The steady Pace of Philosophy of Colour

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I outline five issues in philosophy of colour that deserve greater attention and provide skeletal frameworks for how future work on these topics could be carried out. The issues are: colour and metaphilosophy (§1), colour and artistic practice (§2), colour and virtual/augmented reality (§3), colour and imagination (§4), and colour and the predictive mind (§5). Some of these issues have been a focus of important recent works. Thus, colour conjoined with each of metaphilosophy, artistic practice and imagination have all been examined in at least a few recent publications – see below for references. It is clear, however, that these recent works are signals that there is much still to be done. By contrast, while at present there is a great deal of interest in the predictive mind, the intersection of colour and the predictive mind is vastly underexplored. This is despite the fact that the philosophy and science of colour are rather developed disciplines. Finally, while there have been some very important recent works on virtual and augmented reality, the significance of colour for these studies has yet to be examined. It is my hope that after reading this article readers are convinced not only that the philosophy of colour has a rich, recent history, but also a very bright future.

Keywords: philosophy of colour; metaphilosophy; philosophy of art; virtual reality; philosophy of perception; imagination; augmented reality; predictive coding

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Let me begin by thanking Alice Barale for this wonderful opportunity to help celebrate colour and also the launch of *The Routledge Handbook of the Philosophy of Colour*, edited by myself and Fiona Macpherson (hereafter *Handbook*). This *Handbook* is in many ways an attempt to illustrate how much philosophy can be (and has been) done by considering the nature of colour and colour experience, with the aim of stimulating further research into the topic. The opening section is a collection of broad philosophical topics – such as the mind-body problem, skepticism, philosophy of science, and vagueness – that can be examined using colour as a case study. The *Handbook* then outlines some of the insights into the nature of colour and colour perception gleaned from colour science, and proceeds to dig rather deeply into some of the issues that arise when trying to figure out what and where colours are (colour ontology), how we should understand colour experience, the nature of various colour phenomena, and the relation between thought, language and colour. Since Barale has provided an overview of the *Handbook*, I will focus on something slightly different.

In what follows I will sketch a few trends I see or wish to see in philosophy of colour. This is not to say that these are the only trends or that other topics don't deserve further examination. Far from it. For example, the strong relation between the science and philosophy of colour clearly deserves further exploration, and I expect that will occur in the future. Similarly, the importance of colour ontology to the philosophy of colour and of

colour to the mind-body problem are rich topics that will continue to attract attention. However, some other issues are less visible, but also important, particularly in our current climate. Of these, I will examine: colour and metaphilosophy (§1), colour and artistic practice (§2), colour and virtual/augmented reality (§3), colour and imagination (§4), and colour and the predictive mind (§5). Let's get started.

1. Colour and Metaphilosophy

It is worth highlighting some underexplored issues in colour and metaphilosophy. Metaphilosophy, roughly the philosophy of philosophy, is a broad topic. I focus on issues in metaphilosophy and colour within the analytic tradition. Analytic philosophy is driven by formal methods of logical reasoning and in many instances input from empirical sciences. Philosophy of colour is no exception to this. In the current climate there is an intense focus on topics like the analytic metaphysics of colour and the interpretation of empirical data from the science of colour. While I wouldn't advocate moving away from these topics, within analytic philosophy there are worthwhile instances in which the broadly "scientific naturalist" methods typical of analytic philosophy are being questioned.

In philosophy of colour it is standard to examine colour speech and thought, colour visual systems, the causal interactions between light, objects and retinas that give rise to colour perceptual states, and to do so in a way that leaves room for debate about basic questions like *Are cucumbers really green?* and *Do we ever veridically perceive colours in our environment?*. One motive for leaving such questions open to debate might be respect for scepticism, but another (related) motive is a felt need to justify one's answer in a way that will be informative to, if not convince, one's opponents.

Like some others, Joshua Gert[1] and Keith Allen[2] are colour realists, believing for example that cucumbers are green and that we often veridically perceive colours. They are also colour primitivists, maintaining that colours are *sui generis* properties (i.e. not reducible to basic physical properties like light reflectances). They offer many reasons to

[1] J. Gert, *Primitive Colors: A Case Study in Neo-Pragmatist Metaphysics and Philosophy of Perception,* Oxford University Press, Oxford 2017.
[2] K. Allen, *A Naïve Realist Theory of Colour*, Oxford University Press, Oxford 2016.

accept these claims. One of these – the one I will highlight – is their respective metaphilosophical views. These views independently lead them to viewing the truth of claims such as "cucumbers are green" as a kind of conceptual bedrock that doesn't stand in need of sustained justification. In the briefest of terms, and overlooking many fine points, here is the rough idea.

Gert's colour realism stems in part from his commitment to neopragmatism[3]. Neopragmatists[4] typically endorse minimalist or deflationary accounts of truth and reference. Thus, the question *Are there colours?* isn't about whether "blue", "yellow" and so on refer to genuine properties in our world. Instead, on their proposal the question is about whether *basic colour sentences*, sentences like "cucumbers are green" and "carrots are orange", receive widespread communal acceptance, can be ostensively taught, and can be incorrectly asserted (e.g. in odd circumstances or by persons with deficits in colour vision). Since basic colour sentences arguably do have these features, colours are real. By contrast, according to what Gert calls «scientific naturalism»[5], it is one thing to recognize the communal agreement about the contextually-stable use of basic colour sentences, but quite another to justify the reality of colours[6].

Allen labels his metaphilosophical view «transcendental naïve realism»[7]. Intuitively, naïve realism about perception is the thesis that we can and typically do directly or immediately perceive the reality around us. In philosophy it is often characterized as a claim about perceptual *experience*, namely that perceptual experiences are relations between perceivers and the mind-independent objects that are being experienced. Crucially, the mind-independent objects are not merely represented by perceptual experiential states, they partly *constitute* these states. The transcendental naïve realist sees naïve realism as a

[3] See e.g. J. Gert, *Primitive Colors*, cit., chap. 2.
[4] See e.g. H. Price, *Expressivism, Pragmatism and Representationalism*, Cambridge University Press, Cambridge Ma. 2013.
[5] J. Gert, *Primitive Colors*, cit., p. 68.
[6] For discussion see D. Brown, *Review of J. Gert, "Primitive Colors"*, in "Philosophical Review", 128(3), 2019, pp. 348–352.
[7] K. Allen, *The Value of Perception*, in "Philosophy and Phenomenological Research", 18 January 2019, doi: 10.1111/phpr.12574. See also K. Allen, *A Naïve Realist Theory of Colour*, cit., esp. chpt. 8, where the connection to colour is explicit, though Allen's metaphilosophy isn't quite as developed as in *The Value of Perception*.

kind of bedrock thesis, not in need of «external "rational" justification»[8]. It is instead a «core element of our conceptual scheme», something in need of illumination – but not doubting – through philosophical study[9]. Thus, the prescription is not a critique of naïve realism, but a Kantian-styled transcendental analysis, an attempt to explain the conditions for the possibility of naïve realism. While one can be a naïve realist about visual perception and reject the objectivity and reality of colour, it is difficult to do so. Thus, relatedly, part of Allen's motive for his colour primitivism is his transcendental naïve realism.

My point is not to suggest that we should endorse (or reject) these arguments. My point is that in both cases metaphilosophical commitments – commitments about how philosophy should be done, about what kinds of philosophical questions stand in need of further justification – are at least partly motivating their projects. With this in hand, let me make two comments.

First, it is somewhat easier to now see that different metaphilosophical commitments, those akin to some kind of "scientific naturalism", are often presumed in much contemporary philosophy of colour. Thus, the truth of "cucumbers are green" is not conceptual bedrock for many philosophers of colour. This is in part because they believe in a more substantive notion of reference and truth than the neopragmatist. It is also in part because they believe that external rational justification of colour primitivism (and naïve realism) can and should be sought, thus reducing the weight of transcendental arguments offered in support of these views.

Second, to my knowledge, a map about how these and other metaphilosophical commitments can inform and be informed by philosophy of colour hasn't been charted. Nor has there been a substantive debate about these issues. Given the magnitude of what's in play, a map and debate seems worthwhile.

2. Artistic practice and colour

It is well known that colour has been studied not only in vision science but also in cultural studies, history, literature, visual art, architecture, fashion, and so on. Yet the influence of

[8] K. Allen, *The Value of Perception*, cit., p. 7.
[9] Ibidem.

the science of colour on contemporary philosophy of colour far outweighs not only the influence of these other fields, but arguably the sum of those influences. Consider visual art as an example. Although philosophers of art routinely discuss works where colour plays a prominent role, few philosophers of art explicitly theorize about colour and colour perception[10], and few philosophers of colour use visual art as a focus of study. Setting aside philosophy of art, *artistic practice* itself is even less studied by philosophers of colour. Yet it is well-known that practical work of this sort yields numerous insights in the topics they study. One fascinating example of artistic *colour* practice yielding philosophical insight has recently been discovered. Given *Intinera*'s interest in aesthetics, it is worthwhile introducing readers to it.[11]

The philosophy and science of colour routinely assumes the *opponent process theory of colour*.[12] The rough idea is as follows. Normal human trichromats have three cones, with peak sensitivities to the long, medium and short wavelength ranges of the visible spectrum, yielding L, M and S cones, respectively. According to this theory, human colour vision is further structured by the colour opponent system, which receives information from these cones and processes their differences in an antagonistic manner. The opponent system contains two chromatic opponent channels (red-green and blue-yellow) and an achromatic opponent channel (white-black). Set aside the achromatic channel. The red-green channel receives information from the L and M cones, and calculates the function L – M. If the result is positive, then the channel outputs *red*, if it's negative it outputs *green*, and if the value is null the channel doesn't output anything. The antagonism or opponency is the fact that triggering *green* entails supressing *red* and vice versa. There is no option of triggering both *red* and *green*. The blue-yellow channel receives information from all three cones and

[10] One exception is D. M. Lopes, *Pictorial Color: Aesthetics and Cognitive Science*, in "Philosophical Psychology", 12(4), pp. 415-28.

[11] This example is described in F. Macpherson, *Novel Colour Experiences and their Implications*, in D. Brown, F. Macpherson, *The Routledge Handbook of Philosophy of Colour*, Routledge, London 2020, chpt. 11. Macpherson was made aware of it by M. Newhall, *Painting With Impossible Colours*, slides of a talk delivered at the "Depiction, Pictorial Experience, and Vision Science" conference, Centre for the Study of Perceptual Experience, University of Glasgow, 15 – 17 November 2018 (unpublished).

[12] The opponent process theory was first proposed by E. Hering, *Outlines of a Theory of the Light Sense* (1892), Harvard University Press, Cambridge Ma. 1964. Key psychophysical data in support was added by L. Hurvich, D. Jameson, *An opponent-process theory of color vision*, in "Psychological Review" 64, 6, Part I, pp. 384–404, and various developments (including neuro-biological evidence) have been added since.

calculates S – (L + M). If the result is positive the channel outputs *blue*, and if negative it outputs *green*. On this model, human colour visual systems cannot enter into a state that represents both blue and yellow (at the same location at the same time), or a state that represents both green and red (at the same location at the same time). In short, according to opponent theory we cannot visually represent or experience bluish-yellows or reddish-greens.

In recent years, scientists have seemingly been able to "trick" our visual systems to enter into such "impossible" states[13], providing evidence against the opponent theory of colour. These experiments often use eye-trackers and carefully crafted stimuli, and, crucially, some subjects report experiencing colours that are reddish-green. The kinds of experiences induced in subjects are unfamiliar or novel to subjects, and as such are not easy to reproduce outside the highly contrived experimental situations. This makes the application of these cases to everyday colour vision somewhat limited.

Interestingly, visual artists have also addressed the opponency issue, but the method and result are different. The evening sky generates numerous colours, and at times the blue of the sky or of the sea can be found alongside the yellow of the setting sun, yet the boundaries between these blues and yellows needn't appear sharp. In that case, one might wonder whether the boundary area contains or looks to contain a bluish-yellow colour (i.e. a mixture of blue and yellow). According to the opponent process theory of colour, the area cannot look to be bluish-yellow, because nothing can look this way. From the painter's perspective, the central question is the practical one: Can I paint a smooth transition from blue to yellow without going through any other colour, including white or grey? The answer is that you can paint something that *looks* like a smooth transition from blue to yellow that doesn't go through any other colour[14]. Hence one way to describe the transition area is as looking bluish-yellow, in conflict with the opponent process theory of colour. The paints used to achieve this include a combination of blues, some warm colours like yellows

[13] See e.g. H. Crane, T. Piantanida, *On Seeing Reddish Green and Yellowish Blue*, in "Science", 221(4615), pp. 1078-1080.
[14] See e.g. S. Ryan, *How to Paint a Sky - Acrylic Painting Lesson*, YouTube Video, published on Aug 17, 2013, accessed 19 November 2018.

and reds, and a white. The actual colours of the final canvass at each region are open to a few different descriptions. On one of these descriptions, the canvass has a blue region, a yellow region, and a grey region in between the two. If this is accurate, then the canvass itself doesn't have a bluish-yellow region, even though it arguably looks to. Thus, while there are some questions about how best to describe the *experienced* colours of the canvass, and how best to describe the *colours* of the canvass, we have a purported counterexample to the opponent process theory of colour deriving from artistic practice (not science).

This demonstrates that challenges to colour theory do derive from artistic practice. Perhaps more importantly, this counterexample derives from natural scenes and is readily appreciable by the public. By contrast, the examples from the scientific experiments are, as mentioned, not viewable outside laboratory settings, and their character is difficult for subjects to communicate to experimenters. Thus, although the character of both the colour experiences had during the scientific experiments and the colour experiences of the canvass are difficult to describe, the public observability of the canvass allows for an important kind of public scrutiny and debate about the applicability of various descriptions that the scientific case doesn't readily support. In at least this regard the artistic counterexample is of heightened philosophical interest.

I don't mean to suggest that the purportedly bluish-yellow looking regions of paintings of sunsets demonstrate beyond doubt that the opponent process theory of colour is mistaken. I instead suggest that the case has special value because of its derivation from natural scenes and accessibility for public scrutiny. Given how little attention philosophers of colour typically pay to artistic practice, it is hard to say how many insights into philosophy of colour might be lying in wait.

3. Colour and virtual/augmented reality

Virtual reality is upon us, and it has many philosophically striking aspects. It brings the possibility of a "full visual illusion", and (relatedly) prompts difficult questions about perceptual ontology and perceptual experience. Virtual reality yields ethical questions, such as whether or not and to what extent people should prefer actual reality to virtual reality.

Since, in its current form, virtual reality is predominantly visual, and colour is central to visual experience, colour is immediately at the heart of these issues. Similar issues arise from augmented reality, where virtual elements are "layered on top of" or "inserted into" perceived objective reality. Let me make a few remarks about how colour might figure into the emerging research on these topics

There are obvious perceptual and ontological analogy between virtual reality and representational works of art. Thus, the colours and shapes presented on the screen of the virtual reality headset are analogues of the colours and shapes presented on the canvass of a painting. These presented features serve to *re*present, via *depiction*, objects and features in the depicted scene or world.

Ontologically, how should we understand the reality of the depicted scenes? In the theory of depiction, realists maintain that the depicted scenes are real or exist in a substantive sense, and various proposals try to limit this sense of "reality", including by appeal to universals, ideas, and fictional worlds[15]. In theory, all options are applicable to virtual reality, although debates about these applications are in their infancy (e.g. Chalmers defends a kind of realism, and McDonnell and Wildman defend fictionalism)[16]. While colour may not yield any specific insights here, it is an interesting case study regardless. Colour's significance to the relevant perceptual issues is more pronounced.

How should we understand the perceptual and experiential states that arise from engaging with depictive artworks? Many answers have been proposed. Perhaps such perceptions involve a persistent kind illusion, a view often attributed to Gombrich[17]. Perhaps there is a twofoldness or «seeing-in» to these states, where we in some sense perceive both the presented features on the canvass or virtual reality headset, and depicted

[15] For an overview see e.g. J. Hyman, K. Bantinaki, *Depiction*, in E. N. Zalta (ed.), *The Stanford Encyclopedia of Philosophy* (Summer 2017 Edition) (https://plato.stanford.edu/archives/sum2017/entries/depiction/).
[16] See D. Chalmers, *The virtual and the real*, in "Disputatio", 9(46), 2017, pp. 309–52 (doi: https://doi.org/10.1515/disp-2017-0009); N. McDonnell, N. Wildman, *Virtual reality: digital or fictional?*, in "Disputatio", 11 (55), 2019 (doi: 10.2478/disp-2019-0004).
[17] E. Gombrich, *Art and Illusion: A Study in the Psychology of Pictorial Representation*, Phaidon, London 1960.

scenes[18]. A more recent proposal is that the perceptual states typically involved in picture perception are of the same psychological kind as those involved in everyday «face-to-face» perception, except that during picture perceptions we engage «virtual models» of objects and scenes in pictorial space[19].

Again, in theory these and other options from the theory of depiction are applicable to virtual reality, although debates about these applications have barely begun. Colour is a particularly important case study, because the presented features on the canvass or virtual reality headset typically include *real* colours that are interacting with our visual systems. By contrast the canvass or screen doesn't have real analogues of the depicted objects (e.g. real dogs or goblins), and the 2D shapes on the canvass or screen bear a thorny relationship to the 3D shapes of the depicted objects. Thus, if perceptions of depictive art and virtual reality are twofold, or illusory, or involve engaging "virtual" objects and their colours, the role that the presented real colours play is of particular interest[20].

An important disanalogy between depiction in art versus virtual reality is that, when wearing a virtual reality headset, the screen is arguably impossible to perceive *as a screen* in the way that canvasses are typically perceivable *as canvasses*. In this regard perhaps the default perceptual state in virtual reality is more akin to the kind of state that occurs when viewing *tromp l'oeil* works (i.e. paintings that bound toward looking like a real scene as opposed to a painting of a scene). *Tromp l'oeil* paintings are an infamous trouble case for theories of depiction, and not the kind of case depiction theorists typically build their theories around. These factors arguably make the real colours of the virtual reality screen even more difficult to accommodate in one's theory of perception and experience in virtual reality.

Recall that augmented reality is where images are layered in front of or inserted into the scene before one, for example arising when one wears transparent glasses that selectively

[18] See R. Wollheim, *Art and Illusion*, in "British Journal of Aesthetics", 3(1), pp. 15–37; Id., *Painting as an Art*, Princeton University Press, Princeton 1987.
[19] R. Briscoe, *Depiction, Pictorial Experience, and Vision Science*, in "Philosophical Topics", 44(2), 2016, pp. 43-81.
[20] J. Kulvicki, *Colour and the arts: Chromatic perspectives*, in D. Brown, F. Macpherson, *The Routledge Handbook of Philosophy of Colour*, cit., chpt. 6.

produce images on the lenses. While it is tempting to use the above options and simply apply them to augmented reality perceptions, it would be a mistake to begin this way. In depiction cases, the canvass or virtual reality screen essentially function to depict the represented scene. By contrast, while the virtual images of augmented reality may at times depict the reality "beyond" them, in many instances they may not. Consider some examples.

Suppose first that one's augmented reality glasses do something rather sophisticated like identify human faces in the scene before you and make them appear blue, for example by producing blue patches on the portion of the glasses that overlap with observed faces. It is reasonable to argue that in this case the blue patches on the glasses depict the colours of faces in the scene. The depictions are in general erroneous, as few if any of the observed faces are (by hypothesis) blue. But, for contrast there is a much stronger case to be made for depiction in the "blue face" example than in comparison with a scenario in which one merely wears blue-tinted glasses. The blue of blue-tinted glasses doesn't function as a depiction of any observed scene in any substantive sense. An intermediate case might be one in which one's augmented reality glasses introduce a blue tint to the scene in response to specific general environmental conditions, such as extreme brightness. I suspect in this case the blue in some important senses is depicting the scene, and in other important senses isn't, though space prevents me from fleshing this out. Next, consider a case in which augmented reality glasses provide textual information about the face one is standing in front of, perhaps a name or occupation. Although that text expresses content that is about the face (or about the individual to whom the face belongs), and in this regard represents the face (or individual), the information isn't in any way *depicting* the face (or individual). Finally, suppose the glasses provide textual information about something other than the observed scene, perhaps information about oneself, or a new email, or breaking news in sport. That text, even though it has representational content, doesn't represent anything in the observed scene (unless by chance).

Thus, starting with a depiction framework for understanding augmented reality perceptions is oversimplified and misleading. Another option is to start with perceptions

involving distinct layers where the virtual "proximal" layer isn't essentially functioning as a depiction of the "distal" layer. Colour perception is a crucial case study here as well, for this starting point yields numerous possible kinds of visual experiences, many of which will have application in augmented reality[21].

4. Colour, perception and imagination

It is clear that we can and often do perceptually experience colours, and that these are somehow different from merely imagined colours. How should we understand the difference between them? In what ways do the two interact? Recent work on interrelations between cognition, imagination and perception challenge influential answers to these questions. Here is a brief overview[22].

Imagined colours might be described as *less vivid* than perceptually experienced ones (following Hume), or as more *deliberately* produced or more liable to *fade* away without sustained effort. All of these criteria are instructive, but also fallible. For example, to someone imagining a monster in the closet, the imagined monster might seem extremely vivid (e.g. prompting them to run from the room in terror), non-deliberate (e.g. they don't believe it's their doing, and seemingly can't make it stop), and persistent (e.g. the imagined creature might be present every night for months). Conversely, perceptual experiences can lack vivacity (e.g. viewing something in poor lighting), can seem deliberate (e.g. when an object in a crowded field is only discernible with considerable effort) and can fade rapidly (e.g. fixed, persistent stimuli fade from view very quickly[23]. Thus, enforcing these kinds of criteria to distinguish between perceptions and imaginings is wrong-headed. A more nuanced approach is required.

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[21] D. Brown, *Colour constancy and colour layering*, in "Philosophers' Imprint", 14(16), 2014, pp. 1-31.

[22] For details see e.g. D. Brown, *Infusing perception with imagination*, in F. Macpherson, F. Dorsch (eds.), *Perceptual Imagination and Perceptual Memory*, Oxford University Press, Oxford 2018, pp. 133-160; Id., *Infusing perception with imagination?*, on *The Junkyard: A Scholarly Blog Devoted to the Study of the Imagination*, 19 February 2020 (https://junkyardofthemind.com/blog/2020/2/14/infusing-perception-with-imagination). See also D. Stokes, *Cognitive penetration and the perceptual of colour*, in D. Brown, F. Macpherson, *The Routledge Handbook of Philosophy of Colour*, chpt. 29, and the references therein.

[23] There are different forms of "perceptual fading". Illusions like the Troxler effect provide a striking illustration of one of them (see e.g. https://www.illusionsindex.org/i/troxler-effect).

Setting aside demarcation difficulties, one might ask whether and to what extent perceived and imagined colours can mix or overlap in a single state? There is a body of research pertaining to "memory colour" which provides surprising insights into the issue. The data are controversial, but for purposes of illustration take them at face value. Memory colour effects occur roughly when the experienced colour (e.g. the saturation) of a perceived thing is affected by background beliefs, for example experiencing a Coke can to be more red than a similarly coloured red cube, and, in Scotland, experiencing an Irn Bru can as more orange than a similarly coloured orange cube. Why or how does an Irn Bru can look more orange than the cube? It seems that perception alone can't explain the effects, because (by design) an Irn Bru can isn't more orange than the cube. Belief seems inadequate as well. Although I believe that an Irn Bru can is orange, beliefs are typically quite distinct from perceptions. Beliefs are non-sensory in a way that perceptions are inherently sensory. Also, beliefs don't generally seem to change perceptions. For example, as a perceptual theorist, I know what is illusory about many instances of perceptual illusions, yet that knowledge and the associated beliefs don't prevent me from being susceptible to the perceptual effects the illusions generate.

If perception and belief are inadequate to explain memory colour effects, perhaps imagination can help. Imaginings are typically sensory in a way that beliefs aren't, so imagination is a candidate to explain the sensory aspect of memory colour effects. On Macpherson's proposal[24], an Irn Bru can is experienced as more orange than the orange cube because you believe that an Irn Bru can is orange (a cognitive state), and that triggers an imaginative state of orangeness that is injected into the occurrent perception of an Irn Bru can. Nothing of this sort happens regarding your perception of the orange cube. As a result, an Irn Bru can is experienced as being an overly saturated orange. The proposal is controversial, but assuming memory colour effects occur, some kind of explanation is demanded, and postulating perceptual states that are infused or injected with imaginings is an intriguing proposal.

[24] F. Macpherson, *Novel Colour Experiences and their Implications*, cit.

Memory colour effects are just one kind of case that falls under the label "cognitive penetration of perception", and cognitive penetration cases are just one kind of case that might benefit from postulating states that are a mixture of perceptual and imaginative elements. The clarity and forcefulness of the colour case proves immensely valuable for these issues, and the increased attention these issues are receiving seems well deserved.

5. Colour and the predictive mind

The predictive coding approach to perception and the mind more generally is a very active research area at the moment[25]. However, while colour perception is an extremely well-studied facet of our minds, the ways in which colour perception might inform or be informed by predictive coding are largely unexplored. Let me situate the core issues.

Bayesian approaches to the mind utilize Bayesian probability theory, and in particular Bayes's Theorem, to understand mental processing. In its most general and rough form, Bayes's Theorem describes an event's probability by reference to conditions or *priors* that are assumed to obtain before the event. It is routinely applied to perceptual processing, and in some cases to colour perception. With regard to colour, the starting assumption is usually that a core function of colour vision is to represent the light reflectances of surfaces in one's environment. However, the light entering in the eye doesn't directly provide this information but is instead ambiguous between various combinations of reflectances and conditions of illuminations (and perhaps other factors like light transmission features of media). This ambiguity in sensory information is a classic example of the "inverse optics" problem in perception. Over the last several decades, various models of colour constancy have proposed assumptions that visual systems do or might make to overcome this problem. Some of these have now been re-cast in terms of Bayesianism[26]. In addition, some projects in colour science are more generally built around Bayesianism[27].

[25] A. Clark, *Whatever Next? Predictive brains, situated agents and the future of cognitive science*, in "Behavioural and Brain Sciences", 36 (3), 2013, pp. 181-253; J. Hohwy, *The Predictive Mind*, Oxford University Press, Oxford 2013.

[26] E.g. D. H. Brainard, *Bayesian Approaches to Color Vision*, in M. S. Gazzaniga, E. Bizzi, L. M. Chalupa, S. T. Grafton, T. F. Heatherton, C. Koch, J. E. LeDoux, S. J. Luck, G. R. Mangan, J. A. Movshon, H. Neville, E.

Predictive coding is a sophisticated approach to mental processing, but here are the key ideas for our purposes. The prior assumptions of a perceptual system don't merely serve to disambiguate sensory information (e.g. light reaching the eye) but are more substantively used to *generate a model* of what is perceptually available before a subject. The model is then checked for accuracy against incoming sensory information and updated as needed. This is a significant departure from classical[28] (e.g. Marrian) models of perceptual computation. On classical models, a perceptual system builds a model of what is before the subject by performing various computations on incoming sensory information, computations that utilize stored assumptions and algorithms. Thus, on a classical picture, perceptual models are primarily built around incoming sensory information. On the predictive coding picture perceptual models are primarily built using stored assumptions, and then adjusted against incoming sensory information as needed.

There are numerous questions about how to develop the predictive coding approach, and various challenges are being posed. Colour vision is an obvious case study to examine this project, but at present little to no work has been done to this end. The following kinds of questions are worth examining. How straightforward is it to apply the Bayesian approaches to colour vision to predictive coding? How is the self-generated perceptual model of predictive coding to be understood in the context of colour vision, and what evidence is there for its existence? Some models of colour perception do not assume that a core function of colour vision is to represent the light reflectances of surfaces in one's environment[29]. How are these models expressible with Bayesianism and within predictive coding? There are also open questions about how to understand perceptual representation and perceptual experience within predictive coding. Colour is a natural case study for these

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A. Phelps, P. Rakic, D. L. Schacter, M. Sur, B. A. Wandell (eds.), *The cognitive neurosciences*, Massachusetts Institute of Technology, Cambridge Ma. 2009, pp. 395–408.

[27] E.g. S. Allred, *Approaching Color with Bayesian Algorithms*, in S. Allred, G. Hatfield (eds.), *Visual Experience: Sensation, Cognition and Constancy*, Oxford University Press, Oxford 2012, pp. 212-231.

[29] E.g. D. Foster, *Does colour constancy exist?*, in "TRENDS in Cognitive Sciences", 7(10), 2003, pp. 439-443.

questions. Unfortunately, the topic of the predictive mind isn't discussed in depth in the *Handbook*. It strikes me as worthy of future research[30].

6. Conclusion

The above broad issues – colour and metaphilosophy (§1), colour and artistic practice (§2), colour and virtual/augmented reality (§3), colour and imagination (§4), and colour and the predictive mind (§5) – all strike me as areas ripe for current research. In many instances the *Handbook* only scratches the surface of these topics. To be sure, the many topics that the *Handbook* does delve deeply into are also ripe for current research. This is just to say that the philosophy of colour, as strong as it has been in recent decades, shows no signs of letting up.[31]

[30] I should note that I currently have a doctoral student, Steven Broadrick, whose thesis is on predictive coding and colour. I am indebted to him for helping me appreciate the underexplored opportunities in this domain.

[31] Thank you to Fiona Macpherson and two anonymous referees for helpful feedback on this paper.