S. Laureys (Ed.)
Progress in Brain Research, Vol. 150
ISSN 0079-6123

CHAPTER 13

Visual phenomenal consciousness: a neurological guided tour

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Abstract: The scientific study of the cerebral substrate of consciousness has been marked by significant recent achievements, resulting partially from an interaction between the exploration of cognition in both brain-damaged patients and healthy subjects. Several neuropsychological syndromes contain marked dissociations that permit the identification of principles related to the neurophysiology of consciousness. The generality of these principles can then be evaluated in healthy subjects using a combination of experimental psychology paradigms, and functional brain-imaging tools. In this chapter, I review some of the recent results relevant to visual phenomenal consciousness, which is an aspect of consciousness most frequently investigated in neuroscience. Through the exploration of neuropsychological syndromes such as ‘‘blindsight,’’ visual form agnosia, optic ataxia, visual hallucinations, and neglect, I highlight four general principles and explain how their generality has been demonstrated in healthy subjects using conditions such as visual illusions or subliminal perception. Finally, I describe the bases of a scientific model of consciousness on the basis of the concept of a ‘‘global workspace,’’ which takes into account the data reviewed.

Introduction

The scientific investigation of consciousness has recently stimulated experimental research in healthy human subjects, in neurological and psychiatric patients, and in some animal models. Although this major ongoing effort does not yet provide us with a detailed and explicit neural theory of this remarkable mental faculty, we already have access to a vast collection of results acting as a set of constraints on what should be a scientific model of consciousness. There are many ways to summarize and present this set of ‘‘consciousness principles.’’ One may either use a chronological or a domain-specific strategy. Here, I deliberately adopt a narrative approach driven by a neurological perspective. This approach allows an emphasis on the crucial role played by the observation of brain-lesioned patients affected by neuropsychological syndromes. I argue that as in other fields of cognitive neuroscience, clinical neuropsychology often offers profound and precious insights leading to the discovery of neural principles governing distinct aspects of the physiology of consciousness (Ramachandran and Blakeslee, 1998). Most importantly, many of these principles also prove to be relevant and to generalize to the cognition of healthy human subjects. In a schematic manner, the ‘borderline cases’ provided by clinical neurology have the power to specifically illustrate a single property of consciousness by showing the consequences of its impairment. This magnifying effect makes it easier to isolate and delineate this

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DOI: 10.1016/S0079-6123(05)50013-X

property, and then to take it into account in more complex situations where it is functioning in concert with other processes.

I will focus interest on a selected number of these properties, and will limit our investigation to visual phenomenal consciousness, which is by far the most experimentally investigated aspect of consciousness. Following the psychologist Larry Weiskrantz (1997), our criteria to establish subject's conscious perception of a stimulus will be the "reportability" criteria: the ability to report explicitly to oneself or to somebody else the object of our perception: "*I see the word consciousness printed in black on this page*." This criterion is fully operational, and can be easily correlated to other sources of information (external reality, functional brain-imaging data, etc.), thereby paving the way to an objective evaluation of subjective data, a scientific program called "heterophenomenology" by Daniel Dennett (1992). It can be argued, however, that reportability might be a biased measure underestimating subjects' conscious state, and that forced-choice tasks using signal detection theory parameters such as d' might be preferable (Holender, 1986). However, discrediting reportability on these grounds in favor of purely objective measures is far from satisfying. Firstly, unconscious perception of a stimulus might have an impact on objective measures, as illustrated in many unconscious perception situations such as masked priming paradigms (Merikle, Smilek, & Eastwood, 2001). Secondly, to ignore subjective reports is somewhat of a counterproductive approach, because it may lead to simply giving up the original project of investigating consciousness. Finally, some authors contest the criteria of reportability by establishing differences between phenomenal consciousness and access consciousness (see Cleeremans, this volume), claiming that we are actually conscious of much more information than we can access and report (Block, 1995). This last theory does not discredit our criteria, but suggests limits to its usage as a non-exhaustive index of consciousness.

Thus far, I have justified our adoption of the "reportability" criteria to diagnose conscious perception in subjects. How then may we use it to specify a scientific program to investigate systematically the neural basis of visual consciousness? By first recalling a basic but essential "Kantian" statement: when we report being conscious of seeing an object, strictly speaking, we are not conscious of this object belonging to external reality, rather we are conscious of some of the visual representations elaborated in our visual brain areas and participating to the flow of our visual phenomenal consciousness, as masterly expressed by the Belgian Surrealist Painter, René Magritte in his famous painting "This is not a pipe" ("Ceci n'est pas une pipe" or "La trahison des images", 1928–1929, see Fig. 1). This simple evocation of the concept of representation foreshadows the two fundamental stages in the search of the "neural correlates of visual consciousness"(Frith et al., 1999): (i) make a detailed inventory of the multiple representations of the visual world elaborated by different visual brain areas (from retina and lateral geniculate nuclei to ventral occipito-temporal and dorsal occipito-parietal pathways described by Ungerleider and Mishkin (1982), in addition to superior colliculus-mediated visual pathways); and (ii) identify among these different forms of visual coding which participate in visual phenomenal consciousness, and in these cases, specify the precise conditions governing the contribution of these representations to

Fig. 1. When we report being conscious of seeing a pipe, strictly speaking we are not conscious of this pipe belonging to external reality, rather we are conscious of some of the visual representations elaborated in our visual brain areas and participating to the flow of our visual phenomenal consciousness. (René Magritte, 1928–1929, La trahison des images (The Treachery of Images), reproduced with permission from the Los Angeles County Museum of Art and the Artists Society.) © René Magritte c/o Beeldrecht Amsterdam 2005.

the flow of phenomenal consciousness. One may date the beginning of this scientific program with the influential publication of Crick and Koch (1995) who proposed, mainly on the basis of neuro-anatomical data, that neural activity in area V1 does not contribute to the content of our phenomenal consciousness.

Blindsight: highlighting the role of visual cortex

Somepatients affected by visual scotoma secondary to primary visual cortex lesions display striking dissociations when presented with visual stimuli at the location of their scotoma. While claiming to have no conscious perception of these stimuli, they perform better than chance on forced-choice visual and visuo-motor tasks such as stimulus discrimination, stimulus detection, or orientation to stimulus spatial source by visual saccades. This phenomenon, discovered in the early seventies (Poppel et al., 1973; Weiskrantz et al., 1974; Perenin and Jeannerod, 1975), has been coined ‘‘blindsight’’ by Weiskrantz. Compelling evidence supports the idea that such unconscious perceptual processes are subserved by the activity of subcortical visual pathways including the superior colliculus, and by-pass the primary visual cortex (Cowey and Stoerig, 1991). In a recent study, de Gelder and Weiskrantz enlarged the range of unconscious perceptual processes accessible to blindsight patients by showing that patient G.Y., whose fame is comparable to that of patient H.M. in the field of medial temporal lobe amnesia, was able to discriminate better than chance emotional facial expressions on forced-choice tasks (de Gelder et al., 1999). Taking advantage of this behavioral result, the authors used functional magnetic resonance imaging (fMRI) to demonstrate that this affective blindsight performance is correlated with the activity in an extra-geniculo-striate colliculo-thalamo-amygdala pathway independently of both the striate cortex and fusiform face area located in the ventral pathway (Morris et al., 2001). In fact, this unconscious visual process discovered in blindsight subjects is also active in healthy human subjects free of any visual cortex lesions. One way to observe it consists of using paradigms of masked or ‘‘subliminal’’ visual stimulation in which a stimulus is briefly flashed foveally for tens of milliseconds, it is then immediately followed by a second stimulus, suppressing conscious perception of the former. Whalen et al. used such a paradigm to mask a first fearful or neutral face presented during 33 ms by a second neutral face presented for a longer duration (167 ms). While subjects did not consciously perceive the first masked face, fMRI revealed an increase of neural activity in the amygdala on masked fearful face trials compared to masked neutral face trials (Whalen et al., 1998). This interesting result has been replicated and enriched by a set of elegant studies conducted by Morris et al. (1998, 1999).

The blindsight model and its extension in healthy subjects via visual masking procedures underlines the importance of the neocortex in conscious visual processing by revealing that a subcortical pathway is able to process visual information in the absence of phenomenal consciousness. In other words, these recent data are in close agreement with Hughlings Jackson’s (1932) hierarchical conception (formulated in particular in the 3rd and 4th principles of his ‘‘Croonian lectures on the evolution and dissolution of the nervous system’’) that attributes the more complex cognitive processes, including consciousness, to the activity of neocortex. Nevertheless, should we generalize the importance shown here for the primary visual cortex — the integrity of which seems to be a pre-requisite for visual consciousness — to the whole visual cortex?

Visual form agnosia, optic ataxia and visual hallucinations: the key role of the ventral pathway

As a result of the seminal work of Ungerleider and Mishkin (1982), visual cortex anatomy is considered to be composed of two parallel and interconnected pathways supplied by primary visual cortex area V1: the occipito-temporal or ‘‘ventral’’ pathway and the occipito-parietal or ‘‘dorsal’’ pathway. The dorsal pathway mainly subserves visuomotor transformations (Andersen, 1997), while the ventral pathway neurons represent information from low-level features to more and more abstract stages of identity processing, thus subserving object identification. This "what pathway" is organized according to a posterior-anterior gradient of abstraction, the most anterior neurons located in infero-temporal cortex coding for object-based representations free from physical parameters such as retinal position, object size or orientation (Lueschow et al., 1994; Ito et al., 1995; Grill-Spector et al., 1999; Cohen et al., 2000). Goodale and Milner reported a puzzling dissociation in patient D.F. suffering from severe visual form agnosia due to carbon monoxide poisoning (Goodale et al., 1991). As initially defined by Benson and Greenberg (1969), this patient not only had great difficulties in recognizing and identifying common objects, but she was also unable to discriminate even simple geometric forms and line orientations. Anatomically, bilateral ventral visual pathways were extensively lesioned, while primary visual cortices and dorsal visual pathways were spared. Goodale and Milner presented this patient with a custom "mail-box," the slot of which could be rotated in a vertical plane. When asked to report slot orientation verbally or manually patient D.F. performed at chance-level, thus confirming her persistent visual agnosia. However, when asked to post a letter into this slot she unexpectedly performed almost perfectly, while still unable to report slot orientation consciously. This spectacular observation demonstrates how spared dorsal pathway involved in visuo-motor transformations was still processing visual information but without contributing to patient D.F.'s phenomenal conscious content. This case suggests that some representations elaborated in this "how pathway" are operating unconsciously while the ventral pathway activity subserves our phenomenal visual consciousness. Since this influential paper, many studies have tested this hypothesis in healthy subjects using visual illusions (Aglioti et al., 1995; Gentilucci et al., 1996; Daprati and Gentilucci, 1997). For instance, Aglioti et al. (1995) engaged subjects in a Titchener–Ebinghaus circles illusion task in which a given circle surrounded by larger circles appears smaller than the very same circle surrounded by smaller circles (see Fig. 2). While subjects consciously reported this cognitively impenetrable illusion, when asked to grip the central circle, online measures of their thumb-index distance showed that their visuo-motor response was free of the perceptual illusion and adapted to the objective size of the circle.[1]

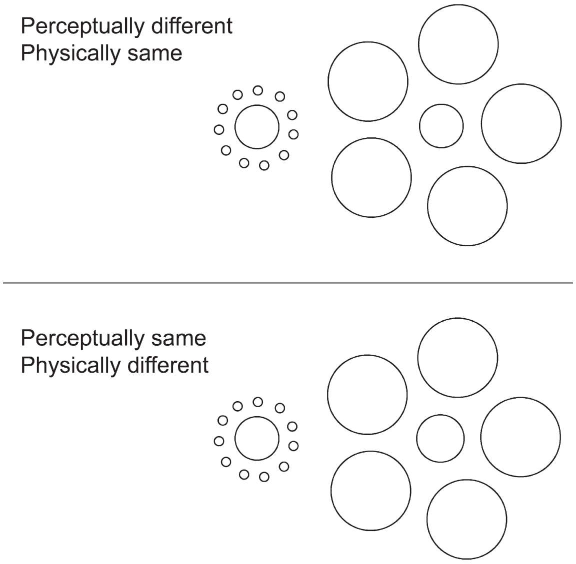

Fig. 2. Size-contrast illusions (i.e., Titchener circles illusion) deceive the eye but not the hand. Upper row panel: The standard version of the illusion. The target circles in the center of the two arrays appear to be different in size even though they are physically identical. For most people, the circle in the annulus of smaller circles appears to be larger than the circle in the annulus of larger circles. Lower row panel: A version of the illusion in which the target circle in the array of larger circles has been made physically larger than the other target circle. The two target circles should now appear to be perceptually equivalent in size. Note that when asked to grip the central circle, Aglioti et al.'s (1995) online measures of thumb-index distances revealed that visuo-motor response is free of the perceptual illusion and is correctly estimating the objective size of the circle. Automatic and metrically accurate calibrations required for skilled actions hence seem mediated by visual processes that are separate from those mediating our conscious experiential perception.

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[1] Since these first reports, Franz and colleagues (Franz et al., 2000; Franz, 2001) challenged this interpretation by showing that when task difficulty was equated between perceptual and grasping tasks, action was not resisting to the illusion. However, recent studies taking into account these possible confounds reproduced the dissociation between perceptual and action performances (for a detailed review see Kwok and Braddick, 2003).

An inverse dissociation supporting the same general principle has been recently reported by Pisella et al. (2000) who demonstrated the existence of an unconscious "automatic pilot" located in the dorsal pathway. Their patient I.G. presented important stroke lesions affecting both dorsal pathways, while sparing primary visual cortices and ventral pathways. They designed a subtle task manipulating online motor corrections of pointing movements on a tactile screen on which visual targets appeared and these could unexpectedly jump from one position to another. While normal subjects were capable of extremely fast and automatic visuo-motor corrections in this task, patient I.G. could only rely on very slow strategic and conscious corrections. Crucially, when tested in a more complex condition in which subjects had to inhibit an initiated pointing correction on some trials, patient I.G. committed far less errors than the controls who were unable to inhibit very fast motor corrections and who reported of being astonished by their own uncontrollable behavior.

Taken together, these results are currently interpreted as dissociations between visuo-motor processes subserved by the activity of the dorsal visual pathway, the computations of which do not participate to our phenomenal consciousness,[2] and other visual processes relying on ventral pathway activity which supplies our conscious perception. The strong version of this theoretical position is defended in particular by authors such as Goodale and Milner. The latter claimed for instance that "we have two (largely) separate visual systems. One of them is dedicated to the rapid and accurate guidance of our movements…, and yet it lies outside the realm of our conscious visual awareness. The other seems to provide our perceptual phenomenology,…" (Milner 1998). Additional data originating from behavioral measures of subliminal priming, and functional brain-imaging data support this thesis (Bar and Biederman, 1999; Bar et al., 2001).

Lastly, a recent functional brain-imaging study of consciously reportable visual hallucinations observed in patients with Charles–Bonnet syndrome[3] reinforces this conception, by revealing correlations between color, face, texture and object hallucinations, and increased levels of cerebral blood flow in the corresponding specialized visual areas located in the ventral visual pathway (Ffytche et al., 1998).

Unilateral spatial neglect: the necessity of attentional allocation

The recent proposal of a cerebral substrate of visual consciousness through the distinction drawn between dorsal ("unconscious") and ventral ("conscious") pathways still bears some similarity to Jackson's conception since it relies on a similar anatomical partition between some sectors of the visual system, which would supply the flow of our phenomenal consciousness, and other sectors, which would process information out of our conscious awareness. However, we may posit a further question: Does visual information represented in the ventral pathway depend on some additional conditions to be consciously accessible and reportable? In other words, are we necessarily conscious of all visual information represented in the ventral pathway? A key answer to this question comes from unilateral spatial neglect (USN), a very frequent neuropsychological syndrome clinically characterized by the inability to perceive or respond to stimuli presented to the side contralateral to the site of the lesion, despite the absence of significant sensory or motor deficits. USN has two interesting characteristics: Firstly, most USN patients display impaired visual phenomenal consciousness for objects located on their left

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[2] Area MT or V5, located within the dorsal pathway, is an important exception to this principle because : (1) its activity correlates directly with conscious reports of genuine or illusory visual motion (Tootell et al., 1995), (2) when lesioned (Zeki, 1991) or transiently inactivated by trans-cranial magnetic stimulation (Beckers and Homberg, 1992) it results in akinetopsia (i.e., the inability to report visual motion), and (3) microstimulation within this area influences motion orientation discrimination in monkeys (Salzman et al., 1990).

[3] This syndrome is characterized by visual hallucinations in people who have a sudden change in vision. Charles Bonnet, a Swiss philosopher, first described this condition in the 1760s when he noticed his grandfather, who was blinded by cataract, described seeing birds and buildings which were not there. It was later defined as "persistent or recurrent visual pseudo-hallucinatory phenomena of a pleasant or neutral nature in a clear state of consciousness "(Damas-Mora et al., 1982)".

side.[4] Some neglect patients even present a very pure symptom called "visual extinction," defined by the specific loss of phenomenal consciousness for left-sided stimuli presented in competition with right-sided stimuli, while the same left-sided stimuli presented in the absence of contralateral competing stimuli are available to conscious report. Secondly, USN syndrome is usually observed with lesions affecting the spatial attentional network — most often right parietal and/or superior temporal gyrus (Karnath et al., 2001) cortices but also right thalamic or right frontal lesions — sparing the primary visual cortex and the whole ventral visual pathway. Recent behavioral and functional brain-imaging studies have reliably shown that this spared visual ventral pathway still represents the neglected visual information at multiple levels of processing that culminates in highly abstract forms of coding (McGlinchey-Berroth, 1997; Driver and Mattingley, 1998; Driver and Vuilleumier, 2001). For instance, McGlinchey-Berroth et al. (1993) demonstrated that left-sided neglected object pictures could be represented up to a semantic stage, as revealed by significant behavioral priming effects on the subsequent processing of consciously perceived semantically related words. More recently, Rees et al. (2000) have shown that an unconsciously perceived extinguished visual stimulus still activates corresponding retinotopic regions of primary visual cortex and several extra-striate ventral pathway areas.

These results demonstrate that ventral pathway activation constitutes a necessary but not sufficient condition to perceive consciously visual stimuli. The additional mechanism, defective in USN patients and mandatory to conscious perception, seems to be the top-down attentional amplification supplied by the activity of the spatial attention network (Mesulam, 1981).

Recently we have been able to generalize this principle demonstrated by USN patients to healthy subjects, by investigating neural correlates of unconsciously perceived words using a visual-masking procedure (Dehaene et al., 2001). Using both fMRI and event related potential (ERP) recordings we observed significant activations of the left ventral pathway — the visual word form area, previously identified as the first non-retinotopic area responding to letter string stimuli (Cohen et al., 2000) — by unconsciously perceived masked words. In a second experiment, we tested the specificity of these activations by using a masked priming paradigm: on each trial subjects consciously perceived a target word and classified it either as man-made or as a natural object. Subjects responded faster to visible words immediately preceded by the same masked word (e.g., table/table) than to different prime-target pairs (e.g., radio/table). This repetition priming effect was correlated to specific reductions of the blood oxygen level dependent (BOLD) signal in the visual word form area on repeated word trials compared to non-repeated word trials. This repetition suppression effect is strongly suggestive of the activation of common neurons sharing the same response tuning properties as by unconsciously perceived masked words and by unmasked words (Naccache and Dehaene, 2001a).

This work enabled us to compare brain activations elicited by briefly (29 ms) flashed words depending on whether it was consciously perceived or not. During masked trials a backward mask suppressed conscious perception of the word, while words that were flashed for the very same duration but were not backward masked were consciously perceived and reported. When consciously perceiving a word, corresponding neural activity is hugely amplified and temporally sustained in the ventral visual pathway in comparison with the neural activity elicited by masked words. Moreover, conscious perception is systematically accompanied by the co-activation of a long-range distributed network, the epicenters of which involve prefrontal, anterior cingulate, and parietal cortices.

Source and effects of top-down attentional effects: attention is not consciousness

The crucial role of top-down attentional amplification on the perceptual fate of stimuli is likely to

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[4] An exact definition of "left side" remains the subject of many investigations, as visual neglect has been reliably observed at several distinct spatial frames of reference such as different subject-centered or "egocentric" frames, and multiple environment or object-centered "allocentric" frames (Mesulam, 1999).

occur recursively at multiple stages of processing all along the ventral visual pathway. This allows large modulations of activation patterns elicited by the same stimulus according to the task presently performed. The rich plasticity of visual representations observed in conscious strategical processing leads to the following question: Are unconscious visual representations impermeable to such top-down effects? Indeed, in most current theories of human cognition, unconscious processes are considered as automatic processes that do not require attention (Posner and Snyder, 1975; Schneider and Shiffrin, 1977; Eysenck, 1984).

Kentridge et al. (1999, 2004) recently questioned this conception by testing the efficacy of several visual cues on the forced-detection of targets in the hemianopic scotoma of the blindsight patient GY. They found that a central, consciously perceived arrow pointing toward the region of the scotoma where the target would appear could enhance GY's performance, although the target remained inaccessible to conscious report.[5] In normal subjects, using a visual-masking procedure, Lachter et al. (in press) recently reported that unconscious repetition priming in a lexical decision task occurred only if the masked primes appeared at spatially attended locations.

We also investigated a similar issue related to the impact of temporal attention on visual masked priming effects (Naccache et al., 2002). In previous studies, we have shown that masked numerical primes can be processed all the way up to quantity coding (Naccache and Dehaene, 2001a, b) and motor response stages (Dehaene et al., 1998b). When subjects had to compare target numbers with a fixed reference of 5, they were faster when the prime and target numbers fell on the same side of 5, and therefore called for the same motor response, than when they did not (i.e., response congruity effect). They were also faster when the same number was repeated as prime and target (i.e., repetition priming effect). In three experiments manipulating target temporal expectancy, we were able to demonstrate that the occurrence of unconscious priming in a number comparison task is determined by the allocation of temporal attention to the time window during which the prime-target pair is presented. Both response-congruity priming and physical repetition priming totally vanish when temporal attention is focused away from this time window. We proposed that when subjects focus their attention on the predicted time of appearance of the target, they open a temporal window of attention for a few hundreds of milliseconds. This temporal attention then benefits unconscious primes that are presented temporally close to the targets.

Taken together, these findings are inconsistent with the concept of a purely automatic spreading of activation during masked priming and refute the view that unconscious cognitive processes are necessarily rigid and automatic. While several paradigms, such as inattentional blindness (Mack and Rock, 1998) or attentional blink (Raymond et al., 1992) suggest that conscious perception cannot occur without attention (Posner, 1994), our findings indicate that attention also has a determining impact on unconscious processing. Thus, attention cannot be identified with consciousness. One of the key criteria for automaticity is independence from top-down influences. However, these results suggest that, by this criterion, masked priming effects or unconscious blindsight effects cannot be considered as automatic. We propose that the definition of automaticity may have to be refined in order to separate the source of conscious strategic control from its effects. Processing of masked primes is automatic inasmuch as it cannot serve as a *source* of information for the subsequent definition of an explicit strategy (e.g., see Merikle et al., 1995). However, this does not imply that it is impermeable to the *effects* of top-down strategic control, for example originating from instructions and/or task context. As a matter of fact, I retrospectively found an explicit formulation of this principle by Daniel Kahneman and Anne Treisman (1984) 20 years ago:

> …a dissociation between perception and consciousness is not necessarily

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[5] This very elegant demonstration in patient GY will require further investigations in additional blindsight patients, given that GY's residual vision has been recently interpreted in terms of low-level phenomenal vision through a set of subtle experiments manipulating visual presentations in both the spared visual field and within the scotoma (Stoerig and Barth, 2001).

> equivalent to a dissociation between perception and attention. (…) To establish that the presentation is subliminal, the experimenter ensures that the subjective experience of a display that includes a word cannot be discriminated from the experience produced by the mask on its own. The mask, however, is focally attended. Any demonstration that an undetected aspect of an attended stimulus can be semantically encoded is theoretically important, but a proof of complete automaticity would require more. Specifically, the priming effects of a masked stimulus should be the same regardless of whether or not that stimulus is attended. (…). These predictions have yet to be tested.

Four principles accounted by a theoretical sketch of consciousness

Thus far, our non-exhaustive review has allowed us to isolate four general principles governing the physiology of visual consciousness. Firstly, a large number of processes coded in some sectors of the visual system — such as the subcortical colliculus mediated pathway, or some areas of the dorsal visual pathway — never participate in conscious visual representations. Secondly, a visual representation is reportable only if coded by the visual ventral pathway. Thirdly, this anatomical constraint is necessary but clearly not sufficient, as is nicely demonstrated in visual neglect. Top-down attentional amplification seems to be the additional and necessary condition for a visual representation coded in the ventral pathway to reach conscious content. Finally, inspired by Posner's (1994) distinctions between the *source* and the *effects* of a top-down attentional process, we propose that only conscious representations can be used as sources of strategic top-down attention, while some unconscious representations are highly sensitive to the effects of such attention. These principles help to better delineate the properties of conscious visual perceptions, and also argue for a distinction between two categories of nonconscious processes: those that never contribute to conscious content, and those that can potentially contribute to it.

These principles can be accounted for within the "global neuronal workspace" theoretical framework developed by Dehaene and co-workers (Dehaene et al., 1998a; Dehaene and Naccache, 2001; Dehaene et al., 2003; also see Baars, this volume). This model, in part inspired from Bernard Baars' (1989) theory, proposes that at any given time many modular cerebral networks are active in parallel and process information in an unconscious manner. Information becomes conscious, however, if the corresponding neural population is mobilized by top-down attentional amplification into a self-sustained brain-scale state of coherent activity that involves many neurons distributed throughout the brain. The long-distance connectivity of these "workspace neurons" can, when they are active for a minimal duration, make the information available to a variety of processes including perceptual categorization, long-term memorization, evaluation, and intentional action. We postulate that this global availability of information through the workspace is what we subjectively experience as a conscious state. Neurophysiological, anatomical, and brain-imaging data strongly argue for a major role of prefrontal cortex, anterior cingulate, and the areas that connect to them, in creating the postulated brain-scale workspace.

Within this framework, the different unconscious visual processes reviewed in this paper can be distinguished and explained. The activity of subcortical visual processors such as the superior colliculus, which do not possess the reciprocal connections to this global neuronal workspace that are postulated to be necessary for top-down amplification, cannot access or contribute to our conscious content, as revealed by blindsight.[6] Moreover, the activity of other visual processors anatomically connected to this global workspace by reciprocal connections can still escape the content of consciousness due to top-down attentional

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[6] Indeed neurons located in the superficial visual layers of superior colliculus receive direct input from parietal areas while projecting indirectly to intraparietal cortex through a thalamic synapse (Sparks, 1986; Clower et al., 2001).

failure. This "attentional failure" may result from a direct lesion of the attentional network (such as in USN), from stringent conditions of visual presentation (such as in visual masking), or even from the evanescence of some cortical visual representations too brief to allow top-down amplification processes (such as the parietal 'automatic pilot' revealed by optic ataxia patients).[7] This model also predicts that once a stream of processing is prepared consciously by the instructions and context, an unconscious stimulus may benefit from this conscious setting, and therefore show attentional amplification, such as in blindsight.

Conclusion

This theoretical sketch will of course necessitate further developments and revisions, but its set of predictions can be submitted to experimentation. For instance, this model predicts that a piece of unconscious information cannot itself be used as a source of control to modify a choice of processing steps. Another prediction is to extend the sensitivity of some blindsight effects to top-down attention to other paradigms or relevant clinical syndromes, such as USN, attentional blink, or inattentional blindness.

As a conclusion, I have tried in this chapter to describe how the observation of neurological patients has played a major role in the discovery of several important principles related to the neural bases of visual consciousness. However, this description is not written as a record of an heroic past era of brain sciences. Clinical neuropsychologists and their patients are not dinosaurs, and so we did not adopt here a "paleontologist attitude." On the contrary, this audacious neuropsychology of consciousness will provide us with exciting and unexpected observations, enabling us to tackle the most complex and enigmatic aspects of visual consciousness.

Acknowledgments

I thank two anonymous referees and Dr. Anna Wilson for their constructive and helpful remarks.

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[7] Within the global workspace model only explicit — or active — neural representations coded in the firing of one or several neuronal assemblies are able to reach conscious content. Therefore, a third class of unconscious processes can be described, those resulting from the neural architecture (fiber lengths and connections, synapses, synaptic weights) in which information is not explicitly coded. This type of unconscious information is also postulated to never participate to conscious content.

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