The target article goes a bit further in its conclusions, casting doubt on the importance of flexible pooling of sensory signals, a form of "early selection". I disagree on this point and would counter that adopting different pooling strategies is a necessary component of implementing the selected task. Depending on the task being performed, the subject may be obliged to pool sensory signals very differently to reach a task-appropriate decision. How these changes in pooling strategies are implemented is a fascinating and poorly understood topic, but there is compelling evidence that task-related feedback actively changes the statistical structure of neuronal activity in visual cortex (Bondy, Haefner, & Cumming, 2018). I would suggest that the alternatives presented in the conclusion of the target article are not mutually exclusive, but instead tightly linked.

There is also an argument to be made for "selection in the middle". In addition to interactions with the basal ganglia, ascending activity from the superior colliculus has an especially large functional effect in the middle of the visual cortical hierarchy, at a stage midway between the representation of basic visual features in early visual cortex and the representation of complex objects in late visual cortex (Bogadhi et al., 2019, 2021). By modulating processing at this middle point, this circuit connects the evolutionarily conserved midbrain mechanisms for fast selection of salient objects with the more recently evolved neocortical mechanisms for extracting detailed information about specific visual objects.

Extending this point about evolution, primates are not the first animals to possess something that can be identified as visual attention. We are understandably proud of our prodigious cortical forebrain, but the emergence of visual attention predates the evolution of the neocortex and involves specializations and extensions of much older forebrain and midbrain circuits (Krauzlis et al., 2018). We should be open to the possibility that understanding visual attention will require a fuller appreciation of how these complex circuits evolved and, even more germane to resolving disorders of visual attention, a fuller appreciation of how they develop and continue to undergo plastic changes even in the adult.

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Attention is doing just fine! Just don't take it too seriously

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Abstract

We do not share Rosenholtz's central worry that visual attention is in "crisis". There are many examples of notable progress in understanding how the brain prioritizes and gathers information about the environment where "attention," as a relatively loose concept, has worked well. We also discuss how focusing on a single definition, the field can be led astray.

While we agree with Dr. Rosenholtz on many points, we do not share her central worry that visual attention is in crisis. Notable progress has recently been made in understanding how the brain prioritizes and gathers information about the environment – where relatively loose definitions of attention seem to work just fine for various paradigms. Cueing studies, visual search, rapid serial visual presentation, ensemble perception, inattentional and change blindness, and other paradigms show how wide the reach of the concept is. Thinking about attention as 'one thing' or even 'a thing' with a specific operational definition may, in fact, dampen progress.

By focusing too narrowly on a particular definition of attention, the field can be led astray. For example, a very popular definition of visual attention was proposed in the two-stage, preattentive vs. attentive model, where feature integration (requiring attentional resources) is needed to find a target unless a particular item stands out in a 'feature map' (Neisser, 1963; Treisman & Gelade, 1980; Wolfe, 1998: see Kristjánsson & Egeth, 2020 for a historical overview).

This model is based on the highly popular present/absent visual search paradigm, and a key assumption is that search slopes of response times against distractor number can be used as a measure of to what degree attention is required for a given task. This logic has taken on a life of its own, however, used as a test of whether attention is involved in performing a particular task or not. If the slopes are around zero, it is often assumed that the target can be detected preattentively, while if search times increase with set size, an attentional spotlight moving between items in the search array is needed.

Note that this is simply a testable assumption about visual attention, and this model has been in trouble for a long time because of findings where it's central tenets are violated (e.g. McLeod, Driver, & Crisp, 1988; Nakayama & Silverman, 1986; Bravo & Nakayama, 1992; Santhi & Reeves, 2004; Schoonveld, Shimozaki, & Eckstein, 2007; Enns & Rensink, 1990; Wang, Cavanagh, & Green, 1994; Wang, Kristjánsson & Nakayama, 2005). Kristjánsson, (2015) showed that with a simple response change (from a present/absent decision to a Go/No-Go decision), search tasks with positive slopes had flat slopes. Nevertheless, the erroneous belief that visual search slopes determine whether attention is needed for a particular task persist (Kristjánsson & Kristjánsson, 2023). This shows how trying to pin attention down too narrowly might do more harm than good.

More generally, attention might simply does not need a specific definition. We do not find ourselves needing to define the term 'perception' in such a limited way, and attention can be discussed in a similarly broad and encompassing way. To paraphrase William James, everyone knows what we mean by "perception," and the same goes for attention as James originally stated. Problems arise when we seek single measures or definitions.

Despite a lack of clear definitions, considerable progress has been made in understanding the functioning of visual attention (Anderson et al., 2021; Kristjánsson, 2023). Rosenholtz discusses how summary statistics can be used to process the visual environment (Balas, Nakano, & Rosenholtz, 2009; Cohen, Dennett, & Kanwisher, 2016), referring to this as a paradigm shift. But this highlights another point where we both agree and disagree with Rosenholtz.

Research into summary statistics has taken many forms. Our work suggests that the idea of simple summary statistics, where rich data are reduced to only mean and variance (Whitney & Yamanashi-Leib, 2018), clearly underestimates how detailed representations of visual ensembles can be. Chetverikov, Campana, and Kristjánsson (2016, 2017a, 2020) used a classic attentional phenomenon – priming of pop-out (Maljkovic & Nakayama, 1994) – to test whether only simple summary statistics are encoded, but instead they found that people can quickly develop detailed probabilistic templates that guide attention and dynamically adapt to task demands. Even more interestingly, this attentional guidance accurately reflected the probabilistic nature of the input. Far more detail is therefore available in perception than simple summary statistics accounts propose (see, e.g., Chetverikov & Kristjánsson, 2024; Khvostov, Ásgeirsson & Kristjánsson, 2025).

Complex summary statistics, such as those in Rosenholtz's own work, computed with thousands of filters, can in contrast fall in line with the probabilistic template idea (Chetverikov & Kristjánsson, 2024). A summary representation created with the same statistics as those in Rosenholtz's Texture Tiling Model (Rosenholtz, Huang, & Ehinger, 2012) projected onto a single task-relevant dimension, such as orientation, can be represented as a noisy version of the true feature probability distribution (Chetverikov, Campana, & Kristjánsson 2017b).

Further progress comes with research showing how attentional templates are strategically learned or biased by perceptual and attentional history (Geng, DiQuattro, & Helm, 2017). For example, Witkowski and Geng (2019) demonstrated how the visual system prioritizes stable features over variable features. Won and Geng (2018) used a similar approach to demonstrate that so-called templates for rejection of distractors are more broadly tuned than target templates (since the latter require sharper tuning). Hansmann-Roth et al. (2022) showed how the tuning process leads to increasingly precise representations of target colour distributions. This work elucidates factors influencing the tuning of attention templates – again without a definition of attention.

Overall, this work provides important clues about how preceding probabilistic information about features and their reliability guides attention. All these insights about how the visual system picks up and learns the statistics of the environment are available without any precise definition of attention. Focusing instead on definitions of the tasks that observers perform and building computational models of their decisions (e.g., Chetverikov & Kristjánsson, 2022), following a long tradition of observer models in vision science, seem to be a more promising avenue, and here we applaud Rosenholtz's proposal.

In our opinion, visual attention research is in fine fettle and precise operational definitions are not needed. In fact, too precise operational definitions can be limiting, as examples from recent decades show.

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Attention is still a productive framework

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Abstract

The debate on attention's validity in cognitive psychology persists. However, attention remains essential beyond peripheral vision constraints, as it is a resource-limited process (Norman & Bobrow, 1975). The outright dismissal of attention proposed in the target article risks conceptual voids without superior alternatives. Instead, refining attention as a theoretical framework offers a pragmatic path for advancing cognitive research.

The concept of attention has come under scrutiny in psychology and neuroscience, with Rosenholtz and some other researchers advocating for its rejection as a meaningful construct in empirical research (e.g., Anderson, 2011, 2023, p. 202; Hommel et al., 2019). Critics argue that "attention" is too broadly applied, leading to ambiguity and circular reasoning. However, dismissing attention entirely risks discarding a framework that has driven significant progress in understanding cognition. Here, we challenge the notion that attention is an outdated or unnecessary construct and argue for its continued relevance as a pragmatic tool in cognitive science.

Is attention a redundant concept?

A major argument against attention as a theoretical construct is its purported redundancy. Critics claim that attentional effects can be explained through alternative mechanisms such as Bayesian decision processes (Anderson, 2011) or low-level constraints such as peripheral vision proposed by Rosenholtz. These perspectives suggest that empirical anomalies in attentional research result from misattributed causal mechanisms rather than failures in theoretical formulation.

However, this reasoning conflates explanatory adequacy with the overuse or misuse of the terminology. As Wu (2024) argues, attention should not be seen as an explanation in itself but rather as the effect that needs to be explained. Replacing attention with constructs such as "coarse-grained processing in peripheral vision" does not necessarily lead to greater precision in understanding cognition and behavior; rather, it shifts the label without resolving the underlying mechanisms. The assertion that attention is redundant assumes that alternative explanations are sufficiently comprehensive, yet they have not demonstrated the predictive