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Subjective inflation: phenomenology's get-rich-quick scheme

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How do we explain the seemingly rich nature of visual phenomenology while accounting for impoverished perception in the periphery? This apparent mismatch has led some to posit that rich phenomenological content *overflows* cognitive access, whereas others hold that phenomenology is in fact sparse and *constrained by* cognitive access. Here, we review the Rich versus Sparse debate as it relates to a phenomenon called subjective inflation, wherein minimally attended or peripheral visual perception tends to be subjectively evaluated as more reliable than attended or foveal perception when objective performance is matched. We argue that subjective inflation can account for rich phenomenology without invoking phenomenological overflow. On this view, visual phenomenology is constrained by cognitive access, but seemingly *inflated* above what would be predicted based on sparse sensory content.

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Introduction

There is a longstanding and currently lively debate about whether or not visual phenomenology overflows cognitive access (see recent themed issue of Philosophical Transactions of the Royal Society B [1–3,4•,5•,6,7•,8,9•,10••]). The question of phenomenological overflow is often rephrased as asking whether phenomenology is rich or sparse. On the Rich view, a snapshot of visual phenomenology is highly detailed across the visual field, while cognitive access is constrained to a subset of that detail given the limited capacities of attention, memory, and reporting mechanisms [2,11–19]. This view is supported by anecdotal reports from subjects in partial-report studies [18–20] in which they indicate having seen more of a given stimulus array than their objective task performance would suggest. The Rich view further posits, based on both partial-report and dual-task studies [9•,21,22], that attention is not necessary for phenomenology.

Proponents of the Sparse view argue, often relying on the results of inattentional blindness [23–25] and change blindness [26] studies, that phenomenology itself is constrained by, and thus scales with, cognitive access. For example, when subjects fail to notice a difference between two consecutively presented images at a minimally attended location, a Sparse interpretation is that there was insufficient phenomenological detail at that location for the change to be noticed. On this view, a snapshot of visual phenomenology is highly detailed around the focal point of attention where there is strong cognitive access, but loses detail as attention drops off in the periphery, where there is minimal cognitive access [3,4•,5•,27–31]. Furthermore, on this view, phenomenology and cognitive access tend to scale with attention, though this relationship is not necessarily monotonic. Importantly, proponents of this view argue that, without consensus on an operational definition of attention, we cannot definitively claim that attention is not necessary for phenomenology [28,29,32].

It has been suggested that the debate about phenomenological overflow, and by extension, the Rich versus Sparse debate, may be empirically intractable [7•,8,27–31,33,34]. The major issue usually raised is that while empirical studies of phenomenology fundamentally rely on subjective reports, unaccessed phenomenology is, by definition, unreportable. And if unaccessed phenomenology cannot be detected, its presence neither confirmed nor denied, then the results of any given study can be interpreted as being consistent with either the Rich or the Sparse view [4•,6,7•,8,28,29,33].

A classic experiment that combines the retrocuing paradigm made famous by George Sperling [18] with a change blindness paradigm [20] provides an example where such alternative interpretations are available. Participants were shown two consecutive arrays of eight rectangles, where each rectangle could be oriented either vertically or horizontally. The subjects' task was to detect whether one of the rectangles switched orientations between the first and second arrays. Because subjects were instructed

to initially fixate at a central point that is roughly equidistant from the locations of each of the rectangles in the to-be-flashed arrays, attention was thought to be diffuse and minimal with respect to each individual object in the first array. The authors found that when a retrocue indicating the location of the object whose orientation could potentially change was presented after offset of the first array, but before onset of the second array, performance on the change detection task was better than it was when no retrocue was presented.

On a Rich interpretation of this result, the orientations of the minimally attended rectangles in the first array are present in phenomenology, and the postcue allows participants to access and remember the orientation of the cued rectangle before that information can be overwritten by the second array. In this case, a failure in change detection amounts to a failure of memory. On a Sparse interpretation, orientation information for each of the minimally attended rectangles is represented unconsciously, with the resulting phenomenology being filled-in and/or summarized. Retrocued attention then makes the initially unconscious orientation information for the cued object available for report. On this interpretation, a failure in change detection amounts to both a failure of phenomenological representation and a failure to access the relevant unconscious orientation information before onset of the second array. Because subjects' behavior could be identical under both views, neither interpretation is obviously more tenable than the other.

A similar problem arises when trying to address more directly whether attention is necessary for consciousness. A common way to test this is to try to demonstrate that some task can be performed in the absence or near absence of attention, for example using a dual-task paradigm [9•,21,22,35•,36]. But again, without a working operational definition of attention, it is unclear how the complete elimination of attention could be unequivocally demonstrated in an experimental setting. Some have argued that this similarly makes the debate about the necessity of attention empirically intractable [28,29,32].

In light of these concerns, Ned Block has suggested that currently the best approach to the Rich versus Sparse debate is to consider the extant empirical evidence and use inference to the best explanation [12,37]. Here, we agree with Block's methodological appeal. We highlight an approach that, instead of attempting to investigate visual phenomenology in the complete or near-complete absence of attention, exploits the fact that attention is graded, and investigates the *interaction* between attention and phenomenology. Such an approach consistently reveals a phenomenon known as *subjective inflation*, wherein study participants exhibit liberal detection criteria or are overly confident when evaluating minimally attended or peripheral stimuli [10••]. We argue, in line with Ref. [10••], that this can explain the subjective impression of richness across the visual field appealed to by Block [12], while accounting for both behavioral [23–26] and physiological [38,39] limitations in minimally attended perception, all without invoking phenomenological overflow.

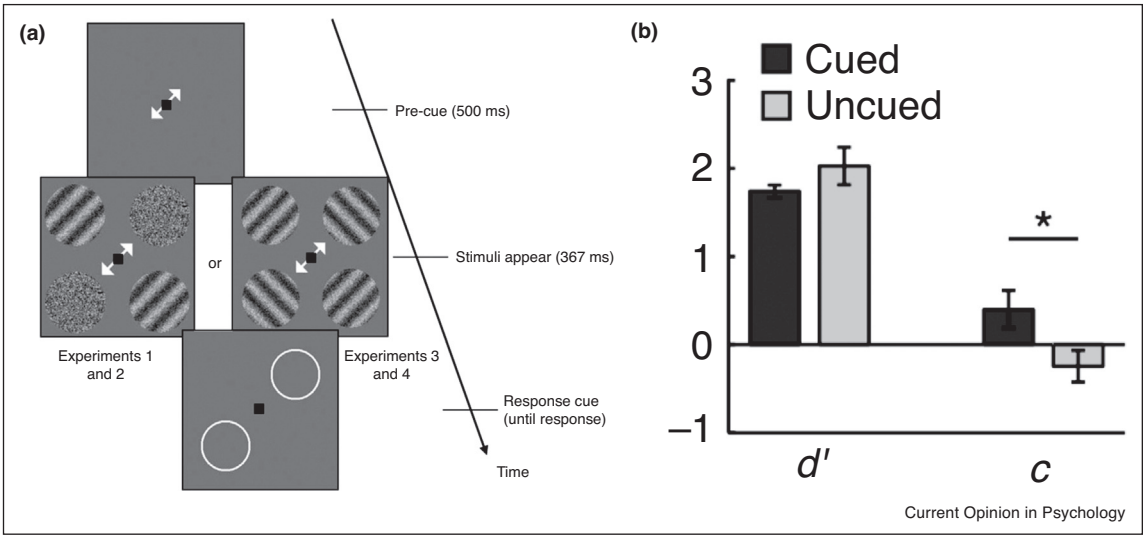
Empirical evidence for subjective inflation

It is well established that attention boosts objective perceptual performance [40]. It has also been shown that subjective and objective measures of perception can be dissociated in clinical cases of blindsight [41,42], as well as in normal observers [43]. It follows that if we want to isolate a subjective measure of phenomenology for comparison between conditions of low and high attention (or low and high retinotopic eccentricity), then objective task performance should be treated as a potential confound and matched between those conditions [44].

Rahnev *et al.* [45] employed the strategy described above by matching objective performance, as indexed by the signal detection theory (SDT) sensitivity measure, d' [46], between attended and minimally attended conditions in a visual detection task (Figure 1). They found that the SDT criterion measure, c, was systematically more liberal in the minimally attended condition (Figure 1b). On a detection task, a lower value of c equates to a higher proportion of trials in which the observer incorrectly reports the presence of the target stimulus, i.e., a higher false alarm rate [45, Supplementary Fig. 3]. This difference in false alarm rate between attended and minimally attended conditions is of particular note given that stimulus strength is matched (at zero) across all false alarm trials.

One could argue that the observed shift in criterion reflects a change in non-perceptual decisional bias [47]. However, we interpret this shift to reflect a genuine change in subjective perception, as it was robust to trial-by-trial feedback and increases in monetary rewards, manipulations that are thought to minimize non-perceptual response biases [45,47,48]. On this interpretation, the observed criterion shifts in Ref. [45] suggest that subjective awareness is systematically *inflated* relative to objective processing capacity in conditions of minimal attention. It is worth emphasizing that this effect may seem, at least initially, to be counterintuitive: despite performance matching, one might reasonably expect that when attention is reduced observers might be more conservative in their detection judgments. This could be due to prior knowledge that, under normal conditions, unattended vision is relatively poor. However, we observe the opposite: given matched objective capacity, when attention is reduced, participants are more likely to say something is there when it is not.

Figure 1



An empirical demonstration of subjective inflation from Ref. [45]. **(a)** Stimuli and task. Each trial was initiated by a pre-cue that indicated to which diagonal (top–right and bottom–left or top–left and bottom–right) the subject should attend. This was followed by a stimulus array, in which each diagonal (independently) contained either a set of tilted gratings embedded in noise or noise alone. This was followed by a response cue, which prompted the subject to indicate, in a forced-choice manner, whether or not the diagonal in the stimulus array indicated by the response cue had contained a set of gratings. The pre-cue and response cues were congruent on 70% of trials. **(b)** Behavioral results show matched detection sensitivity, d', between cued and uncued conditions, but a more liberal criterion measure, c, in the uncued condition relative to the cued condition. Reprinted with modifications and permission from Ref. [45].

This inflation effect has been replicated and extended in several independent studies. One study found a consistent decrease in detection criterion in peripheral vision compared to central vision despite matched detection d' [48]. This effect was again robust to trial-by-trial feedback. Similarly, in a study that was not designed to test inflation, more liberal change detection criteria were observed for fragile visual short term memory compared to working memory, despite matched change detection d' between the two conditions [49]. The authors interpreted this as being analogous to the inflation effect in Ref. [45], as there was presumably higher attention in the working memory condition. Another study, which used a relatively naturalistic setting of simulated driving, found more liberal criteria for detecting the color of a simulated pedestrian's shirt when attention was minimized [50]. In a control experiment in which the identity of the detection target (the color to be detected out of a set of 11 colors) was not revealed until *after* presentation of the target stimulus, the inflation effect was no longer present. This suggests that the observed criterion shift in Ref. [50] was not due to simple confirmation bias, which, much like the trial-by-trial feedback results in Refs. [45] and [48], indicates that the observed inflation effect was perceptual as opposed to decisional.

Inflation was also recently observed in both peripheral summary statistics and crowding tasks [10••]. In the latter task, inflation was indexed by an increase in confidence ratings on incorrect trials for crowded compared to uncrowded stimuli. Surprisingly, this effect was observed despite discrimination d' being *lower* in the crowded condition. Also recently, an inflation-like effect, similar to the flashed face distortion effect [51], was found in which repeatedly flashed peripheral color stimuli were rated as more saturated than physically saturation-matched, non-flashing central color stimuli [52]. Further, an inflation-like effect has been found in which subjects failed to notice drastic changes in peripheral text during reading [53].

Inflation and the richness debate

To see how inflation fits into the Rich versus Sparse debate, it is helpful to consider that phenomenology tends to *feel* rich. For example, in the case of the famous Sperling retrocueing experiments [18], participants indicated, anecdotally [4•], that they felt as though they saw all of the characters in a briefly flashed 3×4 array in detail, despite not being able to report all of that detail after the fact. Proponents of the Rich view traditionally take these reports at face value and assume that this detail was indeed phenomenologically represented outside of focal attention, albeit in a fragile and fleeting manner. It is worth emphasizing, however, that in many partial-report studies these reports of global richness are not systematically collected per experimental procedure, and instead come from retrospective subjective impressions [4•,18–20]. And it is possible that such

retrospective reports result from a demand effect [54]. However, for the sake of argument, we take these reports at face value here.

The Sparse view, on the other hand, suggests that what is phenomenologically represented outside of focal attention is gist-like, a summary representation of low level features [4•,28,55••]. There is evidence for this view from studies in which nonsensical or dramatically homogenized alphanumeric characters in peripheral vision go unnoticed [53,56], and studies in which participants cannot subjectively distinguish between physically distinct images that are matched for low-level image statistics [57,58]. Yet, a proponent of the Rich view might argue that, despite these studies, non-focally attended phenomenology does not *feel* summarized or homogeneous, so there is still something left to be explained. In other words, if the Sparse view is correct, why is introspection so mistaken?

We suggest, in line with Ref. [10••], that this mistaken feeling of richness is the result of subjective inflation. If partially summarized, minimally attended representations are subjectively inflated above what would be expected based on objective processing capacity, as in the examples above, then inflation can explain the apparent richness of the resulting phenomenology despite well-established physiological limitations in minimally attended and peripheral visual processing [38–40].

The exact mechanism of inflation here may be unclear (but see Refs. [10••,45,48]). Still, the very occurrence of inflation provides an explanation based on an operationally defined comparison between attended and minimally attended phenomenology. And that explanation is neutral as regards the more difficult and possibly empirically intractable issues surrounding the overflow argument. Therefore, a combination of summary statistics and subjective inflation arguably provides the best explanation of the subjective phenomena that advocates of the Rich view appeal to. Since this view incorporates both the relevant behavioral data and anecdotal reports of richness, which may well be illusory [28], we suggest that it constitutes a position intermediate between the Sparse and Rich views.

This inflation account is consistent with behavioral results observed in several additional studies of peripheral or minimally attended vision. For example, inflation appears to be similar to perceptual filling-in [10••,59]. A recent study found that filled-in percepts at the blindspot are rated as more reliable than perceptually equivalent, but externally veridical percepts [60]. This shows a similar pattern to inflation in which a percept that is based on a less veridical representation of the external world is actually granted a subjective boost. This leads to the question of whether filling-in at the blind-spot and inflation share a common mechanism. If so, then we might also expect the mechanism that underlies known cases of peripheral inflation [48,50,52] to underlie instances of peripheral filling-in like in the 'uniformity illusion' [61] or in the case of peripheral color in natural scenes [62]. Presumably, such questions are empirically tractable. For example, future studies could combine an approach similar to Ref. [60] with the performance-matching strategies described above, e.g., [45,48], to see if subjective judgements about filled-in percepts are, operationally speaking, inflated relative to judgments about veridical percepts.

Additionally, as the peripheral filling-in examples above are presumably driven by an *expectation* based on foveal perception, inflation similarly appears to be influenced by expectations based on prior knowledge. For example, the control experiment in Ref. [35•], described above, suggests that the content of inflation depended, at least in part, on an expectation about a specific color. This is consistent with the studies mentioned above in which participants failed to notice manipulations to alphanumeric characters during partial-report [56] and reading [53] tasks. It is also consistent with the result that stronger filling-in effects were observed when the to-be-filled-in content of a natural scene percept was colored compared to when it was grayscale, presumably based on the prior knowledge that natural scenes contain color [62]. Similar prior expectation effects based on central visual information have been shown for peripheral motion perception [63] and peripheral object recognition [64].

This reliance on expectation supports the important partial awareness hypothesis put forth by Kouider *et al.* [28,65], and suggests that inflation may underlie cases in which expectation influences minimally attended phenomenology [50,53,56,62]. One benefit is that expectation is an easily manipulated experimental variable; thus, the influence of expectation on minimally attended phenomenology should also be amenable to empirical investigation going forward. For example, one prediction is that inflation should be stronger when expectations are higher. Here, we take expectations to be functionally different from attention in that they depend on the predictability of the stimulus. Experimentally, attention and expectation could be manipulated separately, for example, by telling a subject to attend to location A, where the statistical likelihood of a detection stimulus appearing is known to be low relative to location B [66]. If inflation depends critically on expectation, then we should expect inflation effects to be stronger when the subject attends to location A compared to when they attend to location B.

We therefore propose that the content of inflated phenomenology can be affected by at least 3 factors: first, summary computations of minimally attended and/or

peripheral low-level visual features [31,55••,57,58], second, expectations based on attended and/or foveal representations [61–64,67,68], and third, expectations based on prior knowledge [53,56,62,64]. In the case of prior knowledge, it is a topic for future investigation whether this knowledge needs to be explicit, or if it can be implicit (e.g., as in implicit statistical knowledge found in visual search [69]).

Conclusion

We have argued that subjective inflation may explain the apparent introspective content that the Rich view assigns to minimally attended and peripheral phenomenology. It can explain why phenomenology may appear to overflow cognitive access, without countenancing actual overflow. By denying overflow but explaining why it seems to occur, inflation provides an intermediate position between the Rich and Sparse views that borrows and extends ideas from the partial awareness [28,65] and summary statistics hypotheses [55••]. On this position, minimally attended phenomenology is built on summary representations [55••], the subjective reliability of which is inflated above what would be predicted based on objective performance. This operationally definable effect is likely based on prior expectations [28,50,53,56,62,65]. So phenomenological richness need not be seen as mapping onto high representational capacity, as the traditional Rich view claims to be the case in early visual cortex [11–14]. Rather, inflation supports strong physiological evidence that peripheral representational capacity in early vision is limited [38,39], and suggests that our exaggerated sense of rich peripheral phenomenology is mediated by some later stage prediction-based mechanism [67]. The neural basis of this mechanism is a topic for future investigation, but at this point, it seems to be at odds with the multi-level overflow account offered by proponents of the Rich view [11]. One prediction along these lines is that when comparing false alarm trials to correct rejection trials for minimally attended stimuli in a visual detection task, the decodability of illusory, inflated perception should be high in later stages of the visual processing hierarchy, but not in primary visual cortex [67]. Furthermore, if expectation-based inflation effects are mediated by top–down feedback to visual areas [70], then this should be reflected in the relative timecourses of decodability between fronto-parietal areas and visual areas. This prediction could be tested with a time-sensitive imaging method like magnetoencephalography (MEG).

Finally, one interesting consideration is that whether the inflation hypothesis really favors one side of the richness debate over the other may ultimately depend on the extent to which proponents of the Rich view categorize illusory percepts as instances of 'rich' phenomenology. Indeed, Block [71] and others [17, p. 1395] have conceded this point, for example, acknowledging that 'a minor illusion effect,' [71, p.5], as in Ref. [56], can still be consistent with the Rich view. Whether the majority of the results discussed here would constitute such minor illusions is a topic for future discussion; though it is worth pointing out that the more the Rich view sees such illusion effects as constituting 'rich' phenomenology, the more the dividing lines between the Sparse and Rich views will blur. Most importantly, we hope that the issues raised here in connection with inflation will stimulate new ideas about how to approach the puzzle of phenomenology, ultimately giving the field more useful data for resolving, or perhaps *dis*solving, the richness debate.

Conflict of interest statement

Nothing declared.

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- •• of outstanding interest

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