Effects with action-based measures can also be taken as evidence against task demands (Pitfall 3). Additionally, we have directly measured participants’ willingness to comply with task demands by purposefully inserting task demands into the design of the experiment. Participants were instructed on how to respond (e.g., to make sure to classify all fast speeds correctly), and we grouped participants based on their willingness to conform to these instructions. Importantly, both conforming and nonconforming participants showed identical action-specific effects of paddle size on apparent ball speed (Witt & Sugovic 2013b). The finding that nonconforming participants still show the same action-specific effect is evidence against a task demand explanation (Pitfall 3).

A final set of experiments explored the role of attention (Pitfall 5) in the Pong task by adding a secondary, attentionally demanding task (Witt et al. 2016). In one experiment, the secondary task was to count the number of flashes that occurred at the center of the screen. In another, the secondary task was to fixate on the ball and count the number of flashes that occurred on the ball as it moved across the screen. Regardless of attentional load location, paddle size continued to influence both perceptual judgments and action-based measures of ball speed. In other words, attention-based manipulations did nothing to diminish the action-specific effect; the effect of paddle size on apparent speed persisted in both cases. These studies rule out the possibility of an attention-based potential pitfall by showing that attention does not account for this particular action-specific effect.

We commend F&S for raising concrete concerns and future-oriented suggestions. We applied their checklist to one action-specific effect and found that none of the pitfalls could satisfactorily explain the effect of paddle size on apparent ball speed. We therefore conclude this effect is perceptual and demonstrates a genuine top-down influence on perception. Balls that are easier to catch are perceived to be moving slower than balls that are more difficult to catch. Going forward, researchers should apply this checklist to their own work to differentiate between effects that fall into the category of genuine perceptual effects and those that do not. However, the debate about whether there are any top-down effects on perception is decidedly in favor of a nonmodular view of vision.

Memory colours affect colour appearance

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Christoph Witzel, a,b Maria Oikkonen, c,d and Karl R. Gegenfurtner a

aAbteilung Allgemeine Psychologie, Justus-Liebig-Universität Giessen, 35625 Giessen, Germany; bLaboratoire Psychologie de la Perception (LPP), Université Paris Descartes, 75006 Paris, France; cDepartment of Psychology, Durham University, Durham DH1 3LE, United Kingdom; dInstitute of Behavioural Sciences, 00014 University of Helsinki, Finland.

cwitzel@daad-alumni.de

http://lpp.psycho.univ-paris5.fr/person.php?name=ChristophW

maria.oikkonen@dur.ac.uk

https://www.dur.ac.uk/research/directory/staff/?mode=staff&id=14131

gegenfurtner@uni-giessen.de

http://www.allpsych.uni-giessen.de/karl

Abstract: Memory colour effects show that colour perception is affected by memory and prior knowledge and hence by cognition. None of Firestone & Scholl’s (F&S’s) potential pitfalls apply to our work on memory colours. We present a Bayesian model of colour appearance to illustrate that an interaction between perception and memory is plausible from the perspective of vision science.

When observers are asked to adjust an object with a typical colour (e.g., a yellow banana) to grey in an achromatic adjustment task, they adjust it slightly to the colour opposite to the typical colour (e.g., blue). This result implies that observers still perceive remnants of the typical colour of the object when the object is shown at a chromaticity that would be considered grey otherwise. And that shows that the knowledge about the typical colour of an object influences the perceived colour of that object (Hansen et al. 2006; Oikkonen et al. 2008; Witzel et al. 2011).

In contrast to earlier work on memory colour, including Duncker (1939) and Bruner et al. (1951), we particularly developed our achromatic adjustment method to circumvent problems related to judgment, memory, and response biases. It is important to note that Firestone & Scholl (F&S) did not correctly state our methods and findings. The banana was not “judged to be more than 20% yellow” (sect. 4.4.1, para. 3) at the neutral point; instead, observers needed to adjust the banana 20% in the “blue” direction to make it appear neutral. Yellow judgments would naturally be prone to judgement biases, whereas our nulling method is not, because participants are not asked to implicitly or explicitly rate the object colours. Instead, the achromatic adjustment task involves a genuinely perceptual comparison between the colour of the objects and the grey background to which the observers were adapted (Pitfall 2, “perception versus judgment,” and Pitfall 6, “memory and recognition”).

To make sure that the response biases, we presented the images in random colours at the beginning of each trial (Pitfall 3, “demand and response bias”). Doing so prevented a strategy of merely over-shooting in the opposite colour direction, thus producing a spurious memory colour effect (Witzel & Hansen 2015). Even with this precaution, the observed effects went specifically in the opposite direction of the typical memory colours.

We carefully controlled our stimuli in their low-level, sensory characteristics (Pitfall 4, “low-level differences”). In contrast to F&S’s general critique about the lack of control in luminance (sect. 4.4.1, para. 3), stimuli in the memory colour experiments were matched in average luminance (Hansen et al. 2006; Oikkonen et al. 2008; Witzel et al. 2011). Moreover, the control stimuli used to establish observer’s grey adjustments independent of memory colour effects were matched in spatial and chromatic low-level properties with the colour-diagnostic images.

We also carefully explored the conditions under which the memory colour effect does not occur, providing “uniquely disconfirmatory predictions” (Pitfall 1, “an overly confirmatory research strategy,” sect. 4.1). Objects without a memory colour and objects with achromatic (greyscale) memory colours, such as a striped sock and a white golf ball, do not produce any shift in grey adjustments (Witzel & Hansen, 2015; Witzel et al. 2011). Moreover, the effect lessens when decreasing characteristic features of the objects, such as in uniformly painted objects and outline shapes (Oikkonen et al. 2008; see also Fig. 1 in Witzel et al. 2011).

Finally, the task required observers to pay attention to the image in order to complete the grey adjustment, independent of whether the image showed a colour-diagnostic object or a control object (Pitfall 5, “peripheral attentional effects”). Apart from that, there is no reason a priori to assume that shifts of attention away from the stimulus would produce spurious memory colour effects.

We are left to explain why the greyscale image of the banana in the target article’s Figure 2K does not appear yellow. The sensory signal coming from that figure unambiguously establishes that the colour difference between the leftmost and the rightmost banana is a difference between grey and yellow. The memory colour effect is more subtle and cannot compete with the unambiguous sensory information in Figure 2K (cf. our Fig. 1A). Contrary to Figure 2K, our method allows for detecting the small but systematic deviations of the grey perceived for example on a banana from the grey perceived on a control stimulus. These systematic deviations towards blue show that the recognition of the object as being a banana provides additional evidence for it being yellow that is combined with sensory evidence about the contrast between the adjusted colour and the grey background.
Hansen (2015). We believe the notion that colour appearance is elegantly considered in a Bayesian framework (Maloney & Mamassian 2009). Consider our Figure 1b: When the images are achromatically considered, the yellow shift in the percept towards yellow that corresponds to the memory colour effect. Hypothetical reliability of the sensory signal (blue line) and memory reliability (red line) for the typical yellow of a banana. The Bayesian combination of the two sources of information (grey line) predicts a shift in the perception of grey (at zero) towards yellow that corresponds to the memory colour effect. The observers compensate for this yellow shift in the percept (dotted vertical line) by adjusting the image towards blue.

In vision science, combining different types of evidence is most elegantly considered in a Bayesian framework (Maloney & Mamassian 2009). Consider our Figure 1b: When the images are achromatic, the sensory signal (blue curve) indicates greyness with a certain level of reliability. At the same time, prior knowledge about the typical colour of the object suggests that the object is likely to be coloured in its typical colour (red curve). Because sensory signals always contain uncertainty, combining sensory evidence with prior knowledge is a useful strategy to constrain perceptual estimates. As a result of the combination of sensory signals and prior knowledge in a Bayesian ideal observer model, the perceptual estimate of the colour (grey curve) shifts towards the typical colour of the object. When an observer is asked to make the object to appear grey, the colour setting needs to shift towards the opposite direction, thus producing the memory colour effect.

Whether memory colour effects are an example of top-down effects in the sense of cognitive penetrability of perception depends on the definition of perception and cognition (Witzel & Hansen 2015). We believe the notion that colour appearance is “low-level” whereas object recognition and memory are “high-level” (Eacott & Heywood 1995) is too simplified. In any case, evidence for the memory colour effects has also been observed in neuroimaging experiments (Bannert & Bartels 2013; Vandenbroucke et al. 2014) in early visual cortex, indicating that no matter at what stage they arise, they get propagated back to the early visual system.

The El Greco fallacy and pupillometry: Pupillary evidence for top-down effects on perception

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Weizhen Xie and Weiwei Zhang
Department of Psychology, University of California, Riverside, Riverside, CA 92521.
weizhen.xie@email.ucr.edu  weiweli.zhang@ucr.edu
http://sites.zanewxxie.org/
http://memory.ucr.edu

Abstract: In this commentary, we address the El Greco fallacy by reviewing some recent pupillary evidence supporting top-down modulation of perception. Furthermore, we give justification for including perceptual effects of attention in tests of cognitive penetrability. Together, these exhibits suggest that cognition can affect perception (i.e., they support cognitive penetrability).

Firestone & Scholl (F&S) argue against top-down influences of higher-level social cognitive factors (e.g., beliefs, desires, and emotion) on perception. They stipulate the conditions in which genuine top-down effects could be established and highlight a handful of pitfalls—some previous demonstrations of top-down effects in which the conditions were not satisfied.

For example, F&S criticize a previous finding that positive (vs. negative) thoughts made the world look brighter (vs. darker, Meier et al. 2007). They rule out the possibility that these findings were results of cognitive penetration on perception. Specifically, in a task (Fig. 1A) modeled after Study 4 in Meier et al. (2007), participants discriminate between a darker and a brighter luminance probe following activation of emotional concepts using words with positive or negative meanings. If perception is modulated by emotional concepts, perceptual representations of the brighter probe and the darker probe should both shift rightward by positive concepts, resulting in indistinguishable luminance discriminability (i.e., d’ in Signal Detection Theory, SDT) between the two luminance probes across emotion conditions (dashed lines in Fig. 1B). F&S thus argue that a genuine shift of perception by top-down factors could not manifest in behavioral reports (the El Greco fallacy, Pitfall 1). Therefore, any behavioral manifestation of changes in brightness perception induced by emotional concepts should result from response biases originating from postperceptual judgments (Firestone & Scholl 2014b) or low-level stimulus differences originating from bottom-up features (Firestone & Scholl 2015a; Lu et al. 2015).

While they have clearly demonstrated conceptual problems with the El Greco fallacy, F&S did not propose a solution for it. In the example of perceived brightness, a potential solution for this fallacy is to use direct or indirect assessment of perceived brightness, such as pupillometry, instead of relying on behavioral performance. Pupillary light response is traditionally believed to purely rely on bottom-up factors. However, some recent research has revealed robust cognitive effects on pupillary light responses (Hartmann & Fischer 2014; Laeng et al. 2012). That is, pupil size can be modulated by perceived brightness independent of physical brightness (e.g., Laeng & Endestad 2012; Laeng & Sulsted 2014; Mathôt et al. 2015; Naber & Nakayama 2013). For example, thinking about a bright event (e.g., a sunny day) leads to pupil constriction (Laeng & Sulsted 2014). These pupillary effects have been taken as evidence for cognitive penetrability (Hartmann & Fischer 2014), in that they are similar to pupillary responses to “real” visual perception induced by low-level physical stimuli.

Xie & Zhang (in preparation) generalized these pupillary effects in an experiment (Fig. 1A) modified from Study 4 in Meier et al. (2007). Accuracy in this experiment replicated the previous finding (Meier et al. 2007) that participants were more accurate in making a “brighter” response in the positive