UNIVERSITY OF BIRMINGHAM
University of Birmingham Research at Birmingham

Does unconscious perception really exist?

Peters, Megan A. K.; Kentridge, Robert W.; Phillips, Ian; Block, Ned

DOI:
10.1093/nc/nix015

License:
Creative Commons: Attribution-NonCommercial (CC BY-NC)

Document Version
Publisher's PDF, also known as Version of record

Citation for published version (Harvard):
Peters, MAK, Kentridge, RW, Phillips, I & Block, N 2017, 'Does unconscious perception really exist? Continuing the ASSC20 debate', *Neuroscience of Consciousness*, vol. 3, no. 1. https://doi.org/10.1093/nc/nix015

Link to publication on Research at Birmingham portal

General rights
Unless a licence is specified above, all rights (including copyright and moral rights) in this document are retained by the authors and/or the copyright holders. The express permission of the copyright holder must be obtained for any use of this material other than for purposes permitted by law.

•Users may freely distribute the URL that is used to identify this publication.
•Users may download and/or print one copy of the publication from the University of Birmingham research portal for the purpose of private study or non-commercial research.
•User may use extracts from the document in line with the concept of 'fair dealing' under the Copyright, Designs and Patents Act 1988 (?)
•Users may not further distribute the material nor use it for the purposes of commercial gain.

Where a licence is displayed above, please note the terms and conditions of the licence govern your use of this document.

When citing, please reference the published version.

Take down policy
While the University of Birmingham exercises care and attention in making items available there are rare occasions when an item has been uploaded in error or has been deemed to be commercially or otherwise sensitive.

If you believe that this is the case for this document, please contact UBIRA@lists.bham.ac.uk providing details and we will remove access to the work immediately and investigate.

Download date: 23. Apr. 2024

NEUROSCIENCE of Consciousness

Neuroscience of Consciousness, 2017, 3(1): nix015

doi: 10.1093/nc/nix015
Opinion Paper

Does unconscious perception really exist? Continuing the ASSC20 debate

Megan A. K. Peters[1,*,†], Robert W. Kentridge[2], Ian Phillips[3] and Ned Block[4]

[1]Psychology Department, University of California Los Angeles, Los Angeles, CA 90095, USA; [2]Department of Psychology, Durham University, Durham DH1 3LE, UK; [3]St. Anne's College, University of Oxford, Oxford OX2 6HS, UK; [4]Department of Philosophy, New York University, New York, NY 10003, USA

*Correspondence address. Psychology Department, University of California, Los Angeles, 1285 Franz Hall, Box 951563, Los Angeles, CA 90095-1563, USA. Tel: +1 323-596-1093; E-mail: meganakpeters@ucla.edu
†Megan A. K. Peters, http://orcid.org/0000-0002-0248-0816

In our ASSC20 symposium, "Does unconscious perception really exist?", the four of us asked some difficult questions about the purported phenomenon of unconscious perception, disagreeing on a number of points. This disagreement reflected the objective of the symposium: not only to come together to discuss a single topic of keen interest to the ASSC community, but to do so in a way that would fairly and comprehensively represent the heterogeneity of ideas, opinions, and evidence that exists concerning this contentious topic. The crux of this controversy rests in no small part on disagreement about what is meant by the terms of the debate and how to determine empirically whether a state is unconscious or not.

These are issues that directly concern all of us who study consciousness, so it seems it would be in our best interest to strive for consensus. Given the conversation at ASSC20, we are pleased to have the opportunity to address some of the nuanced topics that arose more formally, and share some of the thinking we have done since the meeting. To reflect the heterogeneity of ideas and opinions surrounding this topic, we have organized this discussion into four distinct contributions.

—M.A.K.P. and I.P.

Practical and theoretical considerations in seeking the neural correlates of consciousness

Megan A. K. Peters

Psychology Department, University of California, Los Angeles, Los Angeles, CA 90095, USA. E-mail: meganakpeters@ucla.edu

As empirical scientists studying consciousness, we should be concerned with one question above all others: How can we design an experiment that will isolate the "conscious" processing of something from the "unconscious" processing of it, so that we can study the neural processing that underlies awareness – the neural correlates of consciousness (NCCs) – without inadvertently including a number of other confounds? This is the foundation of the scientific method.

Of course, this has always been the goal of studies seeking the NCCs, for example via comparing brain activity in "conscious" and "unconscious" conditions (Baars 1993). But a number of confounds continue to plague our experiments. My goal here, therefore, is to briefly enumerate the current practical concerns in experiments seeking to identify the NCCs, and to discuss how a newly developed paradigm can directly address these practical issues (Peters and Lau 2015).

Isolating Awareness: Stimulus Strength and Performance Confounds

Two pervasive and closely related potential confounds in the scientific study of consciousness are stimulus signal strength and task performance capacity (Lau 2008; Aru *et al.* 2012). Each of these needs to be controlled for if we want to isolate awareness to look for its neural correlates.

Controlling the external signal strength of a stimulus is relatively easy, by designing an experiment in which stimulus properties do not vary across "conscious" versus "unconscious" conditions. This means the "conscious" condition should not present a large, bright, leisurely stimulus, while the "unconscious" condition uses a small, dim, brief stimulus. Of course neural processing would differ between these two conditions, but the

Received: 24 March 2017; **Revised:** 22 April 2017. **Accepted:** 15 May 2017

© The Author 2017. Published by Oxford University Press.
This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (http://creativecommons.org/licenses/by-nc/4.0/), which permits non-commercial re-use, distribution, and reproduction in any medium, provided the original work is properly cited. For commercial re-use, please contact journals.permissions@oup.com

difference would likely have relatively little to do with awareness per se: every region of the visual processing system would likely seem to play some critical role, all the way down to retinal ganglion cells (or even the computer screen!).

Although not as obvious as the external signal strength case, an experiment producing unmatched task performance capacity between "conscious" and "unconscious" conditions might imply an internal signal strength difference – especially when one engages in post-hoc data splitting into "seen" versus "unseen" trials (Shanks 2016). As an overly simplified example, imagine a perceptual decision-making experiment in which all stimuli are identical, but the observer blinks on some trials. On "blink" trials the observer does not see the stimulus, and so indicates "unseen" and performs at chance; on "no-blink" trials the observer indicates "seen" and performs well. By post-hoc splitting the trials into "seen" and "unseen" an experimenter has essentially reduced her experiment to the bright versus dim stimulus case, and again has not isolated awareness from the confound of signal strength. Although overly simplified, this example demonstrates the potential for erroneous conclusions if performance is not matched between "conscious" and "unconscious" conditions.

Stringent Definitions: What Should Count as "Unconscious" and "Perception"?

Assuming we can successfully isolate awareness from signal strength and performance, we must next operationally define unconscious versus conscious perception in an experimental setting.

First, let us address "unconscious": for a stimulus to be unconscious, an observer's subjective experience of the stimulus should be no different from the subjective experience of nothing at all. Although one could define being unconscious of a stimulus in other ways, this conservative definition seems closest to what is targeted when researchers want to distinguish a "conscious" condition or stimulus from an "unconscious" one.

A potential objection is that this definition might be too conservative because it fails to capture an important aspect of visual awareness: visual qualia. (For non-visual stimuli, qualia in other modalities should be substituted in this argument.) One might argue that an observer could have an amodal sense or "hunch" that something is present, indicating a lack of true visual awareness of the stimulus. However, this argument requires further definition of just how visual is visual enough to count as visual awareness. Should Type 2 blindsight count, in which some patients with visual cortex damage have residual visual awareness that lacks the usual "particularity, transparency and fine-grainedness" of visual experience (Brogaard 2015, 92; Foley 2015; Foley and Kentridge 2015)?

This objection brings up another more important question, however: are visual qualia necessary to study the NCCs of subjective awareness? I would argue no. Whether a subjective experience is visual or not should only affect experiments seeking to identify the neural correlates of visual qualia, not those seeking to uncover the neural correlates of subjective awareness itself. So, in experiments seeking the NCCs we should adopt this definition: awareness of a stimulus is present if the subjective experience of that stimulus is different from the subjective experience of the stimulus' absence.

To define "perception", I again favor a conservative definition that also will allow us to satisfy the requirement about matched performance. To demonstrate that perception has indeed occurred in a perceptual decision-making task, an observer must be able to make some identification or direct discrimination decision about a stimulus better than just guessing (Green and Swets 1966; Macmillan and Creelman 2004).

Of course, this narrow definition of perception excludes other cognitive processing that may be argued to count as perception, such as priming. A number of studies claim to evince unconscious perception by showing that an unconscious prime (color, word, picture, or even cross-modal event) can influence behavior on a subsequent task (Kouider and Dupoux 2001; Naccache and Dehaene 2001; Kouider *et al.* 2007; Nakamura *et al.* 2007; Faivre *et al.* 2014; Norman *et al.* 2014). Unconscious primes may also influence objective performance in discriminating a later stimulus without affecting subjective evaluations of that stimulus (Vlassova *et al.* 2014).

However, in priming tasks the unconscious prime does not meet our stringent definition of having been perceived: many studies require that discrimination or detection of the prime be at chance performance for the prime to be considered unconscious (e.g., Kouider *et al.* 2007; Norman *et al.* 2014). (Of course, demonstrating true chance performance is a statistical problem in its own right.) Other studies do not ask for any objective or subjective assessment of the prime at all, merely assuming it is unconscious because it has been masked (e.g., Kouider and Dupoux 2001; Naccache and Dehaene 2001; Nakamura *et al.* 2007). So, while studying unconscious priming can certainly provide insight into visual processing, it does not meet the stringent criteria of "perception" required to isolate awareness from task performance or signal strength.

Fortunately, once we have matched stimulus strength and performance, we will have created conditions in which "perception" by this definition is identical as well. Now, the only thing that changes between the two conditions of "conscious" and "unconscious" is awareness of the stimulus – the "subjective awareness" (Giles *et al.* 2016) – meaning that we have successfully isolated consciousness while controlling for other confounding factors.

Exhaustive Measurement: The Criterion Problem

We have but one more obstacle to overcome in order to properly design these experiments: the "criterion problem" (Eriksen 1960; Merikle *et al.* 2001; Hannula *et al.* 2005). Just because an observer reports he did not see a stimulus or has low confidence does not mean he had zero subjective experience of it, only that his experience fell below some (potentially very) arbitrary threshold for reporting "seen" or "high confidence". Unfortunately, all experiments that ask participants to rate stimulus visibility or confidence in a decision on any scale (Ramsøy and Overgaard 2004; Sandberg *et al.* 2010) are potentially prey to this problem, and until now paradigms developed to avoid the problem (Kolb and Braun 1995; Kunimoto *et al.* 2001) have met with replicability issues (Morgan *et al.* 1997; Robichaud and Stelmach 2003) or revealed other theoretical challenges (Galvin *et al.* 2003; Evans and Azzopardi 2007; Maniscalco and Lau 2012). Although criterion effects can reveal important psychological phenomena in other areas of study (Witt *et al.* 2015; Peters *et al.* 2016), in the study of consciousness they represent a very real and fundamental problem by preventing us from exhaustively measuring the presence or absence of awareness (Reingold and Merikle 1988, 1990). Yet these types of scales continue to be used almost exclusively in research seeking the NCCs.

Last year, Hakwan Lau and I designed a new paradigm (Peters and Lau 2015) to exhaustively measure awareness in the hopes of demonstrating that it should be possible to achieve "conscious" and "unconscious" conditions that would allow for matched performance. Our task modified the recent

reapplication (Barthelmé and Mamassian 2009; de Gardelle and Mamassian 2014) of the classic criterion-free two-interval forced-choice behavioral paradigm (Green and Swets 1966; Macmillan and Creelman 2004). On each trial, only one of two intervals contained a masked, low-contrast target to be discriminated, but we asked subjects to discriminate targets in *both* intervals (even though there was actually a target in only one) and to bet on which interval they thought they had discriminated correctly. If subjects could discriminate the target when it was present but could not bet on their choices, this would demonstrate the kind of unconscious perception that would allow for matched performance across "unconscious" and "conscious" conditions in subsequent experiments (Peters and Lau 2015).

But we found no evidence for unconscious perception. Instead, as soon as participants could discriminate the masked target above chance (i.e., they perceived it) they could tell which interval contained the target (i.e., they were conscious of it); that is, if they were unconscious of the target, they demonstrated no perception (Peters and Lau 2015). A follow-up study asked participants to report which interval contained the more "visible" target, thereby directly asking about visual qualia rather than an amodal subjective sense of "something versus nothing". However, the results were nearly identical (Peters and Lau 2015). Although it may be argued that the stimulus manipulations necessary for producing unconscious perception can be challenging and fickle, we measured the entire psychometric function and still were unable to identify any point at which the masked stimulus could produce above-chance performance but fail to rise into awareness.

What This Means for the Scientific Study of Consciousness

Do these results mean that we can never achieve matched performance in "conscious" versus "unconscious" conditions, rendering the requirements for experiments seeking NCCs impossible to meet? Not necessarily. All we can infer from these results, for now, is that unconscious perception of the type we require seems to be harder to induce than the field may have realized. (We haven't yet tried all the possible masking or neuromodulation techniques in existence.) Nevertheless, these experimental findings should make us think critically about what has actually been found in studies that do not control for task performance, may be susceptible to the criterion problem, or use masking or other manipulations to render a stimulus "unconscious".

The first step toward seeking the NCCs must be for the field to agree on the requirements for experimentally isolating awareness and measuring it exhaustively: tasks in which "conscious" and "unconscious" conditions are performance-matched, and which do not depend on arbitrary reporting criteria. Then, we can work to produce an accurate taxonomy of which techniques may produce such matched conscious/unconscious perception, and only then can we use the successful techniques in experiments seeking the NCCs.

Of course, this requires that unconscious perception be achievable in the first place. Most of us in the field do believe the unconscious version of perception exists, but many of us don't believe it has been convincingly demonstrated (Peters and Lau 2015). Despite philosophical objections to the very concept of unconscious perception (Phillips, this commentary), we all need to be convinced we are looking for something that exists – and how to identify it – if we are to use it in experiments that aim to uncover the neural computations, representations, and structures that give rise to our subjective experiences of the world.

Sensation and unconscious perception

Robert W. Kentridge

Department of Psychology, Durham University, Durham DH1 3LE, UK.
E-mail: robert.kentridge@durham.ac.uk

Much has been written about the terms "perception" and "sensation". Whether either or both might occur unconsciously depends critically upon definitions. If the definition of perception includes a proviso that it is, or gives rise to, experience, it is clear that no empirical evidence will ever show that perception can occur without experience. I therefore want to use as simple an "experience-neutral" definition of perception as is possible. I start with the Oxford English Dictionary (Simpson and Weiner 1989). In the OED the most succinct neutral definition of perception is: "The process of becoming aware of physical objects, phenomena, etc., through the senses". What we perceive are objects in the world (rather than events in our retina) and the process of perception is separate from that of sensation. I will adopt a working definition of visual perception simply as the process through which we become acquainted with the visual properties of objects in the world (i.e., their distal properties). The OED also has a straightforward definition of sensation: "…the subjective element in any operation of one of the senses, a physical 'feeling' considered apart from the resulting 'perception' of an object". So we might define visual sensation as the subjective experience one sometimes has when a stimulus acts on the visual system. In terms of these definitions the question of whether unconscious perception is possible boils down to testing whether representations of the distal stimulus can be constructed when the stimulus being represented does not elicit any sensation. Together with my colleagues I recently published a report of an experiment that addressed this question.

Estimation of Distal Stimulus Properties without Awareness: Unconscious Perception?

There is much more to color perception than the activation of cones in the retina. Our color experience depends on complex cortical processes that appear to be involved in constructing an estimate of the properties of the distal stimulus – what is known as color constancy (see e.g., Smithson 2005). Having color constancy means that we are able to judge that two identical material samples are the same color even when we see them under different kinds of illumination. As the two samples reflect light in identical ways, but are illuminated by lights with different variations in power across wavelength, the light reflected from them to our eyes will differ. With sufficient visual context from the surroundings we nevertheless judge the color of the materials as the same. We can, however, also make judgments not about the color of materials in the world, but instead about our experiences of color. If we see two samples of a material, one in shade and one in sunlight, we will judge that the materials are the same but we can also say that the color we experience when we look at the material in the shade is duller than the color-experience when looking at the one in direct sunlight. Our percepts of the colors of the objects can be the same even when we judge the sensations they elicit to be different. The question we addressed in Norman *et al.* (2014) was whether the process of estimating surface color depended upon having color sensations: Was it possible to have color constancy for an unseen surface?

In our study we used meta-contrast masking to render stimuli invisible. In meta-contrast masking the stimulus, in our case a colored disc, is presented very briefly followed after a short interval by a ring whose inner edge coincides with the location that had been the outer edge of the disc. This arrangement can render the disc quite invisible. It can still, however, be shown that the color of the unseen disc is processed by the visual system if we ask observers to make a decision about the color of the ring, which might be green on some trials and blue on others. If the disc matches the ring in color then observers' decisions are speeded even when they did not see the disc. A non-conscious estimate of the color of the disc is clearly influencing behavior. What is the nature of that non-conscious estimate? Is it low-level like the signal generated in the retina or is it something more complex like an estimate of an object's surface reflectance? We test this by presenting the disc and ring in a rich color context (against a background of many differently colored squares) and changing the apparent illumination of the scene between presentation of the disc and presentation of the ring. It appears as if a shadow is moving rapidly across the display during a trial so that the disc is seen under sunlight but, by the time the ring appears, it is in shadow. The color of the disc is the same on all trials. There are two colors of rings, constructed so that one matches the disc in terms of the light it reflects to the observer's eyes (a spectral match) whereas the other matches in the disc in terms of their apparent surface reflectance across the illuminant change from sunlight to shadow (a surface match). We also selected these colors so that one of the rings is generally classified as "blue" (the spectral match) and the other "green" (the surface match). We compare reaction times for discrimination of the ring's color in trials with discs compared to trials without discs and ask whether the spectral-match discs or the surface-match discs are the more effective color primes, that is, speed reaction time more. We found (somewhat to our surprise) that the surface-match disc reliably speeds reaction time more than the spectral-match prime. This remained the case in a number of control experiments. Moreover, in a follow-up phase conducted after the reaction time experiments, observers were unable to guess whether trials contained a disc or not (sensitivity measured as d' was not different from zero), and certainly could not see the discs. We concluded that color constancy, that is, computation of surface color, did not depend upon color experience. Is it reasonable to take this further and conclude that color perception can be unconscious and so perception does not have to follow from sensation?

According to my working definitions, in our experiment the distal property of the disc was represented even though observers could not detect its presence and so the disc was perceived despite being unseen. Is there any reason to doubt this conclusion? The main argument leveled against it revolves around whether perception must be something done by a person, as opposed, say, to a subsystem of the visual system. This is one of Tyler Burge's (2010) stipulations for perception. He says (I summarize) that perception must be sensory, that its content must be of entities in the outside world, that it requires perceptual constancy, and finally, that it must be by the individual insofar as it can initiate or directly guide action by the individual. There is little doubt that the disc in our experiment satisfies the first three stipulations but what about the last? The answer depends upon how the disc speeded reactions; on how this type of "priming" works.

How Different Are Seen and Unseen Primes?

Ansorge *et al.* (2014) recently comprehensively reviewed research on mechanisms of masked priming and their relationship with conscious executive control. One of the longest standing models of masked priming is Neumann's (1990) Direct Parameter Specification (DPS) model. Neumann suggests that primes activate a motor response in line with a pre-existing "task-set" (relations between stimuli and the actions to be made in response to them). This task-set can override more reflexive responses to the prime (e.g., using the left hand to respond to stimuli on the left). In DPS the prime may be contributing to construction of a representation matching that of the target intermediate between the raw sensory input and the motor output. It cannot simply be due to summation between the prime and the target at an early sensory stage (e.g., at the receptor level) stage – if it was then the spectral prime should be more effective than the surface prime rather than vice versa. So, in DPS, "a masked prime that is akin to an action trigger sets off the response that is specified in the task-control representation, although the prime can remain below the threshold of awareness" (Ansorge *et al.* 2014, 272). DPS is almost certainly behind a large fraction of our priming effects and so, in this sense, they are actions, made by the individual, and initiated in response to the prime. Schubert *et al.* (2013) report unseen primes also affecting temporal attention, speeding responses to events following them closely in time. This may explain why even spectral primes speeded responses to some extent in our study. If a distal representation of the unseen stimulus in our study is initiating action by the individual, then, even going beyond my simple definition of perception, it still seems that perception (including invocation of action by an individual) can be unconscious and does not have to follow from sensation.

The action elicited by the unseen prime in our study and in others reviewed in Ansorge *et al.* (2014) appears to be automatic – there is no evidence that it is under voluntary control. One interpretation of Burge's stipulation that perception is done by the individual, insofar as it initiates or guides action, is that these actions must be under conscious voluntary control. One might argue that this is slipping in a requirement equivalent to "perception must be conscious" through the back door (to consciously control something must one inevitably be conscious of the relevant properties of that thing?). Instead, let us ask whether the processing of masked primes is significantly different to that of seen primes. What can unseen primes control? Unseen primes can do much more than elicit motor responses. They can modulate switching between "task-sets" (e.g., Lau and Passingham 2007), they can slow or completely inhibit responses by priming "no-go" signals (e.g., van Gaal *et al.* 2009) and even modify task goals in masked semantic priming (e.g., Fitzsimons and Bargh 2003). Of course, the masked primes in these studies are not testably representations of a distal stimulus. Nevertheless, the range of processes that can be controlled by these unseen primes is not any different from those controllable by seen primes. Ansorge *et al.* (2014) conclude the key difference between conscious and unconscious primes is not in what they can do but in their flexibility. Unseen primes control responses by selecting from a limited set of alternatives that have previously been set by the individual. Seen stimuli allow novel responses to be executed and new task plans to be set up (even here, unconscious stimuli can play a dominant role in arriving at new task plans, e.g., Reuss *et al.* 2014). If unseen primes can be used to modify not only just motor responses to stimuli,

but also so many other aspects of our cognitions about a task is it necessary to also require that these responses also be under conscious voluntary control to qualify as percepts of an individual? Unseen primes can control not just one subsystem used in tackling a task but, apparently, all relevant subsystems, albeit in a less flexible but "fast and maybe more error-resistant" (Ansorge *et al.* 2011, 282) way than seen primes. The ability to use unseen primes in controlling so many diverse aspects of a task suggests that they are available to the individual insofar as the manner of their use is determined by the individual and their processing benefits the individual. The results of our color constancy study satisfy all of Burge's criteria, and primes defined by surface color might, in principle, be used to control all of these other processes (of course, we don't know, more experiments are required). I am tempted to draw a conclusion that if it walks like a duck and quacks like a duck then it is a duck – that unseen primes can be perceived and so that color perception can be unconscious and so perception does not have to follow from sensation.

What we need to think about when we think about unconscious perception

Ian Phillips

St. Anne's College, University of Oxford, Oxford OX2 6HS, UK.
E-mail: ian.phillips@st-annes.ox.ac.uk

Theoretical discussions of unconscious perception typically focus on how consciousness should be operationally defined (Lau 2008; Seth *et al.* 2008; Irvine 2013). However, a compelling case of unconscious perception requires both evidence that consciousness is absent and that perception is present. Consequently, theorists must also consider how perception should be operationally defined, and assess alleged cases of unconscious perception accordingly.

Traditionally, it was assumed that to be perceived a stimulus must contribute to a subject's conscious perspective (Moore 1925). To allow for the possibility of unconscious perception, Kanwisher suggests instead using "perception" to refer to "the extraction and/or representation of perceptual information from a stimulus, without any assumption that such information is necessarily experienced consciously" (2001, 90). Kanwisher's proposal needs refinement. It risks counting distinctive allergic reactions as instances of perception (Dretske 2006). It also fails to secure the idea that perception is an individual-level phenomenon, not merely an occurrence in an individual's visual system or brain (Burge 2010, 368 ff.).

By way of refinement, Burge proposes that perception is constitutively a matter of objective sensory representation by the individual. This means that perceptual states do not merely carry information but represent features of the physical environment as opposed to "idiosyncratic, proximal or subjective features of the individual" (2010, 397). According to Burge, such contents are attributable just when perceptual constancies are exercised. "Perception requires perceptual constancies." (399).

An alternative approach focuses on the "role", as opposed to "content", of perceptual states. Thus, Dretske (2006) proposes that the information which perceptual states carry must be directly available for the control and guidance of action. Similarly, Prinz (2015) stipulates that perception involves the transduction of "useable" sensory information. Content and role approaches are not exclusive. Milner and Goodale understand perception to "refer to a process which [subserves] ... the recognition and identification of [external] objects and events and their spatial and temporal relations" (1995/2006, 2). Here both content and role requirements are in play.

In line with contemporary orthodoxy, all the authors just mentioned claim that perception howsoever defined occurs unconsciously. [See also Block (2016) and Block in Block and Phillips (2016).] Here, I discuss four cases commonly invoked in support of this contention. Thinking about whether perception is genuinely present in these cases demonstrates that matters are much less clear cut than standardly supposed.

Case 1: Blindsight

According to Burge, "blindsight patients perceive environmental conditions. The perception involves perceptual constancies – including motion, location, and size constancies. The perception guides action. There is strong reason to believe that some of these patients lack phenomenal consciousness in the relevant perceptions." (2010, 374) In short: blindsight constitutes genuine perception without consciousness. It is important to consider the possibility that blindsight in fact involves abnormal and degraded, but nonetheless conscious, vision (Phillips 2016). However, my current interest is in the importance of asking whether residual function constitutes genuine perception. For Burge, a positive answer requires the preservation of visual constancies. Yet constancy preservation in blindsight is far from uncontroversial. Patient DB perceives neither surface color nor chromatic contrast, matching colored stimuli purely on the basis of wavelength (Kentridge *et al.* 2007; Alexander and Cowey 2013). Motion detection in GY is limited to "objectless" first-order motion energy (i.e., spatiotemporal changes in luminance) as opposed to changes in position or shape (Azzopardi and Hock 2011). And MS and GY's capacities to locate and detect objects are arguably limited to the detection of sharp luminance contours and stimulus transients, "'events' varying 'in subjective salience'" not objective environmental features (Alexander and Cowey 2010, 532). Assuming with Burge that constancies are necessary for perception, such findings suggest that the relevant preserved capacities of these patients at least do not constitute perception. (See also Case 4 regarding "action-blindsight".)

Case 2: Subliminal Priming

Using a novel metacontrast masking paradigm (Fig. 1), Norman *et al.* (2014) demonstrate preferential facilitation of color identification responses to a target preceded by an undetectable prime matched in surface color when compared with one matched in reflected color (i.e., wavelength).

This suggests that color constancy can occur outside consciousness. Does it evince unconscious "perception"? That turns on how the prime facilitates responding. One possibility is that the prime elicits activity in the visual system, including surface color representations, such that the visual system processes subsequent surface-congruent stimuli more fluently. It is consistent with this understanding that information concerning the prime's surface color is confined to the visual system and so wholly unavailable for action control and guidance. Consider a crude analogy: we do not perceive everything that causes pupillary dilation, yet such dilation makes various subsequent stimuli easier to perceive.

Another possibility is that the prime automatically activates associated responses in the motor system (Schmidt *et al.* 2006). However, such response priming also does not demonstrate

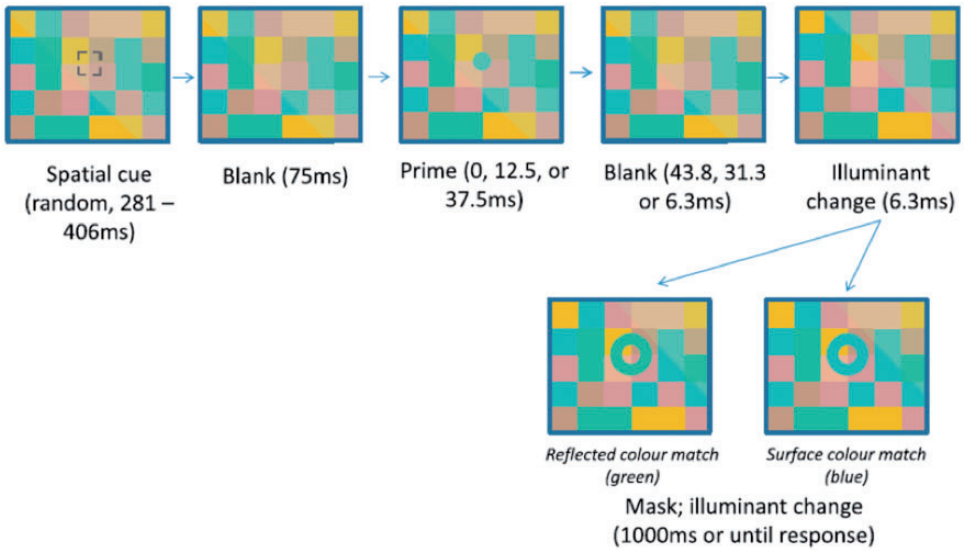

Figure 1. Trial sequence from Norman *et al.* (2014)

Notes: From left to right: a spatial cue and a brief delay precede the presentation of a prime for 0 (prime absent), 12.5, or 37.5 ms; a variable delay follows, after which a change in the display's illumination boundary occurs. This alters the illumination of the region in which prime and target (mask) are presented. Finally, a target (mask) is displayed. This is either green or blue and, given the previous change in illumination, respectively, matches the prime in either "reflected" or surface color. The subject then identifies the color of the target as rapidly as possible.

Source: Reproduced with permission. Copyright © 2014 Elsevier Ltd. All rights reserved.

that the relevant information is available for individual-level action control and guidance. Indeed, evidence suggests that comparable unconscious primes are not available for central, executive control of action (Kunde *et al.* 2003; Ansorge *et al.* 2011; cf. the "radically uncontrollable" effects in Snodgrass and Shevrin 2006; Cressman *et al.* 2013). These concerns have wide scope. They threaten the relevance of much work on subliminal priming to the question of unconscious perception, at least if we adopt a robust role-requirement on genuine perception.

Case 3: Unconscious Attention

There is now compelling evidence that spatial, feature-based and object-based attention can all operate outside of awareness (e.g., Kentridge *et al.* 1999, 2004; Schmidt and Schmidt 2010; Norman *et al.* 2015). However, treated as evidence of unconscious perception, such results merit much the same critique as priming studies: it is one thing for a stimulus to elicit (even widespread) activity in the subject's brain which (perhaps dramatically) affects subsequent visuomotor processing; it is another thing for a representation of that stimulus to be available for voluntary, individual-level control and guidance of action. Burge claims that attention itself "is a type of psychological agency" and "[h]ence … attributable to the individual" (372; see also Block in Phillips and Block 2016). But, in the present context, attention refers to the stimulus-driven modulation of visuomotor processing. Why should we think of the agent themselves as doing this any more than we should think of the agent as dilating their pupils?

Case 4: Vision-for-Action

Superficially the strongest case for unconscious perception in the robust senses here in focus, looks to work on so-called vision-for-action representations associated with the dorsal stream, and in particular to studies of patients with visual form agnosia (Milner and Goodale 1995/2006) and so-called "action-blindsight" (Danckert and Rossetti 2005; Whitwell *et al.* 2011). Such patients fail to reveal evidence of size constancy in their explicit, for example, manual or verbal, reports. However, their accurate scaling of grasp aperture in visually guided grasping provides evidence that (vergence based) size-constancy is preserved (Marotta *et al.* 1997; Sperandio *et al.* 2012; see also Mon-Williams *et al.* 2001; Servos 2006). However, it is far from obvious that vision-for-action constitutes genuine perception. [As ever issues about residual awareness also need pressing. See, for instance Whitwell *et al.* who write of their patient, SJ: "It is important to note, however, [that her] failure to show a target redundancy effect in our experiment does not mean that she is completely incapable of detecting targets in her blind field (using a button press). Had we used a forced-choice variant of this task she may have very well exhibited better-than-chance levels of performance." (2011, 915).] Indeed, although Milner and Goodale do think perception can occur unconsciously, they insist that "[t]he visual information used by the dorsal stream for programming and on-line control … is not perceptual in nature" (2008, 776; cf. 1995/2006, 2).

From the present perspective, a concern is whether the pertinent modulations of behavior (e.g., grasp aperture) witness genuine control and guidance "by the individual", and so meet relevant role requirements for perception. An alternative picture is suggested by the familiar metaphors of an automatic pilot (Pisella *et al.* 2000), tele-assisted semi-autonomous robot (Goodale and Humphrey 1998, §9; Goodale and Milner, 2004, 98–101; Milner and Goodale 1995/2006, §8.2.3), or heat-seeking missile (Campbell, 2002, 56). Such metaphors suggest that the only representations attributable to the individual will be those associated with target and action-type selection (cf. Clark 2007, 576). Representations exclusively involved in fine-grained motor programming will not be individually attributable. Indeed,

Danckert and Rossetti note how, as with unconscious priming discussed above, the parietal system "often functions automatically, rapidly modifying visually guided hand movements ... in contradiction to conscious commands" (2005, 1042, see also Pisella *et al.* 2000).

Conclusion

Proponents of unconscious perception face the challenge of providing an adequately justified operational definition of individual-level perception. Assessed in the light of extant proposals, many apparently clear cases of unconscious perception no longer appear so clear cut. Moreover, an obvious concern lurks in wait. One possible operational test for perception (closely associated with Dretske's role-based proposal above) requires that the information carried by a perceptual state must be exploitable by a subject to make a discriminatory response. Yet this test for perception is equivalent to so-called "objective" measures of consciousness (i.e., above chance discriminative sensitivity) (Green and Swets 1966). As a result, no putative cases of unconscious perception can hope to avoid the familiar concern that they simply involve weak conscious awareness unreported due to a conservative response criterion (Eriksen 1960; Holender 1986; Phillips 2016; Peters, this symposium).

Unconscious perception within conscious perception

Ned Block

Department of Philosophy, New York University, 5 Washington Place, New York, NY 10003, USA. E-mail: ned.block@nyu.edu

The debate on unconscious perception – including much of my own contribution – has been misdirected (Peters and Lau 2015; Block 2016; Block and Phillips 2016). The debate has focused on the efficacy of methods designed to shave off the conscious part of a perception, leaving unconscious perception. Can it be done? I think the answer is yes, but the issue is not straightforward. Whether or not it can be done, and whether or not the resulting unconscious percept would have to be different from the unconscious part it resulted from, unconscious perception is ubiquitous since many (if not all) conscious perceptions have unconscious perceptions within them.

I will start by explaining how we can distinguish conscious from unconscious representations in the visual system. Then I will move to the issue of whether the difference between these conscious and unconscious representations is the same as the difference between personal and sub-personal representations. I am discussing this latter issue because of the issue of whether unconscious visual representation is always sub-personal and hence not genuine perception (Block and Phillips 2016).

How can we distinguish between conscious and unconscious visual representation? One useful approach is to focus on neural bases. Every conscious visual perception in an animal has a neural basis and within that neural basis there is a neural basis of unconscious visual representation.

If the viewer is far enough away from Fig. 2 so that the stripes of the left and middle discs of Fig. 2 subtend one-fiftieth of a degree or less, all three discs will look the same (see Fig. 3). But He and MacLeod (2001) (see also Smallman *et al.* 1996) showed that some gratings that cannot be resolved consciously nonetheless are visually represented. The lense of the eye blurs very fine gratings but they were able to project similar grids directly to the retina through the side of the eye, bypassing the lense, by using laser interferometry, showing that gratings that are not consciously seen produce after-effects of the same magnitude as gratings that are consciously seen, and revealing that both gratings are indeed represented in the visual system, including in the retina and early vision.

An analogous result obtains for color flicker. If two colors alternate at frequencies above 10 Hz (10 cycles per second), "heterochromatic flicker fusion" occurs: viewers consciously see a single fused color rather than flickering colors (so long as the two colors have the same luminance). For example, red and green flickering above 10 Hz looks non-flickering and yellow. (Combining red and green lights – an "additive" mixture, as is used in your computer screen – produces yellow.) However, retinal cells respond to flicker way above the frequency that the subject can consciously see – as high as 40 Hz, and a way station between the retina and the cortex (the lateral geniculate nucleus) responds to frequencies that are almost as high. In the first cortical visual area, V1 (and probably to a lesser degree V2), all cells responded to 15 Hz flicker and most to 30 Hz flicker (Gur and Snodderly 1997). In sum, the retina and early vision registers flicker that the subject does not consciously see as flicker.

How do we know these representations in early vision are unconscious? Subjects show no sign of awareness of them and are at chance in guessing. For example, Haynes and Rees (2005) were able to predict the orientations that subjects were seeing from activity in V1 at a greater than chance level even when subjects were at chance in choosing which orientation they saw.

But are these unconscious flicker and orientation contents really contents of perception or are they just sub-personal representations of information on a par with representations in the brain of autonomic nervous system properties like heart rate or representations in neurons in the gastrointestinal tract? First, the unconscious representations have many of the same

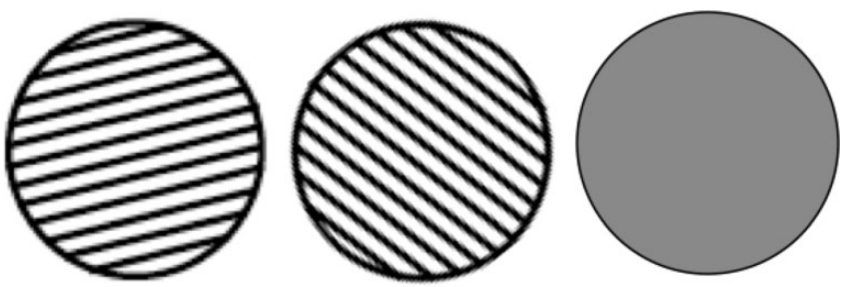

Figure 2. These circles look different to you but if you move further away from the screen or page to the extent that the distance from the beginning of one black bar to the beginning of another in the grid subtends one-fiftieth or less of a degree of visual angle they will look the same.

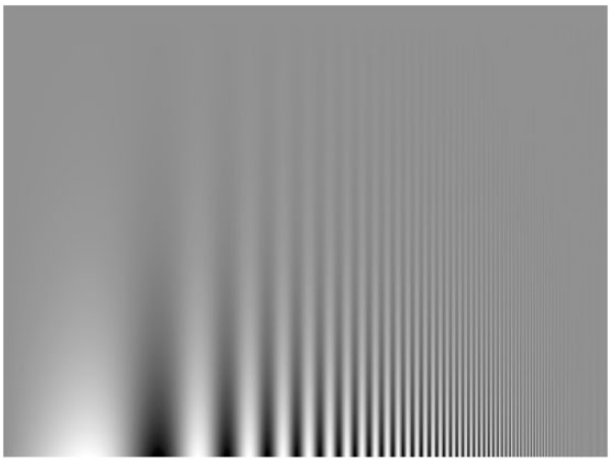

Figure 3. The point at which the bars merge is about 50 cycles per degree of visual angle, which will differ depending on your distance from this figure.

Note: Thanks to Marisa Carrasco for this image.

contents as conscious representations. For example, both conscious and unconscious representations can have contents of flicker under 10 Hz and orientation of grids under 50 cycles/degree. Further, these representations are alike in many respects – for example with regard to perceptual aftereffects and perceptual constancies. Constancies are important to what counts as perception (Burge 2010).

There is strong evidence that size constancy is registered in V1 independently of feedback from higher areas and good evidence that lightness and color constancy is registered in V1 and V2 also independently of feedback (MacEvoy and Paradiso 2001; Hurlburt 2003; Pooresmaeli *et al.* 2013).

While there are clear cases of sub-personal representations (such as gastrointestinal representations) and personal representations (e.g., conscious perceptions), many if not most cases of interest are indeterminate and there is no accepted characterization of the difference. Every proposal that has been made for what the personal/sub-personal distinction comes to has an air of postulation (Block and Phillips 2016). Extreme views abound. For example, according to a widely cited paper by Charles Travis (2004), all perceptual representations are sub-personal. People have intuitions about some cases but those intuitions may concern reasonable postulations about how to use a technical term.

By contrast, there is a robust border between conscious and unconscious representations in some domains. As just explained, 50 cycles/degree is the border between consciously and unconsciously seen gratings: representations in the visual system of gratings that are more fine-grained than 50 cycles per degree are unconscious. And alternating representations of color above 10 Hz are unconscious. (No doubt there are borderline cases and some variation from person to person.)

In short there is a fairly determinate border between conscious and unconscious, at least in some domains, but no one has given a reason to believe in a determinate border between personal and sub-personal, so there is no case that the two distinctions coincide. Anyone who claims that they do coincide owes us a persuasive way of drawing a boundary between the personal and sub-personal that does not beg the question against unconscious perception.

I have tried to give sufficient conditions for the personal level, conditions that I now regard more as useful postulations than as objective facts about the distinction. In previous publications touching on the personal/sub-personal issue (Block 2016; Block and Phillips 2016), I have focused on three supposed indicators of the personal level: whether the perceptual representations guide the person's action, whether they engage the person's preferences or needs, and whether they engage the person's understanding. I have no space to discuss all of them but I will sketch how the first of them does classify some unconscious perceptual representations as personal – and hence as unconscious perception. The cases I have in mind involve the dorsal visual system (Fig. 4).

Mel Goodale and David Milner have extensively tested a brain damaged patient known as DF (or sometimes Dee) who had damage to an area in the ventral visual cortex that underlies form perception (2008). DF could consciously see colors and textures but not shapes or orientations. If shown a slot as in Fig. 5, she was consciously aware of a blob with no orientation and she was nearly at chance in saying what the orientation of the slot was and in matching a card to the direction of the slot as shown on the left. However, and this is the indication of unconscious perception of orientation, she could nonetheless post the card through the slot with accuracy only slightly less than that of normal subjects. The orientation was represented in her dorsal visual system but her conscious visual system represented colors and textures. (The accuracy depictions in Fig. 5 are "normalized". That means that all slots are treated as if they were vertical, and when the subject got the estimations and posting wrong, that is graphed as a deviation from the vertical.)

How do we know that these perceptions are genuinely unconscious? Why else would DF be nearly at chance on matching and saying what the orientation is?

Importantly, this paradigm does not require completely unconscious perceptual states. There is no need to shave off the conscious part of a perception. In this paradigm, there are unconscious perceptual "contents" in otherwise conscious perceptions. DF consciously sees the stimulus but not the orientations of the slot.

In the case of DF there is as definitive an answer to the personal/sub-personal question as one is going to get for this question: her unconscious visual representations are "her" representations because they guide her actions in posting.

Volker Franz and Thomas Schenk have criticized some of Goodale's and Milner's studies (Hesse *et al.* 2011). They argue that DF may not visually represent orientations at all but rather manage to post by a trial and error procedure, adjusting her posting to avoid hitting the edge of the slot. Their evidence derives from a study in which they gave normal subjects the task of posting a card in a "slot" that was really a rectangle that was much wider than the slot at the top of Fig. 5. The length of the rectangle was shorter than the card so subjects could only fit the card through by putting it on the diagonal. Their subjects did do it in part by avoiding the edges. However, their slot was designed to elicit obstacle avoidance and so does not reflect on behavior involving a slot that is not so designed. Further as Goodale and Milner note, "Dee moved her hand forward unhesitatingly, and almost always inserted the card smoothly into the slot. Moreover, video recordings revealed that she began to rotate the card toward the correct orientation well in advance of arriving at the slot." (2005, 20) (I have seen some of this footage and would concur for the footage I have seen.) Further, it would seem that orientation perception would be required to avoid hitting the edge of the slot with the card.

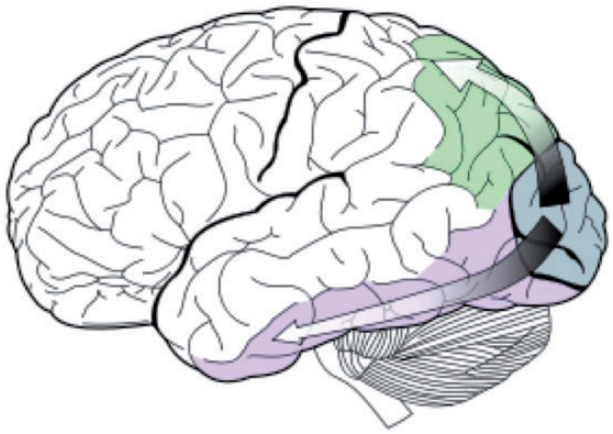

Figure 4. The back of the head is on the right; the conscious ventral visual system is represented by the bottom arrow from gray to purple whereas the largely unconscious dorsal visual system is represented by the top arrow from gray to green.

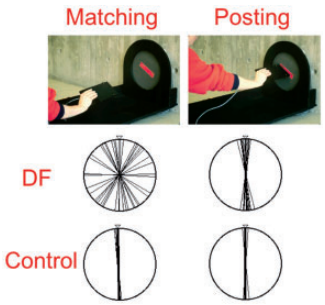

Figure 5. See text for explanation

Note: Thanks to Mel Goodale for this image.

Another experiment that combines conscious perception with partially unconscious contents tested normal subjects on gripping "Efron blocks", blocks that differ in width though with surface area and brightness held constant over the various widths (Goodale and Murphy 1997). They affixed measuring devices to the thumb and forefinger in order to measure grip precision at various angles from fixation of five of these blocks. Subjects also had to say which of the five blocks they were seeing. If you hold out an object at a 70° angle from your line of sight, you will see that you are very dimly conscious of its size: you consciously can tell the difference only between a very large and very small thing. What Goodale and Murphy found was that grip precision did not differ much between 5° and 70°, but numerical judgments of the widths (the blocks were given numbers) had half the precision at 70° as at 5°. This is not surprising given that the conscious ventral visual system that dominates foveal vision is much weaker than the action-guiding dorsal visual system in peripheral vision. The fact that the subjects' grip was much more precise in the periphery of vision than the subjects' size estimates strongly suggests that the guidance of grip is not entirely conscious. In other words, unconscious representation of widths is partly guiding gripping. That unconscious representation of width is – arguably – at the personal level because it guides action. Note that this argument for unconscious perception requires no shaving off of the conscious part of vision. What is unconscious is an aspect of the content of perception.

To conclude: the debate about the existence of unconscious perception has focused on whether the conscious part of a conscious perception can be shaved off, leaving only an unconscious perception. Whatever the resolution of that issue is, much if not all of conscious perception involves unconscious perception.

Acknowledgements

R.W.K. would like to thank Liam Norman, Charles Heywood, and Kathleen Akins, without whom this work would not have been possible.

Funding

This work was supported by a grant from the James S. McDonnell Foundation [to R.W.K.].

Conflict of interest statement. None declared.

References

Alexander I, Cowey A. Edges, colour and awareness in blindsight. *Conscious Cogn* 2010;**19**:520–33.

Alexander I, Cowey A. Isoluminant coloured stimuli are undetectable in blindsight even when they move. *Exp Brain Res* 2013;**225**:147–52.

Ansorge U, Fuchs I, Khalid S *et al*. No conflict control in the absence of awareness. *Psychol Res* 2011;**75**:351–65.

Ansorge U, Kunde W, Kiefer M. Unconscious vision and executive control: how unconscious processing and conscious action control interact. *Conscious Cogn* 2014;**27**:268–87.

Aru J, Bachmann T, Singer W *et al*. Distilling the neural correlates of consciousness. *Neurosci Biobehav Rev* 2012;**36**:737–46.

Azzopardi P, Hock HS. Illusory motion perception in blindsight. *Proc Natl Acad Sci USA* 2011;**108**:876–81.

Baars BJ. *A Cognitive Theory of Consciousness*. New York: Cambridge University Press, 1993.

Barthelmé S, Mamassian P. Evaluation of objective uncertainty in the visual system. *PLoS Comput Biol* 2009;**5**:e1000504–e1000504.

Block N. The Anna Karenina Principle and Skepticism about unconscious perception. *Phil Phenomenol Res* 2016;**93**:452–9.

Block N, Phillips I. Unconscious seeing – a debate. In: Nanay B (ed.), *Current Controversies in Philosophy of Perception*. New York: Routledge: Taylor & Francis Group, 2016.

Brogaard B. Type 2 blindsight and the nature of visual experience. *Conscious Cogn* 2015;**32**:92–103.

Burge T. *Origins of Objectivity*. Oxford: Clarendon Press, 2010.

Campbell J. *Reference and Consciousness*. Oxford: OUP, 2002.

Clark A. What reaching teaches: consciousness, control, and the inner zombie. *Br J Phil Sci* 2007;**58**:563–94.

Cressman EK, Lam MY, Franks I *et al*. Unconscious and out of control: subliminal priming is insensitive to observer expectations. *Conscious Cogn* 2013;**22**:716–28.

Danckert J, Rossetti Y. Blindsight in action: what can the different sub-types of blindsight tell us about the control of visually guided actions? *Neurosci Biobehav Rev* 2005;**29**:1035–46.

de Gardelle V, Mamassian P. Does confidence use a common currency across two visual tasks? *Psychol Sci* 2014;**25**:1286–8.

Dretske F. Perception without awareness. In: Gendler TS, Hawthorne J (eds.), *Perceptual Experience*. Oxford: Oxford University Press, 2006, 147–80.

Eriksen CW. Discrimination and learning without awareness: a methodological survey and evaluation. *Psychol Rev* 1960;**67**: 279–300. https://doi.org/10.1037/h0041622 [US: American Psychological Association].

Evans S, Azzopardi P. Evaluation of a "bias-free" measure of awareness. *Spat Vis* 2007;**20**:61–77.

Faivre N, Mudrik L, Schwartz N *et al*. Multisensory integration in complete unawareness: evidence from audiovisual congruency priming. *Psychol Sci* 2014;**25**:2006–16.

Fitzsimons GM, Bargh JA. Thinking of you: nonconscious pursuit of interpersonal goals associated with relationship partners. *J Pers Soc Psychol* 2003;**84**:148–64.

Foley R. The case for characterising type-2 blindsight as a genuinely visual phenomenon. *Conscious Cogn* 2015;**32**:56–67.

Foley R, Kentridge RW. Type-2 blindsight: empirical and philosophical perspectives. *Conscious Cogn* 2015;**32**:1–5.

Galvin SJ, Podd JV, Drga V *et al*. Type 2 tasks in the theory of signal detectability: discrimination between correct and incorrect decisions. *Psychon Bull Rev* 2003;**10**:843–76.

Giles N, Lau H, Odegaard B. What type of awareness does binocular rivalry assess? *Trends Cogn Sci* 2016;**20**:719–20.

Goodale MA, Humphrey GK. The objects of action and perception. *Cognition* 1998;**67**:181–207.

Goodale MA, Milner D, *Sight Unseen: An Exploration of Conscious and Unconscious Vision*. Oxford: Oxford University Press, 2004.

Goodale MA, Murphy K. Action and perception in the visual periphery. In: Their P, Karnath HO (eds.), *Parietal Lobe Contributions to Orientation in 3-D Space*. New York: Springer, 1997, 447–61.

Green DM, Swets JA. *Signal Detection Theory and Psychophysics*. New York: John Wiley & Sons, Inc., 1966.

Gur M, Snodderly DM. A dissociation between brain activity and perception: chromatically opponent cortical neurons signal chromatic flicker that is not perceived. *Vis Res* 1997;**37**:377–82.

Hannula DE, Simons DJ, Cohen NJ. Imaging implicit perception: promise and pitfalls. *Nat Rev Neurosci* 2005;**6**:247–55.

Haynes J-D, Rees G. Predicting the orientation of invisible stimuli from activity in human primary visual cortex. *Nat Neurosci* 2005;**8**:686–91.

He S, MacLeod DIA. Orientation-selective adaptation and tilt after-effect from invisible patterns. *Nature* 2001;**411**:473–6.

Hesse C, Franz V, Schenk T. Letter posting and orientation matching: two equivalent tasks in action and perception? *Seeing Perceiving* 2011;**24**:151–72.

Holender D. Semantic activation without conscious identification in dichotic listening, parafoveal vision, and visual masking: a survey and appraisal. *Behav Brain Sci* 1986;**9**:1–66.

Hurlburt A. Colour vision: primary visual cortex shows its influence. *Curr Biol* 2003;**13**:R270–2.

Irvine E. *Consciousness as a Scientific Concept*. Dordrecht: Springer, 2013.

Kanwisher N. Neural events and perceptual awareness. *Cognition* 2001;**79**:89–113.

Kentridge RW, Heywood CA, Weiskrantz L. Color contrast processing in human striate cortex. *Proc Natl Acad Sci USA* 2007; **104**:15129–31.

Kentridge RW, Heywood CA, Weiskrantz L. Attention without awareness in blindsight. *Proc R Soc Lond Ser B* 1999;**266**:1805–11.

Kentridge RW, Heywood CA, Weiskrantz L. Spatial attention speeds discrimination without awareness in blindsight. *Neuropsychologia* 2004;**42**:831–5.

Kolb FC, Braun J. Blindsight in normal observers. *Nature* 1995; **377**:336–8.

Kouider S, Dehaene S, Jobert A *et al*. Cerebral bases of subliminal and supraliminal priming during reading. *Cereb Cortex* 2007;**17**: 2019–29.

Kouider S, Dupoux E. A functional disconnection between spoken and visual word recognition: evidence from unconscious priming. *Cognition* 2001;**82**:B35–49.

Kunde W, Kiesel A, Hoffman J. Conscious control over the content of unconscious cognition. *Cognition* 2003;**88**:223–42.

Kunimoto C, Miller J, Pashler H. Confidence and accuracy of near-threshold discrimination responses. *Conscious Cogn* 2001; **10**:294–340.

Lau H. Are we studying consciousness yet? In: Weiskrantz L, Davies M (eds.), *Frontiers of Consciousness*. Oxford: Oxford University Press, 2008, 245–58.

Lau HC, Passingham RE. Unconscious activation of the cognitive control system in the human prefrontal cortex. *J Neurosci* 2007; **27**:5805–11.

MacEvoy S, Paradiso M. Lightness constancy in primary visual cortex. *Proc Natl Acad Sci USA* 2001;**98**:8827–31.

Macmillan NA, Creelman CD. *Detection Theory: A User's Guide*. New Jersey: Lawrence Erlbaum Associates Inc., 2004.

Marotta JJ, Behrmann M, Goodale MA. The removal of binocular cues disrupts the calibration of grasping in patients with visual form agnosia. *Exp Brain Res* 1997;**116**:113–21.

Maniscalco B, Lau H. A signal detection theoretic approach for estimating metacognitive sensitivity from confidence ratings. *Conscious Cogn* 2012;**21**:422–30.

Merikle PM, Smilek D, Eastwood JD. Perception without awareness: perspectives from cognitive psychology. *Cognition* 2001; **79**:115–34.

Milner D, Goodale MA. *The Visual Brain in Action*. Oxford: Oxford University Press, 1995 [2nd ed. 2006, page references are to the second edition.]

Milner D, Goodale M. *Sight Unseen: An Exploration of Conscious and Unconscious Vision*. Oxford: Oxford University Press, 2005.

Milner D, Goodale M. Two visual systems re-viewed. *Neuropsychologia* 2008;**46**:774–85.

Mon-Williams M, Tresilian JR, McIntosh RD *et al*. Monocular and binocular distance cues: insights from visual form agnosia I (of III). *Exp Brain Res* 2001;**139**:127–36.

Moore GE. A defence of common-sense. In: Muirhead JH (ed.), *Contemporary British Philosophy (2nd Series)*. London: Allen and Unwin, 1925. [Reprinted in his Philosophical Papers. London: George, Allen and Unwin, 1959.]

Morgan MJ, Mason AJS, Solomon JA. Blindsight in normal subjects? *Nature* 1997;**379**:401–2.

Naccache L, Dehaene S. Unconscious semantic priming extends to novel unseen stimuli. *Cognition* 2001;**80**:223–37.

Nakamura K, Dehaene S, Jobert A *et al*. Task-specific change of unconscious neural priming in the cerebral language network. *Proc Natl Acad Sci USA* 2007;**104**:19643–8.

Neumann O. Direct parameter specification and the concept of perception. *Psychological Research* 1990;**52**:207–215.

Norman LJ, Akins K, Heywood CA *et al*. Color constancy for an unseen surface. *Curr Biol* 2014;**24**:2822–6.

Norman LJ, Heywood CA, Kentridge RW. Exogenous attention to unseen objects? *Conscious Cogn* 2015;**35**:319–29.

Peters MAK, Lau H. Human observers have optimal introspective access to perceptual processes even for visually masked stimuli. *eLife* 2015;**4**:e09651.

Peters MAK, Ro T, Lau H. Who's afraid of response bias? *Neurosci Conscious* 2016;**2016**:niw001.

Phillips I, Block N. Debate on unconscious perception. In: Nanay B (ed.), *Current Controversies in Philosophy of Perception*. New York: Routledge, 2016, 165–92.

Phillips I. Consciousness and criterion: on Block's case for unconscious seeing. *Phil Phenomenol Res* 2016;**93**:419–451.

Pisella L, Gréa H, Tilikete C *et al*. An "automatic pilot" for the hand in human posterior parietal cortex: toward reinterpreting optic ataxia. *Nat Neurosci* 2000;**3**:729–36.

Pooresmaeli A, Arrighi R, Biagi L *et al*. Blood oxygen level-dependent activation of the primary visual cortex predicts size adaptation illusion. *J Neurosci* 2013;**33**:15999–6008.

Prinz JJ. Unconscious perception. In: Matthen M (ed.), *Oxford Handbook of Philosophy of Perception*. Oxford: Oxford University Press, 2015, 371–89.

Ramsøy TZ, Overgaard M. Introspection and subliminal perception. *Phenomenol Cogn Sci* 2004;**3**:1–23.

Reingold EM, Merikle PM. Using direct and indirect measures to study perception without awareness. *Percept Psychophys* 1988; **44**:563–75.

Reingold EM, Merikle PM. On the inter-relatedness of theory and measurement in the study of unconscious processes. *Mind Lang* 1990;**5**:9–28.

Reuss H, Desender K, Kiesel A *et al*. Unconscious conflicts in unconscious contexts: the role of awareness and timing in flexible conflict adaptation. *J Exp Psychol Gen* 2014;**143**:1701–18.

Robichaud L, Stelmach LB. Inducing blindsight in normal observers. *Psychon Bull Rev* 2003;**10**:206–9.

Sandberg K, Timmermans B, Overgaard M *et al*. Measuring consciousness: is one measure better than the other. *Conscious Cogn* 2010;**19**:1069–78.

Schmidt F, Schmidt T. Feature-based attention to unconscious shapes and colors. *Atten Percept Psychophys* 2010;**72**:1480–94.

Schmidt T, Niehaus S, Nagel A. Primes and targets in rapid chases: tracing sequential waves of motor activation. *Behav Neurosci* 2006;**120**:1005–16.

Servos P. Preservation of Emmert's law in a visual form agnosic. *Neurocase* 2006;**12**:122–6.

Seth AK, Dienes Z, Cleeremans A *et al*. Measuring consciousness: relating behavioural and neurophysiological approaches. *Trends Cogn Sci* 2008;**12**:314–21.

Shanks DR. Regressive research: the pitfalls of post hoc data selection in the study of unconscious mental processes. *Psychon Bull Rev* 2016;**24**:752–75.

Schubert T, Palazova M, Hutt A. The time course of temporal attention effects on nonconscious prime processing. 2013;**75**:1667–86.

Simpson J, Weiner E. *Oxford English Dictionary*, 2nd edn. Oxford: Clarendon Press, 1989.

Smallman HS, MacLeod DIA, He S *et al*. The fine grain of the neural representation of human spatial vision. *J Neurosci* 1996;**16**: 1848–65.

Smithson HE. Sensory, computational and cognitive components of human colour constancy. *Phil Trans R Soc B* 2005;**360**:1329–46.

Snodgrass M, Shevrin H. Unconscious inhibition and facilitation at the objective detection threshold: replicable and qualitatively different unconscious perceptual effects. *Cognition* 2006; **101**:43–79.

Sperandio I, Whitwell RL, Chouinard PA *et al*. Preservation of size constancy for action, but not perception, in a patient with bilateral occipital lesions. *J Vis* 2012;**12**:837.

Travis C. The silence of the senses. *Mind* 2004;**113**:57–94.

van Gaal S, Ridderinkhof KR, van den Wildenberg WPM *et al*. Dissociating consciousness from inhibitory control: evidence for unconsciously triggered response inhibition in the stop-signal task. *J Exp Psychol Hum Percept Perform* 2009;**35**:1129–39.

Vlassova A, Donkin C, Pearson J. Unconscious information changes decision accuracy but not confidence. *Proc Natl Acad Sci USA* 2014;**111**:16214–8.

Whitwell RL, Striemer DL, Nicolle DA *et al*. Grasping the nonconscious: preserved grip scaling to unseen objects for immediate but not delayed grasping following a unilateral lesion to primary visual cortex. *Vis Res* 2011;**51**:908–24.

Witt JK, Taylor JET, Sugovic M *et al*. Signal detection measures cannot distinguish perceptual biases from response biases. *Perception* 2015;**44**:289–300.