CHAPTER 8

Spatial coordinates and phenomenology in the two-visual systems model

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Abstract

The ‘two-visual’ systems hypothesis (Goodale and Milner, 1992; Milner and Goodale, 1995) has recently come under attack regarding its proposed functional dichotomy between vision-for-action and vision-for-perception as well as for the limited interaction it allows between visual awareness and processing in the dorsal stream. Schenk (2006) questions the rigid functional dichotomy between vision-for-perception and vision-for-action arguing that the dual model of vision is best accounted for in terms of a dissociation between egocentric and allocentric spatial coordinate systems. Wallhagen (2007) argues that there is no evidence to claim that the processing in the dorsal stream cannot underlie visual awareness. This paper offers a response to both challenges and disentangles the contribution of two separable factors to the two-visual systems model, namely, (i) how spatial information is coded and (ii) the relation between consciousness and processing in the ventral and dorsal streams respectively.

8.1. Introduction

What is known as the ‘two-visual systems model’ of human vision was first presented by Goodale and Milner (1992). The core of the model involves three complementary ingredients: (i) the functional distinction between *vision-for-action* and *vision-for-perception*; (ii) the mapping of the functional distinction onto the anatomical segregation between the dorsal stream and the ventral stream of the human visual system; (iii) the restrictive link between visual awareness and vision-for-perception at the expense of vision-for-action.

One of the crucial pieces of empirical evidence on which advocates of the two-visual systems model have relied is the close investigation of visual form apperceptive agnosic patient D.F., who is deeply impaired in the visual recognition of the shape, size, and orientation of visual stimuli, but who can grasp objects accurately. Advocates of the two-visual systems model (e.g. Goodale and Milner, 2004) have argued recently that the dissociation between impaired visual perception and spared visuomotor capacities exemplified by D.F. is an attenuated version of the dissociation exemplified by blindsight patients.

Recently, claims (i) and (iii) of the two-visual systems model have been challenged. According to Schenk (2006), the dual model of vision is best accounted for in terms of a dissociation between egocentric and allocentric spatial coordinate systems. He argues that D.F. is impaired, not in perceptual tasks per se, but in either visuo-motor or perceptual tasks that require making use of spatial information coded in allocentric coordinates. According to Wallhagen (2007), the evidence does not show that the dorsal stream cannot underlie visual awareness. He argues that D.F. might well have visual phenomenal experience of the shapes of objects, but she might be unable to form perceptual judgments about the shapes of objects because she fails to conceptualize the content of her visual experience. Since, arguably, there are many cases to which the distinction between visual phenomenal experience and perceptual judgment applies (e.g. in change blindness experiments, in split-brain patients, and in neglect patients), Wallhagen's (2007) conjecture raises an important challenge.

In this chapter, we offer a response to both challenges. In the process, we try to clarify the functional role of two parameters of the two-visual systems model: first, visual perception and visually guided action use different frames of reference for coding relevant spatial information. Secondly, their respective outputs are not equally available to consciousness. In section 8.2, we review the evidence in favour of the dual model of vision. In section 8.3, we analyse the complex links between visually guided action, visual perception, egocentric coordinates, and allocentric coordinates. In section 8.4, we contrast two possible criteria of conscious experience: namely, 'reportable' information and information stored in an 'iconic buffer'. In section 8.5, we argue that D.F.'s visuo-motor computation of aspects of shape is unlikely to make her visually aware of the shapes of objects on which she acts efficiently.

8.2. The evidence for the dual model of vision

Contrary to common sense and much philosophy of perception, human vision is not a unitary psychological activity, whose single purpose is to yield a unified conscious picture of the visible features of the world. As shown by a variety of empirical evidence ranging from electrophysiological recordings in non-human primates, the examination of brain-lesioned human patients and psychophysical experiments in healthy human participants, one and the same visual stimulus can be processed differently according to the task.[1]

Ungerleider and Mishkin (1982) first reported a double dissociation between the results of lesions respectively in the ventral and the dorsal pathways of the cortical visual system of macaque monkeys. They found that animals with a lesion in the dorsal pathway were impaired in their ability to localize an object with respect to a landmark, but were still able to recognize the shape, colours, and texture of objects. Conversely, they found that animals with a lesion in the ventral pathway were impaired in the recognition of the shape, colours, and texture of objects, but were still able to localize an object with respect to a landmark.[2] In brain-lesioned human patients, Goodale and Milner (1992) reported a double dissociation between optic ataxic and visual form agnosic patients.[3] Optic ataxic patients, who suffer from a lesion in the dorsal pathway (but whose ventral stream is intact), are still able to recognize the size, shape and orientation of visually presented targets, but impaired in reaching and grasping them. Conversely, visual form agnosic patients, who suffer from a lesion in the ventral pathway (but whose dorsal stream is intact), are impaired in the recognition of the size, shape and

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[1] The scope of the functional duality between perceptual and visuo-motor processing must be restricted to the visual processing of objects that can be either enumerated or manipulated with one's hand.

[2] On the basis of this dissociation, Ungerleider and Mishkin (1982) labelled the ventral stream the *What*-system and the dorsal stream the *Where*-system.

[3] For experimental evidence challenging the view that visual form agnosic patients and optic ataxic patients exemplify a double dissociation, cf. the chapter by Rossetti et al. (Chapter 10); and for a reply, cf. Milner and Goodale (2008).

orientation of visual visually presented objects. However, their preserved visuo-motor transformation enables them to reach and grasp visual targets (Goodale and Milner, 1992; Milner and Goodale, 1995; Goodale and Milner, 2004; James et al., 2003). For example, patient D.F. was presented with a set of so-called Efron rectangles, all of which with the same surface areas, some of which were squares and others had various elongated shapes. When asked for same/different judgments, she was at chance when the pair of shapes was minimally different. She was also at chance when required to match the width of such simple geometrical forms by scaling the distance between her thumb and index finger. As noticed by Milner and Goodale (1995, p. 200), it is significant that D.F.'s impaired perceptual judgments of shape were tested using a manual, non-verbal report, because it shows that D.F.'s perceptual impairment cannot be caused by a dissociation between visual processing and language processing. By contrast, measurement of her maximum grip aperture (MGA) in visuo-motor tasks of grasping revealed an excellent correlation with the physical width of rectangular blocks. Furthermore, when grasping objects with curved shapes between her thumb and index finger, unlike a patient with optic ataxia, D.F. turned out to select the correct points on the objects' surface on which to apply her thumb and index finger (Goodale et al., 1991; Milner et al., 1991; Milner and Goodale, 1995; Goodale and Milner, 2004).[4]

Further evidence for the dual model of vision has been provided by the psychophysical investigation of the responses of healthy human subjects to illusory displays, such as the Müller-Lyer illusion, the Ponzo illusion, the Titchener (or Ebbinghaus) illusion, or the hollow face illusion. Many such behavioural studies have revealed a subtle dissociation between perceptual judgments and visuo-motor responses. For example, in the hollow face illusion, participants perceive a three-dimensional concave (or hollow) mask as a convex (or protruding) face. If asked to slowly point to a small target attached to the hollow mask, participants directed their finger movements to the illusory location of the target. However, if asked to quickly flick the target off the face (as if it were a small insect), they directed their finger movements to the actual or veridical location of the target (cf. Kroliczak et al., 2006). Similarly, when presented with a Titchener disk illusory display, participants judge that the diameter of a disk is larger when the disk is surrounded by an annulus of smaller circles than when it is surrounded by an annulus of larger circles. But when participants are asked to grasp the central disk, measurement of their maximum grip aperture shows that the visuo-motor computation of the size of the diameter of the disk is not affected by the illusion to the same extent (Haffenden and Goodale, 1998; Haffenden et al., 2001).

Such dissociations in both neuropsychological patients and healthy individuals show the existence of two independent types of visual processing of one and the same stimulus. Either type of visual processing can be selectively impaired, but only one of the two is sensitive to the mechanisms generating size-contrast illusions. The distinction between visuo-motor processing and perceptual processing has been mapped onto the anatomical segregation between the dorsal and the ventral streams (Goodale and Milner, 1992; Milner and Goodale, 1995). Roughly speaking, the dorsal stream projects primary visual areas onto the superior parietal lobe (SPL), which sends further projections to the primary motor cortex via the dorsal premotor cortex (dPM). The ventral stream projects primary visual areas onto the infero-temporal cortex (IT).[5] The anatomical segregation between the dorsal and the ventral streams, however, leaves a number of computational and functional parameters involved in the documented dissociations unsettled.

What is the difference between visually formed perceptual judgments and visuo-motor representations? Recent discussions have stressed three major functional distinctions: (i) the first is the distinction between vision-for-perception and vision-for-action (Goodale and Milner, 1992;

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[4] In his chapter (Chapter 13), Noë emphasizes the limits of patient D.F.'s visuo-motor processing of the shapes of objects, particularly with respect to the object's function.

[5] Gallese (2007) argues for a tripartite model including a dorso-dorsal stream, a ventral-dorsal stream, and a ventral stream.

Milner and Goodale, 1995) or (in slightly different terms) between the semantic and the pragmatic processing of visual information (Jacob and Jeannerod, 2003; Jeannerod and Jacob, 2005); (ii) the second is the distinction between coding spatial information about a stimulus in allocentric and in egocentric coordinates (Milner and Goodale, 1995; Jacob and Jeannerod, 2003; Schenk, 2006); (iii) the third is the distinction between conscious and unconscious processing (Milner and Goodale, 1995; Jacob and Jeannerod, 2003; Pisella et al., 2000). However, it is not entirely clear how these three contrasts are supposed to interact. In the following sections, we shall focus on the last pair of distinctions and address two joint questions. First, we shall try to determine in what way patient D.F.'s spared dorsal stream enables her to code spatial information about the target on which she acts successfully. Secondly, we shall ask to what extent activity in her spared dorsal stream makes D.F. visually aware of the shapes of objects on which she acts successfully.[6]

8.3. Coding spatial information and the two-visual systems model

The functional duality between visual perception and the visual control of actions was first advanced by Goodale and Milner (1992). Whereas segregating an object from both its background and competitors is a *perceptual* process (Shoemaker, 1994), grasping and pointing to an object are *visuo-motor* processes. The action/perception functional distinction has since been embraced under various labels by several authors. For example, Jeannerod (1993, 1997), Jacob and Jeannerod (2003), and Jeannerod and Jacob (2005) have generalized the action/perception model of visual processing into the distinction between pragmatic and semantic processing of visual information. The pragmatic processing of visual information is at the service of promoting an agent's intention by guiding her motor acts (at the various levels of complexity in the representation underlying the hierarchical organization of her action). The semantic processing of visual information is at the service of the elaboration of an agent's beliefs (and knowledge) about her surroundings. Furthermore, Jacob and Jeannerod (2003), Jacob (2005), and Jeannerod and Jacob (2005) have hypothesized that, unlike visual percepts, visuo-motor representations serve motor intentions and have a hybrid direction of fit: they have both a world-to-mind and a mind-to-world direction of fit. In Matthen's (2005) terminology, the action/perception distinction is captured by the distinction between 'motion-guiding' and 'descriptive vision'.

8.3.1. Types of action and the two-visual systems model

For the purpose of understanding the varieties of visual processing, the distinction between perception and action is an unacceptable oversimplification. On the one hand, slowing down or speeding up the timing of a visually guided action makes a difference to which anatomical pathway is likely to underlie the act. For example, visual form agnosic patients with a lesion in the ventral stream are able to produce fast, immediate, and accurate pointing actions towards a target, but they are significantly impaired if there is a delay between the extinction of the stimulus and the onset of the pointing gesture. Conversely, optic ataxic patients with a lesion in the dorsal stream are impaired when requested to produce a fast, immediate, and automatic pointing gesture towards a target, but their performance improves if there is a delay between the extinction of the stimulus and the onset of their pointing gesture (Milner and Goodale, 1995; Milner and Goodale, 2008; Jacob and Jeannerod, 2003; Pisella et al., 2000; Rossetti et al., 2005).[7]

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[6] In addressing both questions, we assume, on the basis of the brain-imaging work reported by James et al. (2003), that the spared parts (if any) of her ventral stream are not doing any work.

[7] As showed by Kroliczak et al. (2006), the same contrast is exemplified in healthy subjects who are asked to point towards a target on a hollow mask.

On the other hand, it would be a mistake to assume that every hand (or finger) action standing in some relation to a visual object is guided by a visuo-motor representation of a target. Some hand actions instead count as perceptual reports. For instance, scaling the distance between thumb and index finger can be involved in either a visuo-motor task of grasping or in reporting a perceptual judgment. Interestingly, the underlying processes are very different. According to Jeannerod (1997, p. 35), in a visuo-motor task of grasping, but not in a manual report, grip formation (i.e. finger shaping) starts during reaching (i.e. transportation of the hand at the object's location): 'preshaping involves a progressive opening of the grip with straightening of the fingers, followed by a closure of the grip until it matches object size'. Maximum grip aperture, which is much wider than, but significantly correlated with, the physical size of the target, occurs at 60% to 70% of the reaching phase. This process can unfold in 'open loop' conditions in which participants have no visual access to their own hand movement and cannot, as in the context of a manual report, visually compare the distance between their thumb and index finger to the size of the target. Indeed, it was a great surprise to discover that whereas patient D.F. was able to accurately scale her finger grip to the physical size of a target in a visuo-motor task of grasping, she turned out to be at chance when asked to scale the distance between her thumb and index finger to provide a manual estimation of the size. Similarly, healthy subjects scale their finger grip accurately when asked to grasp an illusory Titchener disk, but when asked to judge the diameter of the disk, measurement of the distance between their thumb and index finger shows that their estimation of the diameter of the disk is illusory.

On the one hand, an agent could not grasp accurately a target unless she coded the target's position in egocentric coordinates centred on her own body. On the other hand, the size-contrast illusion prompted by the perception of a Titchener disk surrounded by an annulus of circles (either smaller or larger than it) arises from the automatic comparison between the diameter of the central disk and the diameter of the surrounding circles. These results suggest that whether an agent codes the spatial position of an object in egocentric coordinates (centred on her own body) or in allocentric coordinates (centred on an item of the visual array) matters to the accuracy of the movement whereby she scales the distance between her thumb and index finger. In short, visual awareness of shape and size seems to be dissociated from accuracy of grip (cf. Haffenden and Goodale, 1998; Haffenden et al., 2001).

8.3.2. Egocentric and allocentric frames of reference

The notion of a frame of reference was first defined as 'a locus or set of loci with respect to which spatial position is defined' (Pick and Lockman, 1981, p. 40). The spatial location of an object can be encoded in relation to either the agent's own spatial position or the spatial position of some other object independent of the agent. The former frame of reference centred on the agent is egocentric, whereas the latter frame of reference, which depends neither on the presence of the agent nor on her location, is allocentric.

In a task of reaching and grasping an object, the visuo-motor system must compute the absolute (non-relative) size, shape, and orientation of the target and represent its location in an egocentric frame of reference centred on the agent's body.[8] In fact, it must update the representation of the location of the target relative to the agent, as the action unfolds, by converting the representation of the location of the target from eye-centred coordinates, to head-centred coordinates, to torso-centred coordinates, and finally to hand- or finger-centred coordinates.[9]

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[8] By 'absolute size', we mean that the visuo-motor system does *not* compute the size of the target relative to surrounding objects present in the visual array.

[9] Coding a target's spatial position in egocentric coordinates is also necessary for pointing when pointing is a visuo-motor behavior, i.e. when it involves making contact with the target as opposed to producing an ostensive communicative gesture (either as an imperative request or to draw someone else's attention to some target).

By contrast, perceptual judgments exhibit more flexibility: some perceptual judgments use an egocentric frame of reference; others use an allocentric frame of reference. In particular, perceptual judgments about the spatial position of an object can either use an egocentric or an allocentric frame of reference. For example, one can judge (or form the belief) that an apple is on one's right. One can also form the judgment that the apple is on the plate. In the former case, the perceptual judgment uses spatial information coded in an egocentric frame of reference. In the latter case, it uses spatial information coded in an allocentric frame of reference. Now, as emphasized by advocates of the two-visual systems model, perceptual judgments about the size, shape, and colour of objects often require the use of an allocentric (or scene-based) frame of reference centred on items of the visual array (Milner and Goodale, 1995; Jacob and Jeannerod, 2003). The reason is that visually based perceptual judgments of size are typically comparative: in a perceptual task, one automatically sees some things as smaller (or larger) than others.[10] This is why perceptual judgments of e.g. relative sizes or shapes, unlike visually guided actions, are notoriously open to visual illusions. Insofar as a perceptual judgment about an object's shape involves a correlative judgment about its size, if the latter is comparative, so is the former.[11] (For a discussion of this claim, see Bermudez, 2007 and Schröder, 2007. For a reply see Jacob and Jeannerod, 2007b.) Furthermore a goal of perceptual processing is to enable recognition (or identification) of an object over time by linking new visually processed information to older information already stored in memory. Observers never occupy exactly the same spatial standpoint relative to an object twice. Nor are illumination conditions twice ever exactly the same. Thus, recognition of objects over time is best served by an object-dependent and viewer-independent representation.

8.3.4. How does D.F. code spatial information?

Previous investigation has showed that patient D.F.'s spared dorsal stream enables her to grasp a target successfully, and, we suggest, to code its spatial position in egocentric coordinates centred on her hand and fingers. However, D.F.'s spared dorsal stream does not enable her to make perceptual judgments about the size and shape of visually presented objects. As we just argued, unlike perceptual judgments of relative size and shape (which require the use of allocentric coordinates), perceptual judgments about the spatial location of a visual object can be made using either an allocentric or an egocentric frame of reference. So, the question arises whether D.F.'s spared dorsal stream might enable her to make perceptual judgments about the spatial position of a visual object coded in an egocentric frame of reference. This question has been explored in a set of interesting experiments by Schenk (2006). These 2 × 2 experiments were designed to dissociate the contrast between perceptual and visuo-motor processing from the contrast between coding the spatial position of an object in respectively an allocentric and an egocentric frame of reference (see Fig. 5.1).

In the so-called 'allocentric perceptual' task, two dots (one white and one black) were presented at various distances to the left and right of a cross. Participants were asked to judge which of the two dots was closer to the cross (see Fig. 5.1a). In the 'egocentric perceptual task', the cross was replaced by the participant's felt (but unseen) fingertip. The participants' task was to judge which of the two visible dots was closer to the fingertip – using proprioceptive information about the finger's position (see Fig. 5.1b). In the 'allocentric motor task', a dot was displayed to the right of a cross (at various distances) and participants were asked to point their index finger to an invisible target whose distance

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[10] Hence the illusory perceptual judgments in e.g. Titchener illusions.

[11] A perceptual judgment about the location of an object can make use of spatial information coded in some egocentric frame of reference. But if one is to form a perceptual judgment about the relative size and/or shape of an object (i.e. its size and/or shape relative to the size and/or shape of some other neighbouring object), then the spatial positions (relative to one another) of the objects, whose attributes are being visually compared, must be coded in some allocentric frame of reference.

relative to the starting position of their finger was identical to the distance between the dot and the cross (see Fig. 5.1c). In the 'egocentric motor' task, a target dot was presented to the right of the starting position of the participant's index finger and the participant's task was to move his finger from its starting position to the target (see Fig. 5.1d).

As predicted by the action/perception dual model, Schenk (2006) found that there was no significant difference between D.F. and controls in the egocentric motor task (1d), whereas D.F. was deeply impaired in the allocentric perceptual task (1b). The results are more puzzling for the egocentric perceptual task and the allocentric motor task. Despite the fact that the task was perceptual, Schenk (2006) found that D.F. was significantly better in the egocentric perceptual task (Fig. 5.1b) than in both allocentric tasks (Fig. 5.1a) and (Fig. 5.1c). Furthermore, despite the fact that the task was motor, she was deeply impaired in the allocentric motor task (Fig. 5.1c). On the basis of the fact that D.F.'s performances in both egocentric tasks (Fig. 5.1b)–(5.1d) are better than her performances in both allocentric tasks (Fig. 5.1a)–(5.1c), Schenk (2006) argues that the dissociation exemplified by D.F. is not between perceptual and visuo-motor processing, but instead between the ability to code spatial information in respectively allocentric and egocentric coordinates.

Schenk's (2006) argument for the view that D.F.'s impairment is better conceptualized as 'an allocentric than a perceptual deficit' is weakened by two putative confounds. First, it is really unclear that the process probed by task (Fig.1.8c) should be conceived as a visuo-motor process. Instead, as noticed by Milner and Goodale (2008, p. 778), what D.F. is requested to do in task (Fig. 5.1c) is to provide a non-verbal *manual report* of her perceptual judgment about the distance between the cross and the dot. On this account, D.F.'s failure is not evidence of a visuo-motor deficit, but a failure of perceptual judgment tested via a manual report. If so, then D.F.'s failure in task (Fig. 5.1c) jointly shows that she cannot code the position of a dot relative to a cross in an allocentric frame of reference and that her perceptual judgment about the distance between the cross and the dot (as revealed by her manual report) is severely impaired (as predicted by the action/perception dual model).

Nor is it clear which mental process is being probed in task (Fig. 5.1b) in either healthy controls or in D.F. Arguably, for healthy participants, task (Fig. 5.1b) counts as a perceptual task leading to a perceptual judgment about which of two dots is further away from the participant's fingertip. Schenk (2006) assumes that healthy participants code the position of each dot in an egocentric frame of reference centred on their fingertip. However, contrary to Schenk's (2006) assumption, it is unclear whether healthy participants solve the task by making use of spatial information about the positions of the dots in an egocentric or an allocentric frame of reference. The experiment has not ruled out the possibility that healthy participants, who can feel it but can't see it, code the spatial position of their fingertip relative to each dot in an allocentric frame of reference centred on each dot. If so, then it is misleading to describe the task as a perceptual *egocentric* task. Furthermore, as has been suggested by Milner and Goodale (2008, p. 777), the experiment does not rule out either the possibility that D.F. solves the task by using motor imagery, e.g. by imagining pointing her index finger to each dot. If so, then the process whereby D.F. solves task (Fig. 5.1b) is *not* a perceptual process.

Schenk (2006, p. 1370) argues further that D.F.'s 'normal' performance in egocentric perceptual task (1b) casts doubt on Jacob and Jeannerod's (2003, chapter 6) claim that making a perceptual judgment about an object's visual attribute (e.g. size, shape, orientation) requires coding the object's spatial position in an allocentric frame of reference. First of all, it is worth observing, as Milner and Goodale (2008, p. 777) have, that D.F.'s performance in task (Fig. 5.1b), although better than her own performance in task (Fig. 5.1c), is significantly worse than both the performance of average controls in task (Fig. 5.1b) and her own performance in egocentric visuo-motor task (Fig. 5.1d), in which she is as good as the best controls. On the assumption that task (Fig. 5.1b) probes a perceptual process in either healthy controls or D.F., the relevant perceptual judgment is about a dot's spatial location (or position), not about an object's size, shape, or orientation. Secondly, it is open to doubt whether in task (Fig. 5.1b) controls code the positions of dots in an egocentric frame of reference and also whether the process whereby D.F. solves task (Fig. 5.1b) is a perceptual process. If so, then it is at least questionable whether Schenk's results in task (Fig. 5.1b) are inconsistent with Jacob and Jeannerod's (2003) thesis.

In summary, D.F.'s spared dorsal stream enables her to code the location of target of pointing in egocentric coordinates centred on her index finger. Her spared dorsal stream does not enable D.F. to code spatial information about an object in an allocentric frame of reference centred on another item present in the visual array. This is why she fails to make a perceptual judgment about whether a white dot is further away from a cross than a black dot. This is also why she fails to match the distance between a cross and a dot by moving her finger, which of course requires her to make a perceptual judgment about the distance between the cross and the dot. Finally, the evidence reported by Schenk is compatible with the possibility that D.F.'s spared dorsal stream enables her to decide which of two dots is closer to her fingertip by means of a two-step heuristic involving (i) coding the distance between each dot and her finger tip in egocentric coordinates centred on her (felt) fingertip and (ii) imagining moving her finger to each dot.

8.4. Conscious experiences and reportability

We said earlier that the distinction between vision-for-perception and vision-for-action has been tied by advocates of the two-visual systems model to two further distinctions, one of which we just addressed. The second is the distinction between conscious and unconscious processing, to which we now turn. According to Clark's (2001) thesis of 'experience-based selection' (EBS), vision-for-perception enables an agent to select a relevant target present in the visual array by discriminating it from both the background and potential competitors. Once the target has been selected perceptually, vision-for-action takes over the control and guidance of the fine-tuning of the hand movement towards the target. Clark (2001, p. 496) further rejects what he calls the thesis of 'experience-based control' (EBC) i.e. the assumption that:

> conscious visual experience presents the world presents the world to the subject in a richly textured way, a way that presents fine detail (detail that may, perhaps, exceed our conceptual or propositional grasp) and that is, in virtue of this richness, especially apt for, and typically utilized in, the control and guidance of fine-tuned, real world activity.

Joint acceptance of EBS and rejection of EBC entail that visually guided actions are not based on conscious visual representations. On this view, the dorsal pathway is, in Pisella et al.'s (2000) terms, an 'automatic pilot'. If so, then agnosic patient D.F. has no conscious experience of the very properties (e.g. size and shape) of stimuli that she can efficiently process for the purpose of accurate grasp. This is why D.F.'s residual visuo-motor capacities have been compared to those of blindsight patients and her impairment has been described as a lack of visual awareness (or consciousness) of the shape, size, and orientation of objects (Goodale and Milner, 2004, p. 71). Weiskrantz (1997, p. 138) has further characterized 'the dorsal route [subserving] visual action as [...] in a sense, blindsight without blindness'.

In a recent provocative paper, however, Wallhagen (2007) has challenged Clark's (2001) endorsement of EBS and his correlative rejection of EBC on the grounds that it has the unacceptable metaphysical epiphenomenalist consequence that conscious psychological states lack causal efficacy in the production of an agent's behaviour. Wallhagen's goal is to protect the role of conscious experience in the causation of an agent's behaviour by reinterpreting the purported evidence for epiphenomenalism. Wallhagen claims that D.F. has preserved conscious visual experiences. In his view, the evidence has not ruled out the possibility that the dorsal stream could underlie some conscious experiences. Wallhagen's argument for this challenging claim is based on an interesting criticism of the reportability criterion of consciousness to which we presently turn. Wallhagen's suggestion is that, although D.F. might not be able to report her visual experience of the shapes of objects that she is able to grasp accurately, nonetheless she might enjoy some visual experience of the objects' shapes. So Wallhagen's suggestion involves a criticism of the reportability criterion of consciousness.

8.4.1. The reportability criterion

The reportability criterion of consciousness has been endorsed by philosophers and scientists, including those who subscribe to the so-called 'global workspace model of consciousness'.[12] In fact, this model combines two separable theses: (i) a global workspace model of *reportability*; together with (ii) acceptance of the *reportability* criterion of *consciousness*. According to the global workspace model of reportability, what makes the content of a representation reportable is its being broadcast to a wide range of brain areas or equivalently its being made globally available (or accessible) to a wide variety of consuming cognitive mechanisms (attention, working memory, planning, and reasoning). For example, as emphasized by the global workspace model of reportability, unless the content of a subject's representation were being made available to the subject's attention and working memory, the subject would fail to report it. According to the reportability criterion of consciousness, not unless a subject could report the content of a representation could the represented content count as *conscious*.

The workspace model of reportability and the reportability criterion of consciousness are clearly dissociable. For example, Block (2005, 2007, 2008) argues strongly against the reportability criterion of phenomenal consciousness, but he does accept the evidence for the workspace model of reportability or accessibility.[13] There are both grounds for and grounds against the reportability criterion of consciousness. What drives some philosophers and scientists towards the reportability criterion of phenomenal consciousness are two related worries: a verificationist epistemic worry about the intractability of consciousness to scientific investigation, and a worry about the introspective sense of ownership of experience.

If the phenomenal character of one's conscious experience is unreportable (verbally or otherwise), then the risk is that it is bound to escape the scope of objective scientific investigation.[14] The second worry is that if the phenomenal character of one's conscious experience is divorced from reportability, then conscious experience will not be of any relevance for the subject. Suppose that the phenomenology (or phenomenal character) of one's visual experience of e.g. a red tomato outstrips the conceptual content of one's belief that the relevant tomato is red (by virtue of being richer, more fine-grained and more detailed). Suppose also that all one can report (verbally or otherwise) is what one believes and that what one believes depends on one's cognitive (i.e. conceptual) resources. Suppose finally that the phenomenal character of one's conscious experience is partly or fully inaccessible to one's own cognitive resources. If so, then one could have a conscious experience and not believe it, i.e. not be aware of it. If so, then the phenomenal character of one's conscious experience would correspondingly not matter to anyone: it would make no difference to anyone. Furthermore, if a conscious experience is both inaccessible to scientific investigation and to oneself,

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[12] For a defence of the global workspace model, cf. Dehaene and Naccache (2001), Dehaene and Changeux (2004), Dehaene et al. (2006), Naccache and Dehaene (2007). They argue that what secures the reportability of the content of a visual representation is the existence of long-distance neuronal connections between the visual occipito-temporal areas and parietal and frontal areas. Dennett (2001) offers a nice philosophical gloss in terms of the fame theory of consciousness.

[13] What makes a process unreportable (verbally or otherwise) by a subject is presumably that it is cognitively inaccessible to the subject's attention and working memory. If so, then cognitive accessibility (to attention and working memory) is a necessary condition of reportability.

[14] As Dehaene and Changeux (2004) write, for example: '… we shall deliberately limit ourselves, in this review, to only one aspect of consciousness, the notion of *conscious access* […] we emphasize *reportability* as a key property of conscious representations […] Our view […] is that conscious access is one of the few empirically tractable problems presently accessible to an authentic scientific investigation.' See also Dennett (2001). For a reply, see Block (2007).

then one might have a conscious experience and nobody might know anything about it.[15] Hence, the reportability criterion seems to be a useful tool to dispel both the verificationist and the introspective worries.

8.4.2. Unreported conscious experiences

However, what casts doubt on the reportability criterion is the empirical evidence for the existence of unreported conscious experiences suggested by the examination of neglect patients and by experiments on change blindness. There are no doubt cases where a person rightly believes that, although her visuo-motor behaviour shows that she does process some visual information about a stimulus, nonetheless she is visually unaware of it. Blindsight patients, whose condition results from a lesion in the primary visual areas, seem to be such a case (cf. Weiskrantz, 1997). However, there also seem to be cases where a person is visually aware of something but fails to acknowledge it: she sees something and believes that she does not. If such cases exist, then they show that people may have visual experiences that they cannot report because they fail to turn their visual experience into a perceptual judgment. Such cases have been reported and, as we shall argue shortly, the scientific evidence about these cases does not support the application of the reportability criterion of consciousness.

Arguably, among the necessary conditions for forming the introspective belief that one saw (or visually experienced) property *F* of stimulus *s* is that one forms the perceptual judgment that *F* is being exemplified by *s*. Arguably, one could not judge that *s* is *F* unless one possessed and deployed some concept of property *F*. Nor could one believe that one saw *F* unless one possessed and deployed the concept SEE. But now it clearly seems like an unacceptably strong necessary condition for one to visually experience *F* that one deploys the concept SEE. Similarly, it seems too strong to require that not unless one deploys the concept *F* could one visually experience an *F*. For example, it seems overly strong to require that not unless one recognizes or identifies an object's geometrical shape by applying to it the concept *octagonal* could one visually experience an octagonal object. Therefore, a subject can lack the introspective belief that she visually experienced some stimulus *s* or some property *F* (e.g. *octagonal*) of stimulus *s* because of an attentional or a memory failure, and yet she can have the experience in question.[16]

We start with patients with unilateral spatial *neglect* and/or *extinction*, whose impairment results from a lesion in the right inferior parietal lobe. Unlike blindsight patients, patients with unilateral extinction in their contralesional left hemispace may detect an isolated stimulus on their left, but, if they are presented with two *competing* stimuli, the stimulus located more towards the ipsilesional side of the lesion 'extinguishes' its competitor located more towards the contralesional side. As Driver and Vuilleumier (2001) emphasize, extinction reveals that neglect patients have a deep impairment in allocating *attentional* resources to competing stimuli according to their respective positions in the patient's hemispace. For instance, Mattingley et al. (1997) report an experiment in which a parietal patient was presented with bilateral stimuli consisting of partially occluded four black circles that could either give rise to an illusory Kanizsa square or not. Mattingley et al. (1997) found that the extinction was significantly less severe when the stimulus gave rise to the subjective experience of an illusory common surface than when it did not (even though the experience of illusory contours

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[15] Something like this worry seems behind Levine's (2007) claim that 'the idea of phenomenal consciousness totally divorced from any access by the subject does not really seem like any kind of consciousness at all.' For some replies, see Block (2007) and Dretske (1993), who endorses explicitly the view that one might have a conscious experience and not be conscious of it, hence not know it.

[16] Such cases are used by Dretske (2006) as evidence against what he calls the 'subjective test of consciousness' ($_s$Ta) and by Block (2007) who argues that the neural machinery underlying cognitive accessibility is not a constitutive part of the neural machinery underlying visual phenomenology. Block's (2007) distinction between phenomenal and access consciousness can be more or less mapped onto Dretske's (2006) distinction between object-awareness and fact-awareness.

required visual filling-in). The contrast between the two conditions is the contrast between attending either to a *single* object spread over both sides of the patient's visual field or to *four* competing distinct entities. In the first condition, the stimuli are transformed into constituents of a *single* object (e.g. one Kanizsa square). In the second condition, the stimuli compete for the patient's perceptual attention in the neglected hemispace and competition produces extinction on the left side. Thus, the patient's ability to report her visual experience of the stimuli in her neglected visual field depends on whether the task requires her to allocate her attention to one object or more (cf. Fig. 8.1).

Driver and Vuilleumier (2001, p. 54) report a remarkable attentional modulation of extinction according to the requirements of the task. When presented with objects of different shapes in one, two, or possibly four distinct locations and asked to report their location, the patient extinguished left-sided stimuli in bilateral displays. But when shown the *same* stimuli and ask to *enumerate* them (i.e. one, two, or four), the same patient had no difficulty reporting 'two' or 'four' shapes in bilateral displays. In the first localization task, the stimuli compete for the patient's attention and competition produces extinction in the left side of the patient's visual field. In the second enumeration task, it is likely that the patient exploits a subitizing procedure which enables her to extract the cardinality of a small set by processing preattentively distinct elements as members of a *single* set (cf. Fig. 8.2). If so, then it is likely that the patient's preattentive visual experience of the very same stimuli on her left side is the same in both conditions. Arguably, a switch in the patient's allocation of attention is likely to modify aspects of the phenomenal character (e.g. the intensity) of his or her visual experience. However, it does not seem plausible to assume that a switch in the patient's allocation of attention

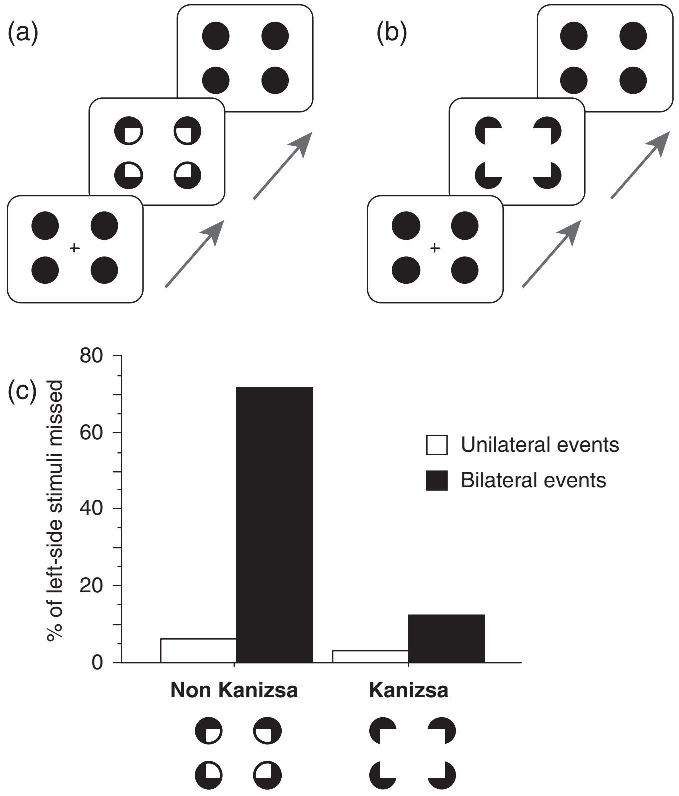

Fig. 8.1 A neglect patient was showed either bilateral or unilateral presentations of either (b) a Kanizsa white square of (a) four partially occluded black circles. (c) shows much lower extinction of bilateral presentations of Kanizsa square than bilateral presentations of non-Kanizsa stimuli. (From Driver and Vuilleumier, 2001. Reprinted with the permission of Cognition.)

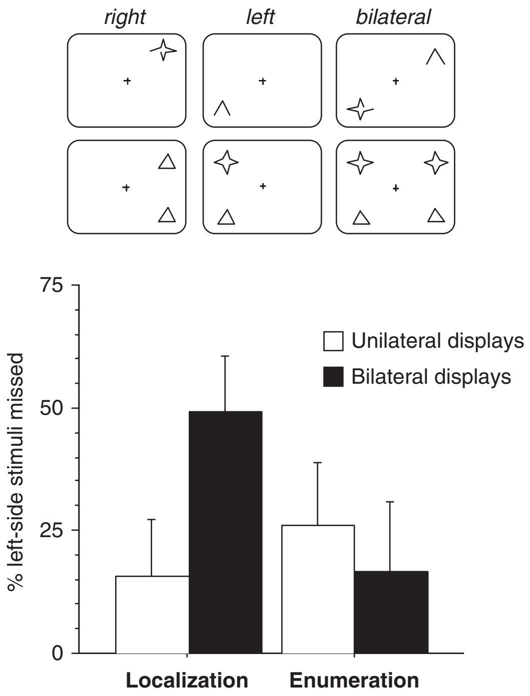

Fig. 8.2 Three right parietal patients were showed visual stimuli in one, two, or four possible locations across hemifields. When asked to report where the shapes appeared (i.e. on the left, right, or both sides), the patients consistently extinguished left-sided stimuli in bilateral displays. However, when shown the same stimuli but now asked to enumerate them (i.e. one, two, or four), the patients had no difficulty reporting 'two' or 'four' shapes in bilateral displays: extinction was eliminated. (From Driver and Vuilleumier, 2001. Reprinted with the permission of Cognition.)

creates (or *generates*) her visual experience. To say that a modulation of attention may alter the character of one's visual experience is not to say that it can *create* it *ex nihilo*. As Block (2007a), Dretske (2006), and Lamme (2006) have argued, failures of attention are consistent with the existence of visual experience in the neglected part of the visual field.

We now turn to instances of so-called *change blindness*, i.e. an experimentally demonstrated phenomenon whereby healthy participants turn out to neglect a significant change in their visual environment. The interpretation of *change blindness* is controversial. Some take it to show that healthy participants believe that they are visually aware of more than they really are (Dennett, 1991, 2001; O'Regan and Noë, 2001; Dehaene et al., 2006). Others take it to show that healthy participants are visually aware of more than they think they are. On this latter view, what subjects believe they are visually aware of results from what they can attend to, judge and report, and not from what they are visually aware of, and what they are visually aware of can be richer and more fine-grained than what they can attend to, judge and report (Block, 2007, 2008; Dretske, 2004, 2006; Simons and Rensink, 2005). Lamme (2003) and Landman et al. (2003) report an experiment that combines features of both the change blindness paradigm and Sperling's (1960) paradigm (for extended discussion, see also Block, 2007). Healthy participants are presented for 500 ms with a circular array of eight rectangles each of which is either horizontally or vertically oriented. Then the array is occluded by a grey screen for a duration varying from 200 ms to 1500 ms. Finally, subjects are presented with a new circular array of eight rectangles either horizontally or vertically oriented. Participants are required to say whether or not the orientation of a particular cued rectangle in the new array is the same as it was in the previous array. In condition (a), the cue appears at the end when participants are asked to judge. Participants respond correctly only 60% of the time (a result in accordance with experiments on change blindness). In condition (b), the cue appears during the initial presentation of the array at the beginning. Not surprisingly, participants' responses are almost 100% correct. The most interesting condition is the last one. In condition (c), the cue is superimposed on the grey screen during the interval between the two array presentations (cf. Fig. 8.3). When the relevant rectangle is cued after removal of the stimulus, participants' performance is almost as good as in condition (b), in which the relevant rectangle is cued while it is visible. As Lamme (2003, pp. 13–14)

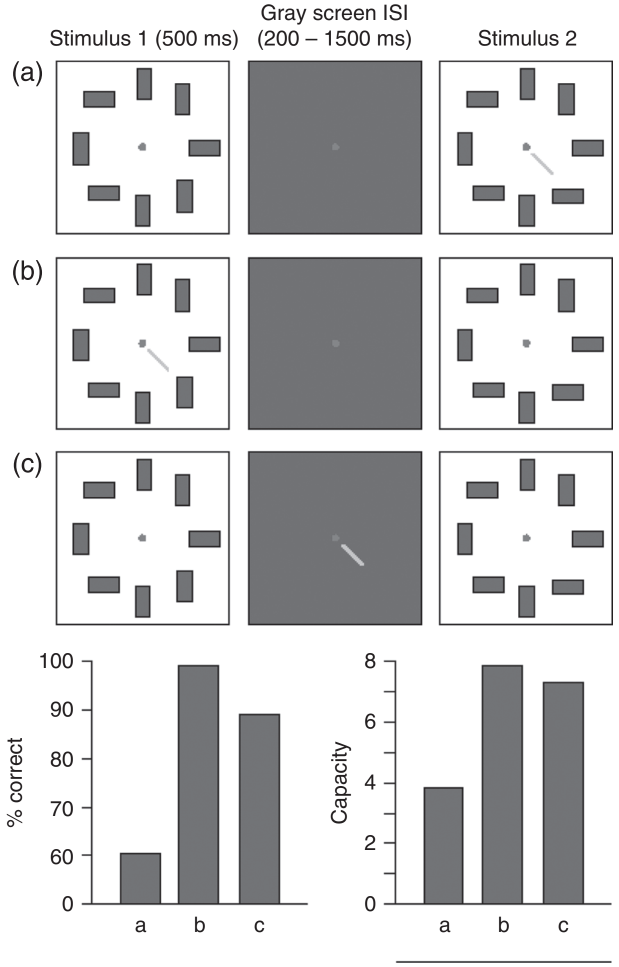

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Fig. 8.3 Subjects see Stimulus 1, followed by a grey screen inter-stimulus interval (ISI), after which they see Stimulus 2. Subjects are then asked whether the cued item (indicated by the orange segment) has changed or not. In (a) it has changed orientation. Subjects perform poorly at this task (60% correct, lower left histogram). Performance can be converted into a 'capacity' measure (lower right histogram) indicating how many items the subject had available (in working memory) for change detection: in this case, approximately four items. When the relevant item is cued in advance (b), subjects perform almost 100% correct (resulting in a virtual capacity of all eight objects). However, when subjects are cued (c) after the removal of Stimulus 1, but before the onset of Stimulus 2, they perform almost as well and seem to have stored information about almost all objects. (From Lamme, 2003. Reprinted with the permission of Trends in Cognitive Sciences.)

observes, cueing a visible item in an array before the change protects against change blindness. Remarkably, this experiment demonstrates that cueing an item before the change, but after removal of the stimulus, also protects (almost as efficiently) against change blindness.

There are two main theoretical options to account for the experimental results reported by either Sperling (1960) or Lamme (2003) and Landman et al. (2003), according to whether or not one accepts the distinction between the content of a visual experience and the content of a perceptual judgment. If one rejects the distinction, then arguably participants' visual experience is generated by attentional processes triggered by the cue. On this view, participants' visual experience (i.e. perceptual judgment) would occur after the cue. However, if one accepts the distinction, then participants' visual experience (unlike their perceptual judgment) may pre-exist to the cue, which acts as a selective mechanism. Rightly in our view, Block (2007, 2008), Lamme (2003), Landman et al. (2003), and Landman and Sligte (2007) choose the latter option.

8.4.3. Iconic buffer and working memory

Both Block (2007, 2008) and Lamme (2003) argue against the reportability criterion of consciousness on the basis of a distinction between two short-term memory systems. The first is an 'iconic' (visual or sensory) memory system with higher storage capacity but shorter persistence, in which all (or almost all) of the items in the first array can be stored for at least 1500 ms. The second 'working memory' system has a longer persistence but a maximum storage capacity of about four items, which have been submitted to attentional processes. They hypothesize that being stored in the working memory system is a necessary condition for being reportable. After an item stored in the iconic memory system has been cued, it is transferred from the iconic to the working memory system for report.[17]

As Block (2008, pp. 307–09) points out, it is likely that information about the orientation of the cued rectangle (in the Landman et al., 2003 experiment) is stored in the iconic memory system *before* being cued. What the cue does is merely to trigger attention to the represented cued item. Attention in turn triggers a process of information transfer from iconic to working memory. Transfer is a selective process of elimination in which some of the information present in iconic memory is being *erased*. On the alternative view, until cueing occurs, no (or little) information about the orientation of the rectangle to be cued would be encoded. The representation of the orientation of the cued rectangle would thus be generated by the creative process following the occurrence of the cue.[18]

To recap, storing information about orientation in the iconic buffer may secure visual experience, but being encoded in the iconic buffer is not sufficient for report. The information needs to be stored in working memory for judgment and report. Arguably to achieve a coherent description of the results of Landman et al.'s (2003) experiment on change blindness, it seems necessary to assume that in condition c), healthy subjects are able to store in the iconic buffer the content of their visual phenomenal experience of the orientation of the rectangle *before* it is cued. After the non-visible rectangle has been cued (i.e. after the rectangle is occluded by the grey screen), information about the orientation of the cued rectangle becomes accessible for report by being transferred into working memory. On this account, a subject's failure to report the orientation of a rectangle entails that the subjects failed to make a judgment about the orientation of the rectangle, but it does not entail that the subject failed to have a visual experience of the orientation of the rectangle. What recommends this account is that on the alternative account, the subject would not form a visual representation of the orientation of the rectangle until the cue occurs, i.e. until the rectangle becomes invisible!

One of the two goals of this chapter has been to assess Wallhagen's (2007) argument for the thesis that, contrary to the standard interpretation offered by advocates of the two-visual systems model,

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[17] For a similar account of Sperling's (1960) experiment, cf. Dretske (2006) and Fodor (2007).

[18] Block's (2007, 2008) further view is that the iconic memory system is a repository for rich visual phenomenology.

apperceptive agnosic patient D.F. might be visually conscious of the sizes and shapes of objects which she can grasp successfully. One major premise in Wallhagen's (2007) argument is the rejection of the reportability criterion of consciousness. In this section, we have examined independent empirical evidence that does support Wallhagen's (2007) rejection of the reportability criterion of consciousness. Nonetheless, as we shall argue in the following section, we think that the evidence about D.F. fails to support Wallhagen's contention that she is visually aware of shape.

8.5. **Is D.F. visually aware of shape?**

We can now turn to the question: does activity in D.F.'s spared dorsal stream make her visually aware of the shape of objects on which she acts efficiently? As Milner and Goodale (1995, p. 200) recognize, what the evidence shows is that D.F. exemplifies a dissociation between visuo-motor processing of size and shape and perceptual report of size and shape. Clearly, D.F.'s impaired ability to report reflects her inability to make perceptual judgments about size and shape. Given our previous description of the results of change blindness, it is still an open possibility that activity in the dorsal stream underlying visuo-motor computations makes D.F. visually aware of size and shape.

8.5.1. **What does failure to report show?**

As Milner (1995) and Milner and Goodale (1995: 200) acknowledge, D.F. is

> unable to demonstrate any recognition of different shapes no matter what form of perceptual report is required, including forced-choice responding […] it could be argued that the best available characterization of the dissociations we have observed is one between perceptual report (by whatever means) and visuo-motor guidance.

D.F. is able to compute an object's size, shape, and orientation in a visuo-motor format for the purpose of grasping it, but according to the reportability criterion of consciousness, she would be visually aware of an object's size, shape, and orientation only if she were able to report manually (or otherwise) her perceptual judgment about an object's size, shape, and orientation, which she is not. As argued in section 8.3, the dissociation between spared visuo-motor processing and impaired perceptual processing of an object's shape exemplified by patient D.F. is a crucial piece of evidence for the claim that activity of the dorsal stream does not underlie visual awareness. Indeed, the dissociation exemplified by visual form apperceptive agnosic patient D.F. has been linked explicitly by Milner and Goodale (1995, p. 200) and Goodale and Milner (2004, pp. 70–1) to similar dissociations exemplified by blindsight patients, who, unlike neglect patients, are recognized widely to lack visual experience.

The inference leading from the fact that D.F. fails to make accurate perceptual judgment about shape to the conclusion that she lacks visual awareness of shape is precisely the target of Wallhagen's (2007) criticism. As Wallhagen (2007) correctly points out, as such, this inference seems to rely on the reportability criterion of consciousness. As we pointed out in section 8.4, there are grounds for rejecting the reportability criterion of consciousness. If this criterion fails, then it is conceivable that D.F. could fail to make accurate judgments of shape and still be visually aware of shape. In Wallhagen's (2007, pp. 18–19) challenging view, the experimental evidence shows only that D.F. is severely impaired in tasks requiring her to make a manual *report* about an object's shape, size, and orientation. The reason D.F. cannot report (manually or otherwise) the shape, size, and orientation of an object is that she cannot make a perceptual judgment about an object's shape, size, and orientation, which she cannot do because her problem is, as Wallhagen (ibid.) puts it:

> a conceptual one: she cannot identify shapes, sizes and orientations, she cannot 'bring them under concepts' […] However, […] it does not follow that she is not aware, in a non-conceptual way, of the shapes, sizes, and orientations of things […] Aspects of form may well be phenomenally present to D.F

Wallhagen (2007, pp. 18–19) argues that, as the experimental evidence shows, D.F.'s intact dorsal stream enables her to grasp objects efficiently, which, he argues, she could not do unless she was visually aware of the shape, size, and orientation of the grasped object. As Clark (2008, manuscript, p. 20) notes, though in different philosophical jargon, Wallhagen's (2007) diagnosis of D.F.'s impairment is reminiscent of O'Regan and Noë's (2001, p. 969) characterization of D.F.'s condition as one of 'partial awareness' whereby 'she is unable to describe what she sees but is otherwise able to use it for the purpose of guiding action' (see Goodale, 2001, for a rebuttal).

In a nutshell, from the fact that D.F. fails to form accurate judgments about shape, it does not logically follow that she is not visually aware of shape; but it does not logically follow either that she is visually aware of the shape. Blindsight patients exhibit visuo-motor capacities but they lack visual awareness of the stimuli onto which they can act. Suppose we apply Wallhagen's (2007) use of the argument against the reportability criterion to healthy subjects whose visual perceptual capacities give rise to visual awareness. In the presence of a Titchener disk surrounded by an annulus of circles either larger or smaller than it, for example, healthy subjects are visually aware of the illusory size of the diameter of a Titchener disk, in accordance with their illusory perceptual belief or judgment (as revealed by their manual report). They also visually compute the non-illusory size of the diameter of the disk when they accurately grasp it (as revealed by their maximum grip aperture), but this does *not* make them visually aware of the non-illusory size of the diameter of the disk. Participants give no evidence that they experience a cognitive dissonance: they do not seem to have contradictory beliefs about the size of the diameter of the central disk. If so, then the visuo-motor processing that leads to the veridical size of the target does not give rise to a belief. It seems as if the content of the visuo-motor representation (if any) does not make its way to the agent's consciousness. Only a manual report of a perceptual judgment is evidence of what a subject both believes and is visually aware.

Now the question raised by Wallhagen's (2007) critique of the application of the reportability criterion of consciousness to patient D.F. can be decomposed into two sub-questions: first, does the activity of D.F.'s spared dorsal stream enable her to compute the shape (or contour) of objects that she can grasp? Secondly, does the output of the visuo-motor computation of the properties of objects that enable her to grasp them make her visually aware of these properties?

8.5.2. Can D.F. compute shape per se?

A recent series of experiments on D.F. reported by Schenk and Milner (2006) are relevant to the first question, i.e. whether D.F.'s spared dorsal stream enable her to compute the shape of objects on which she acts efficiently. Schenk and Milner (2006) ran a series of five experiments designed to explore the parameters involved in D.F.'s representation of an object's shape. In experiment 1, D.F. was showed either a square or a rectangle with the same area and different widths (the rectangle being the wider of the two). D.F.'s task was to name the shape. As in previous experiments, in this task, D.F. was at chance. However, when D.F. was asked to grasp the target object with her right hand while calling out the object's shape during the action (experiment 2) or just before she started her hand movement (experiment 3), her recognition of the object's shape was significantly above chance.[19] This positive effect was lost when D.F. was asked to name the object's shape while pointing to the object (experiment 4). Only grasping, not motor activity in general, enhances D.F.'s ability to recognize an object's shape. So far, the results show that performing a task of grasping considerably helps D.F. make a perceptual judgment about an object's shape. On this basis, one might conclude, as Wallhagen does, that D.F. has a conscious visual experience of shape.

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[19] The result of experiment 3 rules out the putative contribution of proprioceptive information, haptic information, or efferent information about her maximum grip aperture to D.F.'s recognition of an object's shape in experiment 2.

However, Schenk and Milner (2006) performed a last experiment where D.F. was showed objects of identical width and different shapes: either a rectangle or a square (experiment 5). Like in experiment 2, she was asked to grasp the target object with her right hand while calling out the object's shape during the action. In this condition, D.F.'s ability to discriminate between the two shapes was at chance. The contrast with the previous results shows that the relevant parameter in both D.F.'s perceptual judgment and her visuo-motor act is the object's *width*, not its shape proper.

Furthermore, Schenk and Milner (2006) report that, in experiment 3, D.F.'s verbal reports about the object's shape (produced before the onset of her act of grasping) are significantly better than her motor discriminations as revealed by measurements of her maximum grip aperture (MGA). They also report that D.F.'s actual verbal reports (in experiment 3) are significantly better than they would be if they strictly reflected her motor responses as revealed by measurement of her MGA. Now, these two further results raise the following puzzle: the computation of the object's width (presumably performed by D.F.'s intact dorsal stream) is available for both grasping the object and verbally reporting its shape. The puzzle is: why is verbal report more accurate than grasping? Why does processing of width information during the preparation of grasping better serve D.F.'s verbal response than her MGA?

This is puzzling for two reasons. First, earlier evidence seemed to suggest that when showed Efron rectangles, D.F. was significantly better at grasping them than at discriminating them verbally. Secondly, in experiment 3, the route from width information to accurate grasping (grip calibration or motor discrimination) seems more direct than the route from width information to verbal report of shape. Arguably, accurate grip formation just consists in width discrimination, but verbal discrimination (between a square and a rectangle of different widths) requires combining width discrimination with the knowledge that the rectangle is wider than the square. A possible solution to the puzzle is that in experiments 2 and 3, verbal report and motor discrimination compete for access to width information. But in experiment 3 (unlike experiment 2), D.F. is requested to make the verbal judgment *before* starting her motor act. In other words, the former dominates the latter in the competition. If so, then verbal report gains access to width information at the expense of motor discrimination. This might explain the surprising fact that D.F.'s verbal judgments are more accurate than her motor discriminations in Schenk and Milner's (2006) experiment 3.

8.5.3. Visuo-motor computation and phenomenal awareness of width

Schenk and Milner's (2006) experiments show that performing a visuo-motor task of grasping helps significantly D.F. in making a verbal judgment about an object's shape. We suggest that D.F. can make accurate use of visual information about features of the shape of a target when she codes the location of the target in egocentric coordinates centred on her fingers. However, as we argued above, two distinct issues arise: (a) which features of shape does D.F. make use of?; and (b) is she visually aware of the features of shape she makes accurate use of?

Schenk and Milner's (2006) experiment 5 helps us solve question (a): she makes use of width, not shape (or contour) per se. Why? Because when a square and a rectangle are equal in width, she is at chance. Milner and Goodale (2008, p. 777) argue rightly that 'the visuo-motor cueing benefited only width discrimination […], not shape discrimination per se'. In other words, D.F.'s spared dorsal stream enables her to compute accurately width information, not shape information per se. In order to accurately grasp a target, D.F. must combine information about the target's width and the target's location coded in an egocentric frame of reference centred on her fingers. Furthermore, experiment 3 shows that there can be competition between (verbal or manual) report and grip formation for access to width information. In experiment 3, when she was required to make a verbal report before the onset of her motor act, her grip formation turned out to be less reliable than her verbal judgment. Arguably, after being first used as a cue for making a verbal report about the object's shape, width information might have been degraded when later combined with information about the location of the target coded in an egocentric frame of reference centred on D.F.'s fingers. It thus seems as if D.F.

can compute width information (relevant to grasping), not shape information per se, and use the former as a cue for making *guesses* about an object's shape (in restricted conditions).[20]

Let us now turn to the second question: is D.F. visually aware of the features of an object's shape (e.g. width) that enable her to grasp objects? Three pieces of evidence are relevant to investigating the second question. First of all, as the brain-imaging study conducted by James et al. (2003) show, unlike healthy participants, D.F. showed no difference in activity in her lateral occipital cortex (area LO of the ventral stream) for the contrast between scrambled line drawings and line drawings of common objects. This suggests that activity in D.F.'s spared dorsal stream underlying the visuo-motor computation of parameters relevant for grasping is not sufficient for making her visually aware of features of shape.[21]

Secondly, the results from Schenk and Milner's (2006) experiments show that D.F. computes width, not shape per se. Let us suppose that the width and length of a two-dimensional object are features of the object that must be bound together by the visual system to generate a representation the object's shape. One possibility is that the lesion in D.F.'s ventral stream impairs the process whereby in healthy subjects the visual system binds together the width and the length to generate a visual representation of the overall shape or contour of a two-dimensional object. If so, then the question arises whether D.F. is visually aware of width per se.

Thirdly, in section 8.4, on the basis of Landman et al.'s (2003) change blindness experiment, we argued that storing information about the orientation of a rectangle in working memory is necessary for reportable judgment, but not for phenomenal awareness. Following Block (2007) and Landman and Sligte (2007), we hypothesized that it is necessary and sufficient for phenomenal awareness of orientation that information about orientation be stored in the iconic buffer – a sensory memory system with larger storing capacity and shorter persistence than working memory. If we extend this hypothetical condition to D.F.'s visual awareness of width, then it is a necessary and sufficient condition for D.F.'s visual awareness of width that she can store width information in an iconic buffer.

Given these three pieces of empirical evidence, the question whether D.F. is visually aware of the width of objects that she grasps successfully can be reduced to two further empirical questions: (i) can one be visually aware of unbound features of shape (e.g. width)? Or instead does one's visual awareness of the features of an object's shape result from their being bound together into a full shape?; and (ii) can activity of D.F.'s spared dorsal stream store representations of features of shape in iconic memory? If the answer to either question is negative, then it is unlikely that D.F. is visually aware of the width of objects.

8.6. **Conclusion**

In this chapter, we have disentangled the contribution of two separable factors to the two-visual systems model of vision: how spatial information is coded and whether visual information reaches consciousness. We have claimed that visuo-motor processing (or vision-for-action) must code spatial information in egocentric coordinates. By contrast, perceptual judgment is more flexible: judgments about the spatial position of a visual object can make use of either an egocentric or an allocentric frame of reference. But making a comparative judgment about the relative size of an item (in relation to the size of another item) in a visual array requires localizing the spatial position of the first item in an allocentric frame of reference centred on the visual scene. We have also suggested that an agent may be visually unaware of the shape of an object if she codes its spatial position in egocentric coordinates centred on her fingers (as D.F. must in a task of grasping). Clearly, on the reportability

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[20] Visual form agnosic patient S.B. examined by Dijkerman et al. (2004) seems slightly better than patient D.F. at discriminating features of shape.

[21] Preserved islands in her ventral stream seem involved, however, in D.F.'s sensitivity to, and visual phenomenal awareness of, colours (cf. James et al., 2003; Goodale and Milner, 2004).

criterion of consciousness, D.F. counts as visually unaware of the shape of objects. But we also argued against the reportability criterion of consciousness. Finally, we argued in favour of the following conditional claim: if D.F.'s spared dorsal stream does not enable her either to bind the width and the length of a visual object or to store in iconic memory information about bound or unbound width, then it is unlikely that she is visually aware of features of shape (e.g. the width) of objects.[22]

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