CAN HUNTER-GATHERERS HEAR COLOR?[1]

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Forthcoming in *Common Minds: Essays in Honor of Philip Pettit, eds. Geoffrey Brennan, Robert Goodin, and Michael Smith (OUP)*

Philip Pettit (2003) argues that color looks should be explained in terms of manifest powers. He indicates that his view is broadly allied with our own dynamic sensorimotor approach to conscious experience (O'Regan and Noë 2001a, b, c; Hurley 1998, Hurley and Noë 2003a; Noë 2004). Pettit finds support for his view in Ivo Kohler's (1964) report of adaptation to color-distorting goggles. However, a potential objection to Pettit's account of color looks derives from synaesthetic color experiences; this objection has also recently been pressed against our position by Jeffrey Gray (2003). Here we review Pettit's account, consider its relationship to our own view, and state the challenge that synaesthesia presents to the perspective that we share with Pettit. We conclude that further work that brings the brain into the picture is needed to deal with Gray's challenge; we undertake this elsewhere (Hurley & Noë, in progress).

Both color and illusion present challenges for any theory of perception--and perhaps especially for accounts, such as Pettit's and ours, that view perception and action as tightly interconnected. As we explain below, 'colored hearing synaesthesia' combines color experience and nonveridicality. Our aim in this paper is to explore some of the resources for theories like Pettit's and ours to meet this double challenge.

1. Pettit on color looks as manifest powers.

According to Pettit (2003), a red object looks red because perceiving it *manifestly empowers* in certain ways. That is, it manifestly enables certain responses, e.g. precise discriminatory and tracking responses, and manifestly induces certain related expectancies. This *manifest*

[1] Authorship is fully joint and names are in alphabetical order. We are grateful for comments and discussion to: Dominic ffytche, Jeffrey Gray, Anthony Jack, Erik Myin, Philip Pettit, Hanna Pickard, Kevin O'Regan, David Rosenthal, Simon Saunders, Nicholas Shea, Petra Stoerig, and others on various occasions when we have delivered this and related material. We are also grateful to the McDonnell Centre for Cognitive Neuroscience in Oxford for support of this work in the form of a visiting fellowship for AN.

powers account of color experience has two distinct elements: the powers element and the manifestness element.

First, obviously, Pettit's account links color experience to the discriminatory powers that perception of the colors enables. Powers in turn are understood in terms of both responses and expectancies. The red look of a tomato supervenes, in part, on the ways it enables the perceiver to track it against certain backgrounds and sort it from other objects, and induces certain expectancies about the sensory consequences of color-relevant changes, such as specific movements or changes of lighting or background.

Second, more subtly, Pettit's account also treats the linkage of color looks to powers as *perceptual* in character. On Pettit's view, the red look of a tomato doesn't supervene *merely* on such powers, but rather on such *manifest powers*. That is, the red look of the tomato supervenes on the *manifest* empowerment of its perceiver in these ways. To look red is to *look empowering* in certain ways, to advertise visually certain empowerments.[2] Note that Pettit's account is not an account of looks in general, but of color looks.

Pettit contrasts qualia account of color looks with his own manifest powers account as follows. On the qualia view, perceiving a red object manifestly enables certain responses and induces certain expectancies, because the object looks red. By contrast, on the manifest powers view, a red object looks red because perceiving it manifestly enables certain responses and induces certain expectancies. Looks neither cause nor are caused by such manifest empowering, but rather supervene on it. For example, a ball's looking like it is going fast cannot be dissociated from the responses and expectancies that perceiving it manifestly enables. Similarly, for an object to look red cannot be dissociated from certain responses and expectancies that perceiving it manifestly enables.

An essential difference between the qualia view and the manifest powers view is that, on the qualia view, color looks are properties of perceptions that can, in principle at least, vary independently of the manifest powers perceptions provide. That is, the same set of relations could in principle be realized by perceptions with intrinsically different color looks (see, e.g., Palmer 1999). On the manifest powers view, by contrast, color looks are relational all the way down, rather as a point in space-time is. Space-time points are specified in terms of the structural relations they enter into with fields and matter and other space-time points[3], not in terms of intrinsic properties that could vary independently of these relations.

Pettit argues that the manifest powers account of color looks will only be plausible if it meets two conditions. First, the set of manifest powers must be *rich* enough to make it difficult to suppose that this set could be dissociated from looking red and associated instead, say, with looking green. More generally, the richness of the set of manifest powers

[2] We return to this point below; it will be important in distinguishing Pettit's view (and ours) from more behaviorist views.

[3] Thanks here to Simon Saunders.

on which a color look supervenes should make for a one-to-one mapping between looks and sets of powers; it should rule out that a different look could be associated with just the same set of powers, or that the same look could be associated with a different set of powers. Second, the set of manifest powers must such as to give looking red its distinctive *unity* (including the unity of veridical and illusory red looks).

Pettit explains how the manifest powers account satisfies the richness requirement. Color perception requires sensitivity to light intensities, to wavelengths, to the ratios of different wavelengths in reflected light, to edge contrasts of such ratios, and to the similarity of such ratios across intervening contrasts and across contexts. These sensitivities enable us to discriminate and track objects by color, to perceive color constancy across variations in illumination, background, movement, and so on, where some but not all of these variations are produced by the subject's own motor activity. Given the complex, varied, demanding responses associated with looking red, Pettit argues, looking green could not have the same signature in the space of manifestly enabled responses. As light varies, for example, moving green objects but not red objects will be trackable against certain backgrounds.[4]

The unity requirement is met, in Pettit's view, by the fact that manifest powers, by their very nature, extend across contexts, in virtue of the expectancies they essentially involve. Nothing would count as the power to *discriminate* an object with respect to color if it did not allow for the ability to track the object as viewing conditions vary--as lighting conditions change, as the object moves, or as one moves in relation to the object. However, to (not just discriminate but) *experience* something as a given shade of red is to expect such color-relevant changes in movement, lighting, and so on, to produce certain characteristic changes in patterns of sensation.[5] For something to look red isn't just for it to manifestly enable certain responses, but also for it manifestly to induce certain expectancies about "how the object will show up under a range of possible variations", as Pettit puts it. That is, for something to look red is not just to look response-enabling in certain ways, but to look as if it would look in this or that way under various conditions, to solicit such expectancies visually. As a result of these expectancies, the perceivers may also have further expectations also about the discriminating and tracking responses that would be enabled across a range of counterfactual circumstances.

Thus, as Pettit explains, one suite of expectancies unifies looking red across various contexts. However, the truth of these expectancies is not guaranteed by the color look. If those expectancies are false—that is, if they are such as to be disappointed--, then the look the object has in this context is illusory; it isn't really red, even though it looks red. Illusory and veridical looks can thus be unified by expectancies, even though some of those are false for illusory looks. Indeed, illusory looks may persist when the relevant expectancies survive at some level, even though I know intellectually that they are false (for example, in

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[4] Compare Palmer 1999.
[5] See also Noë 2004.

the Mueller-Lyer illusion). We return to Pettit's false expectancy account of illusions below. For reasons explained below, it does not meet the challenge from synaesthesia.

The manifest powers account of color looks thus makes two claims. First, one rich set of manifestly enabled responses and expectancies, or *manifest powers* for short, should not be associated with different color looks. There is a unique mapping from manifest powers to color looks; different color looks should not go with the same manifest powers. In other words, color looks could not be exchanged while corresponding manifest powers are held constant. This claim brings into doubt the possibility of inverted color experiences that the qualia view tolerates.[6] Second, one color look should not be associated with different manifest powers. There is a unique mapping from color looks to manifest powers; different manifest powers should not go with the same color looks. In other words, manifest powers could not be exchanged while associated color looks are held constant.

Pettit invokes Ivo Kohler's (1964) color adaptation results in support of the manifest powers view.[7] The first of the above claims of the manifest powers view, that different color looks should not go with the same manifest powers, predicts the adaptation of color experience to color-distorting goggles that Kohler reports. In Kohler's goggle experiments, which we explain in more detail below, manifest powers (including expectancies) initially disrupted by the goggles are recovered with adaptation, and color looks adapt with them, as the manifest powers view predicts. Kohler's work thus supports the claim that color experience tracks manifest powers.

However, evidence from work with synaesthetic subjects presents a challenge to the manifest powers view. The second of the above claims, that different manifest powers should not go with the same color look, appears to be incompatible with colored-hearing synaesthesia, as Gray has argued. We explore this challenge in what follows.

Before moving on, two sidebars. First, what is the right view of the status of the claims made by the manifest powers theory of color looks—and particular of the claim that there is a the one-to-one correlation of manifest powers and color looks? Should this be treated as an a priori claim or as an empirical hypothesis? We don't pursue this question, or probe Pettit's views on it, here. The method we adopt in what follows is to test the view against empirical considerations about color adaptation and synaesthesia (see also and compare Cole 1990).

Second, a theory about what color looks are is not necessarily a theory about what colors are. A manifest powers account of the experience of color is compatible with a range of different empirical and philosophical theories of the nature of colors. We also leave aside the exploration of this point and related issues.

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[6] For related discussions, see Hardin 1997; Cole 1990; Myin 2001.

[7] Cf. Hurley 1998, which invoked Kohler's results in arguing against the input-output picture of perception and action. See also O'Regan and Noë 2001a.

2. Behaviorism vs. the hunting and gathering perspective on color looks.

At a first, superficial glance, Pettit's manifest powers account of color looks may seem to reduce color looks to certain responses to color perception, and hence to be a species of behaviorism. However, this would be an inaccurate understanding of his view. The second element in Pettit's view – the perceptual manifestation requirement – differentiates his view from behaviorism and makes clear that it is not an attempt at reduction. [8] The experience of redness is not taken to be constituted merely by its behavioral effects or the responses that it enables. Something's looking red is, irreducibly, a fact about how it looks. This second element is also what enables the view to meet the more traditional *qualia* theory on its own phenomenological ground. Pettit's account suggests that to do justice to what it is like to experience a color, we need to recognize that when we experience an object as colored, we experience it as entering into a suite of saliencies: as standing out from a background so as to look fit to empower us in certain ways.

Indeed, we suggest that the difference we have emphasized in explaining Pettit's view between *merely enabling* certain responses and *manifestly enabling* them can be understood partly in terms of the subject's expectations of the sensory consequences of his own potential movements, as well as other possible color-related changes. Part of what it is for perceiving something manifestly to enable certain responses is for the perception to carry with it certain implicit practical understandings, of what the sensory consequences of certain movements would be. The manifestness of the enabling of responses is in part a function of these visually solicited expectancies. The subject can see not just how something looks here and now but also how it would look if he were to do this or that, and hence what he can do; moreover, these sensory and practical implications of given color looks are all tangled up with, not strictly separable from, the color looks themselves (see also Noë, 2004, on the fractal character of color experience).

Consider, for example, Pettit's comparison of color looks with the look of a ball moving towards one's face. Here is the way we would describe the latter experience, emphasizing the difference from more behaviorist views; we believe that our dynamic sensorimotor view is here consistent with Pettit's account (though at times his formulations veer in a more behaviorist direction). Seeing the ball enables ducking to avoid it, and does so manifestly. But it looks as if the ball can be avoided by ducking *because* it looks as if ducking would make the situation look different in certain ways. Thus, when a ball looks as if it is moving towards one's face, it looks as if ducking would make the situation look different; as a result, it looks as if ducking would avoid the ball, and thus ducking to avoid the ball is enabled.

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[8] See also Hurley 1998, pp. 213, 420-421, and Hurley 2001, as well as O'Regan and Noë 2001 and Noë 2004, for more on the difference between our views and behaviorism.

We agree with Pettit that there is no visual quale as of a ball about to hit one's face that is independent of the powers such an experience manifestly enables. In particular, seeing that a ball is about to hit one's face manifestly enables one, by moving in certain ways, to avoid being hit, *because* it manifestly induces expectancies about how things will look if one does. That is, we suggest, the *manifestness* of the enabling of responses by this experience depends on the *expectancies* about the sensory consequences of movement that it manifestly induces. In seeing the ball coming, the perceiver also knows what the sensory consequences of doing this or that will be, and hence knows how to respond for certain purposes.

Thus, for the ball to look as if it is moving towards one's head is not for the ball simply to look as if it affords opportunities for avoidance behavior. Rather, it is the ball to look to be related to one in such a way that the merest movement of the eyes or head or body would alter, in specific ways, the way it looks. Because the dynamics of the perceiver's relationship to the ball are manifest in the experience, the experience normally does acquire an action-guiding role. However, the relevant dynamics concern the sensory effects of movements, expectations about which in turn, in the normal course of things, enable certain responses, bringing the consequences of movement under intentional control. What Pettit's calls 'expectancies' about the sensory consequences of movement are what we refer to as implicit practical knowledge of sensorimotor dynamics. Such implicit understanding of the sensory effects of movement is part of what it is for the ball to look as if it is moving toward one's head. A knowledge of how to exploit the way things look to guide action is a further ability, which one's perceptual skills enable one to acquire.

We have stressed the way in which Pettit's view differs from behaviorism. A similar point applies to our dynamic sensorimotor view, which is sometimes wrong assimilated either to behaviorism or to the view that, since perceptual systems evolved to guide action, a visual experience can be understood solely in terms of its role in guiding action and as inextricably linked to ways of acting that are responsive to certain perceptions.

For example, a certain type of objection may be pressed against positions like Pettit's and our own by adherents of a two visual systems view. On this view, visual processing in the dorsal neural pathway or 'how' stream serves to guide action on line and demonstrates direct perception-action linkages. However, dorsal visual processing does not support conscious visual experience. This is supported only by processing in the ventral neural pathway or 'what' stream, along with perceptual judgments and identifications.[9] Neurological and neuropsychological evidence has been interpreted to show that dorsal and ventral functions are dissociable; some patients can use visual information they do not consciously perceive to guide action, while others cannot use visual information they do consciously perceive to guide action. Such dissociations, it can be argued, show that

[9] See Milner and Goodale 1995; see and cf. Gallese et al 1999; Jacob and Jeannerod, who advocate a 'weak' and heavily qualified version of the two visual systems theory, e.g. pp. 102-4, 188ff, 126, 131-2, 254-5. On the role of dorsal-ventral interactions in visual awareness, see for example Beck et al 2001.

perceptual experience cannot be understood solely in terms of dorsal, action-guiding functions.

However, we do not claim this; nor do we claim that you need to move or act in order to see. This kind of objection is therefore misplaced. We *do* claim that the ability to see is partly constituted by implicit knowledge of the sensory effects of movement, and that an experience is inextricably linked to understanding of the ways experience would change were one to act in various ways.[10] This understanding is of course very useful in guiding action, but whether it is used in this way is a further question. It may not be so used for a variety of reasons.

If the capacity to move were necessary for experience, then experience by the paralyzed or by those with locked in syndrome would be ruled out. Our view, by contrast, has no such implications. Someone can know what the sensory consequences of movement would be even if he cannot in fact move because he is paralyzed. If the ability to use visual information to guide action were necessary for visual experience, then patients with optic ataxia, who cannot use visual experience to guide action, should be blind. Again, our view has no such implication (nor is there any independent reason to believe that optic ataxic patients lack visual experience). Someone can understand what the sensory consequences of certain movements would be, even though she cannot use this knowledge to guide her actual movements. Knowledge of the sensory consequences of movement may be useful (or even necessary[11]), but not sufficient for the visual guidance of actual movements. That is, lack of knowledge of the sensory consequences of movement isn't the only possible reason for which the visual guidance of movement can break down. For example, in principle some motor plans (but not all) might interact with this knowledge in ways that render it ineffective.

However, a cogent further worry is this: we emphasize the expectancies, or implicit practical knowledge of the sensory consequences of movement that perception involves, yet we deny that such knowledge is necessarily available to guide actual movements. But what is implicit practical knowledge of the sensory consequences of movement if not knowledge of how to do certain things, namely, to act in ways that produce certain sensory consequences?[12] In what does the implicit practical knowledge or skill consist, and in what sense is it genuinely implicit practical knowledge, genuinely a skill (as opposed to some other kind of knowledge or understanding), if it cannot be used to guide action?

In a chapter focused on the challenge presented by synaesthesia, we cannot take undertake a full-fledged investigation of how views such as ours and Pettit's should respond to the variety of evidence for the two-visual systems view. This needs to be done elsewhere.

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[10] This account of perception is laid out in O'Regan and Noë 2001a. It is developed in Hurley and Noë 2003 and Noë 2004.
[11] See Cole (1991) on Ian Waterman.
[12] For a related point, see Jacob and Jeannerod, 2003, 172.

However, we do have something more to say, in section 6 below, about the specific challenge the two-visual systems view presents to Pettit's false expectancy account of color illusions. At that point we will offer a partial response to the kind of worry expressed in the previous paragraph.

The burden of this section has been to differentiate Pettit's view, and ours, from other views they may be confused with, such as behaviorism, or the view that perceptual experience can be understood solely in terms of its action-guiding functions. In doing so, we have described important common ground between Pettit's manifest powers account of color looks and our dynamic sensorimotor view (although there are be differences of emphasis and in details). In what follows we will refer to this shared view of color experience as *the hunting and gathering perspective*, to reflect its emphasis on the characteristic sensorimotor dynamics of color experience. This does not mean that we, or Pettit, identify color experience with hunting and gathering behavior, or with the mere capacity for it. Rather, this perspective emphasizes the essentially dynamic and practical aspects of perceptual experience: the ways dynamic, practical interaction between the perceiver and his environment are manifest in perceptual experience, and the understanding on which this depends, in particular, of patterns of dependence of sensation on movement. Normal perceivers can normally use what they see to guide what they do, and this general practical capacity depends on their possession of sensorimotor knowledge, or 'expectancies', as Pettit would put it. In particular, the complex sensitivities that are expressed in color experience enable us to track and discriminate objects—to hunt and to gather—as we move, as objects move, as light and background changes, and so on. The empowerment of hunting and gathering that is manifest in color experience essentially involves understanding of sensorimotor dynamics--as we would say—or—as Pettit would say--expectancies about characteristic ways in which patterns of sensation change with other changes, including movement.

3. Color adaptation for hunter-gatherers.

As mentioned above, Pettit claims that Kohler's color adaptation results supports his manifest powers account of color looks. In this section we explain and probe that claim.

Kohler's subjects wore goggles with vertically divided lenses. The right half of each lens was yellow and the left half was blue, so when subjects looked to the right the world looked yellowish and when they looked to the left the world looked bluish. However, after wearing the goggles for some weeks the subjects' experience of color adapted: they reported that the world no longer looked yellowish or bluish when they look to the right or the left, respectively. Thus a white object viewed by an adapted subject with his eyes looking rightward through the yellow halves of the lenses looked white to the subject. It would continue to look white as it moved sideways in front of the lenses or as the subject moved so that it was viewed through blue halves of the lenses. Moreover, when the subjects removed the goggles after wearing them continuously for 60 days, they experienced color aftereffects: the world now looked bluish when they looked to the right (in the direction the goggles had been yellow) and yellowish when they looked to the left (in the direction the goggles had been blue). Kohler suggests that eye movement switches between color compensation mechanisms. Others have tried to obtain similar or related results, with mixed success[13], so it cannot be assumed that these adaptation results are beyond dispute, but for present purposes we will accept them at face value.

Pettit argues that the manifest powers view of color would predict such adaptation, while the qualia view would not.[14] To this extent, Kohler's results support the manifest powers view. Kohler himself comments that, as the goggle wearer's expectations about color looks are revised, his behavior falls into line with his behavior, so that he is no longer distracted when something changes from looking blue to yellow under certain movements, and then color looks themselves fall into line (1964, 113). How the world is expected to look has a role in determining how it does look. However, these suggestions by Kohler about what happens are not entirely clear. Is his suggestion that we are distracted because color looks aren't obeying familiar sensorimotor rules? Does this mean that we learn new sensorimotor rules in the course of adaptation? Why would that yield changed color experiences, rather than restore veridical experiences?

J. J. Gibson's account in his introduction is somewhat clearer on this issue. Gibson explains that the light delivered by Kohler's goggles to the eyes still carries information about colors in the environment to the eyes, but in a transformed form (Kohler 1964, 8-9, 12). This information can be recovered by factoring out the distortion produced by the subjects' movements from the transformed light produced by the goggles, on the assumption that the proper underlying sensorimotor profile of colors reflects constancy rather than variation across sideways eye movements.

Pettit's interpretation of Kohler and Gibson in effect distinguishes the underlying sensorimotor dynamics of colors, which are invariant, from their particular implementation, which can vary and which the goggles change. As we would put it, adaptation is a process of acquiring skillful familiarity with the new implementation of the familiar invariant sensorimotor dynamics of specific colors. This distinction is important in specifying hunter-gatherer accounts of color looks. The sensorimotor expectancies characteristic of particular colors relate ultimately to the underlying invariant patterns of dependency of sensation on movement, and these do not change when the goggles are worn. But they are given new clothing, a transformed implementation, and as a result the perceivers understanding of

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[13] See Peppman and Wieland 1966 (replication claimed to succeed after only 11 days); McCollough 1965 (replication claimed to fail after 75 days); Harrington 1965 (replication claimed to fail after 103 and 146 days).

[14] Though the qualia view isn't strictly inconsistent with adaptation here, it provides no explanation of it and leaves it looking rather mysterious.

them is disrupted until his expectations have adjusted to this new implementation and related it to the underlying invariant patterns.

Our dynamic sensorimotor view also predicts adaptation to Kohler's goggles (see discussions in Hurley 1998; Noë 2004, ch. 4). As we would put it, the sensorimotor skills of color perception consist in practical knowledge of underlying patterns in the way sensations vary as the perceiver moves and as other environmental conditions change. Color constancy, on this view, depends on discerning a characteristic underlying, invariant structure in the way sensations vary with movement and changes in illumination.[15] Practical knowledge of these underlying patterns and structures enables active hunting and gathering. Part of what color perceivers know is that the world does not in general look a different color from one angle of vision versus another.

When the goggles are first donned, a blue-left yellow-right pattern appears that is not consistent with the underlying dynamics of color *in its familiar implementation.* That is, the goggles create a conflict between implicit expectations about the underlying dynamics of color and implicit expectations about how it is implemented. The apparent change of color with movement is not just illusory, but also contrary to the expectations of color perceivers; as a result, it interferes distractingly with the normal role of color constancy in the active exercise of perceptual skills in hunting and gathering. For example, the blue look of something viewed with eyes leftward by the unadapted goggle wearer involves expectations about the way things will look under movement that turn out to be misleading. The perceiver's practical understanding of the relevant underlying sensorimotor patterns and consequent practical skills are initially disrupted by the goggles.

But this understanding is regained as with the subject learns that the underlying patterns are still present in a new implementation. The goggles transform the way the underlying sensorimotor patterns characteristic of color constancy are registered, and adaptation involves acquiring familiarity with this transformed registration. With adaptation, the misleading expectations are replaced with expectations that again reflect the underlying sensorimotor dynamics of color, but in the new implementation. As this understanding is restored, the blue-left yellow-right appearance fades away and normal color appearances return.

When the goggles are removed, the implementation changes again: the original implementation is restored, and readaptation is now needed to restore normal color experience. At the level of implementation, expectations change, and then change back again. But these changes are driven by the perceivers understanding of what is invariant across these transformations, the characteristic underlying sensorimotor dynamics of color looks. Expectations at the level of implementation are brought into line with implicit

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[15] This suggestion is supported by striking recent work by Philipona, O'Regan & Coenen on the intrinsic sensorimotor information structure of colors, which is invariant across changes in robotic implementation; see below in section 7.

knowledge of the underlying sensorimotor dynamics of color and expectations that color looks will continue, *in one way or another*, to respect them.

Pettit's manifest powers view and our dynamic sensorimotor view are thus closely allied in predicting and explaining Kohler's color adaptation results. However, it is less obvious how our hunter-gatherer perspective on color looks should handle colored-hearing synaesthesia. This presents a challenge to both views, and has indeed been pressed by Jeffrey Gray (2003) as an objection to our view. We first provide some background on synaesthesia, and then explain how synaesthesia challenges the hunting and gathering perspective on color experience that we share with Pettit.

4. Synaesthesia, colored-hearing, and alien color effect.

In synaesthesia, perception in one modality induces illusory experience in another modality. Synaesthesia is normally for life: adult synaesthetes have typically been synaesthetic for as long as they can remember, and recall being astonished to realize at some point while growing up that most other people did not have similar synaesthetic experiences, which they had regarded as normal (Motluk 1997). However, synaesthesia can be induced by lesions or drugs, and it can be lost; moreover, there is some evidence that synaesthesia is more common in children and can disappear with age (Harrison and Baron-Cohen 1997a; Cytowic 1997; Marks 1997). In one case, when a previously synaesthetic subject became color blind as a result of brain damage, he also lost his synaesthetic color experiences (Frith and Paulesu 1997). A disproportionate number of synaesthetes are female or left-handed; synaesthetes tend to have excellent memories, but to be bad at mathematics; synaesthesia runs in families so appears to have a genetic basis (Cytowic 1997; Harrison and Baron-Cohen 1997b). There is strong evidence that synaesthesia can facilitate sorting, remembering and understanding (see Ward et al. [DATE TO BE ADDED]).

While many varieties of synaesthesia are known, by far the most common is auditory to visual induction. We will concentrate here on so-called 'colored-hearing', in which a specific sound, usually the sound of a specific word or the initial letter of a word, induces experience of a specific color. The color may be experienced as nonlocalized but co-conscious with the sound (Gray et al 2002), or as bound to the sound itself (Marks 1997), or to a visual image of the word or letter that is also induced by the sound (Frith and Paulesu 1997), or to a generic shape (as opposed to a well-differentiated image or scene; Cytowic 1997). Synaesthetic colors are not confused with the actual colors of objects, which subjects also perceive reliably (Marks 1997; Frith and Paulesu 1997; Gray et al 2002). Attempts to create synaesthesia by associative training or to explain in it associative terms have generally been unsuccessful (Marks 1997; Harrison and Baron-Cohen 1997b; Gray et al 2002; but see Taylor 1962). Synaesthesia appears not to be merely the metaphorical association of words or letters with colors. For example, in a synaesthetic analogue of standard tests for color-blindness, a synaesthete may immediately see a particular numeral in a pattern of letters because the synaesthetic color of certain letters makes them stand out from the rest, where a nonsyneasthete would see no numeral (Ramachandran & Hubbard 2001a, b).

In one pattern of colored hearing, the initial letter of a heard word, such as 'k' in 'kick' or in 'knock', induces a specific color. The color is only experienced if the word is heard or silently subvocalized by the subject; reading relevant words without subvocalization or inner speech does not induce synaesthetic colors. Moreover, while heard words trigger the experience of synaesthetic color, the mapping from word sound onto color is mediated by spelling. For example, even though the 'k' in 'knock' sounds like an 'n', hearing 'knock' induces the color associated with 'k': 'kind' and 'knock' may induce one color, 'nice' a different color (Frith and Paulesu 1997; Ramachandran & Hubbard 2003, 55). In a variant of this pattern, experience of the color blue might be induced by the letter 'b'; as a result, hearing the word 'black' would also induce experience of color blue.

Jeffrey Gray and co-workers refer to the induction of color experiences by incongruent color names as the *alien color effect* (ACE) (Gray et al 2002; Gray 2003). For example, hearing the word 'red' might induce experience of green, or hearing the word 'white' might induce experience of yellow. They have done experiments on ACE that provide a variation on conventional Stroop effects. Stroop effects are found in normal subjects who are asked to name the color in which words are printed and who show delays when the words are names of colors incongruent with ink color. For example, normal subjects shown a word printed in green ink tend to be slower in naming the ink color if the word is 'red' than if it is 'fed'. Gray and co-workers categorized synaesthetic subjects according to the percentage of color names affected by ACE, and found that subjects with higher levels of ACE were slower to name ink colors.[16] The effect sizes of delays were comparable to those found in conventional Stroop effects. However, the effects were similar whether subjects were naming the ink colors of color words such as 'red' or merely of strings of letters such as 'XXX' (see also Mattingley et al 2001). Gray et al hypothesize that the delay induced by ACE is mediated by subvocal retrieval of the name of the ink color used, whether to print 'red' or merely 'XXX', which induces an interfering ACE synaesthetic color. This delays the correct naming of ink color, even though ACE subjects are able to perceive and name ordinary colors reliably, and do not confuse synaesthetic and ordinary colors.

Gray (2003) suggests that synaesthetic colors can be dysfunctional, on the basis of the delay of color naming attributed to interference from ACE. In effect, delays in color naming such as those found in Stroop effects would be generalized by ACE to all color naming where the

[16] This delay was found when ACE subjects were tested outside an fMRI scanner; they responded quickly and made some mistakes (Gray et al 2002). When tested with a somewhat different experimental design and inside the scanner, ACE subjects took longer to respond, were more careful and did not make mistakes (Parslow et al in progress). The ACE-related delay found in the first experiment was not found in the scanner experiment. However, the delay result from the first experiment is still robust. Being in a scanner may have induced a significant generalized delay in various ways, which overwrote the small ACE-related delay. Thanks here to Dominic ffytche for clarification.

correct color name is associated with an incongruent synaesthetic color. For example, when an ACE child is asked, 'What color is that bus?', and prepares to answer correctly 'red', an ACE experience of green may be induced, delaying the correct response. As Gray et al (2002) argue, ACE adds to the evidence against the hypothesis that synaesthesia results from associative processes.

5. The challenge from synaesthesia to the hunter-gatherer approach to color.

Gray (2003) argues that colored-hearing synaesthesia and ACE in particular provide fatal counterexamples to any account of color experience in terms of the behavioral functions associated with color perception. While he originally conceived this objection as an objection to functionalism, Gray applies it to our dynamic sensorimotor account of qualities of experience (Hurley and Noë 2003; see also O'Regan and Noë 2001a, b, c). If Gray's objection does apply to our account, it may be expected to apply also to Pettit's account of color looks, in view of the common ground between them.

However, as Gray formulates his objection, we doubt it applies to either. His objection bears the traces of its original target: functionalism. We have explained how the hunter-gatherer view of color looks we share with Pettit differs from behaviorism. For related reasons, it should not be assimilated to functionalism—often regarded as a more sophisticated descendant of behaviorism. The functions of standard versions of functionalism, as Gray emphasizes, mediate between sensory input and behavioral output.[17] By contrast, the hunter-gatherer perspective emphasizes understanding of sensorimotor dynamics: the way sensation depends on movement. It treats the way action is guided by color experience as underwritten by understanding of the way sensation depends on movement. Nevertheless, as we go on to explain, a reformulated objection is in the offing from consideration of synaesthesia, which does apply to the hunter-gather perspective.

The target of Gray's objection is the claim that there is a one-to-one mapping between the ways colors look and the behavioral functions. Yet, Gray urges, that is exactly what we find in colored hearing. Green objects look green to a synaesthetic subject. Yet synaesthetic green also looks green to such subjects. While experience of synaesthetic green is not confused with the perception of a green object, these experiences have the distinctive character of greenness in common.[18] However, the experience of synaesthetic green is associated with very different behavioral functions from those associated with perceiving green objects. For example, a red truck comes round the corner and Mother says, "Look at that red truck!" Suppose the synaesthetic child *experiences* green because the spoken word

[17] Hence they are versions of the input-output picture criticized in Hurley 1998. This is explicit in Parslow et al, Evidence against functionalism….; see also…..

[18] Similarly, experience of a green afterimage isn't confused with the perception of a green object, but nevertheless shares the quality of greenness.

"red" is synaesthetically green for this child. What does this situation have in common with one in which the child experiences green because she is looking at an unripe tomato in normal lighting? Not, at any rate, behavioral functions. The experience of synaesthetic green is associated with measurable behavioral effects that are quite different from those of perceiving green objects. For example, experiencing synaesthetic green may delay naming the color of red objects; but it is not associated with the set of hunting and gathering responses that perceiving a green object enables.[19] Same color look, different behavioral functions. Not exactly the same look, of course; different enough looks to tell the difference between seeing green objects and experiencing synaesthetic green. But nevertheless, looks with the character of greenness in common.

Suppose, for the sake of argument, that we concede this objection to functionalism. Gray was nevertheless wrong to think that the objection as formulated applies to our dynamic sensorimotor view of experience. For the same reason, it does not apply to Pettit's manifest powers account of color looks. Neither view identifies color looks with behavioral functions. To put the point in Pettit's terms, the objection as formulated overlooks the important difference between *mere hunting and gathering powers*, and *manifest hunting and gathering powers*, and the way the *manifestness* of empowerment in color looks, as we have argued, depends on 'expectancies' about the characteristic ways in which sensation depends on movement.

However, Gray's objection can be reformulated to take this point into account. Instead of insisting merely that the same color look can go with different behavioral functions, the objector now insists that the *same color look* can go with *different manifest powers and expectancies*, reflecting the subject's understanding of quite different underlying sensorimotor dynamics in the two cases. That is, different manifest powers *and expectancies about the dependence of sensation on movement* are associated with synaesthetic experience of green and with normal perceptual experience of green objects.

This is more worrying for the hunter-gatherer perspective. There is good reason to think not just that the underlying sensorimotor dynamics of normal green and synaesthetic green are quite different, but also that synaesthetic subjects know this, implicitly. Expectancies about the characteristic ways in which sensation depends on movement that are associated with normal perceptual experience of green objects are not associated with experience of synaesthetic green. For example, the subject understands that sensations depend on eye movements in perceptually experiencing a green object. But there is no reason to suppose that a synaesthetic subject has such expectancies when hearing a particular word induces experience of synaesthetic green. As she well understands, she can experience synaesthetic green with her eyes shut!

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[19] This point does not depend on synaesthetic green and normal green being experienced in different contexts. Of course we can have the same kind of experience in different contexts, just as we can use a word with the same meaning in different contexts. Rather, synaesthetic and normal green have different behavioral functions in the same context.

More generally, on the hunter-gatherer view, color looks depend on implicit understanding of the characteristic ways in which sensation changes with movement and other color-relevant conditions; to experience something as green is to experience it in the light of this implicit understanding of changeability. But synaesthetic color looks are not in the same way subject to this sort of changeability, nor are they understood to be. Synaesthetic subjects don't implicitly expect synaesthetic sensations to change as lighting conditions change, or as their eyes move. Synaesthetic color looks do not empower hunting and gathering responses in the way normal color perception does. But the critical point is that synaesthetic color looks do not mislead in this respect. They do not pretend to manifest such empowerment, or visually solicit expectancies they cannot fulfill. The sensorimotor knowledge involved in normal perceptual experience of color appears to be irrelevant to synaesthetic color looks.

How can the hunter-gatherer view respond to this line of argument?

<u>6. Same color looks? A preliminary response.</u>

The reformulation of Gray's objection (like the original) turns on the assumption that color experiences and corresponding synaesthetic experiences are qualitatively alike in respect of color. Greenness is what is supposed to be common to perceptual experience of a green object and synaesthetic experience of green induced by a heard word. If color looks differ between normal and synaesthetic experience of color, then the 'same color look, different manifest powers and expectancies' objection does not apply. Is the 'same color look' assumption justified?

First, synaesthetes with colored hearing do not confuse synaesthetic colors with normally perceived colors; synaesthetic color experience do not misleadingly present themselves as normal perceptual experiences of color. This is not controversial. But nor does it have any tendency to show that these experiences are not experiences of the same color. Many qualitative differences in experience are compatible with sameness in respect of color. Different perceptual experiences of green objects need not be absolutely qualitatively identical in order to they have greenness in common. The assumption is that synaesthetic experience has greenness in common with perceptual experience of a green object, not that it is exactly similar. Similarly, the experience of green in an afterimage isn't confused with the perception of a green object, but nevertheless is reasonably assumed to share the quality of greenness. Green afterimages, green synaesthetic experiences, and normal perceptual experience seem to have something in common, despite the phenomenal differences between them.

Second, there might seem to be a quite different kind of reason for calling into question the assumed common color quality of experience of synaesthetic green and normal perceptual experience of green: disjunctivism (see Snowdon, 1980-81; McDowell 1986). Disjunctivism is an anti-Cartesian view about experience that is motivated by general considerations about illusions and knowledge (among other things). Disjunctivists argue that perceptual experiences are genuine relations between perceivers and the objects they experience. The contents of normal perceptual experiences are, in this sense, object-dependent. For this reason, it will never be the case that perceptual experiences and corresponding illusory experiences have the same content, even though they may seem to be indistinguishable. For in the nonveridical case, the object of the experience is missing. But the content of the original experience was dependent on an actual relation to just that object.

As we've said, synaesthetic experiences of color wear their phenomenal differences from normal perceptual experiences of color on their sleeve. They don't even seem to be indistinguishable from normal perceptual experience. Disjunctivism isn't needed to get this far. But perhaps it could be employed to argue that, not only are synaesthetic and normal experiences of green different in the way they seem to be, but they are even more deeply different: they are not even similar in respect of greenness, since one experience involves a relation to a green object and the other does not. However, we cannot resolve issues about disjunctivism here, and so set this line of response aside.

In what follows we will grant the assumption that synaesthetic experience and normal color experiences can share color qualities. What other responses to the challenge are available to the hunter-gatherer view?

7. The false sensorimotor expectancy account of illusory color looks.

A second line of response is suggested by Pettit's appeal to expectancies to unify color looks and to explain color illusions. We are very much in sympathy with this approach, which converges with our own general views. It is worth exploring in detail in order to understand why in the end it doesn't succeed in meeting the challenge synaesthesia presents to the hunter-gatherer perspective.

A general strategy to account for perceptual illusions is to appeal to sensorimotor expectancies common to illusory and veridical experiences. Take the veridical case first. When you visually experience a tomato as three-dimensionally extended, you expect bits of tomato to come into view as you move that are concealed from the initial vantage point. The experience of the whole tomato as three-dimensionally present on the basis of perceptual contact with a single side of the tomato depends on expectations of this sort about the sensory consequences of movement (see Noë 2004).

Now consider misperception. A glimpse of a plastic tomato façade may trigger just the same sensorimotor anticipations as does the glimpse of a genuine tomato. The suggestion is that the non-veridical experience of the tomato facade as three-dimensionally voluminous is grounded on the activation of the same sensorimotor expectancies that would be triggered by an actual tomato. Normally, these expectancies would be activated along with and against the background of a wealth of other cognitive judgments and expectations. For example, most of us know what tomatoes are and can recognize them on sight; this intellectual skill influences our experience. But it would be a mistake to suppose that the sensorimotor expectancies are themselves a matter of *judgment*. The tomato facade can look three-dimensionally voluminous from a given angle *even when you know* it is only a facade; your sensorimotor anticipations can arise even though you know they will not be unfulfilled. Similarly, in the Mueller-Lyer illusion, the lines still look different lengths even when you know they are the same length; knowledge that the appearance is illusory doesn't make the illusion go away (for discussion, see Jacob & Jeannerod, ch. 4).

Pettit applies this general type of account of nonveridical experiences to color looks. On his manifest powers view, expectancies are critical to explaining how there can be color illusions: how something that is not yellow can look yellow, that is, can look the same color as a yellow object. Perceiving a yellow object does not just empower hunting and gathering, but does so manifestly, which involves generating expectancies about the way patterns of sensations would vary with light, background, and movement. These expectancies unify different instances of looking yellow; but they are not necessarily accurate. Sameness of color looks may thus reflect a similar set of expectancies, even if many of these are false for illusory color looks. Something may look yellow here and now, yet may not fulfill the relevant expectancies--may not vary in the expected way with movement, or changes in light or background, say--because it is not actually yellow. Its yellow look would then be revealed to be a trick of the light or an illusion.

Pettit also notes that illusory looks can persist even though we recognize that the expectancies associated with them are false, as in the Mueller-Lyer illusion. He suggests that certain practical expectancies may be hardwired in normal subjects to certain patterns of sensory input, so that our intellectual recognition that the corresponding experiences are misleading does not penetrate our natural responses and expectancies to constitute practical knowledge. Accordingly the illusions survive recognition that they are illusions.

Whatever one thinks about their "hardwired" character, it seems clear that practical expectancies are often not defeated by intellectual judgments. Nevertheless, there may be reasons to doubt that false practical expectancies can provide a general explanation of persistent illusory looks. These doubts derive from a line of research associated with the two visual systems view, claiming that action resists visual illusions.

For example, one illusion that persists even when you recognize intellectually that it is an illusion is the Titchener circle illusion: disks that are really the same size nevertheless appear to be different sizes, or vice versa, according to the size of surrounding disks. Aglioti et al (1995) claimed to show that certain sensorimotor skills are unaffected by the Titchener circle illusion: normal subjects adjust their grip to the true size of the disks in reaching for them, rather than to the apparent illusory size of the disks.[20] Implicit practical knowledge of the true properties of the disks governs at least some of the subject's interactions with the disks while they are nevertheless subject to the illusion. It would seem that subject's implicit expectancies about how it will feel when they move their hands to touch the disks are correct, yet the illusion persists. If so, then it can be argued that we cannot explain the persistence of illusion here by reference to false sensorimotor expectations, since there do *not* seem to be false sensorimotor expectations.

We offer two responses to the 'action resists illusion' objection, in defense of the false sensorimotor expectancy account of illusory looks.

First, the use of these results *as an argument against the false sensorimotor expectancy account of illusions* is over-ambitious; it does not show what it sets out to show. To see this, recall the context. The false sensorimotor expectancy view of illusions is an aspect of the hunter-gatherer approach that we share with Pettit. As explained above, this does not claim that perceptual experience can be understood solely in terms of its role in guiding action, but gives sensorimotor expectancies a fundamental role. But neither this approach rely on a narrow set of sensorimotor expectancies associated with a particular type of action to capture a look; rather, an important role of expectancies in Pettit's account (and ours) is to unify looks across diverse contexts and potential actions. But only a broad set of specific expectancies can play this role, including expectancies about the specific ways sensation depends on a variety of changes, in movement, lighting, background, and so on. To challenge the false sensorimotor expectancy account of illusions, what would have to resist illusion is a significant part of the relevant broad set of specific manifest powers—of sensorimotor skills and expectancies--, not merely a particular element of it, pertaining say to a particular grasping movement.

But the 'action resists illusion' results do not show this. Subjects in the experiment of Aglioti et al can use what they see to guide certain specific movements correctly, despite the illusion, and with no apparent false expectancies. But that doesn't show that the broad set of sensorimotor powers and expectancies associated with the illusory look of Titchener circles is the significantly different from the set associated with similar but veridical looks in a variety of different contexts. For present purposes, the relevant manifest powers comprise a rich, complex set of sensorimotor skills and expectancies, capable of playing a unifying role across different actions and contexts. Though specific actions, such as grasping in specific contexts, may resist a certain visual illusion, other actions in different contexts may not resist that same illusion. And despite the fact that the sensorimotor expectancies associated with a specific action of grasping in a specific context may be accurate and so not explain the illusion, many other false sensorimotor expectancies from the relevant unifying set of expectancies may still be present and may explain the illusion.

[20] See also Milner and Goodale 1995, 167-168; Jacob & Jeannerod 2003, chapter 4, who also explain similar demonstrations for the Muller-Lyre illusion.

Hunting and gathering powers, including diverse expectancies about how sensation changes with movement, lighting, and background, go far beyond the ability to point or grasp accurately on prompt and the limited expectancies that may be associated with these specific abilities.

However, the more general claim needed to mount the challenge would be hard to defend, since illusion-resistant actions tend to be highly specific to certain tasks or contexts.[21] Moreover, such tasks are prompted within constrained experimental set-ups in which the veridical information is used implicitly, not explicitly. An analogy may help to drive the point home. The fact that blindsight subjects can when prompted localize lights they do not see consciously does not mean that they have a full range of dynamic sensorimotor skills and expectancies in acting explicitly on this spatial information; on the contrary, their powers and expectancies in acting on this information very are severely limited. Similarly, the fact that normal subjects can when prompted use information (in grasping) that they do not see consciously (given the illusion) does not mean that they have a full range of sensorimotor powers or expectancies in acting on this information.

In sum, the relevant sets of sensorimotor powers and expectancies appealed to in the hunter-gatherer approach to illusions is much broader than the actions and associated expectancies in demonstrations of illusion-resistance (cf. Jacob and Jeannerod 2003, p. 172, whose discussion misses this point). Thus, the latter are not counterexamples.

Our second response, in passing, is that the claim that action resists visual illusions is itself controversial; contrary or at least heavily qualifying evidence has been offered.[22] The correct overall interpretation of the mixed evidence is unsettled. However, we cannot do justice to these general issues here, which would require an full-fledged investigation into the evidence for two visual systems and its significance for theories of perceptual experience.

8. Why the false sensorimotor expectancy account of illusory color looks does not meet the challenge from synaesthesia.

We have defended the false sensorimotor expectancy approach to illusion against a general objection from the 'action resists illusion' results. But since our topic here is color looks, we now set aside the question of how successful the false practical expectancy approach is as a general explanation of illusions, in order to focus on how well it handles *illusory color looks* in particular.

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[21] Here we are grateful to discussion with Kevin O'Regan.

[22] See for example Franz 2001; see also Glover 2002; Milner & Dyde 2002; Jacob & Jeannerod (2003), chapter 4; recall that Jacob and Jeannerod advocate a version of the two visual systems theory that is by their own account 'weak' and heavily qualified; see pp. 102-4, 188ff, 126, 131-2, 254-5.

It works well applied to Kohler's color adaptation results. The yellow look of something with eyes rightward for Kohler's goggle wearer did not persist, but adapted away. Recall the explanation: the illusory yellow look experienced with eyes rightward reflects false expectations about how sensations will vary with certain movements. The underlying sensorimotor dynamics of color looks, associated with perception of color constancy across various changes, has not changed. But its implementation has been transformed by the goggles, so that expectations based on the old implementation are now false. The subject learns that her expectations about rightward, initially yellow-looking objects when she or the objects make certain sideways movements are misleading. These sensorimotor expectancies are not hardwired to certain patterns of retinal input. As the subject's expectations come back into alignment with the underlying sensorimotor dynamics of color, they are relocated to their proper, yellow objects, and so too is the yellow look. The goggles temporarily deprive the subject of some of her sensorimotor understanding of how sensations change with movement, but as she learns through active exploration wearing the goggles that the light coming through the goggles still carries the old sensorimotor patterns for color looks but in a new guise, her expectations adapt and veridical color looks return. The illusion of rightward yellow survives the subject's intellectual knowledge that she is wearing the goggles, but it does not survive her reacquisition of sensorimotor skills and understanding.

This account of Kohler's results accords well with recent work by David Philipona and Kevin O'Regan. They analyse patterns of sensorimotor contingency as various colored surfaces are moved in relation to the eyes. Their analysis distinguishes intrinsic or code-independent structures, which are underlying patterns of dynamic sensorimotor contingencies characteristic of specific colors and their relations, from more superficial patterns that depend on the way specific inputs or outputs are coded (see and cf. Ramachandran & Hirstein 1998, 1616, 1623 on labeled lines vs. pattern coding). They show that the intrinsic sensorimotor structure of colors captures intensity, hue and saturation, black and white, and pairwise opponency, which are thus independent of specific neural circuitry. In these terms, our claim is that the subject has practical, skill-enabling knowledge of the deep sensorimotor structure of color. This deep structure survives the superficial change in registration imposed by the goggles. When the subject relocates it and regains the relevant skills, his color experiences renormalize also.

However, the false expectancy account does not fare so well in account for colored-hearing synaesthesia (which Pettit does not discuss). Consider how the Pettit's false expectancy account of illusions might characterize one of Gray's ACE synaesthesia subjects: "The ACE subject's synaesthetic illusion of green when naming red objects is associated with the sensorimotor expectations characteristic of normal perception of green things in hunting and gathering activities (after all, she can also perceive green things). However, these expectations are misleading when they are aroused by the word 'red' or by the naming of red objects: synaesthetic green does not satisfy hunting and gathering expectancies for green. Moreover, the ACE subject realizes this intellectually; after all, she does not confuse normal green and synaesthetic green. But these practical expectancies are in some way hardwired to 'red', so that her intellectual recognition of their falsity does not penetrate her natural responses to constitute practical knowledge; hence illusory synaesthetic experience of green survives her recognition that it is illusory, and generates delays in color naming."

The problem with this story is that there is little reason to think that synaesthetic subjects do in general have *false* sensorimotor expectancies associated with synaesthetic experiences of green. After all, synaesthetic subjects *don't* expect synaesthetic green to display the characteristic combination of variation and constancy under different lighting and contrast conditions that a green object does. They recognize the difference, practically as well as intellectually, between normal and synaesthetic colors, and they use synaesthetic colors for different practical purposes: for example, as aids to memory.[23] Synaesthetic colors achieve constancy on the cheap, with no need to employ one's practical mastery of the sensorimotor dynamics of normal color: for example, if 'red' is synaesthetically green, it is always synaesthetically green; background, lighting, movement, and so on are irrelevant to its constant greenness. The normal hunting and gathering powers and expectancies associated with perceptual experience of green objects are absent. So there is little reason to think synaesthetic color experience is characterized by false sensorimotor expectancies at all (let alone that they are hard-wired).[24]

If color illusions are explained in terms of false sensorimotor expectancies but synaesthetes do not have such false expectancies, than synaesthetic color illusions cannot be explained in these terms. However, one response to the lack of false sensorimotor expectancies in synaesthetic color experience is to suggest that perhaps synaesthetic color experience should not be regarded as *illusory* in the first place, any more than afterimages are illusory. The reason in this argumentative posture cannot of course be simply that no misleading expectancies are aroused. A view that appeals to false sensorimotor expectancies to explain color illusions cannot respond to a plausible counterexample by claiming that because there are no false sensorimotor expectancies, there is no illusion. That would beg the question at issue. But without doing that, we can agree that in neither synaesthesia nor afterimages does the color experience misrepresent itself as a perception of color or prompt us to think

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[23] "…the next time you see her you don't say: 'It's Ethel', so you: 'It's the green blob: therefore, it is Ethel.'" Cytowic 1997, 25.

[24] Not only are the normal hunting and gathering powers and expectancies of perceptual experience of color absent from synaesthetic experience. In addition, the automatic priming powers of synaesthetic color experience are more limited than those of normal color perception and do not extend to masked priming. Normal colors have priming effects when are perceived unconsciously as well as when they are perceived consciously; that is, normal colors can function as primes in naming and pointing tasks even when they are masked so as not to be consciously experienced (Schmidt 2000, 2002; see also Breitmeyer et al 2004a, b). By contrast, synaesthetic colors can function as primes but not as masked primes (Mattingley et al 2001; Rich & Mattingly 2002). Thus colored-hearing does not have all the powers of normal color perception at the unconscious level either. An interesting experiment would compare masked color priming with lack of masked synaesthetic color priming in the same synaesthetic subjects, in effect combining the Schmidt and Mattingley paradigms. As far as we know this has not been done.

an object is colored when it is not. We have no trouble telling these experiences apart from normal perceptual experiences of color. So perhaps there is no real conflict in the case of synaesthesia: no misperception, just different, extra perceptions. In this respect, synaesthesia may be quite different from wearing Kohler's goggles.

Although this point may be correct, it does not resolve the challenge that synaesthesia presents to the hunter-gatherer view of color looks. The challenge does not ultimately depend on whether synaesthetic experience is illusory or not, but merely on the fact that synaesthetic experience of a given color and normal perceptual experience of that color have a color look in common. They share the aspect of, say, greenness, however much they may differ qualitatively other ways, and even if they are not confused with one another and neither is illusory. The challenge is simple: same color look, different sensorimotor powers and expectancies.

In this case, we cannot respond as we did to the 'action resists illusion' objection, by appealing to a broad set of expectancies to unify a look, even if some elements of that set relating to specific actions in specific contexts may be missing. For in the case of synaesthesia, pretty well the whole set of hunter-gatherer powers and sensorimotor expectancies associated with normal color looks is missing. Not only can synaesthetic colors not actually be used to guide hunting and gathering, but synaesthetic color experience does not generate expectations that sensations will vary with movement, with light, with background, or any of the normal sensorimotor expectations that perceptual experience of color generates. It is truly a hard case for the hunter-gatherer perspective.

9. Does ACE provide a way out?

Recall at this point (as explained in section 4 above) that synaesthetic experience can produce mild interference with normal color naming. When ACE synaesthetes exercise the skill of naming ordinary colors, their ACE synaesthetic experience appears to interfere and cause delays in naming. This delay is very different from misleading sensorimotor expectancies of the kind we have been appealing to so far. It is very different, for example, from the misleading expectancies of a novice wearer of Kohler's goggles, who expects an object to be discriminable and trackable in certain ways across different angles of view, and who is distracted by unexpected effects of movement.

However, perhaps Gray's ACE results can be used to extend the manifest powers account to include ACE responses to synaesthetic colors. A normal tendency when asked to name a perceived color is to respond by naming the color; perceiving the color enables the naming response to appropriate queries. Even though this naming power is acquired with language learning, once learned the response tendency may become automatic in some sense. Perhaps the enabling of such automatic naming responses and associated expectances are part of the correct specification of the manifest powers of color perception on which color looks supervene, along with hunting and gathering powers and expectancies.

Suppose that when an ACE subject is asked to name a red object, she will automatically tend to name green as well as to name red, which creates interference and delay in color naming even though it is inhibited. This would be analogous to the false expectances that Pettit suggests may explain why illusions persist even when subjects recognize intellectually that they are illusions, in that the automatic naming tendency in the ACE subject persists even though the subject recognizes intellectually that she has been asked to name the color of the red object, which she sees is not green. This automatic ACE tendency is of course not normal; nor can it be completely hardwired, since it is acquired with language learning. However, on this account, the look of synaesthetic green associated with the word 'red' and the naming of red objects would supervene on the automatic tendency to respond with 'green' when asked to name red objects. Even if *someone else* says 'red', the ACE subject experiences green because she has a nonnormal counterfactual 'expectancy' that she would tend to say 'green' if she were asked to name a red object, which she has to inhibit, and which persists although she recognizes that this response would be erroneous. (The expectancy itself isn't false here, even though the inhibited response would be false.) On this suggestion, the look that unites green objects and synaesthetic green supervenes on this automatic tendency to respond 'green' if you are asked for a color name and associated expectations. The tendency, like Pettit's expectancies, extends across actual and counterfactual conditions to provide the unity of the green look of both green objects and the word 'red'.

But this extension of the expectancy account to exploit the tendencies of ACE subjects is not plausible. We emphasize that we do not attribute this extension to Pettit; it is simply one more (unsuccessful) attempt to respond to the challenge presented by synaesthesia.

The extension is not plausible because it discards the sensorimotor powers and expectancies associated with hunting and gathering, which Pettit and we emphasize, to focus on naming powers and associated expectations as the source of the unity of normal green and synaesthetic green. It thus discards the heart of the hunter-gatherer approach to color. But it is not plausible to claim that naming powers and expectations alone unite normal and synaesthetic color looks.

This claim certainly conflicts with the naïve view that we learn to attach the same color names to colors that look the same to us. The claim we find implausible in effect says the opposite: that colors look the same to us if perceiving them manifestly empowers us to attach the same names to them and induces associated expectations. However, this claim is not made any more plausible by rejecting a view of color experience as having an autonomous universal structure in favor of a more relativistic view of color experience, as culturally constructed and variable to a greater degree than we may naively assume (see Saunders and van Brakel 1997; cf. Berlin and Kay 1969). It may be argued, for example, that color terms are context-dependent in culturally variable ways: one word for 'black' may be applied to night, tattoos, and flying foxes, but not to hair, whales, or fish (Saunders and van Brakel 1997). But if experience of color looks reflects such cultural influences, then synaesthetes should *not* come to experience green when asked to name red objects. Thus, the claim that the ACE subject's naming powers and expectations alone unite synaesthetic and normal green faces a dilemma: it is not plausible *either* on the 'naïve' view that we learn to apply color names according to the colors we experience, *or* on the 'sophisticated' view that our color experiences are to some degree culturally determined and relative.

10. Why don't synaesthetic colors adapt away?

The question at the heart of the challenge from synaesthesia to the hunter-gatherer perspective on color looks is: why don't synaesthetic color experiences, and ACE experiences in particular, adapt away? If color experiences supervene on manifest hunting and gathering powers and sensorimotor expectancies that are familiar to synaesthetes from their perceptions of normal colors but are missing from their synaesthetic experiences, what explains the similarity of synaesthetic and normal color experience? Synaesthetic color experience is not associated with the powers and expectancies characteristic of normal colors, and synaesthetes know this implicitly; they don't have contrary expectations. So how can a given color quality continue to occupy such disparate sensorimotor roles? Why does the synaesthetic experience persist instead of adapting away? How can hunter-gatherers hear as well as see color?

In fact the challenge our discussion raises is broader: how can *any* account of color looks explain *both* why color experience does adapt to Kohler's goggles and why it does not adapt in synaesthesia. The hunter-gatherer perspective can explain the Kohler adaptation but not the lack of it in synaesthesia; other views may have the opposite problem. The trick is to explain why color experience defers to the colors of the world in some cases, such as Kohler's, but not others, such as synaesthesia.[25]

We suggest that in order to respond to this challenge, it is necessary to go beyond the pure hunter-gatherer perspective--though holding on to its insights--and to consider the ways in which the relevant powers of the dynamic, sensorimotor interaction with the world engage and are constrained by the brain and nervous system. We should resist the assumption that the character of experience must ultimately be explained either *just* in terms of what happens in the brain, or *just* in terms of the active subject's relations to the world. Our dynamic view rejects this inner/outer dichotomization of potential explanans. The sensorimotor dynamics that govern experience are in principle distributed across brain, body, behavior, and environment (though they can be so distributed to different degrees).

[25] This is a version of the problem of explaining the difference between neural deference and neural dominance, discussed in Hurley and Noë 2003. In work in progress, we extend our 2003 account to synaesthesia.

What is needed to respond to the broader challenge that synaesthesia presents is to bring brain activity and the extended dynamics in which it is embedded within a unified explanatory framework.

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