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Is Color Experience Cognitively Penetrable?

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Abstract

Is color experience cognitively penetrable? Some philosophers have recently argued that it is. In this paper, we take issue with the claim that color experience is cognitively penetrable. We argue that the notion of cognitive penetration that has recently dominated the literature is flawed since it fails to distinguish between the modulation of perceptual content by non-perceptual principles and genuine cognitive penetration. We use this distinction to show that studies suggesting that color experience can be modulated by factors of the cognitive system do not establish that color experience is cognitively penetrable. Additionally, we argue that even if color experience turns out to be modulated by color-related beliefs and knowledge beyond non-perceptual principles, it does not follow that color experience is cognitively penetrable since the experiences of determinate hues involve post-perceptual processes. We conclude with a brief discussion of the implications that these ideas may have on debates in philosophy.

Keywords: Cognitive penetrability; Color experience; Perceptual modularity; Post-perceptual processes; Phenomenal dogmatism; Epistemic appearances

1. Introduction

Colors are among the most prevalent features that contribute to the phenomenal character of our visual experiences. Our ability to experience colors seems critical to our ability to experience external objects. Certainly, if "color" is understood broadly enough to

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include the experience of luminance, it follows that we could not experience objects without experiencing colors. A black object against a black background cannot be experienced. So we could not detect an object against a background without being able to detect a difference in luminance or chroma. It is nevertheless arguable that the experience of determinate hues is not fundamental to our experiences of objects. So long as objects and their backgrounds differ in hue, the object is easily detectable regardless of its determinate hue.

We know from color science that color experiences are not purely perceptual: which hue we experience depends on a variety of factors besides the spectral properties of the object, the illumination, and the intrinsic makeup of our visual system, including the environment we evolved in, the background of the object, our prior encounters with the object in question, the characteristic color of the object, etc. (Frisby, 1980; Hardin, 1988; Purves & Lotto, 2011). Some of these factors appear to be factors of our cognitive system, specifically color-related beliefs, knowledge, and memory[1] acquired after the maturity of the sensory system. If it turns out that our color experiences are indeed directly affected by color-related beliefs, knowledge, or memory acquired after the maturity of the sensory system, then it follows that color experience is cognitively penetrable.[2]

Recently, philosophers have appealed to various studies from psychology (e.g., Delk & Fillenbaum, 1965; Hansen, Olkkonen, Walter, & Gegenfurtner, 2006; Levin & Banaj, 2006; Olkkonen, Hansen, & Gegenfurtner, 2008; Witzel, Valkova, Hansen, & Gegenfurtner, 2011) to argue that visual experience is not purely perceptual but is instead cognitively penetrable (Macpherson, 2012; Wu, 2013). Despite the initial plausibility of this claim, we argue that the view that color experience is cognitively penetrable is highly suspect. We begin by considering a notion of cognitive penetration of visual experience that has been used to defend the claim that color experience is cognitively penetrable (Macpherson, 2012).[3] We then argue that it fails to distinguish between modulation of perceptual content by non-perceptual principles and genuine cognitive penetration. Once this distinction is taken into account, it is clear that the empirical results suggesting that color experience can be modulated by factors of our cognitive system (i.e., by higher cognitive processes) do not establish that color experience is cognitively penetrable. We argue further that even if color experience turns out to be modulated by belief and knowledge beyond non-perceptual principles, this does not show that color experience is cognitively penetrable since the experience of determinate hues appears to involve post-perceptual stages of visual processing (Beauchamp, Haxby, Jennings, & DeYoe, 1999). We conclude with a brief discussion of some implications of these ideas for two debates in philosophy, viz. the debate about whether intentions penetrate vision and the debate about whether perceptual experience can provide prima facie evidence for our beliefs.

2. Cognitive penetration as cognitive modulation of content

In philosophy, the hypothesis that perceptual experience is cognitively impenetrable is typically defined as a kind of causal claim.[4] Perception is said to be cognitively impenetrable if changes in cognitive; that is, non-sensory, or affective states cannot cause a change in the visual contents that are or would be experienced when certain facts such as the proximal stimulus, the state of the visual neural system, and the location of attentional focus of the subject remain constant (Macpherson, 2012; Siegel, 2012). The location of attentional focus of the subject must remain constant because instances of shifts in attentional focus are compatible with the cognitive impenetrability of visual experience (c.f. Macpherson, 2012). Although psychologists tend to treat attention as a cognitive process, its effects on perceptual experience involve merely some prior or later processing states, and as such they are ruled out as examples of cognitive penetration. The idea is that our perceptual experiences do not differ because of changes in our cognitive states but rather due to shifts in our attention.[5] A subject, for example, can have two distinct phenomenal experiences (at different times) due to attentional shifts, as is the case with ambiguous figures, while being in the same cognitive state. Since such cases do not involve changes in phenomenology that can only be attributed to changes in cognitive states, they are not considered to be cases of cognitive penetration.

Although we have thus far spoken generally about visual perception, the question we want to address in this paper is whether cognitive states such as beliefs about the characteristic colors of objects can directly affect *color* experience. Admittedly, there is no single phenomenon of cognitive penetration since what is supposed to be penetrated can include, among others things, experience, or some contents of experience, perceptual processing in general, or early vision (Siegel, 2012). Although some philosophers have addressed the question of cognitive penetration as it relates to early vision,[6] the notion of cognitive penetration we employ in this paper pertains to the phenomenology of color experience. What we want to address is whether beliefs about the colors of familiar objects affect the phenomenology of our color experiences.

Unlike many other perceptual states, color experience has traditionally been considered cognitively impenetrable, even by many who would reject the cognitive impenetrability thesis as it generally pertains to visual experience. Fiona Macpherson (2012), however, has recently challenged this hypothesis using an old study by Delk and Fillenbaum (1965). Delk and Fillenbaum constructed several figures using the same orange-red cardboard. Some of these figures represented objects that are characteristically red such as a love-heart shape, a pair of lips, an apple, etc. Other figures represented objects that are not characteristically red such as a circle, a horse, a mushroom, etc. Each of the figures was placed in front of each subject one at the time. Subjects were instructed to tell the experimenter to adjust the background color until it matched the color of each figure. They found that figures that represented objects with characteristically red colors (e.g., a pair of lips or a heart) were systematically matched with a background color that was more red than the background color subjects chose to match the figures that did not represent objects with characteristically red colors (e.g., a circle or a mushroom). Delk and Fillenbaum (1965: 293) concluded that color appearance is influenced by previously formed color associations. Macpherson argues that these results lend support to the hypothesis that color experience is cognitively penetrated by cognitive states, that is, beliefs about the colors of familiar objects.

The study cited by Macpherson is by no means the only study that purports to show that cognitive states such as beliefs, desires, intentions, or moods literally and directly affect perception (see also Gegenfurtner, Franz, Fahle, Heinrich, & Bülthoff, 2001; Hansen et al., 2006; Witzel et al., 2011).[7] For example, a study by Hansen et al. (2006) seems to have produced similar results with respect to color experiences. The researchers presented subjects with digitized photographs of natural fruit such as bananas, which were placed against a gray background. Subjects were asked to adjust the color of the fruit until it appeared gray. As a control, subjects were also asked to adjust uniform spots of light and random noise patches. The difference between the controls and the fruit settings were found to be significant: Subjects adjusted the color of the banana (but not the random noise patches) to a slightly bluish hue—the opposite of yellow—in order to make it appear gray. Hansen et al. (2006) argue that these results suggest that long-term memory has a top-down effect on color experience since objects such as bananas that are characteristically yellow continue to appear yellow to subjects even when they are actually achromatic (i.e., gray). Specifically, long-term memory continuously modulates incoming input changing color appearances. If this is right, then it follows that color experience is significantly affected by long-term memory.[8] The question is whether these findings lend support to the hypothesis that color experience is cognitively penetrable. Macpherson (2012) would maintain that they do. We shall show that this conclusion is too hasty.[9]

To explain apparent cases of cognitive penetrability, Macpherson (2012) proposes an indirect mechanism involving two steps. In the first step, cognitive states either give rise to some non-perceptual state with a phenomenal character or alter the phenomenal character of some existing non-perceptual state that has phenomenal character. Imagination, dreams, and hallucinations are cited as examples of non-perceptual states whose content or phenomenal character can be generated or affected by cognitive states. In the second step, the phenomenal character of such non-perceptual states affects the phenomenal character and content of perceptual experiences.

Macpherson uses this mechanism to explain purported cases of cognitive penetration of color experience. On this account, when a subject views a figure that represents an object that is characteristically red, an imaginative state of a red figure is generated. The phenomenal character of the imaginative state, in turn, affects the phenomenal character of the subject's visual experience, giving rise to an experience of a "redder" figure. The imagination and visual states combine to produce a single phenomenal state. That is, subjects are aware of a single phenomenal character and unaware that it is the phenomenal character of their imagery state that contributed to the phenomenal character and content of their perceptual experience.

Macpherson argues that her proposal is plausible since each of these steps can occur independently. However, this suggestion is questionable. The fact that these steps can occur independently is insufficient to establish that they are causally related in the way Macpherson's proposal requires if it is to be plausible. Even though it may be true that imagery states are generated or affected by cognitive states, it need not be true that the phenomenal character of imagery states affects the phenomenal states of visual experience in a way that accounts for the results obtained by Delk and Fillenbaum's study.

Moreover, there is an empirical problem with Macpherson's particular model of the purported cognitive penetration of color experience. Using functional magnetic resonance imaging, Ganis, Thompson, and Kosslyn (2004) found that although there is substantial overlap between the brain areas engaged by visual imagery and visual perception, it is neither uniform nor complete. More important, it was found that visual perception and visual imagery engage frontal and parietal regions in ways more akin to each other than the ways that they engage temporal and occipital regions. Since it is the occipital regions that process visual information and send it to the parietal and temporal regions, if visual experience were cognitively penetrable in the way described in Macpherson's model, we would expect to find greater similarity in the occipital regions. These findings, however, suggest that at least some sensory processes are engaged differently by visual perception and visual imagery. It follows that even if color experience is indeed cognitively penetrable, Macpherson's model fails to provide an adequate explanation of the processes that underlie it.

Deroy (2013) has recently offered a suggestive sketch of an alternative explanation for the results of these studies, which is consistent with the cognitive impenetrability thesis. According to Deroy, apparent cases of cognitive penetrability can be explained by appeal to a higher-level model of sensory integration. On this view, early sensory processing is affected by higher multimodal representation activated by sensory information about the object's color, shape, volume, texture, etc. So, while perceptual processing is affected by top-down influences, these influences are not the processing of beliefs about the characteristic color of objects. This, she claims, is not cognitive penetration, because the early sensory processing is affected by higher multimodal processing rather than cognitive constructs like belief and knowledge.

We agree with Deroy that these studies do not provide sufficient evidence for the claim that color experience is cognitively penetrable. However, the success of Deroy's proposal would require establishing that the resulting representations that influence early sensory processing are not in the same broad category of cognitive constructs as beliefs. A better explanation of the results of the aforementioned studies would be that the shape of the object triggers memory retrieval of its characteristic color. On the now-standard model of memory retrieval, the retrieval of a memory consists in a hippocampus-mediated restatement of activity in the neural region in which the features were originally processed (Danker & Anderson, 2010; Eichenbaum & Cohen, 2001; Rissman & Wagner, 2012; Schacter, Addis, & Buckner, 2007). So, the retrieval of the color of an object should reinstate activity in the color regions that originally processed the color. Though this activity is believed to be considerably weaker than the original activity, it may give rise to an additive effect that is strong enough for subjects to adjust differently for objects that have a characteristic color. For example, retrieval of the semantic fact that bananas are typically yellow instantiates activity in the visual cortex. This activity may add to the activity resulting from the perception of a banana, thus giving rise an overall enhanced perceptual effect. Thus, if this sort of reinstatement of activity following memory retrieval does indeed occur, it could account for the results of the aforementioned studies. This kind of process would nevertheless count as a kind of cognitive penetration, given the standard philosophical account of the phenomenon.

3. Perceptual principles versus cognitive penetration

Many studies, including those discussed above, purport to show that cognitive states penetrate perceptual experience.[10] However, we believe that the problem lies with the notion of cognitive penetrability that has become dominant in philosophy in recent years and which we believe to be problematic. Pylyshyn[11] and others who have defended the cognitive impenetrability of early vision argue that there are perceptual principles, or "organizing principles of vision," that modulate (early) visual processes (Fodor, 1983; Pylyshyn, 1999; Raftopoulos, 2001). For example, in the case of amodal completion, partially occluded figures are not perceived as the fragments of the foregrounded figures but as hidden behind or covered by the occluder. Intra-perceptual principles appear to modulate the visual processes, completing the hidden parts of the occluded figures (Fig. 1).

These perceptual principles are not rational principles, but can be thought of as maximum likelihood or semantic coherence.[12] The visual system employs them to compensate for the inherent ambiguity of proximal stimuli.[13] In Fig. 1, for example, the outermost octagons should make it more likely that the occluded figure is also a regular octagon. But the principles of completion work according to their own algorithms and the occluded object is not experienced as a regular octagon.

The perceptual principles organizing the visual system can also explain the permanence of certain optical illusions. The Müller-Lyer illusion is the quintessential example often cited in support of the cognitive impenetrability thesis since it is taken to signify that how things appear is unaffected by cognitive states (Raftopoulos, 2001; Macpherson, 2012; Brogaard et al., 2014; Gegenfurtner et al., 2001) (Fig. 2). The direction of the arrowheads at the end of lines that are equal in length affect one's perceptual experience: The line appears shorter when the arrowheads are turned inward, but longer when they are turned outward. The illusion persists even when we come to believe that the lines have the same length. We only see the lines as having the same length when we add vertical lines that allow us to compare their lengths.

There are several possible explanations for the occurrence of the Müller-Lyer illusion. One explanation pertains to the eye-movement theory (Carr, 1935). When we observe the bottom line, our eyes follow the arrowheads outward giving us the impression that the

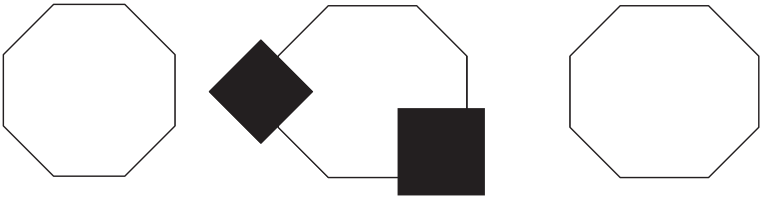

Fig. 1. Kanizsa amodal completion. Despite the flanking cases of octagons, the occluded figure is not seen as a regular octagon. From Pylyshyn (1999).

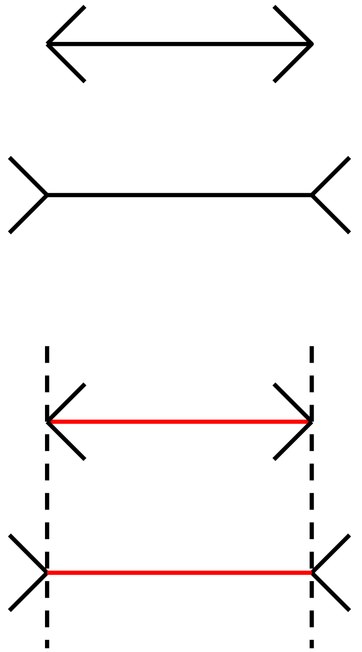

Fig. 2. The Müller-Lyer Illusion. Even when you learn that the line segments on the left have the same length, they continue to appear as if they have different length.

line is longer. But when we observe the top line, our eyes follow the arrowheads inwards giving us the impression that the line is shorter. However, this explanation is implausible since the illusion persists even when the image is flashing faster than our eyes move.

The Intertip Disparity theory provides another explanation, according to which we tend to cognitively measure the length of the line segments as being the distance between the ends of the arrowheads (Oliver, 2006). Since the distance is greater for the bottom line segment than the top line, the bottom line segment appears longer than the top. Studies confirm that the illusion is stronger when longer arrowheads are used, creating a shorter or longer distance between the ends of the arrowheads.

The Limited Visual Acuity theory provides yet another explanation (Gregory, 1968). Visual acuity is the ability to distinguish details in the visual field. When we look at the lines, we tend to fixate on the center of the arrowheads between the two end points, which limits our visual acuity of the arrowheads since they are in our peripheral vision making the top line segment shorter than the bottom.

The most popular explanation of the Müller-Lyer illusion, however, is based on depth perception (Gregory, 1968; Howe & Purves, 2005).[14] Depth perception involves generating an internal three-dimensional model of the environment. Part of the mechanism that produces the three-dimensional model adjusts for the sameness in size of objects located at different distances from us. This is also known as "size constancy." This mechanism ensures that objects are not perceived as shrinking when we move away from them. As a

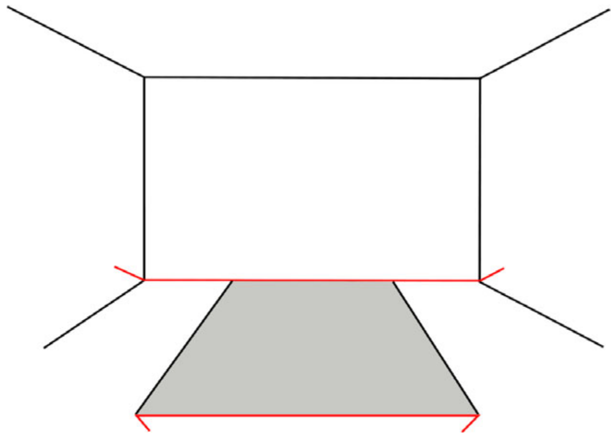

Fig. 3. The Müller-Lyer Illusion: Illustration of how outside corners generate the appearance of the object being further away from us, whereas inside corners generate the appearance of the object being closer to us.

result of this process, the brain projects the retinal image of the outward arrowheads to what would normally be its correct distance in our internal model, thus making the line segment with the outward arrowheads seem longer (Fig. 3).

All of the above explanations are consistent with the hypothesis that intra-perceptual principles modulate visual processing of incoming sensory information, thereby affecting the content of perceptual experience. But the modulation of visual experience by perceptual principles is consistent with the claim that perceptual experience is cognitively impenetrable. This is not because the intra-perceptual principles themselves have neural correlates in visual areas. The neuroanatomical underpinnings of the perceptual principles that govern visual processing are not fully known, and the principles may turn out to be best classified as types of implicit beliefs acquired evolutionarily or developmentally. However, the modulation of visual experience by perceptual principles (unlike modulation by beliefs) does not count as cognitive penetration because these principles do not conform to standard tenets of rationality, which include standard rules of logic, probability theory and statistics, and rational choice theory as norms of reasoning. They are more akin to gestalt laws. The traditional debate about whether visual experience is cognitively penetrated is thus not about whether visual experience can be modulated by perceptual principles but about whether visual experience can be modulated by belief and knowledge acquired after the maturity of the sensory system.

Persistent optical illusions suggest that, at least some, visual experiences cannot be modulated in this way. For example, the principles that govern our perceptual experience in the case of the Müller-Lyer illusion do not conform to the tenets of rationality. Our belief that, contrary to appearance, the line-segments have the same lengths does not modulate visual experience but implicit intra-perceptual principles, which were acquired evolutionarily or developmentally (c.f. Segall et al., 1963). But if optical illusions are not modulated by standard belief and knowledge acquired after the maturity of the sensory system, then it stands to reason that no visual experience is modulated by belief and knowledge of this kind.

The distinction between modulation by perceptual principles and cognitive penetration carries over to color experience. In our environment the level of energy of the light at each wavelength in the visible spectrum, also known as "the spectral power distribution" (SPD), varies greatly across different light sources (illuminants) and different times of the day. Cool white fluorescent light and sunlight have radically different SPDs. Sunlight has vastly greater amounts of energy in the blue and green portions of the spectrum, which explains why an item of clothing may look very different in the store than when worn outside on a sunny day. The SPD of sunlight also varies throughout the day. Sunlight at midday contains a greater proportion of blue light than sunlight in the morning or afternoon, which contains higher quantities of light in the yellow and red regions of the color spectrum. Sunlight in the shade, when it is not overcast, contains even greater amounts of blue light. SPD variations explain why a photograph of a particular scene taken in daylight appears reddish while a photograph of the same scene taken under fluorescent light appears greenish. However, the visual system compensates for such spectral differences. If you were present when the photographs were taken, the scene would appear to have the same SPD under both illuminations. Our perceptual system adjusts for many of these changes in the SPD of natural illuminants, but the adjustment is less likely to occur when the illuminant is artificial. For example, when you look at a dandelion facing away from the sunlight, your visual system adjusts for the change in SPD (Akins, 2001). As a result, the dandelion doesn't look bluish-green but continues to look yellow. These adjustments are constitutively involved in the phenomenon of color constancy, although there is some reason to think that color constancy computations are not obligatorily linked to experiencing color and may precede it (Kentridge, Norman, Akins, & Heywood, 2014).[15] But what is important for our purposes is that the color constancy processes are not triggered by beliefs about the colors of objects.

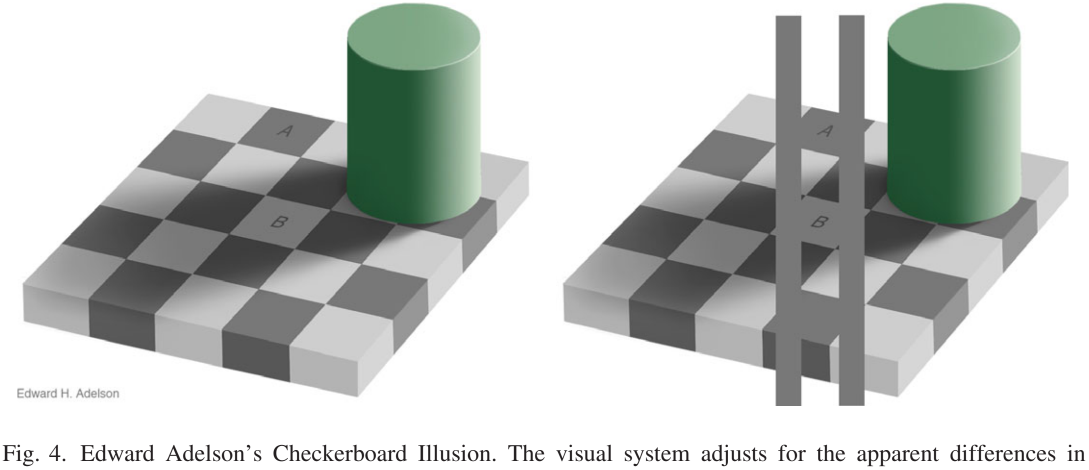

Fig. 4. Edward Adelson's Checkerboard Illusion. The visual system adjusts for the apparent differences in the spectral power distribution of the illuminant, which leads us to perceive A and B as differently colored.

The principles governing these intra-perceptual adjustments are perceptual principles similar to those that govern other visual adjustments in that they are not conforming to any standard tenets of rationality. The checker illusion, for example, occurs because our perceptual system adjusts for changes in the SPD of the illuminant, thus treating an image the same way it would treat an object in natural illumination conditions (see Fig. 4).

Because perceptual principles do not conform to the basic tenets of rationality, cases in which our cognitive system discounts the spectral biases of illuminants do not count as cases of cognitive penetration. In light of these considerations the aforementioned studies demonstrating that the characteristic color of an object can modulate color appearance are not obviously cases of cognitive penetration. The study by Hansen et al. (2006), for example, showed that individuals adjust the color of images of natural fruits to gray in such a way as to counteract the characteristic color of the object. However, it was not shown whether this adjustment was the result of perceptual principles or cognitive penetration since the results showing that we adjust the color of a banana to have a blue tint are consistent with this adjustment being the result of perceptual principles that would normally lead us to adjust for the green or blue appearance of a banana turning away from the sun. That is, color constancy mechanisms would prevent any normally yellow object from looking bluish. So, there is a kind of yellowification of the banana throughout the entire course of the adjustment.

The question, of course, is whether the memory color effect is stronger for yellow and blue. If this is so, then how can the color constancy explanation make sense of this? Presumably there are constancy mechanisms for red and green as well. So, the constancy explanation ought to predict an effect for red and green as well.[16] However, the evidence suggests that the memory color effect does show up for red/green. In the study by Hansen et al. (2006), it is clearly present for green and orange objects (see Fig. 2 of their paper showing cucumber, lettuce, orange, carrot, etc.).

A further question is whether the constancy system corrects for gray as well as hues. The task in the paper by Hansen and colleagues is to adjust to a gray appearance. At the end of the paper the authors discuss the relationship between morning light (short wavelength dominated) and fruit (medium and long wavelength reflectance dominated) and speculate that memory color effects may play a particularly important role at that time where fruit would otherwise likely appear gray. We don't think they are saying that memory color effects would not apply in other circumstances, but rather that, in the real world, this is when they may have the largest impact.

To test for whether color vision is cognitively penetrated we would need to show that (justified) color-related beliefs—that is, beliefs about the colors of objects—would lead us to make similar adjustments.[17] More specifically, what should be tested is whether color-related beliefs, knowledge, or memory acquired after the maturity of the sensory system affect color adjustments. This would make it less likely that it is the evolutionary or developmentally learned perceptual principles that explain the color adjustments and, hence, more plausible that cognitive penetration occurs.

A study of this type, conducted by Witzel et al. (2011), appears to show a memory color effect for various artifacts (including blue Nivea cream, traffic signs, smurf, Milka, the cartoon character Die Maus, etc.). However, that study is methodologically problematic. There is no apparent adjustment for cultural background, prior knowledge of objects, and so forth, by participants. Therefore, it cannot be determined whether the memory-color effects were the result of what people learned in early childhood or later in life. But that is one of the main questions at issue here (in the case of the artifacts), as we already know that our environment contributes to the maturation of the sensory system. Perceptual principles (e.g., constancy computation) are shaped in early childhood. For example, both of the present authors would have been subjects for which the blueness of the Nivea cream was learned in childhood, which would have affected the color constancy computation for this object.

Notice that the German participants (as we assume that they are, having an average age of 26) were probably exposed to the following objects in early childhood: Nivea, traffic sign, smurf, Milka. The fact that these were exactly the objects that gave rise to the greatest effects seems to support the color constancy explanation. In fact, it seems that their reaction time paradigm confirms this interpretation, as it shows the high color diagnostics for the objects in question.

The following conclusion they draw is therefore questionable: "Since these objects are tied to a particular cultural context, their association with a typical color must have been learned in everyday life. Therefore, we conclude that acquired knowledge about objects modulates their colour appearance. These findings provide further evidence that object recognition and colour appearance interact in high-level vision."

The following part of their conclusion is correct but perfectly consistent with the color constancy explanation: "Moreover, they [these findings] show that these interactions are mediated through past experience. In this way, they also support the idea that learning influences perception." This is consistent with the color constancy explanation because the early life experience contributes to the maturation of the sensory system.

The authors, in fact, appear to grant that point themselves when they say: "This supports once again the idea that colour appearance in particular and vision in general is strongly *adapted to ecological constraints*." And again when they write: "Taken together, our findings suggest that the memory colour effect appears most strongly for stimuli that correspond to the visual experiences with which people were *originally familiarised* in their everyday life" (emphasis added in both quotations). The latter parts of the conclusion do not support top-down influences on color processing in the mature sensory system but rather supports the well-known fact that pruning takes place during the maturation of the brain. Pruning changes the neural structure by reducing the overall number of synapses, leading to more efficient synaptic configurations. These processes are governed primarily by environmental factors, particularly learning. This again is perfectly consistent with the color constancy explanation.

The color constancy explanation is further supported by a recent study on color categories, which suggests that color categories affect post-perceptual processing, but do not affect the perceptual representation of color (He, Witzel, Forder, Clifford, & Franklin, 2014). Unlike prior studies, He et al. (2014) equated same- and different-category colors in the number of just-noticeable differences and measured event-related potential to these colors in order to ensure that claims that color categories affect color perception were not confounded by inequalities in color space. Category effects were found (from 200 milliseconds after color presentation) only in event-related potential components that reflect post-perceptual processes.

4. Post-perceptual processes versus the modularity hypothesis

The cognitive impenetrability thesis was not originally stated in relation to visual experience but rather in relation to the visual system. It is generally accepted that vision is heavily influenced by top-down processes. Some, however, deny that early vision, defined functionally, is cognitively penetrable (Marr, 1982; Pylyshyn, 1999: 344; Raftopoulos, 2001). They would thus argue that demonstrating the cognitive penetrability of color experience requires providing a counterexample to the original modularity hypothesis that shows that color experience is the result of processing occurring in early vision (Raftopoulos, 2001). Our argument merely requires that for color experience to be cognitively penetrable the top-down processes influencing color experience must not be perceptual principles and color processing must not be post-perceptual.

To state our hypothesis more generally, in terms of perceptual experience, it must be shown that color experience is modulated only by perceptual principles or is itself post-perceptual. Color experience has traditionally been treated by philosophers as involving paradigmatically purely perceptual processes. Whether that is really the case depends on what we mean by "color experience." If understood in terms of the experience of hues (e.g., red, yellow, green, and blue), then there are two reasons to think that color experience is post-perceptual. The first is empirical: we know from color science that the determination of a determinate hue involves post-perceptual processes (Beauchamp et al., 1999). The second is philosophical: once cognitive penetrability is adequately characterized, it can be shown that the aspects of color experience that are cognitively penetrable are not truly perceptual (since they involve post-perceptual processes). So, if color experience is indeed cognitively penetrable, then that gives us some reason to think that it is partially post-perceptual. We shall deal with these two cases in turn.

As for the first case, three opponent channels originate in ganglion cells in the retinal ganglion layer and the lateral geniculate nucleus that receive information from the cone cells in the retina via bipolar cells (Herring, 1964). The bipolar cells provide either excitatory (On-bipolar) or inhibitory (OFF-bipolar) inputs from cones to ganglion cells, which measure differences between red (L) and green (M), blue and yellow (L plus M and S) and black and white (the sum of L and M). For example, when green dominates, red is inhibited and the result is green. Likewise, when the activity of the S cones is greater than the joint activity of the L and M cones, the result is blue. These processes only explain the human visual system's ability to detect wavelengths; they do not explain (conscious) representation of colors (Lotto and Purves, 2000). People with blindsight, a kind of residual vision in the absence of a functional primary visual cortex, can detect wavelengths but they have no conscious experience of colors (Stoerig & Cowey, 1992).

Likewise, people with achromatopsia, a condition resulting from a defect to extrastriate areas in the neighborhood of V4 that inhibits chromatic color vision, have no conscious hue experience (Heywood & Kentridge, 2003; Heywood, Kentridge, & Cowey, 2001). Conscious perception of the full range of colors apparently requires double-opponent processes in V1 and V4. Double-opponent processes measure the differences in luminance or color between two neighboring areas of the scene. Double-opponent cells in V4, for example, may detect that the L cone is stimulated more than the M cone in one area but that the M cone is stimulated more than the L cone in a neighboring area.[18] This would represent a red-green color contrast—that is, a transition from red to green.

It is not fully known which neural regions compute conscious hue experiences. Evidence from achromatopsia suggests that these experiences may arise from double-opponent processing in V4. However, there is independent evidence suggesting that the neural correlates of conscious hue experience may be further upstream. Studies show that regions in the inferior convexity of the temporal lobe are critical for color processing. Using single-unit recordings Zeki (1977) showed that a cluster of cells in the posterior bank of the superior temporal sulcus that is distinct from V4 was responsive to chromatic stimuli. Several subsequent studies showed that neurons in this area are responsive to specific hues (Komatsu, Acedemy, Kaji, & Yamane, 1992) as well as after-image activity (Conway & Tsao, 2006).

Using a color sequencing task, Beauchamp et al. (1999) identified a wide range of selective color areas, including the left occipital cortex, dorsolateral occipital cortex, and the superior parietal lobe. Although their study shows that color processing is not confined to the ventral stream, it confirms that color processing is concentrated in the ventral occipito-temporal regions. The results also suggest that while passive viewing of colors correlates with activity in the more narrowly defined V4 region, color determination associated with an actual color task recruits areas further upstream, including more anterior and medial color-selective regions in collateral sulcus and fusiform gyrus. The authors suggest that this shows that attention modulated the activity when color information was behaviorally relevant, leading to a recruitment of higher neural areas. These results are consistent with the possibility that in passive and relatively inattentive viewing only general features of the color stimulus are determined such as approximate wavelength and relative local contrast, whereas adjustments for the SPD of the illuminant and the determination of a specific hue only occur as a result of an attention-demanding perceptual task and processing in higher neural regions. The experiences of hues, unlike the experience of an approximate wavelength and a relative contrast, involve post-perceptual processes and can be compared with experiences of faces, the content of which is computed by ventral areas in the close vicinity.

Furthermore, there is also some controversy over the brain areas involved in color constancy (adjustments for differences in the SPD) and color experience. It has been suggested that these might be the same at least insofar as one specific constancy mechanism (comparative color judgments involving retinex-like edge integration between spatially remote surfaces) seems to be lost in a cerebral achromatopsic who has also lost color experience (Kentridge, Heywood, & Cowey, 2004). However, there are good reasons to believe that other aspects of constancy are mediated by different brain areas (Rüttiger et al., 1999) and that color experience may actually arise in even more anterior areas (Murphey, Yoshor, & Beauchamp, 2008), suggesting that more posterior areas (e.g., the human color center V4/V8) may be necessary for color experience but that final integration of signals that elicit experience is in this more anterior area. This anatomy further bolsters the post-perceptual nature of color processing.[19]

The philosophical argument for the claim that color experience involves post-perceptual processes turns on its epistemic features. On a traditional view of appearance, perceptual appearances should be distinguished from epistemic appearances. Chisholm drew a distinction among three uses of "appear words," that is, perceptual verbs such as "seem," "appear," and "look" (Chisholm, 1957; chap. 4): epistemic uses, non-epistemic uses, and comparative uses.[20] Unlike statements containing epistemic uses of appear words, statements containing non-epistemic appear words do not imply that the speaker believes or is inclined to believe that things are as they appear. As Chisholm puts it:

> The locutions "*x* appears to S to be so-and-so" and "*x* appears so-and-so to S" sometimes do not imply that the subject S believes *x*, or is even inclined to believe, that x is so-and-so. I tell the oculist that the letters on his chart "now appear to run together" because both of us know that they do not run together. And when people point out that straight sticks sometimes "look bent" in water, that loud things "sound faint" from far away, that parallel tracks of ten "appear to converge," or "look convergent," that square things "look diamond-shaped" when approached obliquely, they do not believe that these things have the characteristics which they appear to have. In these instances "*x* appears so-and-so" does not mean that *x* is apparently so-and-so. (1957: 44)

In the Müller-Lyer illusion, for example, the line-segments look unequal, even if one knows that they are not. So the locution "the line-segments appear to me to be of equal length" does not imply that the speaker is inclined to believe that the line-segments *are* of equal length. Yet the speaker's belief (that the lines are not of equal length) cannot affect her visual experience.

Chisholm's idea that locutions containing epistemic uses of appear words imply that the speaker believes or is inclined to believe that things are as they appear can be formulated in terms of subjective probability. We can say that when "look" is used epistemically, the sentence conveys what is subjectively probable conditional on (total, total inner, total relevant, total relevant presented so far, etc.) evidence. For example, if I hear on the radio that there will be flooding in our area, I might say, "It looks like we ought to evacuate" in order to convey that we probably ought to evacuate.

Though Chisholm was talking about "appear" words, his distinction can be extended to the mental occurrences that we call "appearances." Following Chisholm's distinction, we can take it to be a definitive mark of epistemic appearances that they go away in the presence of a defeater if the agent is rational. For example, if several reputable news outlets announce that the earlier flooding announcement was a hoax, it will no longer (epistemically) seem this way to me. Of course, if the agent is not rational, she will not be inclined to reason in this fashion. But, in such a case, the problem lies with the agent's abilities (or lack thereof) rather than this feature of epistemic seemings.[21]

Another way to capture this difference is in terms of the notion of cognitive penetrability. Appearances that are the result of cognitive penetration are epistemic, whereas appearances that are cognitively impenetrable are perceptual. Epistemic appearances go way in the presence of a defeater if agents are rational. For example, if I were to compare a figure representing a characteristically red object that initially appeared to me to be more red than it really was with a control figure made out of the same cardboard, I should be able to say that they appear to have the same color. In this case, the appearances are epistemic and thus do not constitute cases of cognitive penetrability. On this view, then, an appearance that is cognitively penetrable is epistemic and hence not truly perceptual. We could also call it a "post-perceptual perceptual experience."

5. Philosophical implications

It was inferred from studies showing that cognitive states may modulate color appearance that color experience is cognitively penetrable. We argued that one problem with this inference is that it rests on a notion of cognitive penetration that fails to distinguish between the modulation of perceptual content by perceptual principles and genuine cognitive penetration. The modulation of visual experience by perceptual principles does not constitute cognitive penetration because these principles do not conform to standard tenets of rationality, even if we allow that the rationality of agents is limited by the available information, the cognitive limitations of an agent's mind, and the finite amount of time an agent has to make a decision, especially when it comes to tasks that involve high uncertainty. As we have argued, the results of the studies reviewed here are consistent with the hypothesis that color experience is modulated by perceptual principles and, hence, with the hypothesis that color experience is cognitively impenetrable.

A second problem with the above inference is that it rests on a notion of cognitive penetration that few would contest. The modularity thesis that has engendered debate in philosophy and the cognitive sciences maintains that color experience is cognitively penetrable by cognitive factors. However, the available evidence suggests that hue processing is post-perceptual and takes place outside the visual cortex in regions adjacent to those engaged in other post-perceptual processing such as face perception. But if color experience is not purely perceptual, then the fact that it is cognitively penetrable is fairly uncontroversial and fails to be relevant to the debate about the modularity hypothesis.

Various recent attempts to establish that visual experience is cognitively penetrable fail to distinguish between the modulation of the perceptual content by perceptual principles and genuine cognitive penetration. For example, Wayne Wu (2013) argues that intentions penetrate visual experience, specifically visual spatial constancy. Changes in the retinal image produced by objects moving in our visual field give rise to the experience of movement (spatial inconstancy). These same changes in the retinal image, however, can also be induced through saccadic eye movements. The difference between changes in the retinal image produced by movement and changes induced through saccadic eye movements is that, in the latter case, we are not experiencing objects as moving (spatial constancy). The retinal image is thus ambiguous: The same retinal image is consistent with both spatial constancy and spatial inconstancy.[22] Wu argues that spatial constancy rests on information exchange between the cognitive, motor, and visual modules (which is contrary to the modularity thesis) and as such it involves motor and cognitive penetration of visual experience.

The problem of spatial constancy involves accounting for (a) how eye movements introduce changes in the apparent location of objects within the visual field and (b) how the visual spatial constancy of objects can be relative to perceivers (i.e., egocentric constancy) (Wu, 2013). The Hierarchical Mapping Account (HMA), proposed by Wu, purports to explain how spatial constancy is visually represented by identifying plausible neural correlates for (a) and (b) in egocentric spatial representations coded in the parietal cortex, which includes the dorsal visual stream. Wu argues that, given the HMA, the visual system is not informationally encapsulated from the motor system in the computation of spatial constancy during normal eye movement since it performs operations over motor information as encoded in corollary discharge.[23] The fact that there is informational exchange between the cognitive and visual-motor systems computing constancy, he argues, gives us reason to think that cognition (i.e., intention) penetrates visual experience.[24] He argues that given that intentions (understood as stored plans constituting an action database) penetrate the motor system, the visual-motor system is (indirectly) penetrated by intentions since they affect basic visual computations that underlie our experience of constancy. He thus concludes that intentions penetrate visual experience.

Distinguishing between modulation of perceptual content by perceptual principles and genuine cognitive penetration can help us see why such arguments are flawed. As we have already argued, the mark of cognitive penetration is not whether perceptual principles can modulate visual experience but about whether visual experience can be modulated by intentions, beliefs, or prior knowledge. Wu's argument does not show whether spatial constancy results from the processes of perceptual principles or cognitive penetration. Recall that, according to Wu, spatial constancy is visually represented by identifying plausible neural correlates for (a) and (b) in egocentric spatial representations coded in the parietal cortex, which includes the dorsal visual stream. Dorsal-stream representations are not themselves subject to influence (Brogaard, 2011; Milner & Goodale, 1995, 2008), and hence may well be the seat of some of the perceptual principles internally governing perception. Cognitive penetration is characteristically penetration by ventral stream processes, not rationally insulated dorsal-stream processes. So, it is unlikely that spatial constancy involves any kind of cognitive penetration.

Spatial constancy is akin to color constancy, i.e., the perceived constancy of the colors of objects under different conditions of illumination (Brainard, MacIntyre, Hurst, & Xiao, 2012). How the visual system achieves color constancy is still unknown. One explanation, consistent with Wu's argument, is that color constancy is an instance of cognitive penetration of visual experience by our knowledge of and predications about our surroundings. However, there are far more plausible explanations that do not appeal to cognitive penetration. One such explanation invokes perceptual principles: The visual system deploys perceptual principles (e.g., about the uniformity of the light source) to estimate background illumination, which it goes on to discount in order to estimate the color of an object. The mere fact that perception is a kind of inference (a claim that both Pylyshyn and Fodor accept) does not entail that visual experience is cognitively penetrable. Another explanation is that color constancy results from hue processing that takes place in neural regions relatively late in the ventral stream. If this is the case, then color constancy is not a result of cognitive penetration. These explanations are consistent with the recent evidence discussed above suggesting that some, although not all, aspects of color constancy and color experience are mediated by the same brain areas.

Our hypothesis that cognitive penetration must be carefully distinguished from modulation of post-perceptual visual processes also challenges recent objections to an epistemological view known as "phenomenal dogmatism." On this view, the perceptual appearances can provide immediate, prima facie justification for belief. Siegel (2012) argues that apparent cases of cognitive penetrability lead to bootstrapping scenarios. Here is an illustrative example. Suppose that Jill believes, without justification, that Jack is angry at her. Assuming that beliefs can penetrate perceptual experiences, Jill's belief that Jack is angry can make him look angry to her. But it seems that Jill's epistemic attitude (that Jack is angry) is inappropriate since she does not have justification for the belief that Jack is angry. Given the lack of justification, the appropriate attitude for Jill to have is suspension of belief. But if we assume that her visual experience of Jack is cognitively penetrated by her belief that Jack is angry, we cannot deny that her epistemic attitude is inappropriate since her visual experience provides justification for her belief. It follows that if perception is cognitively penetrated, Jill's epistemic attitude is not inappropriate.

A similar scenario can be constructed for color experiences. Suppose that Jill believes that the yellow banana in front of her is green prior to looking at it. Assuming that beliefs can penetrate color experiences, Jill's belief that the banana is green can *cause* the banana to appear green to her. According to phenomenal dogmatism, this appearance can now provide prima facie justification for her belief that the banana is green. However, that is unacceptable. Jill's unjustified belief that the banana is green ought not be what indirectly lends justification to itself.

These sorts of cases, however, only count against a version of phenomenal dogmatism that maintains that all appearances can provide prima facie justification for belief. A more plausible version of phenomenal dogmatism holds that only *perceptual* appearances can provide prima facie justification for belief. Bootstrapping scenarios, however, do not involve cases of perceptual appearances but only cases of epistemic appearances. As we have argued above, appearances that are the result of cognitive penetration are epistemic, whereas appearances that are cognitively impenetrable are perceptual. It is easy to show that the appearances Siegel invokes in her argument are epistemic rather than perceptual. Epistemic appearances go away in the presence of a defeater if agents are rational. Jill does not have justification for her belief that Jack is angry prior to seeing him, and the appearance she has (that he is angry) is grounded in this unjustified belief. So, if she were told that he is not angry, the appearance ought to go away, assuming she is rational. The same applies in the color case. Since the appearance that the banana is green is grounded in an unjustified belief, it ought to go away if she were told that the banana is yellow. In other words, appearances that are cognitively penetrable are sensitive to evidence, whereas perceptual appearances are not. A version of dogmatism that maintains that only perceptual appearances can provide prima facie justification for belief is, therefore, not susceptible to these bootstrapping objections.[25]

6. Conclusion

Despite the initial plausibility of the claim that color experience is cognitively penetrable, we have argued that it is flawed. We considered a notion of cognitive penetration of visual experience that has dominated philosophical discussions, and argued that it fails to distinguish between modulation of perceptual content by non-perceptual principles and genuine cognitive penetration. Once this distinction is made, it becomes evident that studies suggesting that color experience can be modulated by factors of the cognitive system do not show that color experience is cognitively penetrable. But even if color experience turns out to be modulated by belief and knowledge beyond non-perceptual principles, it does not follow that color experience is cognitively penetrable since the experience of determinate hues arises from post-perceptual processes.[26]

Notes

1. Psychologists use the term “memory color” to refer to the characteristic colors of familiar objects, such as the yellowness of bananas, we can recall with ease.
2. “Cognitive penetration” has been used to denote, on the one hand, a phenomenon involving belief influence on conscious perceptual experience and, on the other hand, a modularity claim according to which higher cognitive processes do not influence early vision. We will address this distinction below.
3. Wu (2013) uses a similar notion of cognitive penetration to defend the claim that intentions penetrate visual spatial experience.
4. Although the notion of cognitive penetrability applies to a whole host of perceptual phenomena, the focus of this paper is limited to the question of whether our beliefs, knowledge, and memory about the typical colors of ordinary objects (such as bananas) modulate *color* experience.
5. We are indebted to Bob Kentridge for valuable comments on this issue. See also Mcpherson (2012).
6. Marr (1982), among others, argued that early vision involves purely bottom-up processes, which entails that it cannot be penetrated by cognitive states. Pylyshyn

(1999) also defines early vision functionally, as a system using inputs (i.e., attentionally modulated signals from the retina) to produce outputs (e.g., representations of visual properties). For an argument is against the cognitive penetration of early vision, see Raftopoulos (2001), who argues that for cognitive penetration to occur, our beliefs about the characteristic colors of ordinary objects must be able to directly affect early vision. On this view, to show that cognitive penetration occurs, it is not enough to argue that our color experience involves top-down processes. What must be shown is that these top-down processes are not post-perceptual; and since the only stage of the processing at which this can occur is early vision, what advocates of cognitive penetrability must show is that cognitive top-down processes affect early vision.

7. For arguments against the claim that these studies are successful in showing that color experience is cognitively penetrable, see Zeimbekis (2013) and Deroy (2013).
8. We discuss another case by Witzel et al. (2011) in section 3. .
9. Assuming our argument is cogent, it can be extended to Wu's (2013) argument for cognitive penetration of visual spatial constancy (see section 5).
10. It is worth pointing out that it is somewhat questionable that these experiments explicitly involve *phenomenal* judgments; although adjusting the color of a banana until the banana looks gray is not quite the same as adjusting its color until one *visually experiences* gray when one looks at the banana, in these experiments it seems impossible to distinguish between these two judgments. The idea here is that "looks F to s" is ambiguous between "phenomenally looks F to s" and "epistemically looks F to s." Only 'phenomenally looks F to s' is equivalent to 's visually experiences F'. But the experiments do not control for this ambiguity, as adjusting the stimulus until the banana looks gray could be a cognitive rather than a perceptual judgment. We thank Bob Kentridge for valuable comments on this issue.
11. Even though Pylyshyn does not usually say that the thesis he defends, namely that early vision is cognitively impenetrable, is about perceptual experience, his discussion and particularly his reply to his critics in his 1999 paper explicitly shows that it is early visual experience he is interested in. For extended discussion of Pylyshyn's views on cognitive penetrability, see also Tye (1991).
12. These principles are akin to what Helmholtz called "unconscious inferences" (Gordon, 2004), what Gregory (2009) calls "hypotheses," or what Bayesians call "implicit assumptions" (Rescorla, 2013).
13. The proximal stimulus is inherently ambiguous because a single distal stimulus can give rise to multiple retinal images.
14. This explanation is consistent with findings that Europeans are considerably more susceptible to the Müller-Lyer illusion than non-Europeans (Segall, Campbell, & Herskovits, 1963). Since unlike their non-European counterparts, Europeans tend to live in carpentered environments (i.e., environments that consist largely of lines, angles, and rectangular objects), susceptibility to the illusion can be

explained in terms of the differences in their environments. We are indebted to an anonymous reviewer for steering us to this study.

15. There is much that is yet unknown about the phenomenon of color constancy. Our aim is not to elucidate it, but to utilize it to illustrate how intra-perceptual principles can affect color experience.
16. Thanks to an anonymous reviewer for raising this question.
17. Although here we are focusing primarily on justified beliefs given that the studies seem to suggest that beliefs about the characteristic colors of objects are justified, we believe that our proposal is applicable to non-doxastic states such as desires, intention, or emotions, which might bear relevant effects. We thank an anonymous reviewer for comments pertaining to this issue.
18. Cells with chromatic double-opponent responses are not found in the retina. Studies suggest that they are found in striate cortex as well as V1 and V4 (see Conway, 2001, Johnson, Hawken, & Shapley, 2001; and Kentridge, Heywood, & Weiskrantz, 2007)
19. Thanks to Bob Kentridge for suggesting this point.
20. We will not be concerned with the comparative uses here since there are not relevant to the discussion.
21. Epistemic appearances lead us to make judgments on the basis of available epistemic evidence while phenomenal appearances lead us to make judgments on the basis of evidence based on one's phenomenology.
22. As we mentioned earlier, the ambiguity of the retinal image resulting from distal inputs is not limited to spatial orientation. In fact, the problem of vision is to explain how the visual system resolves such ambiguities (c.f. Rescorla, 2013, and Purves & Lotto, 2011).
23. Corollary discharge is invoked by current models of spatial constancy. Corollary discharge signals are a class of representations that carry motor command content to other areas of the brain for further processing. The visual system uses corollary discharge signals to determine which retinal changes are due to the movement of the perceiver and which are due to the movements of objects.
24. Wu shares Fodor's (2000) assumption that informational encapsulation is the mark of modularity. For a rejection of Fodor's view of modularity, see Prinz (2006).
25. The claim here is not that bootstrapping cases force us to accept a weaker type of dogmatism. Because bootstrapping cases involve epistemic, not perceptual, appearances, we can accept the standard formulation of dogmatism to the effect that the *phenomenal* character of experience can confer epistemic justification on belief.
26. We are grateful to Bob Kentridge, Susanna Siegel, and audiences at Carnegie Mellon, Duke University, Stanford University, University of Southern California, Washington University, St. Louis, and Brogaard and Akins' Cortical Color Conference in Vancouver in 2011, as well as three reviewers for this journal for helpful comments on material included in this paper. The research was supported by a CAS Research Award from University of Missouri, St. Louis.

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