4
Untouched Raw Feels?

4.1 Speckled Hen

A well-known philosophical puzzle concerns a speckled hen (Chisholm 1942). Imagine looking at one. Within just half a second, you can probably already see that the bird is speckled. Let's say you close your eyes from there. If I ask you to describe the speckle pattern, you may be able to say: it is lightly speckled, somewhat regular. Perhaps it is less speckled than another bird you just saw earlier. The pattern is somewhat even. There's not a missing patch in one particular place.

So you seem to have perceived a fair bit of detail. But did you see every single speckle? That seems improbable. You didn't attentively *look* at every speckle, as if you were counting them. That would have taken much longer than half a second. But if you saw the hen as evenly covered in speckles, perhaps you didn't *miss* any speckle either. So let's pick a particular speckle. Did you see it or not? Can you answer that question with any degree of certainty?

There are very many variants of this puzzle, and they have exercised the imagination of philosophers and scientists alike for centuries. As in the problem of the neural correlates of consciousness, Matthias Michel conducted a masterful review of the historical literature (2019), tracing the origin of the puzzle back to the nineteenth century.

The puzzle concerns the relationship between attention and the subjective experience of perception. Do we need to attentively look at something to have a subjective experience of seeing it? Or can subjective experience occur without us even *noticing* the relevant events?

This is the second of the five core issues outlined in Chapter 1. As you will see, our answer to this question may not be as conclusive as our answer to the first issue. Fortunately, what we have already learned from the first issue may ultimately inform us here.

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4.2 Iconic Memory

In the modern empirical literature, many relevant experiments employ Sperling's "post-cue" procedure (1960). In this kind of experiment, we usually present an array of 12 letters to subjects, organized as three rows of four letters each. Let's say we only flash these 12 letters on the screen for half a second. If we ask subjects to report all the letters, they can probably only get the first few right. But it would be premature to conclude that subjects can only see a few letters, rather than all 12. That's because, even if all of the letters are recognized during the presentation, subjects may be already forgetting some letters while reporting the first few. In other words, the bottleneck may be reporting and memory, rather than seeing.

So Sperling (1960) presented a tone right *after* the letters disappeared, to tell the subjects which row of letters they had to report. A high pitch meant that subjects had to report the top row, a middle pitch the middle row, and a low pitch the bottom row. This way, subjects could do the task almost perfectly: they could often report all four letters correctly, in *any* of the rows post-cued. This suggests that reporting and memory are indeed the bottleneck. Most of the 12 letters, rather than just a few, were visually processed in the brain, even at this brief presentation (Figure 4.1).

One interpretation would be: this supports the local view. According to the view, subjective experiences arise at some early high-capacity stage, possibly locally within the early visual areas. So that stage may have all 12 recognized letters represented. Attention only limits the capacity for late-stage read out. Without directing our selective attention with post-cuing to a particular row, we cannot report *all* of the letters in the array. But, all the same, all 12 letters were at some point consciously represented. Ned Block describes this interpretation as phenomenological overflow (2007). That is, our subjective experience is richer in details than what we can cognitively access.

F C H D

J R P O

D N B A

Figure 4.1 An example array of 12 letters presented in the Sperling experiments

However, this is not the standard interpretation of these findings in vision science, and perhaps for good reasons. Sperling himself (1960) was careful to call the putative early stage high-capacity storage "iconic memory," without stipulating so strongly that it has to be conscious. As we have learned from the previous chapters, one lesson from blindsight is that being able to report certain visual content does not necessarily imply consciousness. What the Sperling experiments showed is that we have the relevant information for all 12 letters represented briefly. But this doesn't necessarily mean we consciously saw them all in detail.

Indeed, there is some evidence that if we replace some letters in an uncued row with some non-letter symbols, subjects may not notice (de Gardelle, Sackur, and Kouider 2009). So the global theorists can very well argue that the subjects only consciously saw 12 letter-like symbols arranged on a 4 × 3 grid. The conscious recognition of specific letters may only happen at the time of post-cuing, and only for the specific row cued. But as we will discuss next, this view runs into problems too. So this debate is very much ongoing.

4.3 Is Attention "Necessary"?

It may be tempting to formulate the debate as one about whether attention is *necessary* for consciousness. In these terms, the global theorists say that attention is necessary, which the local theorists deny. This is more or less right. The global theorists deny that we consciously see all 12 letters as specific recognized letters, or every single speckle on the hen individually. That's because within a brief presentation we do not have time to attentively look at them one-by-one. Without attention, early sensory information may not be able to enter the central workspace and, therefore, remains nonconscious. The local theorists maintain that attention is only needed for reporting or cognitive access, but not for subjective experience to arise.

But by now the reader should be aware that the notion of "necessity," as applied to cognitive neuroscience experiments, is often misleading and confusing (see Sections 2.3, 2.4, 3.2, and 3.11). Some relevant experimental findings may help to drive this point home.

In Ulric Neisser's classic experiments on the phenomenon of "selective looking" (Neisser and Becklen 1975), subjects were told to pay attention to some specific events, like the number of times some players pass the basketball to their teammate (wearing the same jersey). While the basketball "game" was happening, irrelevant but noteworthy events could happen, such as a person holding an open umbrella walking slowly through the scene. Many subjects entirely missed these surprising events, as they were absorbed in counting basketball passes. There are many variants of this phenomenon, some famously involving a person in a gorilla suit doing a wiggle dance, rather than a person holding an umbrella (Chabris and Simons 2010). These are also sometimes called inattentional blindness experiments.

On the face of it, these findings may seem to support the global view. That is, when attention is directed elsewhere, one seems to be completely unable to notice these remarkable events. But the localists can point out that not all subjects missed the events. Also these may be exceptional situations. There may be some other tasks where the subjects were able to detect some events in the periphery while they were also occupied by the main task (Li et al. 2002). So, attention may be needed for some subjects, in some situations, to detect some stimuli. But not always. Attention is, therefore, not strictly necessary.

But how do we know whether the subjects' attention was sufficiently occupied by the central task, in any of these cases? The trouble is, attention, like many constructs in cognitive neuroscience, is not directly measurable. Therefore, the strategy of trying to occupy it *completely* to test for necessity may not be as straightforward as it seems. This is not to say these findings are anything short of amazing. But for the purpose of arbitrating between the global and local views, we may also need to consider the relationship between attention and subjective perception in more general terms.

4.4 Load Theory

Concerning the general relationship between task demand and perception, few ideas are as relevant and important as Nili Lavie's Load Theory of Attention (2005).

Over half a century ago, at the beginning of cognitive science, there was a classic debate on the role of attention in perception (Driver 2001). The early selectionists held that attention acts like a filter, blocking out unattended stimuli before their meanings are processed. That is, the simple physical properties of a stimulus, like the volume or pitch of a sound, may be preattentively processed. But to understand the meaning of an utterance, or the identity of a word or letter, we need to pay attention. The late selectionists, on the other hand, said that unattended stimuli are also processed at deep levels. When subjects fail to report certain unattended stimuli, the late selectionists argued it may be a failure of memory rather than perception.

Lavie's load theory beautifully resolved the debate. The idea is that our brain adopts different selection strategies depending on perceptual demand. When the perceptual task at hand is difficult, such as having to make decisions based upon multiple features of a stimulus rather than detection of a single feature, we are said to be under high perceptual load. Under such high perceptual load, naturally, the brain needs to filter stimuli out early to avoid congestion. On the other hand, under low perceptual load, the brain may adopt a late selection strategy, because it can afford to do so.

Much of the supporting evidence for Load Theory comes from behavioral studies (Lavie 2005). But in some experiments, functional magnetic resonance imaging (fMRI) was employed to assess how perceptual load at a central task may impact the processing of some peripheral, task-irrelevant stimuli (Schwartz et al. 2005). As predicted by the theory, under high load, there was less brain activity associated with the processing of task-irrelevant stimuli, as if such stimuli were filtered out early on. Interestingly, this effect was observed as early as in V1 (the primary visual cortex), where neurons respond to specific orientations of line segments, among other low-level features. This means that when the perceptual task is challenging enough, attentional filtering may happen even earlier than early selectionists suggested. It seems to take place before the processing of "meaning," as object identity is typically thought to be represented in area IT (inferotemporal cortex), well after V1 processing.

4.5 Post-Cuing Impacts Early Sensory Activity

To put this back into the context of Sperling's post-cue experiments, we can consider some elegant findings by Claire Sergent and colleagues (2011). These experiments employed a similar post-cue procedure. But instead of using letters as stimuli, the authors presented some simple abstract stimuli known as Gabor patches (see Chapter 2, Figure 2.1). The processing of these stimuli is reflected by activity in early visual areas, such as V1 and V2 (another early visual area).

The subjects had to report the orientation of these Gabor patches. Post-cuing improved task performance, as expected. Critically, the authors also found that post-cuing modulated activity in V1 and V2. That is, for early visual regions that are specific to the retinotopic location of a Gabor patch, there was more activity when the relevant Gabor patch was post-cued, as compared to when some other Gabor patch in a different location was post-cued. One may wonder: does this mean that the activity for post-cued stimulus was enhanced, or the activity for uncued stimulus was reduced? The answer is probably both. Given the ubiquitous nature of lateral competition within a cortical circuit, when some activity is enhanced, the nearby activity tends to be dampened (Carandini and Heeger 2011).

This seems to make the simple story favored by local theorists rather implausible. The story is that there is a high-capacity storage mechanism in early sensory areas. Attention does not change its activity, but only limits its readout by a late-stage, low-capacity access mechanism. So if subjective experience happens in these early sensory areas, attention is not that important. But trouble is, attention actually changes these early activities, measurable in direct neuronal recordings too (Treue 2001).

Perhaps the localist can argue that these changes in visual activity by attention are not essential for subjective experience. They only happen after the conscious recognition of the stimuli. But together with the evidence in support of Load Theory reviewed in the Section 4.4, this seems somewhat unlikely. These attentional gating effects on early sensory areas seem functionally important for perception itself. Also, because of the phenomenon of lateral competition mentioned earlier, it is likely that after post-cuing, the uncued stimuli are no longer accessible—all due to local competition with the visual areas rather than late-stage access limitations in, for example, the prefrontal cortex.

4.6 Apparent Richness

So, some problems with the local view have now been highlighted. But the global view is not so appealing either, especially regarding how it can accommodate the phenomenology of perception. In part, the problem is that attention is known to have a limited bandwidth (He, Cavanagh, and Intriligator 1996). If attention is the bottleneck for information entering consciousness, as global theorists suggest, it would be hard to account for the apparent richness of experience.

This point can be appreciated when we consider cases of "selective looking" (i.e., inattentional blindness). Suppose we are one of those subjects who missed the person carrying an opened umbrella, or the gorilla. Our attention is supposed to be focused almost entirely on the basketball passes. And yet, the background at no point looks as if it fades out. Instead, it *seems* to be there, rich and stable—that is why missing the gorilla is so surprising to us. Just how do we account for that appearance of richness? This is a real problem because when it comes to subjective experience, how it *seems* matters.

Local theorists appeal to this richness of appearance too. Block argues that this subjective richness is supported by anecdotal reports from subjects. In turn this "meshes" with the high capacity of early sensory processing (Block 2007). Turns out, these self-reports on subjective richness are far from universal. When asked systematically, many subjects did not report the kind of richness described by local theorists (Cova, Gaillard, and Kammerer 2020).

But let us grant the localists the point that *some* subjects may indeed find perception to be subjectively rich. The problem is that even for these subjects, early sensory representations are modulated strongly by attention, as pointed out earlier in Sections 4.4 and 4.5. Even when you are attending to the same spatial location, these representations are modulated by perceptual load. But to the extent that one claims to have a subjective impression of richness, this impression seems relatively *stable*. A subtle change in the perceptual task does not seem to change this overall impression so much. And yet the early sensory activities are known to change reliably. In this sense, Block's "mesh" argument may actually backfire.

4.7 Too Much Overflow

The last point about backfiring can be further illustrated by a study conducted by the local theorists themselves (Sligte et al. 2010). In the original Sperling experiment, the post-cue was effective up until about half a second after the stimulus array disappeared. Experiments from Lamme's lab have often reported longer effective periods for post-cuing (Landman, Spekreijse, and Lamme 2003). This is likely because they cleverly modified the task into change detection. So in these studies, there was a first array of some items. After a delay, another array was presented, in which one of the items might have changed. Instead of reporting the identities of the items, the subjects only had to report whether there was a change of items between the two arrays in a specific location (indicated by a spatial post-cue *not* shown in Figure 4.2). Under this setup, the post-cue, presented after the offset of the first array, tended to be effective for longer, up to a whole second or more before the onset of the second array.

But a successful detection of change does not necessarily mean that one consciously saw the item in the first array. It could be driven by a hunch that the item in the second array looked somewhat novel, or that there might be some hint of motion or flicker between the arrays. To verify that, Sligte et al. (2010) presented four items to the subjects after there was a change, and asked subjects to identify which one was the prechange item from the first array (Figure 4.2.). A correct identification would indicate that the subject saw the prechange item with at least some detail at "high resolution." Based on the

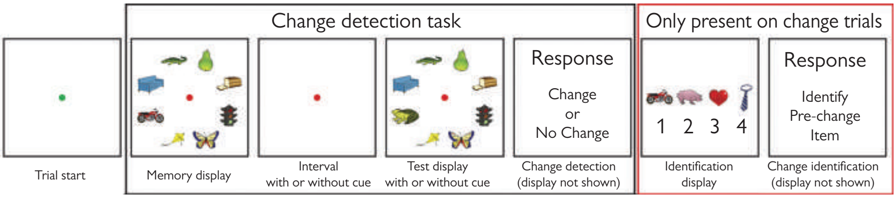

Figure 4.2 The change detection task used by Sligte et al (2010)

Reproduced from Sligte IG, Vandenbroucke ARE, Scholte HS and Lamme VAF (2010) Detailed sensory memory, sloppy working memory. *Front. Psychology* 1:175. doi: 10.3389/fpsyg.2010.00175. This is an open-access article subject to an exclusive license agreement between the authors and the Frontiers Research Foundation

subjects' performance levels, Sligte et al. calculated that "most" items (71%) post-cued in the way described above were perceived at this high resolution.

One could still quibble about the logic of this claim of "high-resolution" perception. Perhaps one does not have to see the prechange item (i.e., from the first array) so clearly to distinguish it from three other items, especially if the items were colorful. Sligte et al. took care to address this point and reported that for gray-scale-only items, successful postchange identification was at 68.8%. One could further argue that even low-resolution perception could support some level of above-chance performance in this four-choice discrimination task. But overall, many have found this to be convincing evidence for perceptual richness in this task; as of 2021, the paper has been cited over 100 times.

Unfortunately, it turns out there was a simple error in Sligte et al.'s calculation. The details are probably not important, but for those who are interested: the authors calculated the number of items perceived at "high resolution" by first calculating Cowan's K (Cowan 2001) for the change detection task (i.e., the average number of items for which a change can be successfully detected), and then multiplying this number by the percent correct score on the prechange identification task. The error here is in not taking into account the fact that chance performance on a four-alternative forced choice (4AFC) task is 25%. Therefore, by their calculation, even chance performance on the prechange identification task would yield a nonzero capacity for the number of high-resolution items. This error can be roughly corrected by normalizing prechange identification percent correct scores by subtracting 25% and dividing by 75%, and then multiplying the resulting normalized score by Cowan's K on the change detection task.

If we correct for that error, the percentage of items supposedly perceived at "high resolution" was only 58.4% for gray-scale items. This is close to what they previously reported (erroneously, from the same error) as the percentage for ordinary working memory (55.0%), assessed in a similar condition without post-cue between the arrays. Prior to the realization of that error, the authors described this range of performance as "sloppy" (from the very title of the article).

So, is the conscious perception of the briefly presented array of items actually "sloppy"? Or is it so rich that it apparently overflows access? Simple errors of the kind made by Sligte et al. are not uncommon in science. My intention here is not to be petty about what is clearly an honest mistake; I myself have no doubt made a countless number of them. But the point is, local theorists have accepted the logic and interpretation of these experiments. If they found the previously reported findings to be exactly congruent with their subjective impression, then this error means that their impression was actually *incompatible* with the data.

4.8 Summary Statistics and Peripheral Vision

In addressing this problem of apparent richness, one solution favored by some global theorists is to think of our representation of the unattended background as a summary (Cohen, Dennett, and Kanwisher 2016). So, instead of representing individual trees in a natural scene background, one may just represent something like: "a bunch of trees of a certain type." Obviously, this does not have to be in the form of a noun phrase as used in natural language. It may contain quantitative information representing the statistics too (e.g., roughly how many trees, the average size, variance, and spatial frequencies of the image). Or it can capture the "gist" of the scene, invoking some complex schematic representations. In fact, this is more than just an idea. This is an active area of vision research with ample empirical support (Alvarez 2011; Rosenholtz 2020).

This is likely how we actually represent things outside of our attentional focus. But it is not clear how this reflects the phenomenology. Some readers may find it odd, too, to think that we consciously see the unattended background as some summary statistics or a gist. At least that isn't introspectively obvious. Instead, some of us may *feel* that one sees the visual world as relatively uniform with details. Perhaps we don't actually represent those details in a picturesque fashion. But all the same, we need an account for why at least some naive subjects feel they do.

This is not to deny that central foveal vision—usually our focus of attention—is subjectively clearer and more vivid. But as one moves away from the fovea toward the visual periphery, the gradient does not seem to fall off as dramatically as the anatomy and physiology of early vision would suggest. Recall from our middle school biology class that the color-sensitive cone cells on the retina are mostly concentrated around the foveal area. And most of our early vision neurons also have receptive fields around the central region. As we move into the periphery, the receptive fields get larger. Roughly, this means our spatial resolution is poorer there. Of course we have *some* color sensitivity and spatial resolution in the periphery. But empirically we seem far poorer than we intuitively think we are (Cohen, Botch, and Robertson 2020).

This seems to create a difficult challenge for both local and global theorists. We just don't seem to have as much visual detail as we feel we have—perhaps anywhere in the brain—because it is missing from the very beginning, sometimes as early as from the retinal level.

Some localists have argued that the paucity of color vision in the periphery may be exaggerated. For example, Block (2019) cited the fact that if we enlarge the stimulus for the periphery, it would look just as colorful as the central stimuli (Tyler 2015). But trouble is, in everyday life, things don't enlarge themselves for our convenience as they enter our peripheral vision. So for a normal, natural stimulus of a constant size, its color would be harder to discern as it moves away from our fovea. And yet, the ordinary, untrained observer tends not to be fully aware of this limitation.

4.9 Inflation

Perhaps the answer to the puzzle of apparent richness is that the details are never represented as such—neither in explicit nor compressed summary forms. Instead, we just *interpret* the sensory representations *as if* they are rich in detail, even when they are not (Knotts et al. 2019). This may not be such a misleading kind of misinterpretation in the end, because the details are actually out there in the world, often just one shift of gaze or attentional focus away. So this may be somewhat like the light inside the refrigerator: because whenever we check it, it is on, we may mistakenly think it is always on (Kouider, de Gardelle, and Dupoux 2007). We can call this an *inflation* account. That is, the richness of a perceptual representation may be overinterpreted or somehow exaggerated at a later stage.

When I say "we" interpret the sensory representation, I do not really mean that we, as people, have to decide to do this with effort. Instead I am referring to some subpersonal, automatic mechanism that is an integral part of the perceptual process itself. This is congruent with the long-standing view in vision science that there is always a decision-making component in perception. It is also true that a person can make postperceptual decisions based on what one learns from perception; I can see an apple and decide to not report it as an apple. But here perceptual decision-making refers to what is part of perception itself. Suppose some neurons are firing in your primary visual cortex. Some process is needed to decide what the neuronal activity really represents: it could be baseline noise, or it could reflect a meaningful signal. Without this process, perception just isn't complete. Inflation is hypothesized to take place at this level of subpersonal perceptual decision-making.

Likewise, inflation can happen at the perceptual metacognitive level too. But this is again not to be confused with the kind of metacognition that involves a person explicitly trying to think about oneself and one's thoughts. It refers to the automatic, subpersonal process of monitoring how well a certain perceptual process has gone. The selective looking (i.e., inattentional blindness) examples help illustrate this point. When we miss the unexpected events, we not only miss it but are also extremely surprised. That's because, based on the perceptual experience itself, we fully expect to be able to see such events. This expectation seems to be formed automatically. Without much effort of introspection, we already "think" we see more than we really do. Perhaps inflation takes place at this subpersonal level too.

There is a fair bit of empirical evidence to support the inflation account. At the perceptual decision-making level, subjects detect stimuli at a less attended spatial location with a more liberal bias. Surprisingly, this happens even when sensitivity for the attended and unattended locations were matched. That is, under relative lack of attention they say they see the stimulus more often, leading to more hits (correct detection), as well as false alarms (apparent "hallucinations," i.e., alleged detection when the stimulus was not really there). This phenomenon was discovered by Dobromir Rahnev, when he was a graduate student in my lab (Rahnev et al. 2011). Brian Odegaard and others followed it up, and found that it replicates robustly and generalizes to more complex and naturalistic stimuli too (Li, Lau, and Odegaard 2018; Odegaard et al. 2018).

These findings suggest some compensatory mechanisms on the subjective level, "inflating" the typically weaker sensitivity associated with the lack of spatial attention. Under the lack of attention, they treated the signal as present even when it wasn't particularly strong. This is true when we compared central versus peripheral vision too. Together with others, another former postdoc fellow in my lab, Guillermo Solovey, found that peripheral vision was associated with more liberal detection, compared to central vision (Solovey, Graney, and Lau 2015).

At the level of perceptual metacognition, stimuli presented at less attended spatial locations also led to higher visibility ratings (Rahnev et al. 2011), even though they were not better discriminated (i.e., again, matched sensitivity). Another piece of evidence concerns crowding, which occurs outside of central vision (Pelli and Tillman 2008). When a perfectly visible stimulus, such as a single letter presented at the periphery, is flanked closely by other stimuli, we may have trouble seeing it. This partly explains why reading in the periphery is close to impossible. Under crowding, subjects seemed overconfident, especially for incorrect trials (Odegaard et al. 2018).

Overall, these empirical findings support the intuition that people seem to generally overestimate how much they see in inattentional blindness and change blindness studies. These intuitions have also been confirmed in studies using questionnaires (Levin and Angelone 2008).

4.10 Limitations of Inflation

I am in favor of this inflation account because I feel that neither the global nor local theories can ultimately account for the apparent richness of subjective experience. The issue is that such richness may not be "real." Some of the details may not actually be represented anywhere in the brain. So fighting over whether such representations are local or global may turn out to be futile. Instead, what we need is a mechanistic account of the *appearance* of stable richness, despite its lack of actually rich content.

But I must acknowledge, the inflation account isn't fully developed, and it has several limitations. The first is that empirical evidence at the level of metacognition is somewhat weak. Besides the reported few cases in Section 4.9, I confess there have also been at least several cases of null results from my own laboratory. Others have even found the opposite results (Zizlsperger, Sauvigny, and Haarmeier 2012; Toscani, Mamassian, and Valsecchi 2021). One possibility is that this kind of effect may only be found for visibility ratings, but not commonly for confidence, as has been suggested by a certain model (King and Dehaene 2014). But also relevant is the fact that in psychophysics experiments, subjects do very many repetitions (i.e., trials) of the same perceptual exercise. Throughout the course they may learn to calibrate their confidence. Even in the absence of feedback, the sheer exercise of repetitive introspection may be sufficient to wipe out the natural tendency to show inflation in metacognitive judgments.

Does it mean the inflation effect isn't real because it is only there for the "untrained" subjects, with their "unreflected" minds? I don't think so.

Instead this may be a reminder that the intuitions of academics on this subject may well be very biased. Many of us have been reflecting on this for decades, and some of us have routinely participated in our own experiments. We may have long forgotten what it was once like. In this sense, questionnaire answers from a large group of untrained subjects may be more meaningful. And as mentioned earlier, they do support inflation (Levin and Angelone 2008).

Incidentally, the evidence at the level of simple perceptual decision-making (i.e., detection bias) is strong. It's been replicated many times, under rather different conditions (Rahnev et al. 2011; Li, Lau, and Odegaard 2018; Odegaard et al. 2018). Perhaps the reason is, when the question wasn't explicitly metacognitive in nature (concerning confidence), they focused less on calibrating their answers, and just reported how the stimulus looked to them.

Some have argued that this kind of detection bias only reflects cognition or responding strategies (Abid 2019). It is unfortunate that this remains a common misunderstanding: to see bias effects as *necessarily* cognitive and postperceptual. In part there might have been historical reasons (Witt et al. 2015; Peters, Ro and Lau 2016). But in fact, many clearly perceptual phenomena show up as effects of biases rather than sensitivity alone (Polat and Sagi 2007; Grove et al. 2012; Meyerhoff and Scholl 2018). See also Michel and Lau (2021) for a review.

It is also true that *sometimes* bias effects are actually uninteresting. If I threaten you and tell you not to say you see anything, and reward you generously for obliging, there's no doubt that this could make you respond more conservatively (i.e., opposite of liberal) without actually changing your visual experience. But in experiments we can carefully rule out such possibilities. For the results reviewed for inflation, some were obtained after considerable training and feedback (Rahnev et al. 2011; Solovey, Graney, and Lau 2015). Subjects were repetitively informed if they were being too liberal for the unattended, and in some cases monetarily incentivized to be neither. The persistence of the liberal biases suggests rather strongly that they were not cognitive. Instead, they likely reflect what people actually consciously saw.

In any case, effects congruent with the inflation account have been demonstrated in other ways too. For example, Valsecchi et al (2018) asked subjects to adjust the stimuli on the screen by pressing keys to match the subjective sharpness of the edges of a pair of stimuli: one presented centrally and one peripherally. Using this matching method, more physical sharpness was required for the central stimulus to appear as sharp as the peripheral one. This means that subjects saw the peripheral stimuli as more sharp and less distorted, subjectively.

Finally, one may have the impression that inflation goes against some well-known findings from Marisa Carrasco's lab (2011). In many experiments, it's been reported that attention boosted the appearance of the stimulus, making it appear to have a higher luminance contrast, for example. Although some of these findings are in dispute (Beck and Schneider 2017), I am inclined to believe that the phenomenon is real. But it does not go against the inflation account, because the inflation effects typically concern the appearance of the stimulus *when* stimulus sensitivity is matched (between the attended and less attended). Under attention, sensitivity is typically boosted. Carrasco's experiments found that under such boosted sensitivity, appearance was boosted too. This is just as expected, assuming stronger perceptual signals should have some positive impact on appearance.

In fact, such effects of appearance boosting by attention may have been partially cancelled out by the inflation mechanisms. This would account for why the effects may be subtle, and therefore controversial at times. Importantly, however, this may reflect cooperation rather than competition. As William James put it (1910), attention makes a perceptual experience more intense, but regarding the true nature of the stimulus "it seems never to lead [our] judgment astray." A light bulb may look *somewhat* brighter when we attend to it, but we have little trouble "inferring" how bright it actually is. As we shift our attentional focus around, we *know* that a light bulb's actual brightness doesn't change. Little cognitive effort seems to be required as we make such automatic "inferences." For this to happen, some compensatory mechanism likely operates as part of the perceptual process itself. So, if anything, this may be yet another argument in favor of the plausibility of inflation.

Earlier I mentioned that in Sperling post-cue settings, the impression of rich perception of all 12 letters is far from universal (Cova, Gaillard, and Kammerer 2020). When asked about it systematically, the majority of subjects did not report the impression of richness. But given that post-cue likely dampens uncued representations (Sergent et al. 2011), this may be just as expected. In a similar fashion as to how we should understand Carrasco's experiments, when the perceptual signal is enhanced, naturally we may expect the subjective appearance to be stronger. It may be the subtlety of the effect on appearance that really calls for an explanation. Likewise, for the 12 letters, we know that visual signals can't be equally strong for the post-cued and uncued letters. In this context, that some subjects reported some degree of uniform richness is rather remarkable. Inflation may help to account for that.

But just *how* does this compensatory mechanism work? How exactly do we inflate representations without detail, *as if* they are full of details? How do we go from confidence and decision mechanisms to apparent richness? We will explore these questions further in the rest of the chapter. We may not have the full answers just yet. But we will come back to these questions again in Chapter 7.

4.11 Filling-in?

Although the mechanisms for inflation aren't fully fleshed out, one commitment of the account is clear: apparent richness is not supported by actual detailed sensory content. This is in contrast with another popular account: "filling-in," which suggests that the details missing from the input stage are visually reconstructed internally. Typically, filling-in accounts involve having the details reconstructed at the early sensory level via top-down influence. If that's right, perhaps a local view can account for the apparent richness of experience too. That is, the higher areas may be involved, but only as distal causes. Ultimately, the constitutive mechanisms may be all within the early visual areas.

Vision scientists often favor this filling-in account. But that may be in part because of the problem of convenience, as mentioned in the Chapter 3: it is easier to *measure* such effects in the visual cortex.

One classic phenomenon of filling-in concerns the blind spot, that is, the part of the retinal location where the optic nerve bundle is, for which we lack sensitivity early on. We are typically not aware of the blind spot because the visual content is "filled-in," at the stage of the early visual cortex (Tong and Engel 2001). However, interestingly, even in this classic case of filling-in, inflation-like mechanisms may take place as well. It has been reported that filled-in content in the blind spot leads to higher subjective confidence, even though the content is no more reliable (Ehinger et al. 2017).

But there are also cases where the filling-in account does not seem to work well. The uniformity illusion is a powerful demonstration that a certain textural character of the central region of an image tends to be subjectively extrapolated into the periphery (Otten et al. 2017).

When one sees the illusion (Figure 4.3), does neural activity in the peripheral region of the early visual area misrepresent the central visual pattern? That would be the prediction of the filling-in account. Suárez-Pinilla et al. tested this indirectly using the psychophysics method of adaptation (2018). Recall from Section 2.10, where we discussed this method. The rationale is that usually when we look at a pattern for a long time, an ambiguous stimulus presented at the same location is more likely to look like the opposite of that pattern immediately afterwards, rather than the pattern itself. Sometimes we

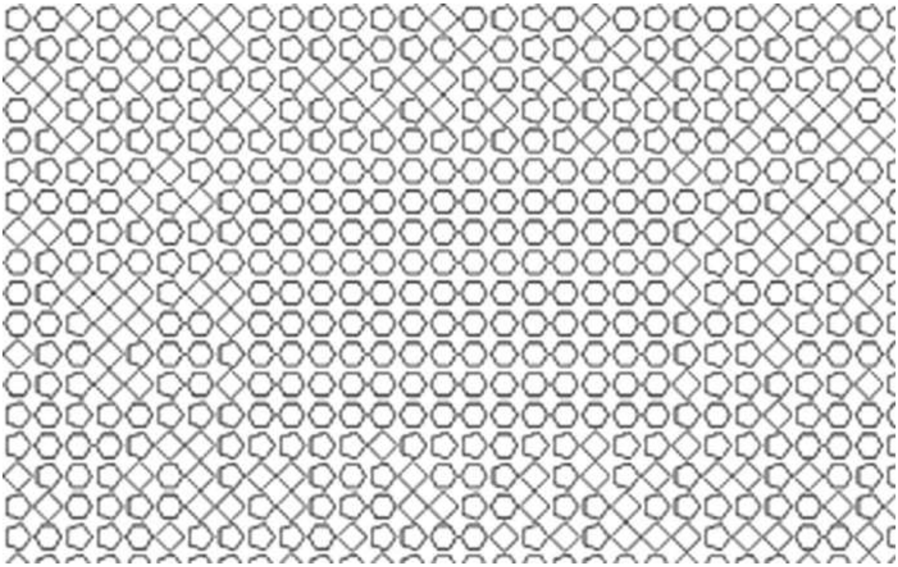

Figure 4.3 A demonstration of the uniformity illusion (taken from Otten et al. 2017); as one stares at the center of the figure, over time, the entire pattern may look uniform, even though when inspected carefully, the patterns in the periphery are varied

Reproduced from Otten, M., Pinto, Y., Paffen, C. L., Seth, A. K., & Kanai, R. (2017). The uniformity illusion: Central stimuli can determine peripheral perception. *Psychological Science*, *28*(1), 56-68. https://doi.org/10.1177/0956797616672270

say that the representation for the pattern is *adapted out*, or that there is a "repulsion" effect. The adapted pattern becomes less likely to win in a perceptual competition, when two alternative percepts are similarly plausible. This is supposed to take place in the early visual cortex when a physical stimulus is presented as the adaptor.

Suárez-Pinilla et al. applied this logic in a behavioral study (2018) to find out the mechanisms for the uniformity illusion. They tested if the extrapolated pattern in the periphery would have equal status to a physically presented stimulus, in terms of its adaptation effects. The answer was no; the physical pattern, not the illusory pattern, drove adaptation. The authors interpreted this to mean that the illusion must take place in later areas, beyond the primary visual cortex.

There may be doubts about this claim because it is possible that the representations in the primary visual cortex were indeed changed under the illusion, just that the changes weren't in ways akin to actual presentation by a physical stimulus. However, other studies of filling-in, such as those concerning the blind spot, typically find adaptation effects (Murakami 1995). And yet they were absent here. So at least, we can say the mechanism for the uniformity illusion is not identical to other filling-in effects.

Incidentally, under the uniformity illusion, the "extrapolated" patterns in the periphery also don't look *exactly* like physically presented patterns congruent with the center. This point was not emphasized in the original report, but is evident in the psychophysical data presented (Otten et al. 2017). When asked, subjects could distinguish the illusory extrapolation from an actually uniform image, much better than chance. One possibility is that the illusion is not "strong" enough to mimic the percept driven by physical stimuli. But phenomenologically, it is hard to deny that the illusion is powerful. So perhaps the mechanism isn't one of simple filling-in at the early sensory level. Something does differ at that level, allowing subjects to distinguish the illusory from the physically uniform scenarios, when needed. The illusory sense of uniformity probably arises at some *later stage* (Knotts, Michel, and Odegaard 2020).

4.12 Single Versus Multiple Levels of Representations

It should be clear that the above discussion isn't meant to be a rejection of the filling-in account in general. Filling-in certainly happens in many cases. But the point is that it is unlikely to account for all of the scenarios we've reviewed in this chapter: the speckled hen, Sperling's letter arrays and the uniformity illusion, for example. Multiple mechanisms are needed to account for the phenomenology of the unattended periphery.

Early on, Dennett wrote about the fallacy in thinking that consciousness must happen at a single place in the brain (1991). Unfortunately, this hasn't stopped researchers from debating whether subjective experience is determined by content in one specific brain area *or* another, as if these possibilities are necessarily mutually exclusive.

To illustrate the point, let us remind ourselves that we routinely make eye movements (i.e., saccades) up to a few times a second. And yet, the world looks relatively stable. Does it mean that eye movements have no impact on our visual phenomenology? That seems highly improbable. As you shift your gaze from one object to another, your retinal input changes. Certainly, we can feel a drastic difference if we think about it as we make these eye movements. But what if you don't think about those eye movements you make a few times a second, just as you normally don't—how does it feel? It is difficult to do the phenomenology justice, but it is probably fair to say that it makes sense these eye movements change your visual phenomenology drastically, and yet, *at the same time*, there is *also* another sense in which they don't.

Likewise, under the uniformity illusion, there is this similarly ambivalent sense that at once the periphery looks like it is an extrapolation from the center, *as if* the whole image is physically uniform; but at the same time, there is also a sense that it isn't identical to a physically uniform image.

Just for another example: when you look at a coin that is tilted sideways so it isn't facing you squarely. Does the coin look round or elliptical? There is a sense that you see the coin *as* round, precisely *because* you see it as elliptical (Noë 2004). Based on a series of ingenious experiments, Jorge Morales and colleagues concluded that our visual system simultaneously represents both (Morales, Bax, and Firestone 2020).

Dennett likened these situations to an author's being in the middle of writing a book (1991). One may be working on "multiple drafts," and they are all relevant. None alone is going to be the final word. So the analogy is that for our subjective visual experience, multiple representations at different parts of the visual cortex may all contribute. Sometimes, the instantaneous content does not have to be strictly coherent. If that's right, it may be rather silly to write off other researchers' favorite brain areas in favor of your own. They may all be just as important, as they contribute in different ways.

Importantly, from Chapters 2 and 3, we have argued that visual consciousness involves more than just the visual cortex. In the prefrontal cortex, representations are complex. Neurons don't just signal the presence and features of some external stimuli. To continue with the analogy, the prefrontal cortex may not just hold "drafts" of images representing the external world. There may also be "*post-it*" *notes*, labeling some *other* drafts as so-and-so, recommending appropriate further actions, just like what you'll find on the editor's desk: *This representation in MT (middle temporal area) is rich in detail. It has real potential. We should count on it with all our confidence.* Or: *This V1 representation looks terrible. Desk reject!*

This may be how the metacognitive mechanisms in the prefrontal cortex are relevant to the subjective experience of seeing—a point we will return to in Chapter 7. And if that's right, the global view isn't quite correct. The role of the prefrontal cortex is not to broadcast, amplify, ignite, or merely represent the content of consciousness. It acts more like an interpreter or a commentator—an idea that is of historical significance in the neuropsychology of consciousness (LeDoux, Michel, and Lau 2020).

4.13 A "Possible" Localist Rejoinder?

There is a position that I anticipate some die-hard localists may take. They may argue that much of the evidence reviewed here concerns high-level recognized and conceptualized details (e.g., letters, objects, and a person in a gorilla suit). Such details may well not be consciously perceived without attention. But some low-level, simple features like color and contrast may be uniformly represented across the visual field, giving us the "raw" phenomenology that can be stably rich (Haun 2020), independently from cognitive access and attention.

One problem with this view is, as we have already mentioned, some details like color and spatial resolution are actually known to be missing early on (e.g., from the retinal level). An interesting rejoinder from the localists may be to say that lack of details should not imply lack of subjective richness. We may just not be aware of what we do not represent (Anstis 1998). So perhaps we should not expect an active sense of blurriness or lack of color when the brain just does not keep track of the relevant information. That may be why we see the visual field as relatively uniform, despite the paucity of detailed information in the periphery.

But I am acutely aware that I do not see through the back of my head. I am not at all surprised by my lack of color vision there. This seems rather unlike the situation of peripheral vision, in which our behavioral deficits are often so surprising (Cohen, Botch, and Robertson 2020).

Let us suppose there is indeed this hypothetical level of representation characterizing the richness of phenomenology (Haun 2020). Just how does it relate to actual perception? We know that crowding applies to simple shapes and line segments, not just letters and other high level stimuli (Pelli and Tillman 2008). So for this account of uniform richness to work, it has to happen at some putative stage *prior* to crowding (Haun 2020). But crowding likely occurs as early as in V1 (Levi 2008). Meanwhile, as we discussed, attention is known to modulate activity as early as V1 as well (Sergent et al. 2011). In fact it could happen earlier still, in subcortical areas like the lateral geniculate nucleus (O'Connor et al. 2002; McAlonan, Cavanaugh, and Wurtz 2008). So where exactly are these simple representations supporting stable richness, resistant to both crowding and attentional modulation?

What I worry about is not only the lack of evidence at the moment. The problem is such putative representations are meant to be detached from actual perceptual *behavior*, which we know is constrained, for example, by crowding or attentional modulation. As such it is unclear how we can *ever* find any direct empirical evidence for them. In Chapter 6 we will discuss this problem further: that some localist claims are just unfalsifiable and empirically meaningless. The inflation account, on the other hand, can be supported by future discovery of concrete mechanisms in, for example, the prefrontal cortex.

4.14 Chapter Summary

In recent years, the debate on the richness of the phenomenology of perception has grown considerably. It is difficult to provide a comprehensive review of this literature. So here, I have not attempted to do so. Instead, I tried to give a gist of the landscape, to see where things stand on a coarser scale.

The debate is difficult, in large part because we cannot objectively and directly measure subjective experience. The problem is harder still for unattended experience, as self-reports can become dicey. So one may be tempted to say, to the extent that a percept isn't reported as such, we do not need to consider it truly conscious (Dehaene et al. 2006). That would make the life of a global theorist easier. But I find this view too restrictive. Certainly, there seem to be things that we consciously see but are so fleeting and complex that we may not be able to report about them. What we see seems not quite like just a gist or a simple statistical summary.

This impression of richness is often thought to be in favor of the local view. But the early sensory activity doesn't really seem to match the actually reported level of richness either (Cova, Gaillard, and Kammerer 2020). Some intuitions turn out to depend on data that aren't quite right.

Additionally, there is the problem of the relative *stability* of richness. However rich one thinks peripheral perception is, it just doesn't seem to be modulated so dramatically by the task that we are doing. Based on Lavie's load theory (2005), such changes in the tasks can be subtle. The tasks can be about the very same spatial location and stimuli and location, e.g. detecting a single feature versus conjunction of features. With such relatively small differences in the tasks, phenomenology for the peripheral background does not seem to change very much. And yet early sensory activities are reliably modulated (Schwartz et al. 2005).

So I introduced the concept of inflation and suggest that it may partly depend on mechanisms in the prefrontal cortex. This is congruent with what we've already discussed in Chapters 2 and 3: that the prefrontal cortex is constitutively involved in consciousness *somehow*. If that's correct, neither the global nor the local views are right on this matter. The phenomenology of perception may seem rich, but much of it may be internally "made up." Or we say it is "inflated," in the sense that the details aren't necessarily filled-in back at the level of early sensory representations. So perhaps the so-called raw feels aren't so raw after all. They hinge on sophisticated metacognitive and decisional processes, through which inflation occurs.

The true aficionados of raw feels may want them less "processed." They may demand raw feels that are truly untouched by cognition. But are there really such things? How would we ever know if they resemble how we feel at all? If we cut a piece of the early visual cortex out, put it on a petri-dish, and keep it alive, would the activity there reflect some raw experience, unbeknownst to anyone? Some authors have in fact urged us to consider such possibilities (as we will discuss in Chapters 6 and 9). But the present science suggests that there may be no need to go this far just yet. If the account of inflation works, we may already have what we need to account for the currently available data.

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