Trends in Cognitive Sciences

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Spotlight

What Is the True Capacity of Visual Cognition?

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How much can we perceive and remember at a time? Results from various paradigms traditionally show that observers are aware of surprisingly little of the world around them. However, a recent study by Wu and Wolfe (*Curr. Biol.* 2018;28:3430□3434) uses a novel technique to reveal that observers have more knowledge of the visual world than previously believed.

Why does it feel like we see so much of the world when virtually all of the available data suggests we actually see very little? The moment anyone opens their eyes, they have the intuitive impression of a rich, detailed perceptual experience that extends well into their periphery [1]. However, a wide variety of results from change blindness, inattentional blindness, the attentional blink, multiple object tracking, and visual working memory all suggest that human observers actually perceive and remember remarkably little of the world around them ([2]; see Figure 1 for a demonstration). In fact, direct estimates of the capacities of visual attention and visual memory show that these mechanisms are limited to a small handful of items (i.e., usually around three items, [3]). How can all of these facts be true? How can personal introspection paint one picture of visual experience, while the empirical data paints another?

Traditionally, there are two ways that researchers try to answer these questions. On one side are those who simply take these empirical results at face value. Under this view, perception is surprisingly sparse and observers□ belief that they enjoy a rich perceptual experience is simply mistaken and perhaps even illusory [4]. On the other side are those who believe that this interpretation is premature. Instead, these researchers believe that while cognitive mechanisms like attention and working memory may be quite limited, perceptual awareness is not. Observers are simply aware of more information than can be attended to and stored in memory [5]. Reconciling these two views is a foundational issue in consciousness studies and is of paramount importance in the search for the neural correlates of consciousness [6,7].

Amidst all of this controversy, a recent article by Wu and Wolfe [8] suggests that the cognitive mechanisms that play a role in phenomena like change and inattentional blindness may not be as limited as has been previously claimed. In their article, the authors make an important methodological contribution to the ways researchers quantify the capacity limits of visual cognition. In the vast majority of studies examining the limits of perception and memory, observers are briefly presented with multiple items and asked to attend to, track, or remember those items. To measure perceptual capacity, researchers give the observers an opportunity to identify the location of a probe item (i.e., □Where is the horse?□). If the first response provided is incorrect, it is assumed that the observer has not maintained that particular item. While this approach makes intuitive sense, Wu and Wolfe explored the possibility that people sometimes fail to report the correct response, not because they have no knowledge of that item, but because their knowledge is imprecise and probabilistic.

To test this idea, Wu and Wolfe used a multiple identity tracking paradigm in which observers had to maintain the location of several moving objects (e.g., drawings of animals such as lions, monkeys, and cows). On a given trial, 6, 16, or 32 animals moved around the screen for 7□20 s (Figure 2A). At the end of each trial, every item stopped moving and was replaced by a gray disc (Figure 2B). When this happened, a probe target also appeared telling participants which particular item to locate (i.e., □Where is the tiger?□). In a normal identity tracking paradigm, participants would provide only one response, and performance from those individual responses would be averaged across trials to estimate an observer□s capacity. Here, Wu and Wolfe analyzed the first responses participants provided and estimated a capacity of 2.7 items, consistent with previous studies (Figure 2C). However, the key insight by the authors came in the form of a very simple question: what would happen if participants were allowed to provide multiple responses instead of just one?

The motivation behind this question is that even though participants may not be aware of a target□s precise location, they may still have some imprecise knowledge about the target location. To give a real-world example, the authors highlight how there is an important difference between saying that □Jeremy is somewhere near the table□ and □I have no idea where Jeremy is□. To examine this possibility, Wu and Wolfe instructed participants to keep clicking until they successfully found the target. The authors then modeled the response patterns of these clicks and discovered that participants' awareness of multiple items is more than three times the usual capacity estimates in certain cases, reaching a maximum capacity of 9.9 items. Of course, it should be stressed that the authors do not ever claim that observers have a precise awareness of that many items; instead, they claim that observers have an approximate, probabilistic awareness of those items (i.e., □I know the tiger is somewhere over on the bottom left corner of the screen, but I'm not entirely sure where□; Figure 2C).

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Figure 1. Demonstration of the Limits of Visual Cognition. Try and identify all of the differences between these two images. For example, maybe the easiest difference to spot is that the rug on the floor in the left image is not present in the right image. More subtly, note how the pillows on the couch, the objects on the coffee table, and the items on the shelf have all changed, disappeared, or shifted.

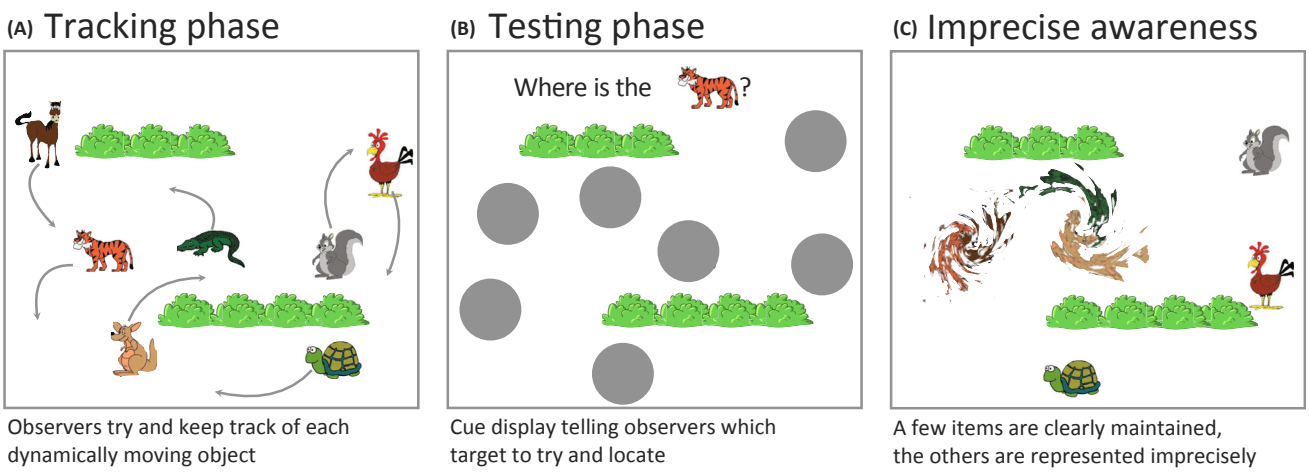

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Figure 2. Visualization of Paradigm and Key Idea. (A) Example display of tracking experiment in which observers were instructed to maintain the location of each individual object as it moved around the display. (B) After 7□20 s, each object was occluded by a gray disc and observers were prompted to report the location of one particular object. (C) Visualization of the notion of imprecise awareness. While observers may have precise knowledge of a small handful of items, they also have imprecise knowledge of even more items (i.e., □I know the tiger is somewhere on the left side of the screen, though I□m not entirely sure if it□s here or there□).

In the broader context of perception and awareness, these results are important because they suggest that there may not be as much of a disconnect between introspective intuitions and empirical observations as is widely believed. Instead, the findings from this paper highlight how many of the contents of awareness may come in the form of probabilistic, statistical representations. This idea is thematically consistent with prior claims that many aspects of perceptual awareness are represented in the form of visual ensembles and summary statistics [9]. To drive this point home, consider the change blindness demonstration from Figure 1. While it may take a while to notice that every pillow has changed on the couch, that the Christmas lights have been turned on, and that the curtains have been drawn back, it is clearly not the case that you only see about three items at a given moment. Instead, you are aware of numerous items in the display, it is just that your awareness maybe somewhat imperfect, imprecise, and probabilistic. But as Wu and Wolfe write in the title of their paper, □Imperfect knowledge□is still knowledge□.

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