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Perception: Visual adaptation on the move

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https://doi.org/10.1016/j.cub.2025.10.069

How does the visual system calibrate to a world that moves? A new study shows that adaptation to number moves with objects across a scene, showing that short-term visual plasticity is object-bound despite the visual system being fundamentally retinotopically organized.

Vision is inherently dynamic. Animals capable of self-propelled movement, us included, constantly navigate changing environments, rapidly adapting to new lighting conditions[1], optic flow[2], and scene statistics[3]. In fact, motion itself is essential for seeing: when every striated muscle in the body is paralyzed, causing the visual input to be perfectly stable, perception fades[4], as continuous exposure adapts neuronal responses in the visual brain. This fundamental adaptability is not limited to low-level visual features, such as luminance, color or orientation. Adaptation experiments have revealed that the visual system extracts and recalibrates to seemingly abstract attributes — from gender in biological motion[5] and the egocentric viewpoint of objects[6], to causal interactions between objects[7]. Among the most striking examples is adaptation to numerosity[8]: after viewing a patch with few dots, the dots in subsequent patches

appear more numerous; adapting to many dots has the opposite effect. Such negative after effects are the hallmark of visual adaptation[9]. Although the underlying mechanisms remain debated[10,11], the phenomenon is robust and easily demonstrated (see https://cm.perceptionresearch.org/demo/index.html). As Burr and Ross[8] put it: "just as we have a direct visual sense of the reddishness of half a dozen ripe cherries, so we do of their sixishness". A study reported recently in *Current Biology* by Myers *et al.*[12] adds a surprising new twist: adaptation to number is not fixed in retinal coordinates but can remain bound to objects as they travel across the scene.

Understanding why this is surprising requires revisiting a long-standing puzzle in vision science — how perceptual continuity is achieved in active observers. The visual system is organized in retinotopic maps[13], where each neuron responds to a specific retinal location — a

distinctive signature of visual as opposed to cognitive processing[14]. Every movement of the eyes, head, or body shifts the retinal image, displacing each object's location across this map. This raises a key question: if adaptation depends on retinotopic coding, how could it serve a functional role for observers in motion? One hypothesis could be that the brain constructs world-centered representations, invariant to movement, that keep visual features anchored to their real-world locations. However, evidence for such stable world-centered adaptation has remained controversial. Myers *et al.*[12] now provide compelling data that adaptation to numerosity can move with objects, revealing a new bridge between retinotopic encoding and the perception of continuity in a dynamic world.

In a series of experiments, Myers *et al.*[12] elegantly extended the original numerosity adaptation paradigm — putting it into
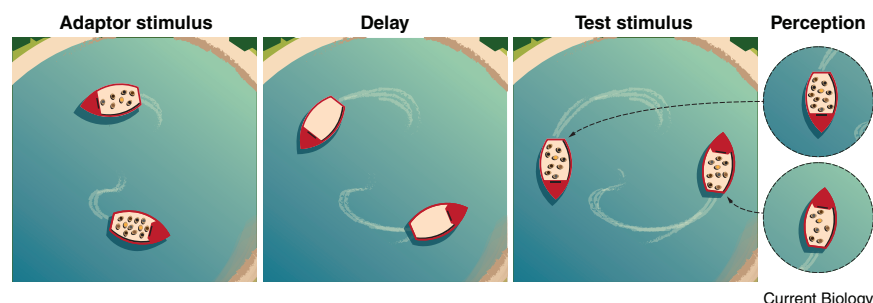
Adaptor stimulus   **Delay**   **Test stimulus**   **Perception**

Current Biology

Figure 1. Adaptation to number in moving objects.
In the new study by Myers *et al.*[12], the adapting stimulus consisted of two moving objects — one containing many dots and the other fewer — while the observer maintained fixation. The illustration depicts this with two boats cruising across a lake, each carrying a different number of passengers. The lake represents the retina, and each boat's wake marks the retinotopic path it has traversed. After the passengers were removed for a brief delay — until the boats reach locations not previously visited — test stimuli were presented (the passengers reappeared). In the example depicted here, both boats now contain the same number of passengers, yet the left boat would appear to have more, reflecting a negative perceptual after effect of the smaller number it carried during adaptation.

motion. In their first experiment, observers adapted to patches of dots depicting either 'many' or 'few', but these patches were now embedded within moving discs that drifted across the display while participants maintained central fixation. To visualize this, imagine two boats, one hosting many and one hosting fewer passengers, traversing a lake (Figure 1). When tested afterwards on critical trials, matched for the number of dots (or passengers) at test, the numerosity after effect followed the object's motion: a disc that had carried a 'many' adaptor elicited a reduced sense of number than one that had carried a 'few' adaptor, even after it had moved to a new retinal location.

In a second experiment, the researchers added random motion to the dots within the discs — the passengers walk around on the boat — and replicated their object-based after effect. As the next step, the dots were presented still within a disc but this time with 'invisible' boundaries — much like a herd of sheep or a flock of ducks on the water. Again, adaptation persisted. The results of these first three experiments showed that numerosity adaptation is non-retinotopic. Because the experiments thus far had compared after effects of discs on opposite sides of fixation, there was still a chance that the adaptation was hemifield- rather than object-specific. In a critical fourth experiment, therefore, the authors included an empty disc on both sides of the display. In the adaptation phase, dots now appeared in one of the discs,

while the other one remained empty as it randomly moved about. When the test stimulus now appeared within the same adapted discs, a robust after effect was observed. However, when the test was presented in the empty disc — which had traversed the same hemifield for the same duration — no after effect was observed, confirming that numerosity adaptation was bound to the object.

Together, these findings reveal that numerosity adaptation can remain yoked to the objects that elicited it, showing that adaptation is not tied to static retinotopic maps but instead tracks visual objects as they move through the scene. This object-bound, non-retinotopic adaptation promises to bridge two fundamental goals of the visual system — visual stability and perceptual plasticity — suggesting that adaptation is not merely a local fatigue process but one that dynamically updates representations that travel with the objects we see (see also Melcher[15]).

By showing that adaptation to number can move with objects, Myers *et al.*[12] extend the reach of visual plasticity into the dynamic realm that perception routinely operates in. Their findings suggest that the visual system does not simply recalibrate fixed sensory maps but continuously updates its internal representations in step with the world. Consistent with their finding, numerosity adaptation is specific to salient features like color or auditory pitch[16], which could be a result of these features giving rise to visual or auditory objecthood.

The findings of Myers *et al.*[12] leave us on a cliffhanger, with exciting new directions ahead. A key task will be to find out how exactly object-based adaptation occurs. To shine light on this question, future studies need to look at coding principles involved in object-specific adaptation[17] and be tied in with the theories of object files[18] and object-based attention[19]. Another intriguing question is whether object-specific adaptation extends beyond number. Myers *et al.*[12] focused on numerosity because the intraparietal sulcus of the primate brain is central to both number processing and object tracking. Yet similar object-bound recalibration might occur for other features. Color adaptation, for instance, can be object-specific[20], though it remains unknown whether such effects persist when objects move. Similar questions could be asked for other perceptual dimensions like facial identity or expression, material properties such as gloss or texture, or even higher-level attributes like viewpoint, all of which are known to respond to visual adaptation[9]. Testing whether these forms of adaptation remain bound to moving objects, and to what extend they are robust to intermediate eye movements[15], would reveal how deeply the active visual system integrates perceptual recalibration with object-based representations.

Object-bound numerosity adaptation shows that the visual system is capable of flexibly preserving perceptual history across motion and change. In this light, the same processes that recalibrate vision moment by moment may also preserve its continuity, allowing perception to remain responsive yet coherent as objects and observers move.

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Social behavior: Not so good vibrations

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https://doi.org/10.1016/j.cub.2025.10.084

Ants primarily communicate via pheromones, and other modes of communication have remained understudied. A new paper shows that fire ant workers employ substrate-borne vibrations to induce the killing and cannibalism of young queens when the colony is starved, showing that ant communication can be multifaceted.

Ant colonies are bustling cities in miniature: teeming with activity from thousands, sometimes millions of workers, each specializing on different tasks that contribute to the harmonious functioning of the society. The success of ant societies depends on effective communication. For over a century, scientists have strived to decode what and how ants communicate to one another, yet much about their communication channels remains mysterious. A new paper in this issue of *Current Biology* by Wennan Dai, Liangyu Lu, Hualong Qiu and colleagues[1] identifies a striking novel communication mechanism in fire ant colonies, which

under nutrient scarcity cannibalize their virgin queens. The authors show that workers use vibration signals to recruit other workers to attack and kill specific queens.

Most research on ant communication has focused on chemical compounds, which mediate a wide range of social behaviors[2,3]. Most, possibly all, species of ant use highly volatile alarm pheromones to alert nestmates to threats and trigger defensive responses. Many species deposit less volatile pheromones during foraging to create odor trails that connect the nest to food sources and enable efficient navigation. While these pheromone classes are broadly conserved

across the ant phylogeny, the specific compounds involved and the exocrine glands that secrete them vary substantially between species. The identification of novel pheromones is an active research frontier, with a recent pre-print identifying the first brood pheromone produced by ant larvae to regulate adult reproduction[4]. Finally, ants use complex mixtures of low-volatility hydrocarbons that coat the body surface (cuticular hydrocarbons) to distinguish nestmates from non-nestmates[5]. These compounds ancestrally served to prevent desiccation but now additionally signal colony identity.

By contrast, non-chemical modes of communication in ants have only rarely