proteins (MUPs) convey dominance-related information in mice[12]. To evaluate whether the volatile chemicals serve as a potential universal dominance cue that contributes to behavioral flexibility in hierarchy testing, Borak *et al.*[1] 'scent-swapped', or this is to say painted, subordinate male mice with urine from dominant, unfamiliar males and found that their partners could accurately generalize rank and adjust behavioral repertoires in accordance with the previously subordinate animals' updated (by scent) dominant status. This indicates that olfactory cues alone can overwrite prior experience and drive social behavior.

To test whether chemosensation is necessary for this ability, the team temporarily disabled olfaction using methimazole (which disrupts the main olfactory epithelium). When administered concomitant with NMDA-induced excitotoxic lesions of the accessory olfactory bulb, winning probabilities of experimental mice were disrupted with lower-ranking animals becoming more likely to win tube tests. That this intervention abolished the typical dominance behaviors — lower-ranking mice began winning tube tests — suggests a breakdown in rank inference due to impaired scent detection.

Together, these findings present a potentially major shift in our understanding of how social information is processed. Rather than relying on repeated contest outcomes, mice may detect rank externally through volatile and contact-based chemosensory cues. Social hierarchies, then, may be more biologically encoded than previously appreciated.

There are, naturally, several open questions. The study excluded female mice, despite evidence that the tube test can reliably assess hierarchy in females[13]. Could males and females rely on different sensory mechanisms for dominance inference? And while the authors highlight MUPs as carriers of dominance signals, they do not directly show whether these proteins fluctuate with changing social status or are mechanistically critical during physical encounters. Moreover, while olfactory and contact cues were shown to guide behavior, it remains unclear whether the loss of scent detection disrupted specific dominance perception or broader social behavioral plasticity. That is, if chemosensory input helps encode social memory, then disrupting it might impair recall and lead to generalized social dysfunction — mistakenly interpreted as a loss of hierarchy inference.

These questions only highlight the exciting new directions that are now possible to probe in the future, and the critical role that sensory-perceived, rather than competition-based, hierarchy inference may play in behavioral neuroscience. Perhaps most provocatively, as this is a purely behavioral description of the phenomenon, this new study raises the question of where in the brain sensory-inferred dominance rank is represented and encoded. Is scent detection enough to encode social position, or are higher-order brain regions integrating this input to guide behavior?

Finally, Borak *et al.*[1] suggest that stable hierarchies may be maintained not through constant contest, but through perceptible signals that minimize conflict. Pragmatically, this highlights that experimental animals' behavior may be significantly influenced by sensory perceptible, but not experimentally used, conspecifics housed within the same vivarium; yet another factor for behavioral neuroscientists to think about as they interpret their experimental outcomes.

In sum, the scent of dominance may be more powerful — and more scalable — than the scars of battle.

DECLARATION OF INTERESTS

The authors declare no competing interests.

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Eating and obesity: Is the effort its own reward?

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Palatable high-fat diets reliably cause overeating and weight gain in lab animals. New experiments demonstrate that this overeating doesn't occur when mice work to earn the food, raising important questions about motivation to overeat and the methods used to model obesity in animal studies.

In recent decades, industrialization and globalization have made the American food supply increasingly sweeter, fattier, and more energy dense, with palatable, highly processed food becoming less expensive per calorie and aggressively marketed[1]. To understand how such changes affect the brain, motivation, and metabolism to cause overeating and weight gain, animal experiments are used to model various features of the Western diet and the food environment to identify the drivers of hedonic overeating. *Diet-induced obesity* refers to weight gain attributable to the rewarding sensory and nutritional properties of high-fat and high-sugar foods which elicit overeating and rapid weight gain in the absence of any pre-existing genetic or metabolic dysfunction[2]. Other work modeling the modern food environment typically concerns how non-food stimuli like sights, sounds, times, and locations associated with palatable foods can act as Pavlovian triggers for cravings and promote eating in the absence of hunger[3]. New work by Barrett, Pan *et al.*[4] published in this issue of *Current Biology* provides a striking demonstration that another feature of the environment — the relative ease of effort in accessing high-fat food — may be equally influential in promoting (or preventing) diet-induced obesity in lab animals. They report that the excess eating and weight gain typically observed with high-fat food is almost completely prevented when mice are required to perform a simple task to earn it.

In their experiments, Barrett, Pan *et al.* used two different open-source devices for continuously monitoring the eating patterns of individual mice in their home cages. Both devices make use of a programmable microcontroller to govern food access (either opening/closing a food hopper or dispensing individual pellets) while sensing and logging eating events (contacts with the hopper or removing a pellet), enabling detailed analysis of meal patterns over time. When allowed unlimited access to the high-fat formulation commonly used in obesity experiments, the mice overate and gained weight as expected. However, when the device required a mouse to nose-poke at a sensor port to open the hopper or deliver another pellet, intake patterns were quite different. Meals become smaller and fewer, and, perhaps most importantly, mice no longer gained excess weight as a result.

This underscores the crucial role of the environment, over and above the sensory and nutritional properties of the diet itself, and also raises important questions about how animal experiments should model the food environment. In the past century the Western diet has changed not only in types and sheer quantity of foods available, but also in the number and spatial distribution of the many places food is obtained[1]. Most recently, food delivery apps further increased accessible options while reducing the effort involved in having a meal. Increasing portion sizes especially in convenience foods and in meals served outside the home, along with changes in food shopping habits, such as making fewer but larger shopping trips so that more is on hand at home, all mean that more people have food within easy reach more often, reducing the effort necessary to continue eating once started.

From the perspective of behavioral ecology of course it's to be expected that the 'effort cost' required to obtain food would influence intake, since models of optimal foraging fundamentally depend on animals being sensitive to energy spent on food procurement relative to caloric payoff. Behavioral economics, which applies principles of microeconomics to complex behaviors like foraging, has described how animals