Visual adaptation and the purpose of perception

IAN PHILLIPS AND CHAZ FIRESTONE

1. Introduction

What is the purpose of perception? And how might the answer to this question help distinguish perception from other mental processes? Block's landmark book, *The Border Between Seeing and Thinking*, investigates the nature of perception, how perception differs from cognition and why the distinction matters. It is, as one would expect, wide ranging, deeply informed by relevant science and hugely stimulating. Here, we explore a central project of the book – Block's attempts to identify the features of perception that distinguish it from higher level cognition – by focusing on his suggestion that such features closely relate to perception's purpose. As well as offering a detailed critical discussion of these proposals, our more general aim is to advertise both the promise and pitfalls of asking: *what is perception for?*

2. Purpose in perception science

Many theories, hypotheses and explanations in vision science appeal to the evolved purpose(s) of perceptual systems. Consider three examples.

First, Goodale and Milner motivate their highly influential two visual systems hypothesis by appealing to the evolutionary benefits of separate processing streams: 'It seems plausible from a functional standpoint that separate processing modules would have evolved to mediate the different uses to which vision can be put' (1992: 20). Specifically, they contend that we should distinguish two such systems: an evolutionarily more ancient system whose function is to guide visuomotor action, and a more recent system that constructs a stable, conscious visual representation of the world, for use in memory, planning and decision-making. Similarly, Xu introduces her related two visual systems account by noting two competing functions of visual processing: 'Visual information processing contains two opposite needs. There is both a need to comprehend the richness of the visual world and a need to extract only pertinent visual information to guide thoughts and behavior at a given moment' (2018: 312). Xu's hypothesis is that one system is 'invariant' (constructing a detailed model of the world independent of the perceiver's goals or intentions) and the other 'adaptive' (representing only salient and task-relevant information to inform decisions).

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Second, both proponents and critics of the cognitive penetration of vision appeal to functional considerations. Bhalla and Proffitt (1999) notoriously claim that wearing a heavy backpack makes slopes look steeper, arguing that such an effect dissuades people from climbing slopes beyond their physiological potential (though see Durgin et al. 2009, Firestone 2013). Similarly, Balcetis and Dunning claim that desirable objects (e.g. chocolate) are seen as closer than undesirable objects (e.g. faeces), proposing that 'these biases arise in order to encourage perceivers to engage in behaviors leading to the acquisition of the object' (2010: 151). In contrast, Gilchrist offers a functional argument *against* penetration, likening an encapsulated architecture to a 'free press'. His point is that visual (like public) information is needed for myriad, perhaps unpredictable purposes, and that distorting it for one end may leave the well 'poisoned, with serious damage to other functions' (2020: 1002). For example, exaggerating slopes and heights may mislead perceivers who intend to use a hill as a landmark for later navigation or to escape a flood (Firestone and Scholl 2016).

Finally, many theorists offer functional arguments for the veridicality of perception.[1] For instance, Palmer writes: 'Evolutionarily speaking, visual perception is useful only if it is reasonably accurate' (1999: 6). Against this, Hoffman et al. (2015) make the striking claim that perception's goal – guiding adaptive behaviour – supports an opposing view on which our percepts are wholly non-veridical, deliberately hiding objective reality and instead offering an easily engageable interface (for criticism, see Berke et al. 2021).

Block joins this tradition in outlining his approach to determining the border between perception and cognition. He begins by refining our commonsense grasp of the distinction, seeking out 'scientific indicators that make sense of the pretheoretic classifications' (33). Such markers offer empirical purchase on the joint between perception and cognition, and position us to ascertain its fundamental nature.

Block offers five such indicators: rivalry, pop-out, illusory contours, processing speed, but, first and foremost, adaptation – the phenomenon whereby perceiving a given stimulus feature (e.g. blue) temporarily biases perception away from that feature (e.g. towards yellow; though see below for refinement). He singles out adaptation as 'the main scientific indicator ... of what is perceptual and what cognitive' (33) and 'the most useful of the methods' (61) for distinguishing perception from cognition. For Block, although not constitutive of perception, adaptation represents 'a basic feature of perception that is present in all known perceptual systems' (102). In an especially tantalizing passage, he suggests that these claims are connected to the purpose of perception: to deliver 'news'.

> What do the indicators have to do with what perception is at the most fundamental level? Are they mere symptoms of perception or are they

1 For discussion, see Burge 2010: 301ff. and Graham 2014.

> more deeply connected with what perception is? In the case of adaptation, one connection is very likely evolutionary. The evolutionary purpose of perception is acquiring information about what is happening here and now. Call that "news".
>
> Any feature of the visual system that produces a constant effect has to be filtered out in order to focus on news. This evolutionary explanation of adaptation is commonly cited. "Sensory adaptation allows us to tune out stimuli that do not provide us with new information needed to cope with the environment. This is the property of adaptation that is generally used to define adaptation in textbooks" (McBurney, 2010, 406) ...
>
> By contrast, for cognition, facts that are not news are important too. We want to continue to know that tigers are dangerous, for example. In short, the psychological indicators for distinguishing the perceptual from the cognitive ... are closely related to the different functions of perception and cognition. (119–20)

Here, we explore these ideas in more detail. We first look critically at the claim that adaptation is a key indicator of perception. Then, we turn to the connection Block draws between adaptation and the putative evolutionary purpose of perception, namely news. We cast doubt on the idea that the function of news acquisition distinguishes perception from cognition, and so question its usefulness in determining the markers of perception. More positively, we end by considering what light might be shed on other putative features of perception by reflecting on its purpose(s).

3. Adaptation as a specific marker of perception

What is perceptual adaptation (Figure 1)? Sceptical of strict definitions, Block proposes that adaptation is a natural kind, offering a paradigm example: the motion after-effect. A classic motion after-effect occurs after staring at continuous motion in one direction (e.g. leftward) for an extended period. Immediately afterwards, stationary stimuli in the same location will appear to move in the opposite direction (e.g. rightward). This example is paradigmatic in being short-lived (lasting seconds to minutes), repulsive (biased 'away' from what was experienced earlier) and retinotopic (specific to the retinally defined location of the original stimulation; Knapen et al. 2009). Importantly, however, not all adaptation exhibits these features. As Block notes, the McCollough effect, in which one adapts jointly to colour and orientation, can last months (72), and sometimes adaptation can be attractive (73). Nor is all adaptation retinotopic: some adaptation effects are spatiotopic (specific to an environmentally defined location, rather than the retinally defined location of earlier stimulation; Turi and Burr 2012), and many higher level effects are plausibly global and cross-modal (Storrs 2015).

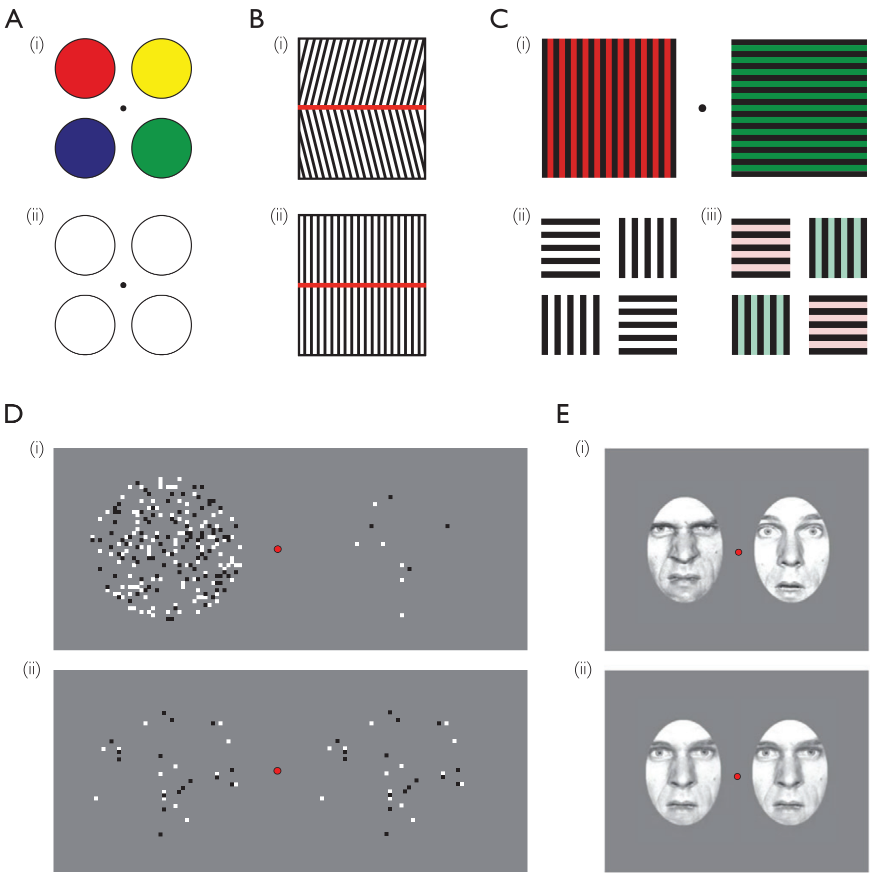

Figure 1. Demonstrations of visual adaptation. In each panel, the relevant effects can be experienced by first staring at display (i) for approximately 30 s, and then moving one's gaze to display (ii). (A) Colour: after staring at coloured circles in the top display, white circles in the bottom display appear in the top circles' opponent colours (such that, e.g. the white circle in the bottom left appears yellow). (B) Orientation: after letting one's eyes move along the horizontal red line in the top display, the straight lines in the bottom display appear tilted. (C) The McCollough effect: after staring at vertically oriented red bars and horizontally oriented green bars, neutral vertical bars appear green and neutral horizontal bars appear red. Here, display (iii) roughly depicts the expected phenomenology. (D) Numerosity: after staring at the two arrays in the top display (one of which is numerous and one of which is not very numerous), the two equinumerous arrays in the bottom display look different from one another – the left one appears less numerous than the right one. (E) Facial emotions: after staring at the angry and surprised faces in the top display, the identical faces in the bottom display look different – the left face appears less angry (and more surprised) than the right face (demonstrations adapted from Thompson and Burr 2009, Burr and Ross 2008, Webster et al. 2004).

For adaptation to play its putative role in distinguishing perception from cognition, it must be both (i) *sensitive* and (ii) *specific*, as an indicator of perception. In other words, (i) cases of perception without adaptation must be rare (or at least isolable), as must (ii) cases of adaptation without perception.

Consider first, specificity. Since adaptation is not claimed to be constitutive of perception but rather a symptom of its underlying nature, Block's view can accommodate exceptional cases of non-perceptual adaptation. However, adaptation would clearly be a poor marker of perception if cognitive adaptation were widespread – for example, if merely considering or judging some property (such as the price of an expensive car) caused later judgements to be temporarily repulsed (such that, e.g. subsequently considered cars seem less expensive than they would otherwise). This possibility connects to a serious methodological issue which besets much work on adaptation (Storrs 2015, Smortchkova 2021) – namely, establishing that a pattern of responses reflects *perceptual* adaptation as opposed to shifts in decision criteria. Recall the motion after-effect. Here subjects who adapt to leftwards motion tend to classify subsequent stationary stimuli as moving rightwards. But – a sceptic might ask – is this because they *experience* the stationary stimuli as moving rightwards, or is it that their threshold for judging a stimulus to be moving rightwards has shifted?

Block offers two replies to this methodological puzzle: retinotopic/spatiotopic localization and phenomenal character. On the former, Block claims: 'No criterion effect has ever been shown to be retinotopic or spatiotopic. Since many perceptual adaptation effects are retinotopic or spatiotopic to some degree, criterion effects can often be ruled out' (75; also Figure 2.7, caption, 88)

We have three concerns about this reply. First, as Storrs (2015) points out, and Block (89) acknowledges in discussing Matsumiya and Shiori (2008), this approach cannot be applied to putative high-level perceptual adaptation effects (e.g. seeing faces as 'happy' or 'sad'; Matsumiya 2013), since these can be spatially global, and indeed cross-modal. Second, whilst we agree that retinotopy specifically is evidence against mere decision-criterion shifts (see Hafri and Firestone 2021), it is difficult to see why criterion effects cannot be spatially local.[2] Decision criteria are (at least in theory) flexible and under voluntary control; indeed, observers who are explicitly asked to favour one of two responses can intentionally alter their decision criteria without altering precision or sensitivity (Morgan et al. 2012). Thus, any subject capable of tracking stimulus location could theoretically adopt spatiotopic decision criteria. Certainly, it would seem that a committed psychophysicist could

2 Block's book is primarily about seeing, but he claims that his points apply 'at least to all the spatial senses' (2), which for him include smell (though see 180, fn. 4). Yet retinotopy cannot be a general mark of spatial perception, since it reflects a peculiar feature of (most) *visual* systems. Over-emphasizing retinotopy may also be in tension with Block's view that 'visual perception, is characteristically multi-modal, even at the level of the first cortical stage of visual processing' (396).

produce a spatiotopic criterion effect. Again, consider the motion after-effect. Our psychophysicist could decide to adjust their criterion for rightward motion where they have been recently staring but not in other locations. This would recover the basic pattern of responses characteristic of adaptation, without any change in perception.[3] Finally, insofar as retinotopy or spatiotopy is diagnostic of perception, it is unclear how central or useful an indicator adaptation per se is. After all, non-local 'adaptation' effects may simply reflect shifts in decision criteria. Moreover, establishing that an effect is retinotopic will suffice to count it as perceptual (or at least non-cognitive), whether it involves adaptation or not. For instance, residual attentional traces are left behind following saccades (Golomb et al. 2010, Talsma et al. 2013). These might be argued to be perceptual on the basis that they are retinotopic – but they are not adaptation effects. In other words, retinotopy, not adaptation, is doing the work-separating perception from cognition.

Block's second reply to the methodological puzzle of ruling out shifts in decision criteria appeals to introspection. Consider an experiment where participants adapt to two dot arrays, a more numerous one on the left and a less numerous one on the right, before looking at two equinumerous displays (Figure 1D). Commenting on such a set-up, Block remarks as follows:

> Standard psychophysical approaches fail to consider an obvious way of avoiding criterion issues. In the numerosity experiment just described, it briefly *looks* as if there are more dots on the right than on the left. I have shown these displays in many classes and I have to assure the audience that I have not tricked them with a video that starts with more dots on the right and shifts to equal numbers of dots. There is no reason to expect criterion effects to fade. This is not the first-person experience of a criterion effect. It is a robust effect that you can experience for yourself despite the absence of laboratory conditions. This point might fall on deaf ears in the psychophysics community because of suspicion of "introspective" reports, but a rational reader should be persuaded by it. (75)

What should we make of this appeal to our first-person experience of adaptation effects? An immediate concern is whether we really have so firm a grip on the phenomenology of a criterion effect. After all, what *would* it feel like to experience a strong and sudden change in one's classificatory dispositions? It is not obvious to us that such a change could not fade or be robust. Nor

3 Of course, further features of the effect (e.g. its time course, signature limit or encapsulation from voluntary control) may count against its being a criterion effect. But, as we argue below, it would not then be adaptation specifically which was marking out perceptual processes.

is it clear that such a change would not be perfectly natural to report using comparative *looks* constructions (cf. Martin 2010, Phillips 2016).

However, a further concern arises, even granting the probity of introspection. If we appeal to first-person judgements to distinguish perceptual adaptation proper from criterion effects, then it is again unclear what work adaptation itself is doing. Rather it seems that our prior grasp on the perceptual, grounded in our first-person perspective, does the heavy lifting. This echoes our earlier concern about retinotopy. Recall that, for Block, adaptation is supposed to be 'the main scientific indicator' of perception. However, if in tricky cases it turns out that other features – features which are independent markers of perception – are needed to show that the effect is really perceptual, the centrality of adaptation per se is cast into doubt.[4]

So far, we have considered explanations of putative perceptual adaptation in terms of shifts of decision criteria. However, our fundamental concern is with the specificity of adaptation as a marker of perception. As Block writes: 'If adaptation is to be useful in distinguishing perception from cognition, there would have to be adaptation for perception but not cognition' (97). Block doubts that there are any examples of cognitive adaptation. Yet criterion effects would seem a ready source of cases where an aspect of cognition (i.e. one's decision criterion, and so judgement) is repulsively affected by a prior cognitive state.

A nice example is random number generation (Figure 2). Notoriously, humans struggle to generate genuinely random numbers, and exhibit instructive biases in trying to do so. On top of a (zero order) non-uniformity in the distribution of numbers chosen, subjects also avoid repetition and tend to produce numbers in close proximity to the last number produced. For instance, if asked to produce a long sequence of random numbers in the interval [0, 9], a subject might rarely if ever say '5' twice in a row; but, having said '5', the subject will show a marked tendency to subsequently say '6' or '4' (as opposed to, say, '2' or '8'). Moreover, these effects are plausibly short-lived, such that the number one says at a given time biases the choices of numbers in the moments following, but not on the scale of (say) days or weeks.

Treisman and Faulkner (1987) provide a powerful model of random number generation in terms of *criterion setting theory* (CST; Treisman and Williams 1984) – a model originally developed for psychophysical tasks. CST posits two mechanisms: tracking and stabilization. For our purposes, stabilization is key since it is the sibling of adaptation. In psychophysical tasks, stabilization ensures that one's criterion remains in the centre of the sensory

4 Unlike retinotopy, phenomenal character might be proposed as a unifying marker, or even a constitutive feature, of perception in general. However, this view is unavailable to Block, since he is a proponent of unconscious perception; that is, he believes there are genuinely perceptual states that have no phenomenal character. For discussion, see, for example, Phillips and Block 2017.

distribution, maximizing response informativeness. It does this by shifting one's criterion towards the value of the most recent input, thus lowering the probability of responding the same way on the next trial. Treisman and Faulkner show that this mechanism can explain the absence of repetition in random number generation. Positing an internal analogue source which produces a genuinely random variable, the stabilization mechanism leads to negative dependencies, specifically absence of repetition. The tracking mechanism (a positive mechanism for exploiting environmental continuity, described in the more recent literature on sequential dependencies as a 'continuity field') explains the tendency to produce numbers in close proximity.

The overall pattern of data in attempted random number generation does not exhibit pure adaptation; to explain the data, both mechanisms are needed. Our point, however, is that random number generation as understood by Treisman and Faulkner is partly driven by stabilization processes which are naturally described as cognitive adaptation. Moreover, as we shall see below, the dual operation of mechanisms leading to both negative and positive sequential dependencies is equally at work in perception. Perception too is arguably not a purely adaptive process.

Note also that this example of cognitive adaptation would seem to resist Block's reply to other proposed cases. For instance, Block discusses Helton's (2016) example of medium-size homes seeming small after first thinking about very large homes; he suggests that this could simply be regression to the mean. But regression to the mean cannot explain the response patterns

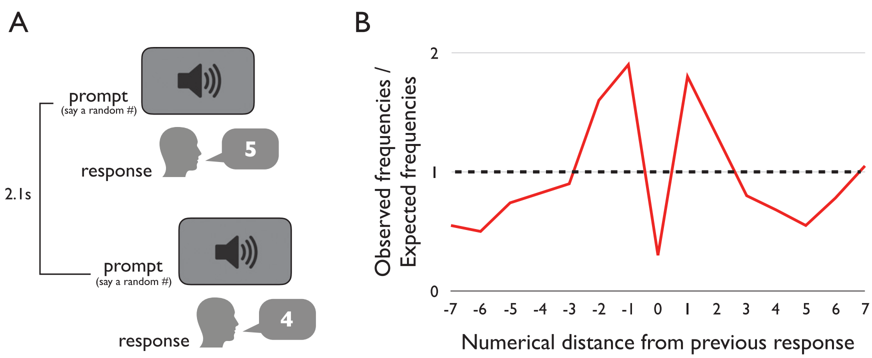

Figure 2. Criterion setting as cognitive adaptation. (A) In experiments by Treisman and Faulkner (1987), subjects are asked to produce random numbers at regular intervals. (B) The figure approximately reproduces the data from a typical subject. In general, subjects are very *unlikely* to repeat the same number twice (as indicated by the central dip), but very *likely* to produce subsequent responses near to their previous response. For example, after saying '5', subjects are unlikely to say '5' on the next trial, but also unlikely to say '1', '2', '8' or '9'; instead, they are repelled to only a small extent (e.g. with '3', '4', '6' or '7' much more likely than other responses). In Treisman and Faulkner's model, the fact that subjects are unlikely to repeat numbers is explained by a stabilization mechanism which shares the 'flavour' of visual adaptation.

in attempted random number generation. The observed tendency is not towards the mean of the distribution of numbers but rather in any direction away from the previously given number (including directions *farther* from the mean).

Block discusses another putative example of cognitive adaptation, Wexley et al.'s (1972) employment experiments in which actors posing as job candidates were ranked on suitability. Repulsive responses (negative sequential dependencies) were found, such that interviewing a high-quality candidate led interviewers to rate subsequent candidates lower than they otherwise would. Block comments that explanations of these dependencies (e.g. in terms of attention to novelty) lack 'the flavor of adaptation' (99) as well as its signatures. However, it seems natural to model these data using CST. Insofar as CST provides a good fit, the explanation *will* have the flavour of adaptation. Moreover, the fact that stabilization occurs in tandem with tracking could well explain the more complex pattern of data and the absence of adaptation's classic 'signatures'. There is no reason to insist that cognition must reveal its adaptive effects in uncontaminated form.

Indeed, there may well be other forms of cognitive adaptation, including forms explicitly referred to as 'adaptation' in their relevant literature. One example might be hedonic adaptation (Frederick and Loewenstein 1999), whereby an individual's well-being apparently adjusts to newly positive or negative circumstances such as a sudden change in wealth. Does this phenomenon exhibit the hallmarks of adaptation? Perhaps so: after winning the lottery, a subject's happiness might temporarily increase; but then after some time, luxuries that would normally have brought joy are experienced as less pleasurable than they were previously. Similarly, someone whose circumstances change for the worse might find happiness in activities that most others (and even their past self) find neutral or unpleasant. Another candidate for cognitive adaptation is boredom. Performing the same activity for an extended period often makes that activity seem less interesting or engaging, and may make other activities (including previously unappealing ones) seem more attractive. Indeed, bored subjects prefer to self-administer painful electric shocks rather than stay bored (Wilson et al. 2014), even though such actions are normally quite aversive. Of course, these cases are not straightforward. But note that, while they are at least *plausible* cases of adaptation, they are manifestly not plausible cases of perception, and clearly lack features such as retinotopy. These examples suggest that adaptation falls short of serving as perception's 'main scientific indicator'.

Concluding his discussion of cognitive adaptation, Block addresses something like the above point: 'let us suppose, no doubt contrary to fact, that there is cognitive adaptation. We can still distinguish cognitive adaptation from perceptual adaptation by consideration of the specific features that I have been mentioning of perceptual adaptation'. These features include (i) retinotopy and spatiotopy (as discussed), but also various other specific features: (ii) conforming to models of either multichannel or norm-based adaptation, (iii) the effect's magnitude being a logarithmic function of adapting stimulus duration, and (iv) a pattern of attraction and repulsion explicable in terms of 'known visual properties' like centring and scaling mechanisms (99).[5]

Since Block's view is that there are multiple interdependent markers of perception which converge to pick out perception, Block could also reply by de-emphasizing adaptation and insisting on the importance of other markers. Either way, by substantially relying on other features to produce a specific test for perception, Block would be relinquishing the idea that adaptation is 'the most useful of the methods' we have for distinguishing perception from cognition. Furthermore, in appealing either to highly specific features of perceptual adaptation, or to other indicators, Block needs to say more about how such features should be weighted and combined, and whether a suitably weighted cluster truly marks a general joint between perception and cognition.

4. Adaptation, sensitivity and the purpose of perception; is perception about 'news'?

Thus far, we have questioned whether adaptation is a specific indicator of perception. But is it a sensitive indicator? Is adaptation 'present in all known perceptual systems' (102)? As discussed by Block, one of us (CF) previously noted various properties that are arguably perceptual but may not adapt. For example, it seems that we can see objects as located to our left; but does seeing several things as being to our left make a central item appear to our right? Likewise with seeing objects as near/far, connected/disconnected, symmetric/asymmetric, homogenous/heterogeneous and doubtless many others. There may also be structural features of the different perceptual modalities which do not adapt (e.g. the structure of the visual field itself).

Discussing these examples (81), Block suggests that Finke's (1989) prism glass studies may show left/right adaptation. In these studies, a prism shifts the perceiver's point of view slightly to the right or left, such that objects that would otherwise have appeared straight ahead appear slightly right of centre (say), and objects that would otherwise have appeared slightly left of centre now appear straight ahead. When the prisms are removed after prolonged use, the visual world reportedly overshoots in the other direction, such that a subject who is asked to point at a physically straight-ahead object will point slightly *left* of centre. However, it is doubtful that Finke's studies show a 'classic repulsive adaptation effect' with respect to the perception of left-locatedness and right-locatedness. First, one might think that the effect

5 Much could be said about each of these features. For instance, cognitive effects can be log functions and arguably may involve centring or scaling mechanisms.

is purely a matter of visuomotor recalibration, as seems to be the case with inverting goggles (Linden et al. 1999). Second, it is unclear how Finke's study speaks to the original thought about seeing many things on one side. Finke's prisms do not cause the wearer to see many things on one side; instead, they create a systematic distortion across the entire visual field.

Block does provide evidence that adaptation occurs for facial asymmetry (Rhodes et al. 2009). However, he recognizes that this finding doesn't demonstrate adaptation for symmetry in general. Gheorghiu et al. (2014) report some tentative evidence in that direction, though only for collections of objects (rather than, say, a single symmetric or asymmetric object), and only for symmetry, not for asymmetry (i.e. prolonged exposure to symmetric stimuli made other stimuli appear less symmetric, but prolonged exposure to asymmetric stimuli did not make other stimuli appear more symmetric). However, Block is surely right to conclude that we don't yet know the scope of adaptation in general.

Here is where Block's appeal to the purpose of perception may seem probative. As we saw in the passage quoted earlier, Block offers a powerful evolutionary rationale for expecting adaptation to be a general perceptual phenomenon. Recall that this argument begins with the idea that 'the evolutionary purpose of perception is acquiring information about what is happening here and now' – what Block calls 'news' – and then suggests that adaptation is precisely a mechanism for screening out constant effects 'in order to focus on news'. In contrast, 'for cognition, facts that are not news are important too'. In this way, adaptation's role in distinguishing perception and cognition is 'closely related to the different functions of perception and cognition'.

This is an extremely interesting line – and indeed, style – of argument. There is, of course, a rich literature exploring what can (and, importantly, cannot) be learnt about human and animal cognition by approaching it as the product of natural selection (for different perspectives, see Godfrey-Smith 1996, Lloyd 1999, Sterelny 2003, Buss 2014, Cosmides and Tooby 2013, Smith 2020).[6] However, this literature has typically not engaged with the kinds of precise and empirically informed proposals concerning visual perception which Block offers. Moreover, in contrast to capacities such as language or moral cognition, hypotheses about vision can be tested across a wide range of taxa. Block's remarks thus highlight a substantial interdisciplinary opportunity to gain fresh insight by reflecting on the evolved purpose(s) of perceptual systems.

However, despite the promise in bringing such considerations to bear on our theorizing about perception, we see significant pitfalls with its present

6 There is also an important literature distinguishing different notions of function and functional explanation (see, for instance, Cummins 1975, Godfrey-Smith 1993, Millikan 1989, Wright 1973).

application. The central difficulty is that perception and cognition plausibly have multiple, potentially conflicting, evolutionary purposes, including – in *both* cases – the acquisition of 'news'. In that case, appeal to news acquisition does little to support the specificity or sensitivity of adaptation as a marker of perception.

Multiple purposes are the norm for evolved systems. Does hair have a single function? No. It functions to regulate body temperature; it protects us from dirt, dust, rain, sweat and in some cases physical damage; it enhances our sense of touch; it can signal emotions; and it may play other social roles. Do tongues have a singular function? No. In humans, tongues are used for speech, taste, chewing, kissing and wound licking; in other animals, we might add grooming and predation.[7] Perception plausibly serves multiple purposes too. As Marr notes (in a section titled 'The Purpose of Perception'): 'Vision ... is used in such a bewildering variety of ways' (1982: 32), including navigation, movement, detection (of food and motion), discrimination (of mates from meals), and initiation of reflexes such as blinking and ducking. We might add many others: perception forms and triggers memories, allows us to learn and communicate, induces emotional states, gives pleasure, and so on. Marr infers from his list that because of such different purposes in different animals, 'it is inconceivable that all seeing animals use the same representations' (32). Vision comes in different forms for different purposes. We ought to consider a similar possibility regarding mechanisms.

A hint of this diversity of purposes can already be found in Rhodes et al.'s (2009) study of facial symmetry adaptation discussed above. There, Rhodes et al. offer a highly specific evolutionary explanation for the adaptation effects they report. This explanation is based on the difference between fluctuating asymmetries, which indicate developmental instability and so are relevant to mate selection, and directional asymmetries, which are not relevant. Adaptation filters out directional asymmetries, allowing better appreciation of fluctuating asymmetries. This is a highly contingent and specific explanation, and we should not expect it to generalize. Indeed, there may be properties where it would be quite maladaptive to filter the analogue of directional asymmetry (i.e. cases where directional asymmetry is the survival-relevant property), making adaptation counter-productive. This all suggests that we should be live to highly specific and idiosyncratic variation in mechanisms, given the wealth of different purposes perception may serve.

Might news acquisition be an overarching, general purpose of vision? To answer this question, we need more clarity as to what is meant by 'news'. If news simply refers to important information about the here and now, then it will be hard to disagree that perception cares about news. The problem, however, is that it is quite unclear why the purpose of acquiring news in this

7 Graham (2014: 15) makes a similar point. Another of his examples is hands.

broad sense should produce a visual system that exhibits visual adaptation. Adaptation is characteristically a repulsive effect along a particular feature dimension. Such a mechanism will only aid news acquisition if we understand 'news' as referring specifically to *changes* in the environment.

Many of the purposes listed by Marr do seem consistent with a narrow focus on change detection (e.g. ducking and blinking). But facts that are not changes are clearly also important for perceptual purposes. Perched on a lofty tree branch, a hawk will wish to keep an eye on her prey, keeping its location at the front of her mind while she plans her descent (even if the prey's location is entirely unchanging). It would be a disaster to filter her prey out of the scene simply because it is stationary. In navigating, a creature (or sailor) may wish to continually track the position of some unchanging feature of the environment so it can ensure it is heading home (or to port). Similarly, you might bring a map on a walk so you can see (and return to) the layout of the landscape and where you are in it in a distinctively rich, visual way (contrast a verbal route description, or relying only on memory). Here, the map is not changing, nor are you expecting it to – and yet it is crucial to continue perceiving it. Other cases may arise when we simply study an unchanging object or scene – for example, determining whether a plant is edible or whether some terrain would make a suitable campsite. In such cases, we may evaluate what's before us for many minutes, scrutinizing and double-checking key visual features; we wouldn't want such features to disappear just because we're staring at them.

Block may well agree with this and deny that his sense of 'news' refers only to changes. But this returns us to the question of why news acquisition in this broader sense should predict *adaptation*. In other words, Block faces a dilemma: either understand 'news' broadly as 'information about what is happening here and now' and give up on the idea that this purpose explains perception as characterized by adaptation; or understand 'news' more narrowly as referring to changes along a specific feature dimension, but then lose the plausibility of the claim that detecting news is a general purpose of perception.

One theorist who does make an explicit appeal to news in the narrow sense of change is Gilchrist. In discussing his related analogy between vision and a free press, he claims that 'our senses have evolved to detect change' (2020: 1002). On this basis, Gilchrist contends that resolving the ambiguity of visual signals according to prior probabilities constitutes 'a terrible way to run a visual system'. However, this seems surprising in two respects. First, anyone acquainted with the last several decades of vision science has reason to be puzzled at the idea that perception's primary goal is to tell us what's changing (or indeed simply novel). The extensive and highly influential literatures on change blindness, inattentional blindness, and object tracking are widely taken to suggest that change detection is highly limited and unreliable – and it would be odd indeed for perception to be so inept at carrying out its allegedly primary (or even exclusive) function. Such results seem more consistent with a system which has change detection as one amongst several goals, performing adequately but imperfectly as it trades off the costs and benefits of these different ends (we return to this idea below).

Second, there is excellent evidence that, alongside mechanisms of adaptation, the visual system does exploit mechanisms of the kind which Gilchrist deems 'terrible'. Fischer and Whitney highlight such a complementary mechanism in reporting their influential discovery of 'serial dependence' (Figure 3):

> A crucial function of vision is detecting important changes in the environment, and sensory adaptation aids in maximizing sensitivity to change. … Adaptation is a simple, but powerful, mechanism for leveraging past visual input to maximize change sensitivity, but there is a flip side to the coin: the physical world is largely stable and continuous over time. Objects, scenes and physical properties tend to persist over time, making the recent past a good predictor of the present. The visual system may therefore delicately balance the need to optimize sensitivity to image changes with the desire to capitalize on the temporal continuity of the physical environment. It may often be advantageous to assume that the present visual environment is similar to the one seen moments ago. (2014: 2)

Here, Fischer and Whitney agree that change detection is one important goal of vision, but they point out that even with this goal in mind (let alone with others), there is reason to exploit prior experience. In line with this,

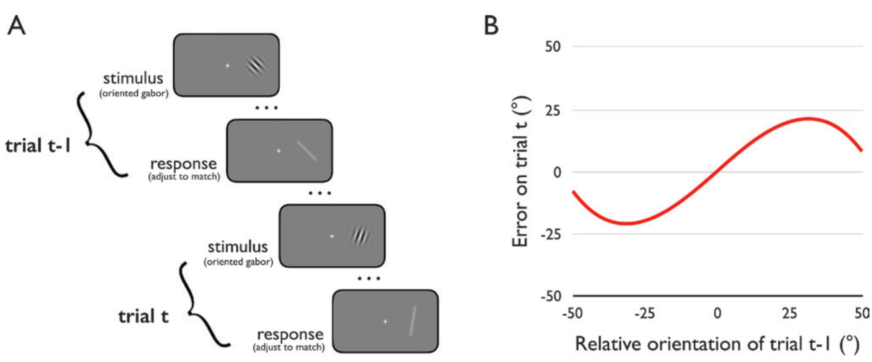

Figure 3. Serial dependence in visual perception. Not all sequential effects in vision are repulsive. (A) In experiments by Fischer and Whitney (2014), subjects adjust a faint bar to match the orientation of a Gabor patch. (B) The results show that recent stimulus history can attract (rather than repel) subsequent perception, such that estimates on the next trial are drawn towards the orientation seen on the previous trial (figure redrawn based on Fischer and Whitney, with data only approximated here).

Fischer and Whitney report systematic positive serial dependences in vision. Specifically, perception of oriented stimuli appears systematically biased *towards* recently perceived orientations. Their findings have been generalized in great detail in subsequent years (Kiyonaga et al. 2017).

Consistent with our suggestion that perception has multiple purposes, Fischer and Whitney argue that positive serial dependence and negative adaptation effects 'reflect different, competing goals of the visual system'. In doing so, they make the important point that perception is inherently noisy. Some changes in input may not reflect relevant changes in the environment but rather passing shadows, blinks, saccades, or internal noise (as it were, *fake news*). Thus, even if perception were purely focused on change, it would not follow that adaptation is the only relevant mechanism. Integrating information over time in more complex ways may lead to a more reliable and trustworthy view of the world.

Ultimately, Fischer and Whitney suggest that positive and negative mechanisms operate simultaneously at different levels and timescales throughout the visual system. Even so, it is not obvious that both positive and negative mechanisms will operate in all modalities, for all features, timescales and species. For instance, Van der Burg et al. (2021) found only positive sequential dependencies for intensity and familiarity in odour perception, and none for valence and arousal. They also note: 'Positive sequential effects for intensity ratings have been reported within the auditory domain when participants were instructed to judge the loudness of a sound (Holland and Lockhead 1968, Jesteadt et al. 1977), while a negative sequential effect has been found for taste intensity (sweetness: Schifferstein and Frijters 1992)'. Perception may be quite various.

Conversely, it is hard to see why the theoretical rationales for adaptation in perception would not also apply in many cases of cognition. Consider social cognition: why would it not be important to be maximally sensitive to changes in one's social hierarchy? A sudden change in allegiances, power structures and coalitions might be vital to one's prosperity or survival. Or consider games such as blitz chess: perhaps adaptation to position or structure enables rapid detection of subtle positional shifts leading to tactics and strategic play. Thus, even if perception is news focused, this does not provide a solid rationale for the contention that adaptation is *distinctive* of perception.

How should Block react to these points? One option would simply be to accommodate positive serial dependence as another feature of vision. However, this would reduce the plausibility of the claim that vision/perception was distinctive in its diachronic profile. As Pascucci et al. write, in general, 'short-term dependencies are not peculiar to visual perception but permeate a wide range of cognitive processes, including attention, decision-making, memory, confidence in performance, and motor behavior. This implies that, at multiple stages, our cognitive system is anchored and calibrated to the recent history of sensory and decisional processes' (2019: 2).

Another option would be to double down on adaptation as the true mark of perception and deny that serial dependence is a genuinely visual phenomenon. There is indeed evidence for a two-stage model in which adaptation is a 'low-level sensory' process and serial dependence is a 'higher-level process' (Fritsche et al. 2017, Pascucci et al. 2019, Ceylan et al. 2021). It would be an exciting result if indeed all serial dependencies were truly post-perceptual. However, it is more plausible that (as Fischer and Whitney suggest) such dependencies occur at multiple levels, both perceptual and post-perceptual. Indeed, there is evidence for retinotopic positive dependencies (Collins 2019). Moreover, on the model defended by Pascucci et al. (2019) and Ceylan et al. (2021), whereas the source of serial dependence is higher level/decisional, its *site* is perception. That is, such dependencies show up in changes in perceptual phenomenology. The difference is a difference *in* perception. Perhaps, then, one possibility is that adaptation is a signature of low-level (as opposed to high-level) visual processing. But even on this view, it will not be a mark of perception per se.

5. *Other features*

Block connects other features of perception with function. 'The winner-takes-all aspect of perception is required because the perceiving subject has to act, often quickly. It won't do for perception to wallow in ambiguity as with the more leisurely activity of cognition' (120). This is an intriguing argument. However, it is unclear how a winner-takes-all conception of perception is consistent with the psychophysical evidence supporting signal detection theory (SDT). SDT has long emphasized that decisions, including decisions to act, must be understood as based on a continuous evidence variable or likelihood ratio which (in the simple case of, say, tiger detection) is always to some extent 'ambiguous' between signal (tiger) and noise (see e.g. Swets 1961, Swets et al. 1961; also McLean et al. 2020). One standard finding which is hard to explain on a winner-takes-all model is that observers perform above chance when asked to make a second choice in multi-alternative forced-choice tasks (Figure 4). For instance, when asked to select a target from a set of four options, participants who choose wrongly on their first guess will do better than 33% on their second. Such evidence suggests that perception contains more information than simply a single 'winning' option. But in any event, since in the case of non-reflex actions there must always be a decision to act or not, it is unclear why ambiguity precludes quick action. If one sets a criterion which says: 'Run if there is even a 1% chance of a tiger being present', one does not need a winner-takes-all tiger percept to run quickly.

Despite these critical remarks, we are nonetheless optimistic that considerations of purpose in perception will provide substantial insights. In particular, we suggest that another central feature of perception is very plausibly closely connected to purpose. A core thesis of Block's book is that

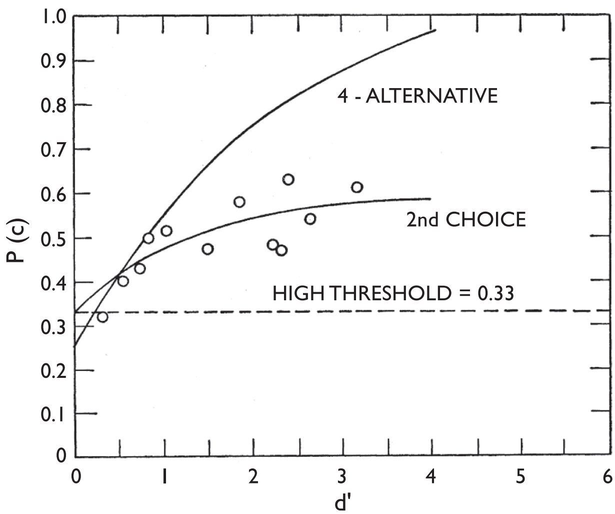

Figure 4. Guessing correctly when given a second chance. Even after an initially incorrect response on a four-alternative forced-choice task, subjects who choose among the remaining three options perform well above chance (Swets 1961). These results are difficult to explain on 'winner-take-all' models of perception.

'perception is constitutively iconic as contrasted with cognition, which is paradigmatically discursive' (166). It is tempting to motivate this feature by appeal to perception's function (just as theorists have long made a functional case for the discursivity of cognition). Recall Xu's (2018) remark that vision in part needs 'to comprehend the richness of the visual world'. Whether or not all perception is purely and constitutively iconic (cf. Quilty-Dunn 2020), it might well be argued that this purpose is best served by iconic representations. The critical idea here is that iconic representations are especially well suited to encoding rich information about multiple, simultaneous features of the external environment – a picture is worth a thousand words (see e.g. Dretske 1981, Fodor 2000, Kosslyn 1994, 1996; for a somewhat different functional argument for iconicity, see Kulvicki 2015).

Xu's remark might also be paired with an idea of Gilchrist's intended to make a different point. Gilchrist argues that cognitive penetration is problematic since visual information has to serve many purposes, and that these purposes are together best served by a free press. But the same idea that vision must serve many purposes – purposes which may not be predictable in advance – suggests that there would be value in initially gathering a great deal of information and only then allowing more flexible, task-dependent (attentional and cognitive) processes to begin filtering. Such an idea also has affinities with Block's views on phenomenal overflow.

These are large and complex issues which we cannot explore satisfactorily here. Instead, we end with an invitation to Block and other theorists. How should we determine the purpose – or purposes – of perception? How can we avoid the notorious perils of adaptationist approaches in doing so (e.g. Gould and Lewontin 1979, Fodor 2000), including the problem of distinguishing present functions from the purposes for which the capacity originally evolved to serve? And how do these purposes relate to the distinctive indicators and constitutive features of perception?[8]

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Johns Hopkins University
USA
ianbphillips@jhu.edu

Department of Psychological and Brain Sciences
Johns Hopkins University
USA
chaz@jhu.edu

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Responses to my critics

Ned Block

1. Adaptation, signal detection and the purposes of perception: reply to Ian Phillips and Chaz Firestone

Ian Phillips and Chaz Firestone have written a wonderful article on the rationale for adaptation as an indicator of perception, and more generally, on the purpose of perception, full of insights and challenges.

1.1 Adaptation

The issue they raise that I find the most interesting and challenging, and that I didn't say enough about in the book, is whether there is any independent justification for adaptation as an indicator of perception or whether my reliance on phenomenology (and also retinotopy) to ground adaptation makes adaptation superfluous.

I will approach the issue by reminding the reader of my three-layer methodology as explained in Chapter 1.

Here are the three layers: (i) use armchair criteria of perception and of cognition to roughly delineate the categories of perception and cognition. (ii) Use those categories to isolate scientific indicators. In particular, I chose perceptual adaptation, rivalry, pop-out, illusory contours and speed of processing, but as I indicated, I could have picked many other indicators. (iii) Use the scientific indicators to isolate the underlying constitutive features of perception and of cognition.

As I also explain, the use of a variety of scientific indicators raises a problem of circularity. The problem is that the justification of any given indicator depends on invocations of other indicators. I argued that the circularity is benign so long as the indicators converge on the same results and those results match up better with the armchair criteria than they would have with alternatives.

My case for benign circularity is threatened by the issue raised by Phillips and Firestone of whether some of the indicators play no real role at all. In particular, do I validate adaptation by appealing to retinotopy and phenom-

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