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Review

Are there unconscious perceptual processes?

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ABSTRACT

Blindsight and vision for action seem to be exemplars of unconscious visual processes. However, researchers have recently argued that blindsight is not really a kind of unconscious vision but is rather severely degraded conscious vision. Morten Overgaard and colleagues have recently developed new methods for measuring the visibility of visual stimuli. Studies using these methods show that reported clarity of visual stimuli correlates with accuracy in both normal individuals and blindsight patients. Vision for action has also come under scrutiny. Recent findings seem to show that information processed by the dorsal stream for online action contributes to visual awareness. Some interpret these results as showing that some dorsal stream processes are conscious visual processes (e.g., Gallese, 2007; Jacob & Jeannerod, 2003). The aim of this paper is to provide new support for the more traditional view that blindsight and vision for action are genuinely unconscious perceptual processes. I argue that individuals with blindsight do not have access to the kind of purely qualitative color and size information which normal individuals do. So, even though people with blindsight have a kind of cognitive consciousness, visual information processing in blindsight patients is not associated with a distinctly visual phenomenology. I argue further that while dorsal stream processing seems to contribute to visual awareness, only information processed by the early dorsal stream (V1, V2, and V3) is broadcast to working memory. Information processed by later parts of the dorsal stream (the parietal lobe) never reaches working memory and hence does not correlate with phenomenal awareness. I conclude that both blindsight and vision for action are genuinely unconscious visual processes.

0. Introduction

It is uncontroversial that there are phenomenally unconscious visual processes. For example, processes in the retina are visual processes that do not correlate with visual awareness. It is harder to say whether there are unconscious perceptual processes. An unconscious perceptual process, as I shall construe the term here, is a kind of representational mental process that occurs below the level of phenomenal awareness.

Before continuing it is important to point out that, strictly speaking, all processes of vision are unconscious. Only the representations computed can be conscious. So when we speak of a process correlating with visual awareness or a process being conscious, this should be understood as meaning that the product of the process is conscious or accessible to consciousness.

Blindsight has been thought to be an exemplar of an unconscious perceptual process. Blindsight occurs as the result of damage to the primary visual cortex which results in a scotoma, or region of blindness. Individuals with a scotoma typically report no visual awareness of visual stimuli represented to them in their blind field. But they nonetheless have a preserved ability to predict attributes of visual stimuli. They typically make above-chance predictions about the motion, location and

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colors of objects they report not seeing. The visual processes underlying these predictions thus seem to be good candidates to be unconscious perceptual processes. They certainly seem to be mental representational processes.

However, it has recently been called into question whether blindsight really is a form of unconscious vision. It has been argued that better methods of reporting are needed to determine whether blindsight patients are aware of stimuli in their blind field. Morten Overgaard and colleagues have recently developed such methods, and subsequent studies have shown that when these methods are used, reported visibility of stimulus correlates with accuracy in both normal individuals and blindsight patients. It has been concluded that blindsight is not a kind of unconscious vision, but rather highly degraded conscious vision.

Dorsal stream processes, too, seem to be exemplars of unconscious visual processes. Dorsal stream processes compute information about the absolute size of objects and the properties of objects in egocentric space. Goodale and Milner (1992, 2004), Milner and Goodale (1996, 2008) have argued that this information never reaches conscious awareness but is translated directly into online, or immediate, action. Milner and Goodale warn against confusing vision for action with perceptual processes. As they put it:

> But what about visually elicited activity in the dorsal stream? This activity certainly does not give rise to visual awareness [...], but that doesn't mean that it has anything to do with unconscious perception. Use of that phrase carries the implication that such visual processing could, *in principle*, be conscious. The fact is that visual activity in the dorsal stream can never become conscious – so 'perception' is the wrong word to use. The dorsal stream is not in the business of providing any kind of a visual representation of the world: it just converts visual information directly into action (2004: 114).

Milner and Goodale's claim that vision for action is not a kind of perceptual process is easily refuted. Elsewhere they argue that vision for action represents properties of objects in egocentric space. This suffices to make vision-for-action processes representational processes. Milner and Goodale are primarily concerned with arguing that these representations are not broadcast to working memory and hence do not reach visual awareness. However, independent evidence reviewed by, for example, Gallese (2007), Jacob and Jeannerod (2003) seems to show that part of the information processed by the dorsal stream does reach visual awareness. This indicates that dorsal stream processes are not genuinely unconscious processes.

The aim of this paper is to provide new support for the more traditional view that blindsight and vision for action are genuinely unconscious perceptual processes. I briefly review Block's distinction between access consciousness and phenomenal consciousness. I then argue, against Block, that accessibility does correlate with phenomenal consciousness. So, to show that a process is genuinely unconscious it suffices to show that the information it computes is not cognitively accessible. In the final sections of the paper I revisit the empirical data aimed at demonstrating that blindsight and vision for action are not unconscious processes. I show that in the case of blindsight, researchers confuse global broadcasting of cognitive information and distinctly visual awareness. In the case of dorsal stream processing I argue that while information processed in the early dorsal stream contributes to visual awareness, representations computed in the later parts of the dorsal stream never reach global workspace. Hence, both blindsight and vision for action are genuinely unconscious perceptual processes.

1. Blindsight

Blindsight is a kind of residual vision found in individuals who have suffered damage to certain areas of their visual cortex which has resulted in a blind region in their visual field. Individuals with blindsight are able to make above-chance predictions about the color, location, motion and orientation of visual stimuli presented to them in their blind field. But they report that they are unaware of them.

Blindsight would seem to be an exemplar of unconscious perception. However, this hypothesis has been contested. It has been argued that we do not know enough about the basis on which people report seeing something in order for us to conclude that individuals with blindsight are unaware of visual stimuli in their blind field (Natsoulas, 1997). Studies of blindsight typically do not use a sufficiently sensitive method for gathering subjective reports. Most traditional studies use a yes/no report strategy ("Did you see the stimulus or not?"). This is then followed up with questions about the patient's confidence level. Such tests do not adequately detect visual awareness. Blindsight patients sometimes misunderstand the question of whether they see the stimulus and sometimes have a threshold for what counts as awareness that is higher than the researcher's (Lau & Passingham, 2007).

Findings of weak visual experiences in blindsight have been reported by several researchers (Overgaard, Fehl, Mouridsen, Bergholt, & Cleeremans, 2008; Persaud & Cowey, 2008; Stoerig & Barth, 2001; Weiskrantz, Cowey, & Hodinott-Hill, 2002; Zeki & Ffytche, 1998). Zeki and Ffytche (1998) used a more fine-grained scale for evaluating visual awareness in blindsight patient GY, When the more fine-grained scale was used, GY reported that he had feelings of stimuli presented to his blind field ("feelings of something happening"). It was shown that activity in V5, thought to correlate with visual awareness of moving targets, was more intense in studies of awareness without discrimination than in studies of discrimination without awareness. The researchers concluded on these grounds that the damage to the primary visual cortex may have caused a disassociation between visual discrimination and visual awareness.

In studies conducted by Larry Weiskrantz and colleagues, DB, the first extensively tested blindsight patient, was also found to experience feelings when presented with visual stimuli in his blind field (Weiskrantz, 1986; Weiskrantz, 1987; Weiskrantz et al., 2002).

Other studies suggest blindsighters might have some sort of non-visual consciousness of stimuli in their blindfield. In one study conducted by researchers at University of Aberdeen, DB was presented with Gabor patches on a grey screen for two seconds (Trevethan, Sahraie, & Weiskrantz, 2007). DB was able to detect the presence of small, low contrast patches which even normal perceivers find it difficult to see. In 150 presentations, DB was able to identify the stimulus 87% of the time as compared to chance performance in his sighted field. This group has also done work training blindsight subjects to guess which of two stimuli had been presented to their blind fields (Sahraie et al., 2006). After 3 months of practice, the subjects' correct responses increased by 25% and, interestingly, they also reported being more consciously aware of the correct answer.

However, as Weiskrantz points out, research supports the notion that blindsight vision and normal vision are qualitatively different (Weiskrantz, 2009). For example, it has been found that some blindsight subjects have selective loss of color contrast but not luminance contrast, and DB was found to have colored negative after-images to "unseen" stimuli. Other studies seem to confirm that the information processed in the cortex of individuals with blindsight is qualitatively different from the information processed in the cortex of normal individuals. One study showed that GY was able to report the opposite of the location of a target stimulus in an area of his visual field (Persaud & Cowey, 2008). GY was able to do this in his normal field but responded inaccurately when the target appeared in his blind field.

Studies showing that blindsight subjects have feelings of something happening or awareness of the correct answer do not give us reason to take blindsight to be genuinely conscious vision. However, more recently it has been argued that blindsight is not, in fact, unconscious vision at all but rather severely degraded conscious vision. Morten Overgaard and colleagues conducted studies on a 31-year old woman, GR, who was cortically blind in the upper right quadrant (Overgaard et al., 2008). The studies indicated that GR's ability to discriminate among visual stimuli reflected degraded conscious vision rather than unconscious vision.

The researchers designed a new test for testing visual awareness. Instead of the traditional yes/no strategy, they developed a so-called 'Perceptual Awareness Scale' (PAS). Normal individuals were asked to evaluate the clarity of their perceptual experiences when presented with visual figures of different shape. Most individuals spontaneously evaluated the stimuli on a four-point scale. (CI) "clear image" ("I know what was shown"), (ACI) "almost clear image" ("I think I know what was shown") (WG) "weak glimpse" ("something was there but I don't know what"), and (NS) "not seen". The scale was tested on other participants who were questioned about the meaning of their evaluations. The researchers found a strong correlation between reported clarity and reaction time/accuracy. When the stimulus was reported as a clear image, the response was faster and more accurate.

The team then used PAS to evaluate visual awareness in GR (Overgaard et al., 2008). The first experiment was done to show that GR's blindness was genuine. GR was given instructions to report whether there was anything in her blind field. Letters were presented to her in her blind field, and she reported not seeing anything. This demonstrated that she did not have a normal functioning of conscious vision in that area. A second experiment was done to determine the relationship between GR's discrimination ability and her visual awareness using standard methods for testing visual awareness. GR was asked to report whether she saw something or not using a standard method and then guess which figure was presented to her. Many more stimuli were reported to be unseen than seen in the blind field. Among the unseen stimuli a significant number of them were predicted to have the right attributes. A different result was obtained for the intact upper left quadrant of the visual field. In this normally functioning area, far the most stimuli were reported to be seen.

A third experiment used the PAS method for testing for visual awareness. Several trial sessions were done, and GR and the researchers discussed how her experiences appeared to her. GR never reported "not seeing anything" in the normal part of her visual field. Reported clarity of visual stimulus correlated with accuracy. In trials on GR's blind field, not nearly as many stimuli were reported as being clear as in the trials on her normal fiend, but it was found that accuracy correlated with reported visual clarity of the stimulus. The relationship between accuracy and awareness was the same in the intact and the blind fields.

Reported awareness is thus predictive of accuracy. When comparing the trials where standard methods were used to the trials using the PAS method, it was evident that GR's threshold for reporting awareness was lower when the PAS method was used than when standard methods are used. The researchers concluded that their findings call many of the traditional studies demonstrating unconscious vision in impaired or normal individual into question. Most empirically demonstrated cases of unconscious perceptual processes, they argue, may simply be severely degraded conscious vision. These new studies cast serious doubt on the hypothesis that there are genuinely unconscious visual processes.

2. Vision for action

Traditional research in phenomenology and neuroscience indicated that a single visual system is used for both action and perception. On this view, the visual system creates a single representation of the external world that provides a frame of reference for both cognitive operations and real time control of goal-directed actions.

Yet recent research by Milner and Goodale and others has shown that vision is not a single fully integrated system that creates a single representation in the brain. The visual system consists of the dorsal stream and the ventral stream. Both steams start in the early visual areas of the occipital lobe (V1, V2, and V3) but later they diverge. The ventral stream runs into the temporal lobe and then connects to other temporal and frontal lobe structures that are responsible for episodic memory, working memory, reporting, decision-making, and so on. The dorsal stream runs upwards through the occipital lobe into the parietal lobe and continues until it makes contact with the primary somato-sensory cortex and the primary motor cortex.

Studies have shown that damage to structures in the dorsal stream can impair visuomotor control while leaving visual perception intact, and damage to structures in the ventral stream can impair visual perception while leaving visuomotor control intact. Goodale and Milner conducted a series of neuropsychological studies on a patient, DF, with severe visual agnosia, which involves damages to structures of the ventral stream. DF could consciously see some color and texture, but she was unable to recognize shapes. Her dorsal stream was intact. She could accurately grasp objects. For example, she could post a card into a slot she could not describe. She could also adjust her finger-thumb grip size perfectly to the width of a rectangular block, even though she could not report on its width.

Milner and Goodale's hypothesis was further tested on optic ataxia patients. Optic ataxia is the mirror syndrome of visual agnosia. It has been shown that individuals with optic ataxia cannot adjust their handgrip to the size of objects in real time. But they can perform delayed action tasks off-line as well as normal individuals (Milner, Dijkerman, & Pisella, 2001).

A third kind of evidence for the disassociation hypothesis comes from studies of optical illusions (e.g. the Ebbinghaus illusion, Fig. 1). These studies have shown differential effects of optical illusions on perception and action (Aglioti, Goodale, & DeSouza, 1995).

In recent years a number of researchers have shown that some illusions do not give rise to a differential effect in grasping behavior and perception. However, many of the skeptical studies of the effect of illusions on grasping behavior did not control for factors that require ventral stream processing (Vishton & Fabre, 2003). Moreover, it has been shown that there is cooperation between the two visual streams when decisions about visual stimuli (e.g. color or size) have to be made explicitly via motor responses (Claeys et al., 2004) and when subjects need to contemplate action in order to reach a target (Gallese, 2007). Milner and Goodale have concluded on the basis of these and other studies that our visually guided real time actions are not in the direct control of what we consciously see. The ventral system is responsible for object recognition and classification. It codes abstract allocentric (scene-based) information for storage in and retrieval from memory and generates our perceptual phenomenology. The ventral stream also allows us to plan our actions off-line rather than in real time. The ventral stream is furthermore utilized in carrying out familiar activities that are grounded in information stored in visual memory.

The dorsal system, on the other hand, is dedicated to the rapid and accurate guidance of our movements and computes information about the object in egocentric space and the absolute size of the object required to accurately reach to it and grasp it online. Dorsal stream information guides programming and unfolding of on-the-fly actions needed when delayed action is counterproductive. Though the dorsal stream mediates actions in real time, under delayed movement conditions dorsal stream representations decay and actions become mediated by the ventral stream.

According to Milner and Goodale, the spatial coding that takes place in the dorsal stream does not affect conscious visual awareness at all but lies outside the realm of conscious awareness. Because DF had no visual awareness of the shape of objects, she had no working memory of the objects she could reach to and grasp without difficulty. The information in the dorsal stream thus is not stored in visual memory. Actions on the basis of visual memory require the ventral stream.

This disassociation of vision for perception and vision for action has turned out to be evolutionarily beneficial to us. Many action tasks have strict time constraints. For example, life and death decisions cannot await rational decision. To meet the time constraints visual information must be passed on directly to the motor system without first passing through a slower conscious decision-making process. Visual stimuli thus do not need to reach visual awareness in order to guide rapid online motor responses.

However, there is still some question as to whether Milner and Goodale's hypothesis that dorsal stream processes do not contribute to visual awareness is correct. On an older classification made by Ungerleider and Mishkin (1982), the cortical ventral stream is responsible for identifying and recognizing objects and the dorsal stream is responsible for computing spatial representations. According to Ungerleider and Mishkin, the dorsal stream lies beneath our conscious perception of spatial information.

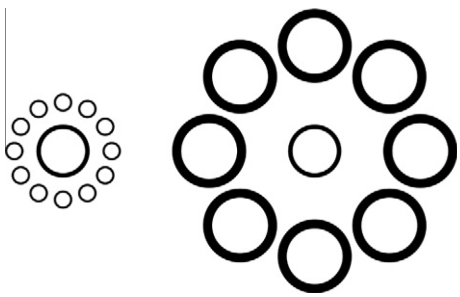

Fig. 1. The Ebbinghaus illusion. Studies have shown that this illusion led to a misperception of the size of the central circle but only marginally affected grasping behavior directed at the central circle.

Fig. 2. Tilted bracelet. The bracelet is represented as having oval cross-sections from the perceiver's point of view. But it is also represented as being at an angle and as being circular.

It is still an open question whether there is conscious perception of spatial information computed by the dorsal stream. For example, one could make an argument analogous to that made by researchers on blindsight to the effect that people are unable to accurately report the information processed in the dorsal stream but that it nonetheless is associated with phenomenal consciousness (see Wallhagen, 2007).[1] This would make sense, as episodic memory of rapidly disintegrating information would not be possible.

Other considerations more straightforwardly demonstrate that dorsal stream information contributes to visual awareness. Size, shape and color constancy refers to our ability to perceive the size, shape and color of objects as constant despite considerable changes in viewing conditions. As such it is most important for object recognition (Noë, 2004). While shape, size and object constancies are critical for object recognition, representations of shape, size and object constancies probably do not exhaust conscious visual representation. In addition to perceiving a tilted bracelet as circular-shaped, we also at least sometimes perceive it as having oval cross-sections (Fig. 2).

There is a long-standing debate in philosophy about what to make of these ego-centric representations. Peacocke (1983) has suggested that visual experience possess both representational and non-representational phenomenal properties. Egocentric properties (e.g. the oval-cross sections), he says, are non-representational properties of conscious experience. Peacocke introduced the problem as a conundrum which is now often referred to as 'Peacocke's trees'. Here is one rendition of the quandary. Two equally-sized trees at different distances from the perceiver are normally represented to be the same size, despite the fact that the nearer tree phenomenally looks bigger (Fig. 3). The two trees look to be the same size. I have a visual experience as of the trees being the same size. But one tree takes up more of the space in my visual field. So, the two trees also look to me to be different in size. My experience is not illusory. The trees veridically look to be same-sized and they also veridically look to be differently sized.

Michael Tye's take on the phenomenon is that the bracelet is represented as having boundaries 'which would be occluded by an elliptical shape placed in a plane perpendicular to the line of sight of the viewer ... In this sense, the [bracelet] is represented as being [oval] *from here*. But it is also simultaneously represented as being at an angle and as being itself circular. This is why the tilted [bracelet] both does, and does not, look like the same [bracelet] held perpendicular to the line of sight' (1996: 125, fn 10).

Similarly, in addition to perceiving two trees at different distances as same-sized we also perceive them as differently sized. If two trees of the same size appear both to be of the same size and to be of different sizes, this is because our visual experience represents two things of the tree. One is an intrinsic property: its size. The other is a relational property: the amount of visual angle the tree subtends relative to the perceptual perspective.

Tye's suggestion is that perceptual experiences have a layer of content that represents intrinsic shape, size and so on, and an additional layer of content that is egocentric or viewer-centered and represents the properties of an object as seen from a perspective or point of view.

[1] Wallhagen responds to Andy Clark's argument that work on the two visual systems should be read as refuting what Clark calls the Hypothesis of Experience Based Control. Wallhagen argues that the dorsal stream may after all support some kind of Experience Based Control. If this is true it follows that vision for action isn't blindsight as Milner and Goodale sometimes claim. See also Clark's (2007) response and Clark (2009).

Fig. 3. Peacocke's trees. Equally-sized trees at different distances from the perceiver are normally represented to be equally sized, despite the fact that the nearer trees look bigger phenomenally.

There is some disagreement about the core of Tye's thesis. Based on priming studies, Sean Kelly has provided suggestive evidence that experiences could not simultaneously represent relational and intrinsic properties. The findings are reported in a contribution to the *Philosophy and Phenomenological Research* symposium for Alva Noë's *Action in Perception* (Kelly, 2008).

But we do not need to enter this debate. It seems plausible that we can turn our attention to the relational size of a tree or the relational shape of a bracelet even if this is not what we ordinarily experience. This would not show that our experiences simultaneously represent relational and intrinsic size anymore than the fact that we can attend to the duck in a duck-rabbit picture shows that we are simultaneously representing the duck and the rabbit. But like the stronger view, the weaker view has the implication that we can be consciously aware of viewpoint-dependent properties.

These considerations have direct bearing on Milner and Goodale's dissociation thesis. Shape, size and color constancies are less important than viewpoint-dependent features for vision for action. Action limits the viewing time and changes viewing conditions drastically. Immediate action must thus to a large degree make use of the viewpoint-dependent features of objects. Goodale and Milner put it as follows:

> For the purposes of identification, form information [. . .] needs to be 'object-centred'; i.e. constancies of shape, size, colour, lightness, and location need to be maintained across different viewing conditions [. . .] this supports the view that the ventral stream of processing plays an important role in the computation of such object-specific descriptions. In contrast, *action* upon the object requires that the location of the object and its particular disposition and motion with respect to the observer is encoded. For this purpose, coding of shape would need to be largely 'viewer-centred' with the egocentric coordinates of the surface of the object or its contours being computed each time the action occurs. We predict that shape-encoding cells in the dorsal stream should predominantly have this property. Nevertheless, certain constancies, such as size, would be necessary for accurate scaling of grasp aperture, and it might therefore be expected that the visual properties of the manipulation cells [. . .] would have this property (1992: 23).

But if viewpoint dependent features are among the features computed by the dorsal stream, and these features do sometimes play a role in the content of conscious experiences, then the dorsal stream plausibly has a direct impact on conscious perception.

There is empirical evidence for this hypothesis. Electrophysiological studies have shown that the cells in the dorsal stream continuously update information relative to viewpoint, illumination conditions and head position. The amplitude of the cells' response to visual stimuli depends on gaze direction, not retinal projection (Andersen, Asanuma, Essick, & Siegel, 1990). Some areas of the dorsal stream code for the motion of an object, size changes, rotation changes, and so on (Oliver & Thompson-Schill, 2003; Saito et al., 1986). This viewpoint-dependent information is important for on-the-fly action. For on-the-fly action, it does not usually matter what the object's color and absolute shape is. What matters is how the object relates to the hand and body of the perceiver. The acceleration of a moving body part is controlled by the rate of expansion of an object on the retina (Revonsuo & Rossetti, 2000; Savelsbergh, Whiting, & Bootsma, 1991).

The cells in the ventral stream, on the other hand, are highly selective for form, pattern and color. The computations of the ventral stream are much more interpretive in nature. The ventral stream passes on information from the primary visual cortex to higher-level areas of information processing, and properties of objects are calculated independently of their location, illumination conditions and the viewpoint of the perceiver (Lehky, Juneja, & Sereno, 2006).

The dorsal stream thus calculates viewpoint-dependent properties and relations between the object and the perceiver, whereas the ventral stream calculates more fine-grained perceiver-independent and object-centered properties.

Goodale and Milner's research on subject DF also confirms this hypothesis. DF had no problem reaching for and grasping object despite having no shape awareness. As mentioned above, Goodale and Milner speculate that one reason for this is that information relevant for size and shape constancies are necessary for visual awareness. If you were unaware of the size and shape constancies of a bracelet, you would not recognize it as a bracelet but merely as a featureless mass. The fact that size and shape constancies are necessary for visual awareness, however, does not suggest that the viewpoint-dependent information calculated by the dorsal stream is irrelevant to conscious awareness, but only that viewpoint-relative information serves a purpose that is independent of object recognition.

Some of the evidence presented against the unconscious nature of the dorsal stream comes from cases of neglect. Gallese (2007) has argued that we should think of the inferior parietal lobule (IPL) as forming a part of what he calls the "ventral–dorsal stream". He then goes onto argue that the ventral–dorsal stream (and IPL in particular) plays a role in our visual spatial awareness.[2] He presents a range of cases in support of the claim that some space and body representations required for action are conscious representations. Vision, sound and action, he says, 'are parts of an integrated system; the sight of an object at a given location, or the sound it produces, automatically triggers a "plan" for a specific action directed toward that location. What is a "plan" to act? It is a simulated potential action.' Gallese (2007: 7) cites studies of neglect owing to lesions in dorsal stream recipient parietopremotor circuits in monkeys and humans. Patients with neglect owing to lesions in these areas appear not only to fail to attend to objects contralateral to the lesion, they also fail to reach to objects in contralesional peripersonal space, the space within which we can grasp objects. The same patients often have no trouble reaching to objects in extrapersonal space.

Gallese concludes on the basis of these and other data that Head and Holmes' (1911) and Schilder's (1935) distinction between an unconscious body schema and a conscious body image is too simplistic. Because neglect leads to a lack of awareness of peripersonal space, he says, areas of the brain involved in action is partially responsible for computing conscious spatial representations.

The above considerations indicate that dorsal stream processes are not genuinely unconscious processes after all. Defenders of enactive views of perception, such as Alva Noë, should, and often do, welcome and further these integration views. On Noë's (2004) enactive view, perceptual experience is the exercise of sensorimotor know-how. But Milner and Goodale's disassociation hypothesis presents a prima facie challenge to this view. As Ned Block points out in his (2005) review of Noë's book, if sensorimotor know-how includes know-how of visually-guided action, then the enactive view is not true to the phenomenology of perceptual experience.

To back up this claim, Block cites a study by Goodale and Kelly Murphy (1997) that shows that even when conscious vision represents an object as blurry, we can reach to it and grasp it without difficulties. In the study, five rectangular blocks were presented at various positions in the visual field ranging from 5° to 70° off the line of sight. At 70° the participants' conscious vision presented the blocks as blurry and hard to distinguish but the participants were perfectly able to reach to and grasp the blocks. In fact, there was no significant difference between the subjects' grasping abilities at 5° and 70°. The study shows that we can grasp objects that have nearly no visibility.

Block's point here seems to be that the study indicates that whatever lies beneath our online action cannot be what lies beneath perceptual experience (Block speaks of the visual *guidance* of action, not visually-guided action, which of course does not lie beneath perceptual experience). As sensorimotor know-how lies beneath online action, sensorimotor know-how does not lie beneath perceptual experience.

There is a simple way for Noë to respond to this argument. If I did not have a mouth, I could not chew my food.[3] Chewing food is physically, functionally and phenomenally different from talking. But it does not follow that my mouth is not involved in talking. Physical structures often serve more than one purpose. Just as my mouth is involved in both talking and chewing, so the dorsal stream could be involved in both perceptual experience and online action.

However, we can strengthen Block's objection against Noë's enactive view, as it is presented in *Action in Perception*. If the exercise of sensorimotor know-how is exhausted by dorsal stream representations guiding online action, and Milner and Goodale's disassociation hypothesis is correct, then perceptual experience is unconscious. But perceptual *experience* essentially is not unconscious. So, Noë must hold either that Milner and Goodale's disassociation hypothesis is incorrect or that sensorimotor know-how is not exhausted by dorsal stream representations guiding online action.

There are many places in the book where Noë appears to take sensorimotor know-how to be knowledge of how sense inputs vary as you move (p. 78). But knowing how sense inputs vary as you move is not true know-how. It is not true procedural knowledge. It's rather in the same category as knowing how warm the seminar room is when every seat is taken or how President Obama responded to the agreement to curtail greenhouse gas emissions at the climate meeting in Copenhagen as the meeting approached the end. Despite the deceptive linguistic appearance, this sort of language does not reflect knowledge-how but knowledge-that. You know how Obama responded if you know *that* he told the world leaders 'not to talk, but to act'.

Elsewhere Noë says that 'the basis of perception, on our enactive, sensorimotor approach, is implicit practical knowledge of the ways movement gives rise to changes in stimulation' (p. 8). This way of formulating the enactive view seems to implicate the parts of the dorsal stream potentiated for online-action representation as a constituent, or supervience basis, of perceptual experience. If this is indeed what Noe has in mind when he speaks of 'implicit practical knowledge', then his best option out of Block's conundrum is to reject Milner and Goodale's disassociation hypothesis. So, Noë should welcome results indicating ventral–dorsal streams and conscious dorsal representations.

The focus of this review article is whether there are unconscious perceptual processes, not whether the enactive view is right. Both Noë and the present author could have a slice of the cake, even if it turned out that dorsal processes are conscious.

[2] Jacob and Jeannerod (2003: 252–255) also have an interesting discussion of IPL and its role in visual awareness.

[3] Admittedly, chewing food is not constitutive of my mouth. But presumably the dorsal stream is not constitutive of vision for action or perceptual experience either.

It certainly does not follow from any of the above considerations that there are no unconscious perceptual processes. Masked priming studies appear to demonstrate forms of unconscious perception (see Kiefer (2007) for a review). Semantic priming effects are the relatively faster and more accurate responses observed in, for example, lexical decision tasks in the presence of a primer. For example, individuals asked whether 'lemon' is a real word or a pseudo word provide a faster response if a prime word (e.g. 'sour') precedes the target word than if an unrelated word precedes it. Masked and subliminal priming studies have demonstrated priming effects even though the prime is subliminally demonstrated or masked. But, I will now argue, we need not go beyond blindsight and dorsal stream representations to find examples of unconscious perception. For, upon further consideration, both blindsight and dorsal stream representations are unconscious perceptual processes.

3. Access consciousness versus phenomenal consciousness

Block (1995, 2007, 2008) has famously argued that there are two kinds of consciousness that sometimes are confused in the literature. On the global workspace model of consciousness, perceptual systems send representations to a storage system which then provides information to a global workspace in the pre-frontal cortex. According to Block, we can think of perceptual mechanisms as suppliers of representations to the consuming mechanisms involved in reporting, reasoning, decision-making, and so on. When perceptual representations are globally broadcast in the frontal cortex, they can be accessed by cognitive mechanisms without further processing.

Block questions this model as a model of phenomenal consciousness, the sort of consciousness we associate with what it is like to undergo an experience. He proposes that we call the former kind of consciousness 'access consciousness' or 'A-consciousness', and the latter 'phenomenal consciousness' or 'P-consciousness'. In his (1995), Block stipulates that for information to be A-conscious, it must be poised for the direct rational control of action. For it to correlate with P-consciousness, on the other hand, there must be something it is like for us to have access to it. Information in working memory is accessible, and hence correlates with A-consciousness but need not correlate with P-consciousness.

Block notes that he does not think all kinds of cognitive access to information are instances of access consciousness. For example, he thinks that the access a blindsighter has to visual stimuli presented to him in his blind field should not be characterized as access consciousness. As far as Block is concerned, individuals with blindsight have neither phenomenal nor access consciousness. They do not have access consciousness because they need prompting by an experimenter before they will make a guess about attributes of a stimulus.

But, Block says, we could imagine a case of a super-blindsighter, who has acquired the ability to guess when to make correct guesses about the attributes of an object in her blind field. While she has no phenomenal awareness of the objects in her blind field, she is able to give accurate verbal reports about them. So, a super-blindsighter would be A-conscious but not P-conscious of the stimulus in her blind field.

Block thinks Milner and Goodale's disassociation hypothesis could provide further evidence for the distinction between P-consciousness and A-consciousness. According to Block, ventral stream processing correlates with P-consciousness, whereas the dorsal system correlates with A-consciousness. So, according to Block, it is possible that someone who has endured damage to their dorsal stream but who has an intact ventral stream has P-consciousness but no A-consciousness. As we will see below, this is not ultimately a good example of a case where P-consciousness and A-conscious come apart, for genuine dorsal stream representations are not broadcast to working memory, unless we take working memory to include the center for online motor control, which would be rather controversial.

However, Block offers another example of P-Consciousness without A-Consciousness, viz., cases of inattentional inaccessibility (Block, 1995, 2001). We may see or hear features but fail to notice them because they are not conceptualized at a level that allows cognitive access. Suppose you are having a conversation with someone when suddenly you notice the steady ticking of a clock which has been there all along. You were aware of it all along but you did not notice it. In Block's terminology, you were P-conscious of the noise, but you were not A-conscious of it. In order for you to be A-conscious of the noise, you must shift your attention to it. Below I will argue that shifting one's attention to a stimulus cannot make a stimulus A-conscious unless it already was A-conscious to begin with.

In response to Block's paper, Daniel Dennett (1997) argues that Block's distinction between A-consciousness and P-consciousness can be understood as a difference between how rich and influential the experiential content is. Some experiential contents are impoverished. Others are rich. Impoverished contents can be poised for direct control of action. For example, in people with blindsight, information in the blind field is poised for the direct control of action even though there is no accompanying rich awareness. According to Dennett, a person with blindsight has a limited amount of information about stimuli in the blind field even though this information is poised for action. However, the sparseness of the content also severely limits the influence of the content on the subject's actions. In forced-choice tasks, blindsighters can act on unseen stimuli but the information is not rich enough to make them act on it on their own.

As I will argue below, however, it is not clear that there is any tension between Block's and Dennett's claims. It is plausible that the content of the perceptual states of people with blindsight is sparse and less influential because it is not associated with a distinct visual phenomenology but only with a cognitive phenomenology (when prompting actually occurs).

The distinction between access consciousness and phenomenal consciousness seems coherent. However, it is not entirely clear how best to understand 'access consciousness'. In his (2007) paper, Block provides further support for his claim that phenomenology overflows cognitive accessibility. Here he offers a new definition of 'cognitive accessibility'. Information is accessible, for Block, if it is actually in working memory. So, his thesis here is that the capacity of the visual phenomenal memory system is greater than that of working memory. Advocates of the view that visual experience is sparse think that visual experience is correlated with information in working memory. Advocates of the view that visual experience is rich think that experience can be correlated with information that is not actually in working memory. Block's thesis is that experience is rich.

Block thinks that cognitive accessibility must be understood as accessibility from working memory. The information in working memory does not have to be processed by cognitive mechanisms in order for it to be accessible, but it must actually be in working memory. It does not suffice that it is potentially in working memory by being in visual memory or long-term storage. Hence, accessibility cannot be understood in a broader sense that includes, for example, stored information. One reason for this, cited by Block, is that a completely unconscious representation can be potentially in working memory. If attention were shifted slightly, the information would be in working memory. So, Block says, on the broader notion of accessibility, an unconscious representation can be A-conscious.

In support of his view, Block cites studies by (Carrasco, 2007; Carrasco, Ling, & Read, 2004). In these studies an attention-attracting dot was presented on one side of a screen before a pair of gratings with different contrasts and a certain orientation. Carrasco then asked participants to report the orientation of the one of a pair of gratings that seemed to have the higher contrast. The findings showed that attention can make a grating that was lower in contrast than the comparison seem higher in contrast. Similar findings were reported in color saturation studies (Carrasco, 2007). According to Block, the studies show that a shift in attention can affect phenomenal consciousness to a degree that suffices to make it accessible in global workspace.

However, I think that there is good reason to doubt Block's claim that completely unconscious representations can be potentially in working memory because they would be there if attention were shifted. Selective attention is a top-down factor that modulates representation. Attention can affect the representational phenomenal character of a representation (this, in fact, seems to be the most natural reading of the conclusion made by Carrasco et al. (2004)). For example, the clock now in the periphery of my visual field is presented to me in a way that leaves out information. I am aware of its round shape and some pattern in the middle. When I attend to it, I am also aware of the numbers and their colors. So, attention can change the representational phenomenology of my experience. In a phrase, attention alters representation.

The findings in the studies cited by Block do not show that a completely unconscious representation can be enhanced by attention. At best they show that attention to the meaning of a previously unconscious state can generate a conscious representation. It should be fairly uncontroversial that completely unconscious representations do not generate awareness regardless of how much they are enhanced by selective attention. So, despite the vagueness of the notion of 'potential', there is no good reason to think that potential accessibility does not actually correlate with phenomenal consciousness.

When I say that there is no good reason to think this, I do not mean to deny Block's hypothesis that phenomenal consciousness and cognitive access have different neural correlates. It seems plausible that they do. But if a representation cannot reach working memory, then the representation is phenomenally unconscious. As we will see below, blindsight representations of the qualitative information of stimuli cannot fully reach working memory, and they do not generate awareness regardless of how much they are enhanced by selective attention. So, they are genuinely unconscious processes.

I thus prefer a notion of accessibility that takes information to be accessible if it is potentially in working memory, for example by being stored in potentiated neurons. Access consciousness, thus understood, plausibly correlates with phenomenal awareness or P-consciousness.

There is some recent empirical evidence to back up this claim. Nathan Cashdollar and colleagues (2009) have provided suggestive evidence that there is not a strict dichotomy between short-term and long-term memory. The typical assortment of data on memory has come from work on amnesiacs. Amnesiacs are unable to form long-lasting memories but fully capable of keeping information in their head for a short time period. Cashdollar found that epileptics with damages to the hippocampus behaved like amnesiacs in these two respects, but the study further showed that they could not recall details of pictures they had just seen (e.g. whether the table was located to the left or the right of the chairs). The findings suggest that there are two kinds of short-term memory: one that involves sensory and temporal brain areas and another that involves the pre-frontal cortex.

Now, imagine you partake in the same experiment. Before you are asked whether the table in the picture you just saw was located to the left or the right of the chairs, there is still something it is like for you to experience the table as located to the left of the chairs, and what that is like is different from what it would be like for you to experience the table as located to the right of the chairs. So, the table's location makes a difference to the phenomenology of your perceptual experience. But in order for you to manipulate this information, it may be necessary to ask you questions about it. Something will need to happen for you to go get that information from the sensory and temporal structures of the brain.

Of course, it is at least conceptually possible for an individual to have A-consciousness but no P-consciousness. A philosophical zombie can be A-conscious of a visual stimulus but, by definition, philosophical zombies have no P-consciousness (Chalmers, 1996). However, this does not undermine my point that accessibility and phenomenal consciousness actually occur in combination. My modest aim here is just to demonstrate that if a process is completely unconscious, the information it computes is not cognitively accessible: It cannot be retrieved from the hippocampi or visual or working memory.

My suggestion is thus more in the spirit of a proposal David Chalmers (1997) set forth in his reply to Block's target article in *Behavioral and Brain Sciences*. According to Chalmers, the notions of access consciousness and phenomenal consciousness are conceptually distinct, but Chalmers proposes to amend Block's initial definition of A-consciousness in terms of whether the content is poised for direct rational control of action. On a weaker notion, information is A-conscious if it is directly available for use in directing behaviors. Thus, on Chalmers' notion of A-consciousness, the sound of a ticking clock can be A-conscious even if it is not actually in working memory, as long as it can be accessed after a shift in attention.

On the view I propose here, if information computed by some process cannot enter working memory, then the process is genuinely unconscious. My proposal is meant to be a heuristics for determining which processes are completely phenomenally unconscious in individuals who have conscious processes. I do not hold that only inaccessible processes are completely unconscious. For example, information can be broadcast to working memory in my philosophical zombie. Yet philosophical zombies do not have phenomenal consciousness.

The amended notion of access-consciousness proposed here will prove important in explaining why blindsight processes are not visually-phenomenally conscious. Block holds that super-blindsighters do not have P-consciousness even though they have A-consciousness. But that seems wrong. Arguably, super-blindsighters have P-consciousness of the visual stimulus albeit of a different nature than normal-sighted individuals. Occurrent thoughts have phenomenal character. But on what arguably is the dominant view of occurrent thoughts, the phenomenology is not of a visual variety. Of course, the idea of cognitive phenomenology that is appealed to here is hardly uncontroversial. There is an ongoing debate in philosophy of mind about whether occurrent thinking has a non-imagistic phenomenology. But we do not need to enter that debate. For, there is certainly no doubt that the phenomenology of some occurrent thoughts is distinctly non-visual or non-imagistic. Take the thought expressed by the sentence 'mental states are abstract'. It is hard to even begin to imagine what sort of imagistic phenomenology this thought could involve. For me, the thought has a phenomenal character of a distinctly non-visual variety.

Likewise, I suggest that the information accessed by super-blindsighters has phenomenal character albeit of a non-visual nature. So, super-blindsighters' P-consciousness of the visual stimulus is simply different from a normal-sighted individual's P-consciousness. Super-blindsighters have a kind of cognitive P-consciousness. There is visual information which blindsighters cannot access even when prompted, for example information about the purely qualitative nature of the color of the visual stimuli presented to them in their blind field (studies suggest that the culprit is a lack of color contrast. See Morland et al., 1999). Because they cannot access this information, they do not have perceptual states with, say, a purely qualitative color phenomenology. Hence, their visual processes can justly be said to be processes without a distinctly visual phenomenology. I develop this point in more details below.

4. Blindsight revisited

We are now in a position to evaluate whether blindsight is a genuine unconscious perceptual process. As noted above, studies seem to show that blindsight is not a genuinely unconscious process but is merely degraded conscious vision. Overgaard et al. (2008) argued that the traditional methods for testing whether individuals are visually aware of stimulus presented to them in their blind field fail, because the individuals tend to operate with different measures of what counts as being visually aware. Research using the Perceptual Awareness Scale seemed to show that reported clarity of a stimulus and accuracy in guessing shape or orientation were as strongly correlated in individuals with blindsight as in normal individuals. The researchers took this to show that blindsighters merely have severely degraded conscious vision, and hence that blindsight processes are not genuinely unconscious. Individuals with blindsight merely have greatly degraded but essentially normal conscious vision in their scotoma, that is, there is a merely quantitative difference between sighted sight and blindsight.

These findings would seem to add support to Dennett's hypothesis that it is not the case that there are two kinds of consciousness. Rather, Dennett could say, the differences in consciousness turn on the richness and influence of the content accessed. With reference to the new blindsight studies Dennett could say that blindsighters do not have perceptual experiences with content that is as rich and influential as the experiential content of normal-sighted individuals. The perceptual processes in normal individuals and individuals with blindsight can nonetheless be broadcast to working memory. Hence, Dennett could infer, both kinds of processes are conscious processes. There is no need to introduce a further notion of phenomenal consciousness and say that individuals with blindsight lack phenomenal consciousness.

However, I think that there is some reason to question the conclusion drawn from the empirical findings. I grant that the Perceptual Awareness Scale (PAS) for determining visual awareness is better than traditional binary methods. I also grant that the studies show that reported visual clarity and consciousness are correlated. What is missing in the studies is some measure of *what* individuals with blindsight are aware of. Clarity of the visual stimulus helped them make correct guesses about the attributes of stimuli presented to them in their blind field. But the studies do not show that the individuals were aware of the attributes. What these studies show is more similar to what was shown in the earlier studies demonstrating that blindsighters have vague feelings associated with their predictions about the location of "unseen" stimuli. The scale does admittedly say "clear *image*". However, subjects may not have a good sense of the difference between an image and a thought (see Hurlburt & Schwitzgebel, 2007, p. 61). Furthermore, even if a stimulus perhaps does give rise to an experience with a "clear" phenomenology, this does not provide any evidence of visual awareness of color, shape, or location, though PAS could perhaps be adopted to gauge, for example, visual awareness of color.

When a guess about a stimulus is made, information about the stimulus is broadcast to working memory. The information is then accessed and reported. Information that is broadcast to working memory is occurrent information (as opposed to information stored for the long term). Occurrent information is presented with a representational phenomenal character. There is something it is like to have a thought to the effect that "something is there". The phenomenal character of thought probably does not have the sort of phenomenal character that we associate with visual experience in normal individuals. But thought nonetheless has a phenomenal character. Individuals with blindsight can make correct guesses. Guesses come with a phenomenology, just not the kind normal individuals have when a visual stimulus is presented to them. Looking at it this way, there is some sense in which it is correct to say that blindsight is severely degraded conscious vision. But it has not been shown that the phenomenal consciousness blingsight involves is distinctly visual. I suspect that it is not.

To recap: I hypothesize that blindsight, when carefully examined, is best understood as a kind of genuinely visually-phenomenally unconscious process. The consciousness involved in blindsight most plausibly is a kind of consciousness that arises from making a correct guess about the location, orientation or color of the stimulus. The visual process itself most likely does not correlate with distinctly visual consciousness.

This hypothesis is compatible with Dennett's claim that we can distinguish between cases in which the content of an experience is rich and influential and cases in which it is sparse and has less influence on the individual's behavior. However, what is missing in Dennett proposal is an explanation of the difference in influence. One hypothesis is that distinctly visual phenomenology found in the sight of normal individuals plays a role in action guided by visual experience. This suggestion is not incompatible with Milner and Goodale's disassociation hypothesis. Milner and Goodale hypothesize that processes that correlate with conscious vision play a role in delayed action. But if distinctly visual phenomenology plays a role in guiding delayed action, then we can explain the difference in the influence of visual information in normal individuals and blindsighters. In normal individuals, the content of visual experience is rich and influential because it is associated with a distinctly visual phenomenology that can guide delayed action. In blindsighters, the content of visual experience is sparse and not very influential because it is not associated with a distinctly visual phenomenology. Hence, something else, for example the phenomenology associated with a forced guess, is required to guide action.

Block's super-blindsighters have acquired the ability to guess when to make a guess about the location or color of an object in their blind field. So, they are able to give accurate reports about objects in their blind field without being prompted to guess. These blindsighters would have a phenomenology associated with visual stimuli in their blind fields. When they make a second-level guess about when to make a guess about the location or color of an object in their blind field, information about the stimulus presented to them in their blind field is broadcast to working memory. Information available in working memory is associated with a kind of cognitive phenomenology. Yet super-blindsight processes would be unlikely to have a distinctly visual phenomenology. Super-blindsighters conceivably would have ventral stream damage that would prevent, for example, purely qualitative color information from being computed or from being passed onto working memory. In cases of normal individuals with induced blindsight, it has been shown that "unseen" visual stimuli are processed primarily in the dorsal stream, which according to Goodale and Milner does not lead to visual awareness (Ro, Shelton, Lee, & Chang, 2004).

It is reasonable to conclude that in the case of blindsight, guesses about the attributes of a stimulus presented to a blindsighter in her blind field are associated with a cognitive phenomenology that arises when information is broadcast to working memory where it is available for reportability. But blindsighters lack the sort of distinctly visual awareness that includes a purely qualitative color phenomenology and arises as the result of ventral stream information processing. When visual information is broadcast, a cognitive phenomenology arises but no distinctly visual consciousness occurs. As blindsight is not associated with a distinctly visual phenomenology, it is a genuine type of unconscious visual processing.

5. Vision for action revisited

The question that remains is whether dorsal stream processes are genuinely unconscious perceptual processes. I argued above that evidence indicates that dorsal stream mechanisms process information that contributes to visual awareness. But it is one thing to say that some of the information processed by the dorsal stream contributes to visual phenomenology and quite another to say that genuine dorsal stream processes themselves correlate with a distinctly visual phenomenology. I shall argue that they do not.

It is hard to even begin to imagine what it would be for the output of a dorsal stream process to be unconscious. To be conscious of dorsal stream processing is not simply to be conscious of our actions. To a first approximation, an output of a dorsal stream process is unconscious if it represents properties of our bodies, the environment or a target object, and we are not phenomenally aware of these properties.

On this characterization, it is easy to see that the outputs of upstream dorsal processes are unconscious. When I reach for my coffee mug next to my computer, I am aware of the color and shape of the mug. I also have some visual and bodily awareness of my arm doing the reaching. However, to actually perform the action of reaching to my cup, I must make numerous calculations, including how much I should bent my arm in order to reach to the cup without banging my hand against the computer screen, which 3D-directory is the most direct way to the cup, how wide my grip aperture must be in order for my fingers to fit snugly around the handle, and so on. With some skill and practice, we could learn to calculate representations of most of these properties. But when we act on the fly, we do not engage in delayed action that requires strategy and planning. We just act. When I act online, I do not calculate how wide my fingers must open and close to grab the handle of the cup. I just grab the handle of the cup. Most of the time, I do this perfectly. I do not reach too far to the left or right, too high or too low, and I do not bang into the computer screen or close my grip aperture prematurely.

Milner and Goodale's work shows that when I act online, or on-the-fly, the dorsal stream is responsible for completing these calculations. The dorsal stream completes the calculations extremely rapidly, which saves me time. I do not need to engage in complicated arithmetical exercises in order to take a sip of my coffee.

When representations of 3D trajectories, relative distances, grip aperture, and so on, are computed by the fast dorsal stream, I cannot access them. I can access a representation of the action itself, I can feel the cup in my hand and how heavy it is, but I cannot access the representations of my grip aperture before my fingers close around the handle, the exact 3D trajectory my hand took, and so on. These representations are inaccessible to me. Since inaccessible representations are unconscious, these representations are unconscious. They are nonetheless perceptual representations insofar as they are the result of processing of sensory stimuli that give rise to spatial representations.

What should we say in response to Gallese (2007), who argued that we should think of the inferior parietal lobule as forming a part of what he calls the "ventral–dorsal stream", and that the ventral–dorsal stream (and IPL in particular) plays a role in our visual spatial awareness?

It is certainly an interesting hypothesis. However, it does not seem to me that the cases cited by Gallese support the notion that representations of peripersonal space are conscious representations. Gallese's argument was, roughly, that neglect leads to a lack of awareness of peripersonal space, and that areas of the brain involved in action, therefore, are partially responsible for computing conscious spatial representations. Neglect probably is an attentional disorder that interferes with what the patient pays attention to (Driver, Mattingley, Rorden, & Davis, 1997). Evidence for this hypothesis comes from cases of extinction, where only bilateral stimulation leads to neglect of ipsilesional stimuli. The theory is that the damaged brain areas win the competition for attention, which leads to a failure to attend to stimuli contralateral to the lesion.

A complete loss of attention plausibly leads to a loss of awareness. However, the cases cited by Gallese do not show that parietal representations of peripersonal space are conscious. Gallese is presumably right that IPL plays a role in visual spatial awareness, and the studies he cites show that damage to the IPL affects both visual spatial awareness and online action, but they do not show that dorsal stream representations of peripersonal space are conscious. Myriads of other hypotheses explain the data equally well (Rossetti, 1998). One is that the IPL transmits information to the ventral stream, perhaps via feedback to V1, and that this feedback of information is required in order for ventral stream processing to give rise to conscious spatial representations.

Of course, I would never dare question the more general hypothesis that the ventral and dorsal streams interact in nontrivial ways both in action simulation and action itself. Research shows that they do. For example, in one study it was shown that attempts to memorize actions in order to imitate them activate dorsal stream processes, whereas attempts to memorize actions in order to recognize them on a later occasion activate ventral stream processing. In the study, brain scans were performed on individuals presented with videos of meaningful and meaningless actions and requested to observe the stimuli either to imitate the action or to recognize it (Decety et al., 1997). The findings indicated that observation of action in order to imitate the action was specifically associated with bilateral activation of the dorsal pathways, reaching the premotor cortex. The ventral pathway was activated when the task was to observe in order to recognize the action after the scan (Decety et al., 1997).

In another study, PET scans were performed in two sessions using meaningless and meaningful actions (Grezes, Costes, & Decety, 1998). In the first session, subjects were asked to look at videos without any specific aim. In the second, they were asked to look at the videos with the aim of imitating the actions presented. In the first session it was found that the pattern of brain activation was dependent on the nature of the movements presented. In the second session, the task representation initiated information processing in the dorsal pathway.

But none of this undermines the hypothesis that dorsal stream representations required for online action, including representations of peripersonal space, are unconscious. On-the-fly action requires discharging potentiation (the transmission efficacy at the synapses) in the sites hosting procedural, or routine-based "how-to", memory, viz., the basal ganglia (the striatum) and the cerebellum (Cavaco, Anderson, Allen, Castro-Caldas, & Damasio, 2004). Neither the basic ganglia nor the cerebellum produces direct conscious outputs.

There is no way to completely access and verbalize stored procedural information. The only way to teach someone how to reach to and grasp a letter and slide it through a slit in a box is to demonstrate the action. Of course, we could offer instructions such as: "Move your hand towards the letter, scale your grip aperture to fit tightly around the letter. Then lift your arm without letting go of the letter and deposit it through the slit." What is interesting about instructions like these, however, is that they are not verbalizations of dorsal stream representations.

A verbalization of a series of dorsal stream representation involved in reaching to an object and grasping it would sound more like the following: "The width of the object is 2 cm, and the object is 320 mm away from you. To reach to it and grasp it, gradually increase your hand velocity to 800 mm per second over the next 400 ms while you adjust your grip size to 30 mm. Then gradually decrease hand velocity while you adjust your grip size to 88 mm. Finally tighten your grip". But it is evident from what we know about reaching behavior that reaching to and grasping an object does not involve conscious representations with this sort of content.

Furthermore, unlike vision for perception, vision for action is multi-modal. It integrates visual, tactile and proprioceptive stimuli in the representation of the body's relation to the object. For example, it has been shown that even when we are not consciously aware of a change in the size of an object, we still change our hand aperture to fit the object (Gentilucci, Daprati, Toni, Chieffi, & Saetti, 1995). Tactile and proprioceptive information from the hand about the size of the object is normally used to determine the kinematics of reach-to-grasp movements.

More recent findings seem to contradict the multi-modal nature of vision for action. A study conducted by Robert McIntosh and Gavin Lashleya indicated that the ventral stream contributes to the spatial programming in the dorsal stream by mediating access to stored object knowledge (McIntosh & Lashleya, 2008). Subjects were asked to reach for the standard large *Swan Vestas a*nd the standard small *Scottish Bluebell match* box in a series of baseline trials. In the perturbation trials subjects were instructed to reach for a smaller replica of the *Svan Vestas* match box and a larger replica of the *Scottish Bluebell* match box (Fig. 4).

The findings demonstrated that the expected size of the match boxes affected both the pre-shaping of the hand and the amplitude of reaches to grasp them. The researchers hypothesize that the grasp effects could arise either because the retinal size of the targets is modified by familiar size or because the familiar size contributes more directly to the programming of grasp formation. However, a third possibility is that the baseline trials created a kind of potentiation or depression of synapses in procedural memory sites. This would explain why subjects did not adjust for the new size.

Jeannerod (1984) suggested that reaching and grasping involve unrelated representations, but the suggestion has been questioned. If the size or location of an object is altered during a reaching movement, spontaneous adjustments to the transport time and grip aperture occur (Paulignan, MacKenzie, Marteniuk, & Jeannerod, 1991). It has also been shown that if an arm is perturbed during reaching, there is automatic adjustment of the hand aperture and trajectory (Haggard & Wing, 1991). These findings show that the same underlying control mechanisms are involved in reaching and grasping.

Reaching and grasping behavior makes use of both visual information about the object's location and proprioceptive information about the location of the arm relative to the object. Calculating reaching and grasping requires visual representations of the object and proprioceptive representations of the hand and arm. If the object's location suddenly changes, changes in arm velocity and trajectory are made in less than 100 ms, which is not sufficient time to consciously represent the change in object location and consciously represent a corresponding change in velocity and trajectory (Paulignan et al., 1991). In one study, the subjects used a vocal utterance (Tah!) to signal their awareness of the object perturbation (Castiello & Jeannerod, 1991; Castiello, Paulignan, & Jeannerod, 1991). The study showed that hand-motor reaction occurred significantly faster than the vocal reaction. Unlike corrections of trajectory and hand aperture, which occurred within 100 ms, the vocal response occurred after 420 ms.

Research on pointing behavior indicates that subjects can change a pointing movement faster than they can perceive a change in object location (Goodale, Pelisson, & Prablanc, 1986; Pelisson, Prablanc, Goodale, & Jeannerod, 1986). In one study subjects were asked to point as fast and accurately as they could to stimuli occurring in the dark. In the first series of trials, the target made a jump from an initial position to a randomly selection position. In the second series of trials, the target made a second jump in the same direction as the initial jump. Subjects reported that they were unaware of the second jump and were unable to predict its direction, but while their saccadic eye movements as well as their pointing movement were initially aimed at the target's position after the first jump, both immediate adjusted to fit the target's new location. The participants were clearly seeing and acting on the second jump, even though they had no conscious awareness of it. The findings indicate that target location and movement trajectory can be updated without any conscious awareness of the update.

Jakobson and Goodale (1989) reported a similar result. They first showed that subjects were not able to detect a 3° shift in vision through wedge prisms. They then monitored participants' movements. Despite no reported conscious awareness of the shift in vision, the shift led to a modified hand-path curvature.

Other studies have shown that while subjects are unaware of relying on visual information about their hand prior to movement, they perform with better accuracy when this information is available (Desmurget, Rossetti, Prablanc, Stelmach, & Jeannerod, 1995; Elliott, Carson, Goodman, & Chua, 1991; Prablanc, Echallier, Jeannerod, & Komilis, 1979; Rossetti, Stelmach, Desmurget, Prablanc, & Jeannerod, 1994).

These studies indicate that subjects implicitly rely on various sources of inaccessible information in grasping, reaching and pointing behavior. This strongly suggests that dorsal stream representations are genuinely unconscious perceptual processes.

6. Conclusion

Blindsight, the sort of residual vision found in people with damage to striate regions in their visual cortex, and dorsal stream processes which code information about properties of objects in egocentric space and guide online action, would

Fig. 4. The four matchboxes. Upper row: the standard *Swan Vestas* and *Scottish Bluebell* boxes. Lower row: 0.8-scale replica *Swan* box and 1.25-scale replica *Bluebell* box (McIntosh & Lashleya, 2008).

seem to be exemplars of unconscious perceptual processes. However, there is also some reason to be skeptical of the claim that they are unconscious perceptual processes. Blindsight studies have shown that there is a correlation between reported clarity of stimuli in blindsighters' bind field and their accuracy on forced-choice tasks. This has suggested to some that blindsight is not really unconscious vision but rather severely degraded conscious vision. Likewise, there is some evidence that information computed by the dorsal stream can contribute to visual awareness. This may seem to suggest that dorsal stream processes correlate with visual awareness and hence are not unconscious perceptual processes.

I have argued, however, that there is good reason to think that both blindsight and genuine dorsal stream processes are unconscious perceptual processes. I argued that while phenomenal consciousness is conceptually distinct from access consciousness, access consciousness provides a good heuristics for determining whether a process correlates with phenomenal consciousness. Information which cannot be broadcast to working memory is not cognitively accessible and hence does not correlate with phenomenal consciousness.

Blindsighters can guess the location, orientation and color of visual stimuli when prompted. This suggests that when a guess is made, information about the visual stimuli is broadcast to working memory. Blindsighters thus have cognitive access to information about visual stimuli in their blind spot. However, there is distinctly visual information which blindsighters have no access to. This includes the purely qualitative color and shape information computed by the ventral stream of normal individuals. There are two possible explanations of this lack of access. Either the information is computed by the blindsighter's ventral stream but is not broadcast to working memory, or the information is not computed at all. In either case, there is good reason to think that the visual processes in blindsight patients are not correlated with distinctly visual awareness. Arguably, this sort of distinctly visual awareness would require broadcasting of purely qualitative color and shape information to global workspace. So, while blindsight processes correlate with a certain cognitive phenomenology, they do not correlate with a distinctly visual phenomenology. Hence, I argued, blindsight processes are genuinely unconscious visual processes.

I argued further that while some information computed by the dorsal stream does indeed contribute to visual awareness, this information is plausibly computed in early areas of the dorsal stream that interact with the ventral stream. Genuine dorsal stream processes take place in later parts of the dorsal stream that do not interact directly with the ventral stream. In these areas, full representations of objects in egocentric space are calculated. These representations include representations of the body, trajectories in space, and information about perspective-relative properties and absolute size. These representations are not broadcast to working memory but are passed onto brain regions responsible for fine motor-control. Hence, genuine dorsal stream processes are unconscious processes. They do not reach working memory and hence are not cognitively accessible.

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